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EFFECT OF CROP ROTATION WITH SHORT DURATION LEGUMINOUS TREE CROPS ON THE NUTRIENT STATUS OF SOIL IN CLEAR FELLED TEAK PLANTATION SITES

(Final report of the project KFRI 569/09)

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CONTENTS

PROJECT PROPOSAL

1. Project code : KFRI 569/09

2. Title of the project : Effect of crop rotation with short duration leguminous tree crops on the nutrient status of soil in clear felled teak plantation sites

3. Objectives : To study the changes in soil physical and chemical properties and nutrient status in the experimental plots

   To evaluate the litterfall pattern, rate of decomposition and incorporation of nutrients in the soil

   To assess the site quality variation due to crop rotation

4. Date of commencement : April 2009

5. Duration : 3 years

6. Funding agency : KFD

7. Investigators : Thomas P. Thomas
   R. C Pandalai

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ABSTRACT

Teak plantations in Kerala have suffered deterioration in site quality due to successive rotations since the land is sloping and the climate humid tropical. Rotation with short duration tree species might go a long way in mitigating some of the harm done to the soil and thus may prove beneficial in the long run. *Acacia auriculiformis* and *Acacia mangium* were planted along with teak in separate blocks with four replications to study the changes, if any, that these short rotation leguminous trees can imprint on the soil. It was seen that both the species of acacias were able to improve soil aggregation and nitrogen availability though they were found to be instrumental in reducing the soil pH which is not good for the acidic soil that is present in the sites. Litter fall was maximum in *Acacia mangium* (6077 kg/ha) which was followed by *Acacia auriculiformis* (5090 kg/ha) and *Tectona grandis* (3101 kg/ha). But litter decomposition was much faster in teak compared to the acacias. It took only an year for all the teak litter to decompose while only 93% of *A. auriculiformis* and 83% of *A. mangium* could decompose in an year's time. Root nodulation was present in both the acacia species. Nitrogen content of soil in the acacia plots was found to be more than that in the teak plots.

INTRODUCTION

Crop rotation is an accepted practice in agriculture to restore the soil health by cultivating another crop that is different from the main crop in its demand on soil. Legumes are normally rotated with cereals to obtain the desired effects. But such a practice is uncommon in forestry due to the long gestation period of forest trees.

Teak (*Tectona grandis*) is the main species raised on a plantation scale by the Kerala forest department. Cultivation of teak on the same site over several rotations has been found to cause land degradation due to its selective demand on the soil for nutrients as also the ill effects of monoculture that failed to provide adequate protection from the harmful effects of climate. Site quality deterioration due to continuous monoculture of teak had been reported by Jose and Koshy (1972), Alexander et al, (1980), Thomas et al, (1997) and Balagopalan and Chacko (2001).

On an average 1000 ha teak is being felled and replanted every year (Prabhu, 2003) in Kerala and it has been general observation that the performance of teak declines with successive rotations on the same site. Crop rotation with suitable short rotation tree species has thus gained importance in teak silviculture. Exotic species are often introduced to rehabilitate degraded lands (Ashton et.al.,2001). *Acacia auriculiformis* is such an exotic species that has wide adaptability, capable of fixing atmospheric nitrogen (Sprent and Parsons,2000; Sankaran et al, 1993; Balasundaran et al, 2000) and enriching macrofaunal composition (Mboukou-Kimbatsa et al,1998), low allelopathic effects (Bernhard Reversat,1999) and ability to pump nutrients from the subsoil (Kang, 1993). Improvement in soil quality due to *A. auriculiformis* growth has been reported by many workers (Swamy, 1989; Jha *et al*, 1992; Mausbach and Seybold, 1998; Chazdon, 2003; Brockwell *et al*, 2005; Peng *et al*, 2005; Doi and Ranamukhaaracchi, 2007). At the same time introduction of such exotics may result in biological deserts and these species may spread to adjacent areas threatening native species (Hartley, 2002).

Acacia mangium is another species that has attracted attention due to its nitrogen fixing ability, straight bole and faster growth compared to *A. auriculiformis* and *T. grandis*. Considering these aspects Kerala Forest Department has raised experimental plots of *Acacia auriculiformis*, *Acacia mangium* and *Tectona grandis* in clear felled teak plantation sites at Nilambur and Thrissur to study the impact of acacia species on the soil and its properties and assess its feasibility for crop rotation. The present study was taken up in these research plots with the following objectives.

Objectives

1. To study the changes in soil physical and chemical properties and nutrient status in the experimental plots
2. To evaluate the litterfall pattern, rate of decomposition and incorporation of nutrients in the soil
3. To assess the site quality variation due to crop rotation

MATERIALS AND METHODS

Study Area

The study was carried out in the research plots established by the Kerala Forest Department in Vadapuram, Nilambur and Cheppilakkode, Thrissur. The research plots of 20 x20m were planted with *Tectona grandis, Acacia auriculiformis* and *Acacia mangium* in the year 2005 at 2 x2m spacing in randomized block design with 4 replications. Thus there were 12 plots at each site.

Nilambur Site

The site at Vadapuram, Nilambur is on the banks of Karimpuzha with deep fertile alluvial soil. The growth of all the three species are good. The area gets around 2500-3000mm rainfall distributed mainly over the two monsoons.

Thrissur Site

The site at Cheppilakkode in Thrissur is on gentle to steep terrain with lateritic soil in the sloping parts and deep fertile soil in the gently sloping areas. Growth of the trees vary with the site and its quality. Cheppilakkode also receives around 2500-3000mm rainfall.

Soil sampling and analysis

Soil samples were collected from the surface upto a depth of 60cm in three equal layers of 20cm depth. Three soil pits were taken from each plot. Core samples were collected separately for bulk density and big clods for aggregate stability estimation. Soil samples were air dried, passed through 2 mm sieve and subjected to analyses following procedures given in ASA Monograph (1965) and Jackson (1973). Sand, silt and clay (0.02-2, 0.002-.02 and < 0.002mm) were determined by hydrometer and particle density (PD) by using standard flask. Water stable aggregates were quantified using a Yoder type wet sieving apparatus; pH in 20:40 soil: water suspension and organic carbon (OC) by potassium dichromate-sulphuric acid wet digestion. Exchange acidity (EA) was determined by 0.5 N barium acetate and exchangeable bases by 0.1 N hydrochloric acid. Nitrogen (N) and Phosphorus (P) were estimated by autoanalyser, potassium (K) by colorimeter and calcium (Ca) and magnesium (Mg) by Atomic Absorption Spectrometry. Mean Weight Diameter (MWD) was calculated using the formula MWD = $\Sigma x_i w_i$ where x_i is the mean diameter of a particular size class and w_i is the weight in that range as a fraction of the total sample weight.

Litter fall and decomposition

In each plot, 5 litter traps of 1m diameter bamboo baskets were kept and litter samples collected at monthly intervals and quantified. Litter bag technique (Anderson and Swift, 1983) was employed to study the pattern and rate of litter decomposition and nutrient release of the three species. Fifty grams of oven-dried leaf litter of *Tectona grandis*, *Acacia auriculiformis* and *Acacia mangium* were kept in 0.5cm mesh litter bag of size 35 cm × 35 cm and laid in the respective plots. Thirty six litter bags were laid randomly in each plot so that 3 bags could be retrieved every month. The bags were carefully taken to the laboratory, the contents emptied and extraneous materials such as soil, visible animals and fine roots were removed. The sample was oven-dried at 70 ^{o}C to constant weight and analysed for N, P, K, Ca and Mg contents.

The exponential model of Olson (1963), $X/X_0 = e^{-kt}$ was used to estimate the annual decomposition rate of litter, where ‘X’ is the weight of litter remaining after time ‘t’, ‘X_0’ is the initial weight of litter, ‘e’ is the base of natural logarithm and ‘k’ is the decomposition rate constant. This model was also used to calculate the half life of litter decomposition. Statistical analysis of data was carried out by SPSS 10.0 package.

Root nodulation

Nodulation was estimated by exploring an area of 1m radius around trees selected at random by carefully removing soil particles from roots and exposing the roots and the nodules attached to it to a depth of 10cm. The resultant volume works out to 0.314m^3 of soil. The method, though cumbersome and destructive to some extent was adopted after trying out core samples at radial distances in different directions and ascertaining the superiority of the preferred method. The nodules were graded into small, medium and large categories in the size range of 1- 5mm, 5-8mm and 8-10mm. Nodules bigger than 10mm were not obtained. Sampling was done around 3 trees in each plot to obtain a representative estimation.

RESULTS AND DISCUSSION

Results of soil analysis, litterfall and litter decomposition as well as root nodulation are presented in the following tables 1-15 given below.

Soil physical properties

The physical properties of soil samples in three different depths of 0-20, 20-40 and 40-60cm are given in tables 1-4. It can be seen from the tables that there was not much difference in the soil particle size separates between the plots of *T. grandis*, *A.auriculiformis* and *A. mangium*. The soil was coarse textured with about 70 to 83% sand 12 to 19% silt and 6 to 12% clay. The sand content decreased slightly with depth while the finer separates of silt and clay registered a slight increase. Bulk density (BD) value of the soil ranged from 1.02 to 1.4gcm^{-3} with slightly lower value in the surface horizons. Bulk density was lesser in the acacia plots compared to the teak plots. Particle density (PD) values ranged from 2.34 to 2.43 g cm^{-3} and did not have any pattern of variation with soil depth or with the species. Porosity values ranged from 46 to 54% and was found to be higher in the acacia plots irrespective of soil depth.

Table 1. Soil physical properties in 0-20cm depth

Species	Sand %	Silt %	Clay %	BD gcm^{-3}	PD gcm^{-3}	Porosity %
T. grandis	78 ± 4*	14 ± 2	8 ± 2	1.2 ± 0.1	2.40 ± 0.03	50
A. auriculiformis	79 ± 4	14 ± 2	9 ± 2	1.1 ± 0.1	2.38 ± 0.04	54
A. mangium	77 ± 5	15 ± 2	8 ± 3	1.1 ± 0.1	2.39 ± 0.04	54

*Standard deviation

Table 2. Soil physical properties in 20-40cm depth

Species	Sand %	Silt %	Clay %	BD gcm^{-3}	PD gcm^{-3}	Porosity %
T. grandis	76 ±5*	15 ±3	9 ±2	1.3 ±0.1	2.40 ±.003	46
A. auriculiformis	77 ±6	16 ±2	7 ±2	1.2 ±0.1	2.38 ±0.04	50
A. mangium	76 ±5	15 ±3	9 ±3	1.2 ±0.1	2.39 ±0.04	50

*Standard deviation

Table 3. Soil physical properties in 40-60cm depth

Species	Sand %	Silt %	Clay %	BD gcm^{-3}	PD gcm^{-3}	Porosity %
T. grandis	75 ±4*	16 ±3	9 ±2	1.3 ±0.1	2.40 ±0.03	46
A. auriculiformis	76 ±4	15 ±3	9 ±2	1.2 ±0.1	2.40 ±0.04	50
A. mangium	75 ±5	16 ±3	9 ±3	1.2 ±0.1	2.40 ±0.04	50

*Standard deviation

Soil aggregates of bigger size (4.76 – 6 mm) fractions were found to be more (22%) in *A. auriculiformis* plots. *A. mangium* plots had slightly lower (18%) percentage of such aggregates and still lower values (15%) were obtained from *T. grandis* plots. Aggregates in the size range of 2 - 4.76 mm was found to be 6.8% in T. grandis, 5.2% in A. auriculiformis and 5.6% in *A. mangium* plots. The respective values in 1-2mm size class were 8.2, 6.4, and 7.56% and that in the smallest size class of 0.2-1mm was 7.2, 5.3 and 6.34 percent. Thus it can be seen that the smaller size aggregates were comparatively more in T. grandis plots which was followed by *A. mangium* plots and *A. auriculiformis* plots. Mean weight diameter (MWD), an index of aggregate stability was highest with a value of 1.5 in *A. auriculiformis* plots. *A. mangium* plots had a value of 1.3 while a mean weight diameter of 1.2 was recorded from *T. grandis* plots.

Table 4. Aggregate stability

Species	0.21-1mm	1-2mm	2-4.76mm	4.76-6mm	MWD
T. grandis	7.2	8.2	6.8	15	1.2
A. auriculiformis	5.3	6.4	5.2	22	1.5
A. mangium	6.34	7.56	5.6	18	1.3

It was thus seen that the coarse textured soil with around 70-80% sand, 12-19% silt and 6-12% clay did not exhibit any significant difference in the texture and the particle density of 2.4 gcm^{-3}. Differences were noticeable in bulk density values which were lower and porosity values that were higher in acacia plots compared to teak. These results can be due to the greater proportion of bigger sized aggregates in acacia plots that leads to lower bulk density and higher porosity.

Soil chemical properties

Chemical properties of the soil samples from the experimental plots are given in tables 5-7 below. Soil pH values were found to be in the range of 5.3 - 6.4 in *T.grandis* plots , 4.7 - 5.9 in *A. auriculiformis* and 5.0 - 5.6 in the *A. mangium* plots. The differences in pH values were consistent with the species irrespective of soil depth. Organic carbon (OC) contents were found to range from 12.2 – 13.0 gkg^{-1} in *T. grandis* plots, around 16.8 gkg^{-1} in *A. auriculiformis* plots and 13.8 - 14.6 gkg^{-1} in *A. mangium* plots in the surface layer of 0-20cm soil. Lower values of around 6.6 - 7.4, 8.22 - 8.5 and 7.2 - 8.0 in the 20-40 cm layer and 5.4 - 6.4, 4.7 - 5.9 and 5.0 - 5.6 gkg^{-1} in the 40-60cm layer were recorded for *T. grandis, A. auriculiformis* and *A. mangium* respectively.

Table 5. Soil chemical properties in 0-20cm depth

Species	pH	OC g kg^{-1}	EA cmol kg^{-1}	EB cmol kg^{-1}	CEC cmol kg^{-1}
T. grandis	5.8 ^{a} ±0.5*	12.6^{a} ±0.4	62 ±8	54 ±7	116 ±7
A. auriculiformis	5.25 ^{b} ±0.6	16.8 ^{b} ±0.15	64 ±7	46 ±6	110 ±6
A.mangium	5.3 ^{b} ±0.3	14.2 ^{c} ±0.4	66 ±7	48 ±7	114 ±7

*Standard deviation; dissimilar alphabets as superscript indicate significant difference

Table 6. Soil chemical properties in 0-20cm depth

Species	pH	OC g kg^{-1}	EA cmol kg^{-1}	EB cmol kg^{-1}	CEC cmol kg^{-1}
T. grandis	5.9 ^{a} ±0.5*	7.0 ^{a} ±0.4	58 ±6	58 ±8	116 ±7
A. auriculiformis	5.3 ^{b} ±0.6	8.4 ^{b} ±0.15	59 ±7	50 ±8	109 ±8
A. mangium	5.3 ^{b} ±0.3	7.6 ^{c} ±0.4	60 ±8	50 ±6	110 ±7

*Standard deviation; dissimilar alphabets as superscript indicate significant difference

Table 7. Soil chemical properties in 40-60cm depth

Species	pH	OC g kg^{-1}	EA cmol kg^{-1}	EB cmol kg^{-1}	CEC cmol kg^{-1}
T. grandis	5.9 ^{a} ±0.5	4.2 ^{a} ±0.4	59 ±7	57 ±5	116 ±6
A. auriculiformis	5.35 ^{b} ±0.6	5.3 ^{b} ±0.15	58 ±8	54 ±6	112 ±7
A. mangium	5.3 ^{b} ±0.3	5.2 ^{c} ±0.4	58 ±6	52 ±6	110 ±6

*Standard deviation; dissimilar alphabets as superscript indicate significant difference

Exchange acidity (EA) was not much different between soil depths or between species though slightly lower values were obtained in *T. grandis* plots in the surface two layers while the third layer of 40-60cm depth did not show any difference between species. The surface soil of 0-20cm depth was found to have an exchange acidity value of around 62cmol kg^{-1} in *T. grandis* plots, around 64 cmol kg^{-1} in *A. auriculiformis* plots and around 66 cmol kg^{-1} in *A. mangium* plots. In the 20-40cm layer, the corresponding values were around 58, 59 and 60 and in the 40-60cm layer around 59, 58 and58 cmol kg^{-1}. The exchangeable bases (EB) , on the other hand were higher in teak plots as compared with acacia plots with around 54, 58 and 57 cmol kg^{-1} in the three soil depths. The corresponding values were around 46, 50 and 54 cmol kg^{-1} in *A. auriculiformis* plots and around 48, 50 and 52 cmol kg^{-1} in *A. mangium* plots. Exchangeable base values exhibited an increasing trend with depth in all the plots. Cation exchange capacity (CEC) was around 116 cmol kg^{-1} in *T. grandis* plots irrespective of soil depth. It was around 110 cmol kg^{-1} in 0-20 and 20-40cm and 112 cmol kg^{-1} in 40-60cm depths of *A. auriculiformis* plots. In the *A. mangium* plots, the CEC values were around 114 cmol kg^{-1} in the surface 0-20cm and around 110 cmol kg^{-1} in the succeeding layers.

Soil nutrient contents

Nutrient contents in the soil were estimated and the data is presented below in tables 8-10. Nitrogen content in the surface 0-20cm was found to lie in the range of 109-139 mg/kg in *T. grandis* plots, 120-158 mg/kg in *A. auriculiformis* plots and 128-148 mg/kg in *A. mangium* plots. The respective values in 20-40 cm depth were around 82, 94 and 92 mg/kg and 40, 48 and 46mg/kg in the 40-60cm depth. Nitrogen content was significantly different in the surface soil between the species with acacia plots registering higher values. The trend was similar in 20-40cm and 40-60cm depths also though not significant. Phosphorus content was very low in all the soil depths with values around 3-4mg/kg irrespective of species.

Potassium content in the 0-20cm layer was found to be in the range of 121-141 mg/kg in the T. grandis plots. It was around 122-132 mg/kg in *A. auriculiformis* plots while *A. mangium* plots contained 118-142 mg/kg of potassium. In the 20-40cm layer potassium contents were around 76 mg/kg in the case of T. grandis plots and 67 mg/kg each in the acacia plots. The potassium content in the 40-60cm depth was around 52, 54 and 55 mg/kg in the respective plots. Potassium content did not vary much between the species. Calcium content in the surface soil of T. grandis plots was found to vary from 304-346 mg/kg while in *A. auriculiformis* plots, calcium content ranged from 189-239 mg/kg and in *A. mangium* plots the values ranged from 189-225 mg/kg. In the 20-40cm soil layer the respective values were around 245, 158 and 175 mg/kg and in the 40-60cm layer around 250, 140 and 132 mg/kg. Calcium content in *T. grandis* plots were always more than that in the plots of acacia species and the differences were significant also. Magnesium content was found to vary from 200-231 mg/kg, 216-264 mg/kg and 219-255 mg/kg in the plots of *T. grandis*, *A. auriculiformis* and *A. mangium*. Magnesium content in 20-40cm soil was found to be around 187, 163 and 167 mg/kg and in the 40-60cm depth around 160, 115 and 112 mg/kg in the respective plots. Magnesium content was slightly more in the surface soil of acacia plots but the reverse was the trend in the subsurface soil layers with slightly higher values in the teak plots.

Table 8. Soil nutrient contents in 0-20cm depth

Species	N (mg/kg)	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
T. grandis	124 ^{a} ±15*	4 ±0.5	131 ±10	325 ^{a} ±21	215 ±16
A. auriculiformis	140 ^{b} ±18	5 ±0.8	127 ±5	214 ^{b} ±25	240 ±24
A. mangium	138 ^{b} ±10	4 ±1	130 ±12	207 ^{b} ±18	237 ±18

*Standard deviation;   dissimilar alphabets as superscript indicate significant difference

Table 9. Soil nutrient contents in 20-40cm depth

Species	N (mg/kg)	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
T. grandis	82 ^{a} ±15*	3 ±0.5	76 ±10	245 ^{a} ±21	187 ±16
A. auriculiformis	94 ^{b} ±18	3 ±0.8	67 ±5	158 ^{b} ±25	163 ±24
A. mangium	92 ^{b} ±10	3 ±1	67 ±12	175 ^{b} ±18	167 ±18

*Standard deviation; dissimilar alphabets as superscript indicate significant difference

Table 10. Soil nutrient contents in 40-60cm depth

Species	N (mg/kg)	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
T. grandis	40 [a] ±15	4 ±.5	52 ±10	250 [a] ±21	160 ±16
A. auriculiformis	48 [b] ±18	4 ±.8	54 ±5	140 [b] ±25	115 ±24
A. mangium	46 [b] ±10	4 ±1	55 ±12	132 [b] ±18	112 ±18

*Standard deviation; dissimilar alphabets as superscript indicate significant difference

Nitrogen content was more in the acacia plots, phosphorus was very low in content and without any pattern of distribution across plots or soil depth. Potassium content also did not have any trend in distribution. Calcium content was always more in the teak plots compared to acacias. Magnesium content was more in the surface soil of acacia plots while reverse was the trend in the succeeding soil depths. Significant difference was noted in the case of nitrogen and calcium only. Acacia plots had higher nitrogen content while teak plot had higher calcium content.

Litterfall

Litterfall was quantified monthly for two years and the data presented in table 11. It can be seen from the table that maximum amount of litter fell during the months of December to February in the case of *T. grandis* and September to February in the case of both *A. auriculiformis* and *A. mangium*. Annual litterfall was highest in *A. mangium* plots with 6077 kg/ha which was followed by *A. auriculiformis* with 5090 kg/ha and *T. grandis* with 3101 kg/ha of litter. Litterfall occurred in all the months of the year and the least quantity fell during the rainy months of June- July in the case of *T. grandis* while it was during the summer months of March-April that minimum litterfall occurred in the case of acacia species. Litter of *A. auriculiformis* consisted of 67% leaf, 6% inflorescence, 14% twig and 13% pod while the respective percentages in *A.mangium* was 70, 5,13 and 12% and in the case of *T.grandis* 90% of litter mass was contributed by leaf and 10% by twigs.

Figure.1 Litter traps in the field

Table 11. Litter fall (kg/ha)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T. g	583 ±19*	550 ±28	252 ±21	142 ±19	150 ±35	122 ±19	112 ±31	142 ±27	206 ±30	145 ±31	206 ±25	491 ±19
A. a	647 ±40	479 ±38	211 ±31	247 ±32	331 ±32	384 ±33	313 ±29	315 ±21	473 ±28	468 ±25	537 ±17	685 ±20
A.m	888 ±32	797 ±30	338 ±34	364 ±29	379 ±31	341 ±22	445 ±30	382 ±31	548 ±21	489 ±29	538 ±22	568 ±15

* standard deviation

Nutrient contents in fresh litter

Nutrient contents in fresh litter is shown in table 12. It can be seen that litter of *T. grandis* contained 0.73% nitrogen 0.72 % phosphorus, 0.60% potassium, 1.65% calcium and 0.26% magnesium. The corresponding values in the litter of *A.auriculiformis* were 1.02, 0.16, 0.64, 1.25 and 0.77 percent and in the case of *A.mangium* the values were 0.78, 0.07, 0.40, 0.78 and 0.23 respectively.

Table 12. Nutrient contents in fresh litter

Species	N%	P%	K%	Ca%	Mg%
Tectona grandis	0.73	0.721	0.601	1.654	0.265
Acacia auriculiformis	1.02	0.165	0.645	1.25	0.768
Acacia mangium	0.78	0.074	0.401	0.78	0.23

Litter decomposition

Litter decomposition pattern of the three species, namely, *Tectona grandis*, *Acacia auriculiformis* and *Acacia mangium* estimated employing the litter bag technique is depicted in table 13-14. It can be seen that decomposition of teak litter was completed in an years time. The rate was slightly less in the case of *A.auriculiformis* in which case 93% litter was lost through decomposition and still less in the case of *A.mangium* where only 83% was found lost during the same period of one year.

Figure.2. Litter bags laid in the field

Table 13. Percent loss in litter due to decomposition

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T. g	10	19	21	25	29	35	51	68	82	93	98	100
A.a	10	18	20	24	27	32	45	56	63	68	78	93
A.m	18	28	34	38	39	41	49	56	58	64	75	83

Table 14. Decomposition rate constant k (day^{-1}) and half life T $^{1/2}$ (days) decomposition of dry matter litter

Species	*Acacia auriculiformis*	*Acacia mangium*	*Tectona grandis*
k(day^{-1})	0.02	0.05	1.2
$T^{(0.5)}$	270	250	200

Decomposition rate constant (k) was lowest in the case of *A.auriculiformis* (0.02), slightly higher in the case of *A.mangium* (0.05) and much greater in *T.grandis* (1.2). Time required for half the litter to decompose, T $^{(0.5)}$ was found to be 270 days for *A.auriculiformis*, 250 days for *A.mangium* and 200 days for T.grandis.

Root Nodulation

Nodulation on the roots of both the acacia species were assessed and is depicted in table 15. It can be seen that the number, size and shape of nodules varied much between the species of *A.auriculiformis* and *A.mangium*. The size of nodules varied from 2mm to 10mm though most of nodules were in the range of 4mm to 8mm. Nodule size was more in *A.mangium* compared to *A.auriculiformis*. The shape of nodules also varied from oval to finger shaped and even irregular. Some of the nodules lacked the typical pink pigmentation of leghaemoglobin and such nodules were considered ineffective. Most of the nodules were attached to the medium to fine roots with least number on finest as well as coarsest roots irrespective of species. Nodules were found mostly in the 0-5cm topmost layer of soil and under decaying litter. Total number of nodules was more in *A.auriculiformis* while size of nodules was more in *A.mangium* soil. Number of nodules in the case of *A.auriculiformis* was found to be around 50 in the large category, 250 in the medium category and 2300 in the small category giving a total figure of 2600 numbers in 0.314 m^3 of soil. In the case of *A.mangium* the respective figures were 70, 150, 1850 and 2070 nodules in the same volume of soil.

Table 15. Root Nodulation

Species	GBH (cm)	Mean No. of nodules per plant			
		Large (8-10mm)	Medium (4-8mm)	Small (2-4mm)	Total
A. auriculiformis	45 ±10	50 ±12	250 ±58	2300 ±340	2600 ±420
A. mangium	60 ±8	70 ±15	150 ± 50	1850 ±225	2070 ±355

Figure.3. Root nodules of A.auriculiformis

Figure.4. Root nodules of A.mangium

Discussion

Crop rotation with short duration legume tree species like *Acacia auriculiformis* and *Acacia mangium* was found to influence the soil and its properties differently from *Tectona grandis*. Acacia species had both positive and negative effect on the soil. Bigger water stable aggregates were found to be more in the acacia plots compared to the teak plots; A. auriculiformis exerted comparatively greater influence in encouraging the formation of water stable aggregates. Mean weight diameter, an index of aggregate stability was higher in the acacia soils compared to that in teak plots. This might be due to higher amounts of fine roots that press the soil particles on the one hand as also exert differential pressure during absorption of moisture. These roots also contribute more towards humus on senescence. Bulk density was slightly less and porosity slightly more in the acacia plots as compared to the teak plots. Thus it was seen that both the acacia species were able to improve soil structure and associated soil physical properties.

Soil chemical properties were also influenced by the growth of the species differently. Exchange acidity was more and exchangeable bases less in the plots of acacia as compared to teak. This was seen reflected in soil pH values which were lower in the acacia plots. Similar results were reported by Sankaran et.al., (1993) also. Teak on the other hand was seen to improve the base status of the soil as is seen in the values of potassium and calcium compared to the acacias. Magnesium content as also contents of nitrogen and phosphorus were more in the acacia plots. Organic carbon content was more in acacia soil though the litter decomposition rate is lower than that of teak. Higher litterfall might have compensated for the lower decomposition rate cumulatively over the years. Microbial associations of mycorrhiza and rhizobium (Sankaran et al., 1993) would have assisted the acacias in solubilising phosphorus and fixing nitrogen. Root nodulation by rhizobium was present in both the species of acacias. Number of nodules was more in the case of *A.auriculiformis* while size of nodules was more in the case of *A.mangium*. Effective nodules were present in both cases.

Litterfall was maximum during the December- January months for all the three species though there was marked variation between the species; acacia species seemed to have an extended period of high litterfall compared to teak. Plants are adapted to utilise nutrients for biomass production maximum during periods of sufficient soil moisture. As the soil starts drying up, the tree starts shedding its foliage to reduce transpiration as well as evaporation losses. Litter decomposition was faster in teak; it was slower in A. auriculiformis and slowest in *A. mangium*. It took only an year for all the teak litter to decompose while only 93% of *A. auriculiformis* and 83% of *A. mangium* could decompose in an year's time. Low rate of acacia litter decomposition was reported by others also (Byju 1989; Swamy, 1989; Sankaran *et al*.,1993). Teak being an indigenous species, has co-evolved with the native climate and the native fauna so that its litter is easily decomposable. Acacia species that are exotics may not have this advantage. The decay rate of acacia litter remained lower in spite of the fact that litter with greater nitrogen content are known to decompose rapidly (Singh and Gupta, 1977; Meentemeyer, 1978). The high content of crude fibers in the phyllodes and the presence of thick cuticle (Widjaja, 1980; Byju 1989) and the higher lignin content of acacia litter (Kumar and Deepu, 1992) might be responsible for the slow decomposition. It is also reported that decomposition of lignin of nitrogen rich litters is significantly lower than those with poor nitrogen content (Berg *et. al*, 1992).

Decomposition rate constant, k, which gives an indication of the decomposability of litter ranges from 4 for climax tropical African forest to 0.25 for pine forest of south eastern United States to still lower values of 0.0625 for Minnesota pine down to 0.0094 for lodge pole pine at 3000 m altitude (Jenny *et. al* .,1949). The values of 0.02 for *A. auriculiformis* and 0.05 for *A. mangium* can thus be seen to be in the lower range of pine forests with low decomposition rate while k value of 1.2 in the case of teak is definitely indicative of faster decomposition.

CONCLUSION

Thus, it can be concluded from the limited period observation of the present study that both the species of acacias, namely *Acacia auriculiformis* and *Acacia mangium* had both positive and negative influence on soil and its properties. It had a positive effect in soil aggregation and nitrogen enrichment while the negative influence results from the acidifying nature and the slow rate of decomposition. Litter fall was highest in *A.mangium* followed by *A. auriculiformis* and *T.grandis* while litter decomposition was faster in T.grandis followed by *A. auriculiformis* and *A.mangium*. Root nodulation was present in both the species with higher numbers in *A.auriculiformis* plots. Rotation with acacia on degraded sites for a short period seems to be an option to improve some of the soil properties.

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