COCOS (1996), 11, 40 - 52
Printed in Sri Lanka

ROLE OF *Gliricidia sepium* ON PHYSICAL IMPROVEMENT OF GRAVELLY SOIL

L P Vidhana Arachchi and M de S Liyanage

Coconut Research Institute, Lunuwila, Sri Lanka

ABSTRACT

The Andigama soil series, which is widespread in coconut lands, is known to have poor physical characters restricting palm growth and yield in the intermediate zone of Sri Lanka. This study was carried out to investigate the possibility of improving degraded soil conditions of Andigama series by intercropping with *Gliricidia sepium* under coconut. *Gliricidia sepium* was established in a 45 year old coconut plantation in double rows of 2 m x 1 m and arranged in a Randomized Block Design with four replicates. The effect on soil physical characters such as texture, bulk density, aeration capacity, moisture retention and root distribution pattern of *Gliricidia sepium* were studied.

Results revealed that clay fraction cemented with gravel significantly increased ($P<0.05$) bulk density (1.62 ± 0.07). It acts as a physical barrier and reduced readily available water fraction in B horizon. The available water fraction in A, AB and B horizons decreased by 66% before reaching 1 bar (100 kPa) suction in 7, 9 and 11 days respectively during the dry period. Root proliferation of *Gliricidia sepium* through hard layers significantly reduced the bulk density ($P<0.001$) which resulted in improving aeration capacity, total and readily available water. Moreover, results showed that with the improved soil conditions by *Gliricidia sepium*, coconut root growth also increased by 5.3%, 91% and 21% in A, AB and B horizons respectively. These studies strongly suggested that *Gliricidia sepium* plays a major role in improving physical characters of infertile gravelly soils.

INTRODUCTION

Due to the low income level from coconut monocultures and fluctuating prices, high priority is given to optimize the use of land and other resources for increasing land productivity of coconut. Numerous studies have been undertaken to achieve this target through several agronomic practices, especially, by improving fertility status of soil (Liyanage *et al.*, 1993). However, very little attention has been given to study the possibility of improving coconut lands with marginal soils by introducing multipurpose tree species.

Gliricidia has a great potential as a multipurpose tree in agroforestry systems, and could be useful in improving the gravelly soils such as Andigama series, which occur in large extents in the low country intermediate zone of Sri Lanka.

The Andigama series is a moderately well drained, shallow to moderately deep, sandy clay loam soil mixed with a considerable amount of iron stone gravel and classified under the great group of Red Yellow Podzolic soil. In general, this series has moderate to severe limitations against moisture availability and root penetration of coconut due to adverse soil physical characters. The occurrence of a hard, compact, iron stone gravel layer in Andigama series at a depth of 30-75 cm from the surface hinders the root penetration seriously (Vidhana Arachchi *et al.*, 1994).

In addition, low available water and poor aeration capacity in soil restrict root growth and their physiological functions (Brady, 1990). Hence, clear identification of the limitations and improvement of unfavorable soil physical characters such as poor aeration capacity and low availability of water in low productive soils such as Andigama series is important in order to increase coconut production.

Multipurpose tree species have the ability to reserve more carbohydrates in their roots (Combbin, 1994). Reserved carbohydrate could have ability to compensate soil physical stress by providing more energy. Hence, multipurpose trees could be capable of breaking down hard layers of soil, resulting in improving soil physical conditions. Moreover, low cost agronomical methods such as growing Gliricidia to improve infertile soils is economically viable and scientifically sound. The objective of this study was to investigate the possibility of improving poor soil characters of Andigama series by adopting an agroforestry system with Gliricidia and coconut.

MATERIALS AND METHODS

The experiment was established during December 1990 at Rathmalagara Estate, Madampe in the Low Country Intermediate Zone (08° 02 N, 79° 50 E; 35 m altitude) of Sri Lanka in Andigama series belonging to the Red Yellow Pod Zolic group . The mean annual rainfall and ambient temperature were 1660 mm and 23.8°C-30.4°C, respectively.

Ten soil pits (1.0 x 1.5 x 1.5 m) were cut randomly in different location under coconut monoculture for accurate representation of the Andigama soil series. The examination of the soil profiles of experimental sites showed three distinct soil horizons namely, A, AB and B corresponding to 0-15, 15-50 and 50-100 cm depth respectively.

Samples were taken from each 5-cm up to 1.3 m depth for the analysis of texture and gravel percentage. Sieves of different mesh size (12, 5, 3, and 2 mm) were used to determine the percentage of gravel sizes. Undisturbed soil core samples using steel core of 7.5 cm diameter and 5 cm in height were obtained for bulk density and 4.5 cm in diameter and 3.5 cm in height for soil water relationships.

Undisturbed core samples for soil water determination were transferred to aluminum rings (4.5 x 3.0 cm). These samples were saturated and water retention measurements were taken using standard pressure plate apparatus for thirteen suction intervals ranging from 1 - 1500 kPa. The gravimetric water content at each suction level was estimated and converted to the volumetric water content using the corresponding bulk densities. The mean values of volumetric water content between 10 kPa and 100 kPa suction was used to calculate the percentage of readily available water fraction of all three soil horizons of Andigama series (Mapa and Bodhinayake, 1988). Moisture depletion pattern was also estimated as a percentage of available water under different suction increments.

Hydrometer method was used for soil texture analysis (Gee and Bauder, 1986). Total porosity was obtained using bulk density and particle density values. Particle density was assumed as 2.65 g/cm^3. Volumetric water content at saturation was estimated using porosity values. Water in pores which drained out at 10 kPa (Diameter 0.03 mm) were estimated as macropores and rest as micropores.

The same soil characters were evaluated under coconut (45 years old) intercropped with *Gliricidia sepium* (4 years old) in double rows of 2 m x 1 m and arranged in Randomized Block Design with four replicates to study the effect of *Gliricidia sepium* roots on adverse soil conditions of Andigama series.

Soil core samples (25 cm^3) were taken within the distance of 1.5 m, from the base of *Gliricidia sepium* towards the manure circle of coconut palm, and upto a depth 1.5 m represent A, AB and B horizon of Andigama series. Live *Gliricidia sepium* roots and coconut roots in each core sample were separated and their dry weight was taken by drying at 105°C for 24 hrs in the oven and total root mass of coconut and *Gliricidia sepium* was calculated for each horizon. Root system of *Gliricidia sepium* was exposed by using a power sprayer to observe the root distribution pattern in the soil profile.

RESULTS AND DISCUSSION

Soil Physical Characterization

The clay fraction and percentage of different gravel sizes (>12, 12-5, 5-3, 3-2 mm) were significantly ($P<0.01$ and $P<0.001$) respectively) higher in the B horizon than others. In the B horizon, gravel particles were cemented with clay fraction forming a hard layer of which the bulk density was significantly greater than that of other horizons (Fig. 1 & Table 1). Atwell (1988) reported that compaction of soils and natural impedance of sub soils often constitute a major barrier to root growth. The field capacity (17.96 $\pm$ 3.58 vol/vol) and permanent wilting percentage (14.31 $\pm$ 3.02 vol/vol) were significantly higher ($P>0.05$) in the B horizon compared to A and AB horizon but its available water fraction of B horizon was lower (36.5 mm/m). This is due to high compaction of clay fraction with gravel compared to the A and AB horizons. Result also showed that (Table 1) aeration capacity of A horizon of Andigama series is higher than AB and B horizons. The available water fraction in horizons A, AB and B decreased by 66% before reaching 1 bar (100 kPa) suction in 7, 9 and 11 days respectively during the dry period.

Effect of *Gliricidia* Root on Soil Physical Properties

Effect on Soil Particle Size and Bulk Density

Data in Fig. 1 and 2 showed the effect of *Gliricidia sepium* on percentage of gravel size classes and primary soil particles. Results revealed that percentage of gravel size class (>12 mm) significantly ($P<0.001$) decreased due to particle fragmentation by the root growth of *Gliricidia sepium*, specially in the B horizon. Overall results suggest that roots growth of *Gliricidia sepium* caused fragmentation of the gravel particles in AB & B horizons of Andigama series. Effect of this fragmentation by *Gliricidia sepium* roots significantly ($P<0.001$) reduced the bulk density of AB and B horizons over A horizon and coconut monocrop. Reduction in gravel size and bulk density improved soil physical conditions, specially B horizon of Andigama series. Gunasena *et al.*, (1991) observed that by growing *Gliricidia sepium*, soil bulk density was reduced and steady infiltration rate increased. This type of improvement through breaking of hard-pan by *Gliricidia sepium* roots would help to improve poor physical conditions of soil to enhance growth and development of coconut roots.

Furthermore, growth of *Gliricidia sepium* roots significantly increased sand fraction compared to the control, which resulted in increased of aeration capacity of Andigama series (Table 1). The fragmentation of gravel by roots of *Gliricidia sepium* also resulted in increase of sand fractions in Andigama series. Due to increase of sand fraction, clay and silt fraction were also proportionately decreased. Although clay and silt fraction are important for nutrient retention, this reduction could not make any significant change in nutrient retention due to high clay and silt content of Andigama series (Fig. 2) compared to other soil series.

Effect of Gliricidia sepium on Pore Size Distribution of Andigama Series

Results in Table 1 show that total porosity of A, AB and B horizons increased significantly by the root growth of *Gliricidia sepium*. As macropore volume represents the field air capacity (aeration capacity) of soil, aeration capacity in each horizon was increased significantly under *Gliricidia sepium* (for A, $P<0.001$ and for AB and B, $P<0.01$) compared to the control. This increased aeration leads to increased drainage that could enhance coconut root growth and proliferation due to better functioning of respiratory organs. Joshua (1985) explained that aeration is the responsible process for maintaining the supply of oxygen to soil. Because of its direct involvement in respiration, oxygen is necessary for the proper functioning of roots and beneficial for decaying processes (Brady, 1990).

In addition, clay and silt fractions were found to be significantly lower ($P<0.001$) in *Gliricidia* grown plots than in the coconut monocrop. Roots of *Gliricidia sepium* caused fragmentation of larger gravel particles which increased total sand fraction throughout the soil profile. This process has contributed to an increase in aeration capacity of the Andigama series. Due to the increase of sand percentage, silt and clay fraction proportionately reduced which led to a reduction in moisture retention at field capacity (FC) and permanent wilting point (PWP) (Table 2). As micropore volume was higher in *Gliricidia sepium* grown AB and B horizons of Andigama series (Table 2), their moisture retention ability was higher compared to the coconut monocrop.

Effect of Gliricidia on Available Water

Results in Table 2 show that total available water in *Gliricidia* grown plots was significantly higher $P<0.001$), although their moisture retention capacity at field capacity and permanent wilting point was significantly lower than the control.

It has been reported that readily available water in root-soil interface is more important than the total available water, because this is the fraction which can be absorbed by the plant without any stress (Brady, 1990). Results in Table 2 show that the percentage increase of readily available water fraction as a percentage of the control in each treatment. Results revealed that growth of *Gliricidia sepium* resulted in an increase in percentage of readily available water fraction in AB and B horizons of Andigama series compared to the control, while *Gliricidia sepium* is likely to reduce percentage of readily available water fraction in A horizon, more than the control. However, *Gliricidia sepium* is capable of improving the soil physical characters in Andigama series. This result proved that *Gliricidia sepium* has the ability to improve aeration capacity and available water retention capacity which resulted in increasing root growth and development of coconut. These results are supported by Senevirathna Banda and Sangakkara (1994) who reported that *Gliricidia sepium* enhanced moisture extraction from deeper layers of Rhodustalfs soil in the dry zone. In addition, Liyanage *et al.*, (1993) reported that *Gliricidia sepium* also has an ability to improve nutritional status of gravelly soils.

Table 1. Effect of alley cropping on soil bulk density and porosity for different soil horizons

Treatment	Bulk density (g/cm^3)	Total porosity (%)	Macro-porosity (%)	Micro-porosity (%)
Horizon A				
Coconut Monocrop	1.43	41.3	28.3	12.9
Alley Cropped	1.41	53.6	43.3	10.3
LSD	- NS	6.2 **	7.2 **	2.4 **
CV%	4.21	7.8	8.3	8.2
Horizon AB				
Coconut Monocrop	1.60	39.2	22.6	16.6
Alley Cropped	1.43	46.2	30.2	16.0
LSD	0.06 **	4.2 *	4.1 *	- NS
CV%	1.82	4.9	7.6	18.3
Horizon B				
Monocrop	1.62	35.2	21.2	14.0
Alley Cropped	1.33	50.2	33.6	16.6
LSD	0.13 **	5.6 **	13.2 *	- NS
CV%	4.12	8.6	17.3	26.1

LSD- Least significant difference, NS-Not significant;
$P<0.01$-*; $P<0.001$-**; $P<0.0001$-***

Table 2. *Effect of alley cropping on Field capacity (FC), Permanent wilting point (PWP), Available water (Av. W.) and Readily available water (R. Av. W.)*

Treatment	FC	PWP	Av. W.	R. Av. W.
	<------------------------		Volumetric (%)	------------->
Horizon A				
Coconut Monocrop	13.2	8.70	4.5	2.94
Alley Cropped	9.6	2.20	7.4	4.30
LSD	1.4 **	1.1 ***	2.2 **	
CV%	5.3	8.4	9.3	
Horizon AB				
Coconut Monocrop	14.3	10.3	4.0	2.82
Alley Cropped	16.0	4.5	11.5	7.78
LSD	2.0 *	0.8 ***	3.5 ***	
CV%	5.8	4.6	6.8	
Horizon B				
Coconut Monocrop	18.0	14.3	3.7	2.26
Alley Cropped	14.9	7.1	7.8	6.17
LSD	1.9 **	1.1 ***	3.2 **	
CV%	4.95	4.34	8.8	

LSD - Least significant difference; NS-Not significant; P<0.01-*; P<0.001-**

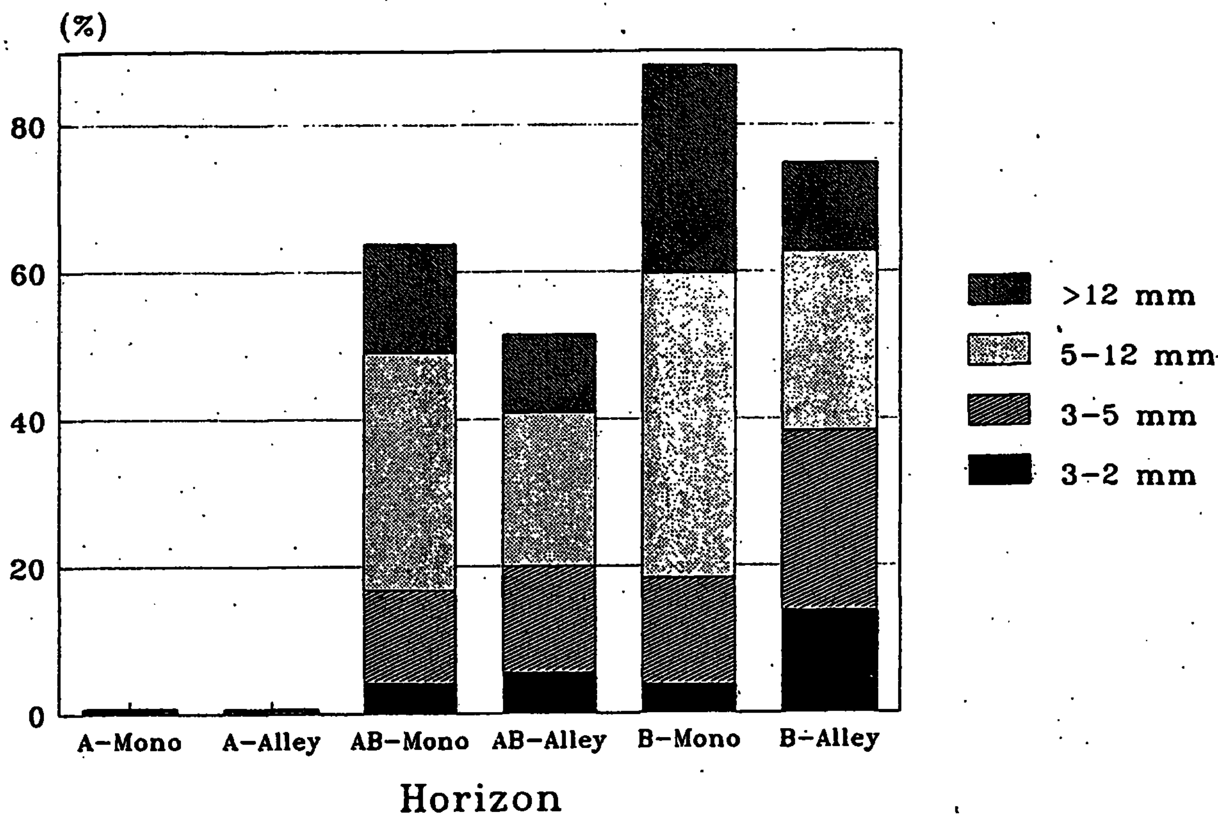

Figure 1 Gravel content in Mono and Alley cropped treatments.

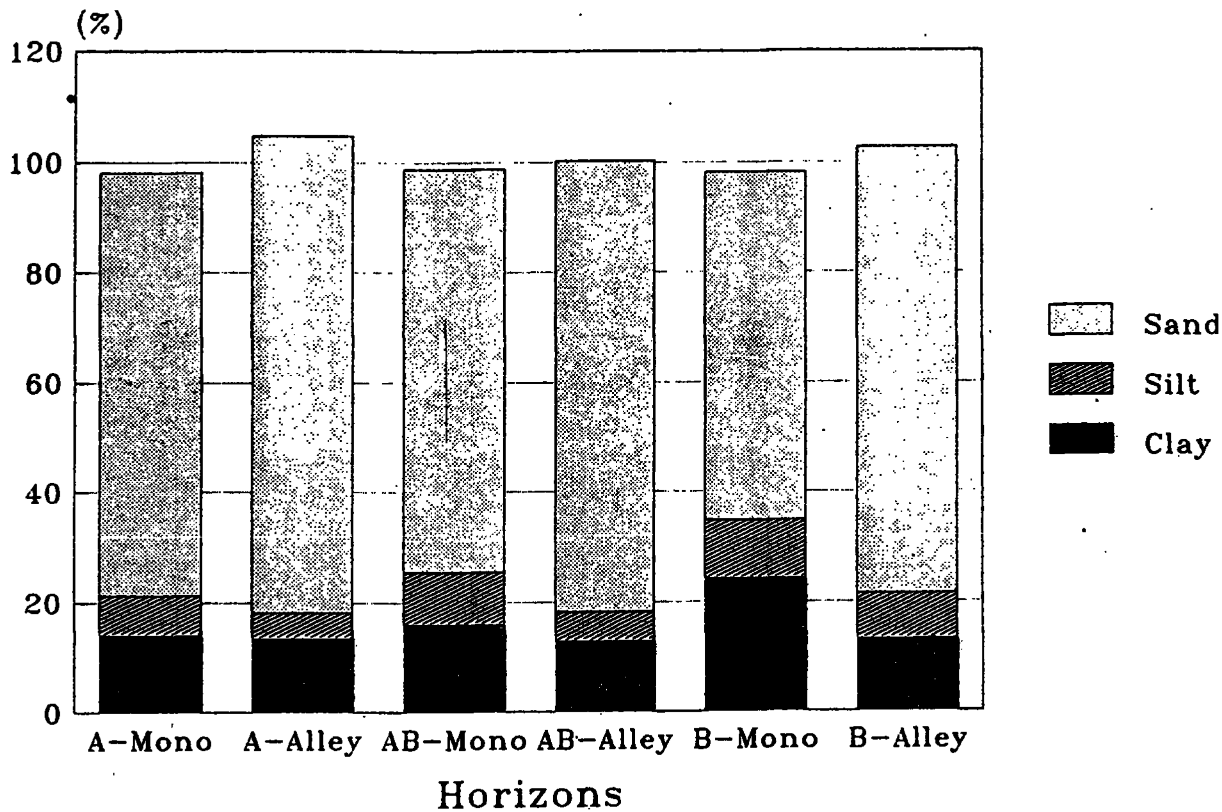

Figure 2 **Primary particles in Mono and Alley cropped treatment**

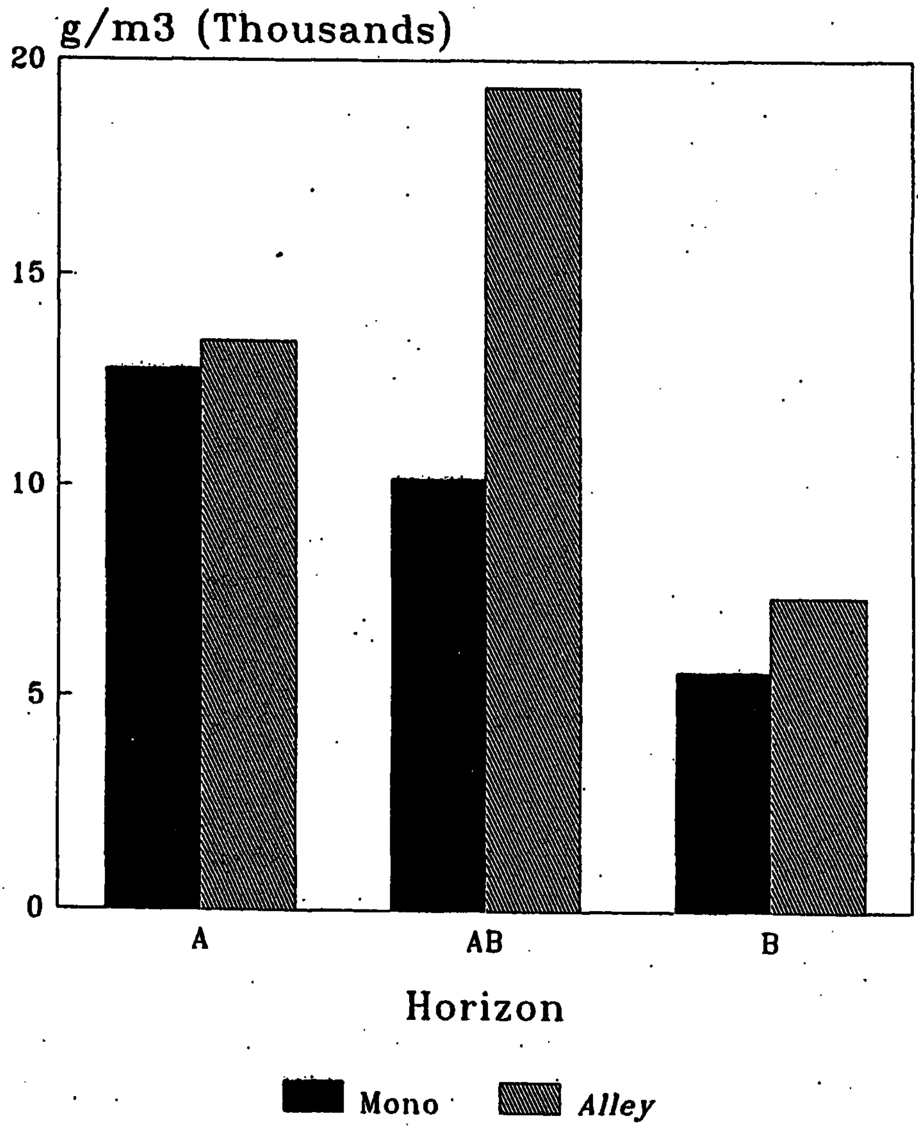

Figure 4 Root distribution of coconut

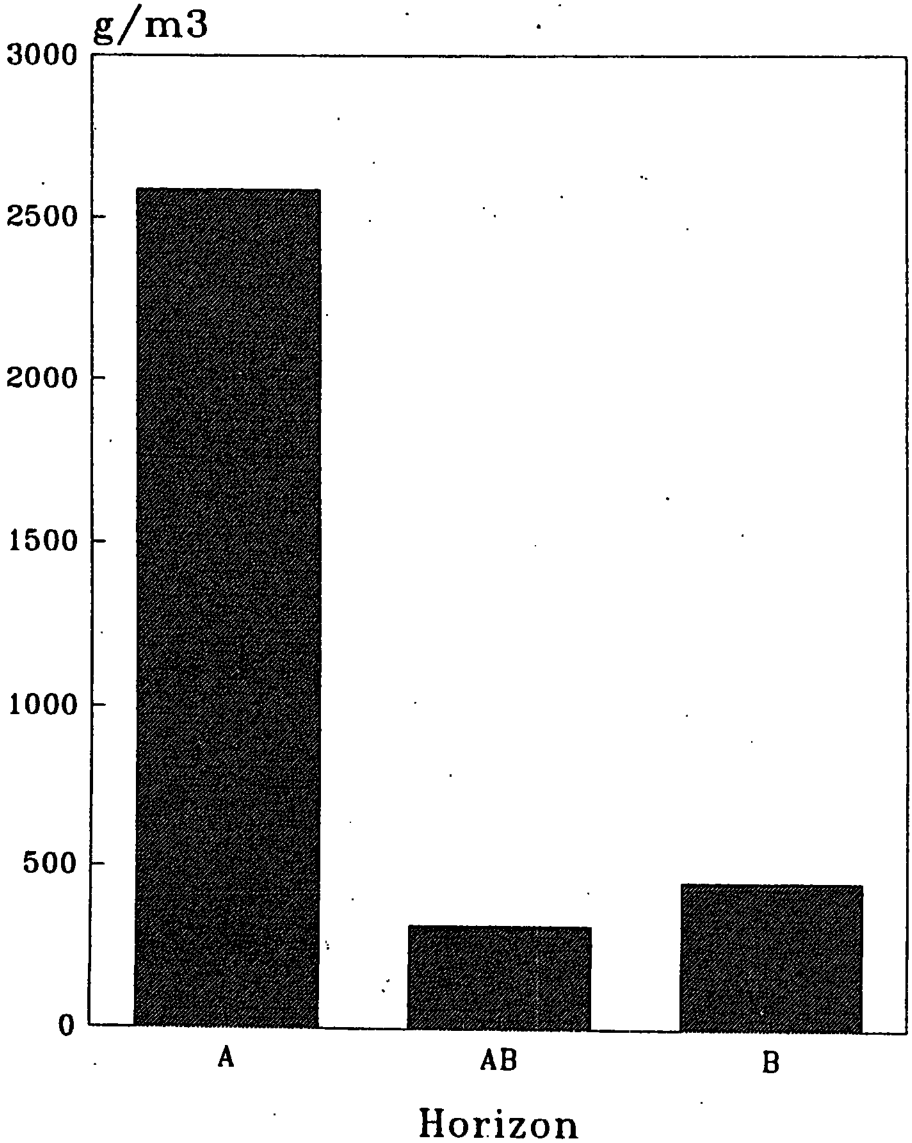

Figure 3 **Root distribution of Gliricidia**

Root Distribution

Mean values of root mass of coconut within the distance between *Gliricidia sepium* and manure circle of coconut palm is shown in Fig. 3. Results revealed that coconut root proliferation decreased with increasing depth of soil profile. The highest root growth of coconut in monoculture was found to be in the A horizon (12765 g/m^3). Results also showed that the vertical growth of coconut roots was confined to 1.25 m depth.

Root growth of *Gliricidia sepium* throughout soil profile was limited up to 1.25 m depth and 1.5 m distance away and, the highest root growth (2586 g/m^3) was observed in the A horizon (Fig. 4). The highest coconut root growth (19355 g/m^3) in *Gliricidia sepium* grown plots was observed in AB horizon compared to the A and B horizons and the control ($P<0.01$) when coconut was intercropped with *Gliricidia sepium* (Fig. 3 & 4). This result proved that roots of *Gliricidia* are much effective for improving soil conditions which favor coconut root growth. Overall results revealed that with the improved soil condition by *Gliricidia sepium*, coconut root growth also increased to 5.3%, 91% and 21% in A, AB and B horizons respectively. Moreover the total root mass of coconut within the depth under investigation was significantly ($P<0.01$) higher in plots under *Gliricidia sepium* compared to coconut monocrop.

However, results also suggested that higher coconut root growth in AB and B horizon caused by getting benefits from alley cropping and that could also result in improving soil physical conditions in AB and B horizons in Andigama séries.

CONCLUSION

It is evident from the results, that roots of *Gliricidia sepium* effectively penetrated to B horizon of soil profile of Andigama series and reduced its bulk density and increased aeration capacity itself. Not only that but *Gliricidia sepium* is also capable of improving total available water fraction throughout soil profile of Andigama series upto 1.25 m depth, resulting in enhanced coconut root growth and proliferation.

ACKNOWLEDGEMENTS

Authors wish to thank the Head, Agronomy Division, Coconut Research Institute, Sri Lanka for providing facilities to carry out this study and Mr. H. A. Abeysoma and Mr. K. R. E. M. Fernando for their invaluable assistance.

REFERENCES

Atwell, B. J. (1988) Physiological responses of lupin roots to soil compaction. *Plant and Soil* iii. 277-281.

Brady, N. C. (1990). Physical properties of mineral soils. In *the Nature and Properties of Soils.* 10th edition pp. 91-175.

Cobbin, J. (1994). Strategies for increased fodder production from *Leucaena* and *Gliricidia* to eliminate dry season feed shortages in the humid tropics. *International Tree Crops Journal*, Vol. 8, 27-35.

Gunasena, H. P. M., Mapa, R. B. and Pushpakumara, D. K. N. G. (1991). Effect of alley cropping on soil physical and chemical properties in the mid country intermediate zone. *Proceedings of the fourth regional workshop on multipurpose trees*, Kandy, Sri Lanka, P. 78-92.

Gee, G. W., and Bauder, J. W. (1986). Particle-size analysis. *In* Method of soil analysis. *Part 1. 2nd Ed. ASA Monograph 9. Ed: A. Klute.* pp. 404-411. Am. Soc. Agron. Wisconsin, USA. Deanna.

Joshua, W. D. (1988). Physical properties of Reddish Brown Earth soils (Alfisols) and their relationship to agriculture, *J. Soil. Sci. Sri Lanka* 5: 1-42.

Liyanage, M. de S., Bastian, M. and Wijeratna, A. M. U. (1993). Performance of four multipurpose tree species under coconut plantation in Sri Lanka. *Proceedings-fourth regional workshop on multipurpose trees, Kandy, Sri Lanka.* p. 80-89.

Mapa, R. B. and Bodhinayake, W. L. (1988). Characterization of soil moisture retention relationship in Non-Calcic Brown soils (Haplustalfs). *Tropical Agriculturist, Sri Lanka.* 144: 145-153.

Senevirathna Banda, K. M. and Sangakkara, U. R. (1994). Influence of alley cropping on moisture depletion of a Rhodustalf soil in the dry zone of Sri Lanka. *Proc. fifth regional workshop on multipurpose trees, Kandy, Sri Lanka.* 21-29.

Vidhana Arachchi L. P., Mapa, R. B., Yapa, P. A. J. (1994). Characterization of soil physical properties and moisture retention in Andigama series. *Annual Session of Sri Lanka Association for the Advancement of Sciences. Colombo,* B-85. Sri Lanka.