

# Performance of Medium term Agro-Forest treespecieson hard Laterite Soils

S.C. Somasiri<sup>1,2\*</sup>, M. K. F. Nadheesha<sup>3</sup> and S. Ediriweera<sup>4</sup>

<sup>1</sup>Department of Animal and Food Sciences, Faculty of Agriculture, Rajarata University of Sri Lanka, Sri Lanka

<sup>2</sup>Former address: Agronomy Division, Coconut Research Institute, Sri Lanka

<sup>3</sup>Soils and Plant Nutrition Division, Coconut Research Institute, Sri Lanka

<sup>4</sup>Department of Science and Technology, UvaWellassa University, Badulla, Sri Lanka

**Abstract**— A long term research was initiated in 1999 using medium term agro-forest trees in a shallow Andigama series soils having a hard laterite gravel layer. The present paper focuses on the growth and survival of the medium term forest tree species planted in 1999 and their performance by the year 2016. *Acacia* species had the fastest ( $P < 0.05$ ) growth in terms of tree diameter at breast height (DBH) during the time period (1999-2016) followed by *Macaranga peltata*, *Gliricidia sepium* and *Tectonagrandis*. In contrast, *Swietenia macrophylla* had the lowest ( $P < 0.05$ ) growth during the same period. Further, *Bridelia moonii* had a lower ( $P < 0.05$ ) growth compared to *Acacia* species and *Macaranga peltata* but not different from other species. Thus *Acacia* species, *Macaranga peltata*, *Gliricidia sepium* and *Tectonagrandis* could be selected as better agroforest tree species for medium term basis to be grown in hard laterite soils in Andigama soil series Shallow Phase.

**Keywords**—agroforest tree species, Andigama soil series, hard laterite soils.

## I. INTRODUCTION

The soils with laterites, a form of rock found in lowlands, uplands and highlands in Sri Lanka, are rich with ferrous, aluminium and silicon oxides due to the weathering process called laterization (Dahanayake, 1982). Depending on the severity of the weathering process these laterites can be either hard laterites or soft laterites. When it is hard laterites it is difficult to use for agricultural purpose unless the laterites are broken into soft laterites. Likewise, it has been noted that the expected growth and the yield could not be achieved when coconut palms are established in hard laterite soils (CRI Advisory Circular No. 1, 2008). It is mainly due to the shallow top soil layer followed by a hard lateritic layer obstructing coconut roots to penetrate/break into the deeper soil layers.

The Andigama series soil found in Andigama area is one of soils used for cultivating coconuts in Sri Lanka (Somasiri et al., 2006). This soil series belongs to the Red Yellow Podzolic Great Soil Group with a gravel

layer. Andigama soil series is divided into three phases considering the depth; Moderately Deep Phase, Shallow to Moderately Deep Phase and Shallow Phase. Parrotta et al., (1997) documented that there is a possibility of improving soil physical and chemical properties by establishing deep rooted tree plantations. Thus, a research was implemented in 1999 to improve the Andigama soil series Shallow phase using medium term agro forestry tree species. The present paper focuses on the growth and survival of the medium term agro forest tree species planted in 1999.

## II. METHODOLOGY

Experimental site was located at the Rathmalagara Research Centre, Coconut Research Institute (Longitude 7.5° 32' N and Latitude 79° 53' E) in the Puttalam district (North western Province) in agro-ecological zone IL<sub>1a</sub> in the intermediate low country, Sri Lanka (Punniyawardena, 2008).

Ten medium term agro forest tree species that were commonly found in the area were planted in an area of one hectare in a layout of Randomized Complete Block Design with three replicates in October 1999 (Table 1). Initially one replicate had 10 plants of the respective species. The soil series at the site was Andigama soil series Shallow Phase with a hard laterite gravel layer at various depths. The initial depth of top soil was 15 cm in average.

Table.1: The scientific names of 10 forest tree species selected for the study in 1999

Species	Family
<i>Acacia auriculiformis</i>	Fabaceae
<i>Acacia mangium</i> provenance 1	Fabaceae
<i>Acacia mangium</i> provenance 2	Fabaceae
<i>Calophyllum inophyllum</i>	Clusiaceae
<i>Grewia tilifolia</i>	Tiliaceae
<i>Macaranga peltata</i>	Euphorbiaceae
<i>Gliricidia sepium</i>	Fabaceae
<i>Tectonagrandis</i>	Lamiaceae
<i>Swietenia macrophylla</i>	Meliaceae

*Brideliaretusa*

Euphorbiaceae

One year old seedlings of each species were planted in a 30x30x30 cm planting hole. Spacing between plants varied depending on the plant species i.e. *Gliricidia sepium* 2x1 m, *Acacia* species 2x2m and for other species 2.5x2.5 m between and within row spacing. Plants were monitored closely and irrigated whenever needed at the seedling stage.

However, by the end of year 2002, only one replicate of *Grewiatiliifolia* and *Calophyllum elatum* species survived at the experimental site. Therefore, neither of those two species considered as a treatment in the present paper. Further, even though all replicates of the three *Acacia* species survived up to the year 2016, all three *Acacia* species were considered as one treatment and randomly selected any *Acacia* species from any block for data collection. At the beginning of experiment the parameters such as leaf litter content, weed biomass, weed species and soil organic matter contents were measured inconsistently. These data were presented and used in the discussion of this paper for the mere understanding of the growth and survival of these agro forest tree species. Tree girth at breast height (GBH) was measured at two heights (30 cm and 130cm) above ground using a tape during the years 2000, 2002, 2003 and 2016. Later, all GBH values were converted to diameter at breast height values (DBH). Tree diameter measurements were analysed using repeated measure analysis using the procedure for general linear

model (proc GLM) in SAS version 9.1 (SAS, 2002). The means were separated using least significant difference (LSD) procedure in proc GLM.

### III. RESULTS AND DISCUSSION

Six medium term forest tree species *Acacia* species, *Macaranga peltata* (Kenda), *Gliricidia sepium*, *Swietenia macrophylla* (Mahogany), *Bridelia moonii* (Ketakela) and *Tectona grandis* (Teak) survived during the period 1999 to 2016 except *Grewiatiliifolia* and *Calophyllum elatum* mentioned above.

*Calophyllum elatum* (Dombe) and *Grewiatiliifolia* (Damminna) did not survive after the year 2002. The reason could be the hard laterite soils presence at the experimental site was not supportive for their natural growth as *Eldridge et al.*, (1994) observed with *Eucalyptus deglupta* species. The above authors have noted that *Eucalyptus deglupta* would not survive in degraded soils as it thrives in well-drained tropical alluvial soils naturally. Similarly, *Calophyllum elatum* and *Grewiatiliifolia* may not be successful in hard laterite soils. It was documented in *Annual Report* (2000), *Calophyllum elatum* had the lowest growth rate and was susceptible to drought and pests during the early growth stages. Thus *Calophyllum elatum* being grown in an unfavourable hard laterite soils plus its inability to withstand the drought and pest conditions could be the reasons for not surviving at the experimental site.



Fig.1: An uprooted *Acacia* tree at the experimental site in 2016

By the mid of year 2016, there were number of trees of *Acacia* species, *Macaranga peltata* (Kenda), *Gliricidia*

*sepium* (*Gliricidia*), *Bridelia moonii* (Ketakela) and *Tectona grandis* (Teak) were fall due to the effect of a

minor cyclone that swept through the area during May, 2016. Field observations showed that the tap root was hard to distinguish in these uprooted trees (Figure 1). It may be due to the hard laterite layer at the experimental site

Diameter at 30 cm and 130 cm of the agro forest tree species in year 2000 and 2016 are given in Table 2. By the end of year 2000, *Acacia* species and *Macaranga peltata* were having significantly higher diameter at 30 cm and 130 cm heights in comparison with other agro forest tree species. In 2016, *Acacia* species reached the highest ( $P < 0.05$ ) growth rate compared to *Macaranga peltata* which in turn was higher ( $P < 0.05$ ) than that of *Gliricidia sepium*, *Swietenia macrophylla*, *Bridelia moonii* and *Tectonagrandis*. *Swietenia macrophylla* had the lowest ( $P < 0.05$ ) growth rate in 2016 after approximately 17 years of planting. *Gliricidia sepium* and *Tectonagrandis* had similar growth rates in 2016 while, the growth rate of *Bridelia moonii* was different ( $P < 0.05$ ) from *Acacia* species and *Macaranga peltata* but not differ ( $P > 0.05$ ) from other tree species.

During the early stage of the experiment leaf litter content, weed biomass, light availability at ground level and soil organic matter percentage were measured. The

obstructing the downward penetration of the tap root damaging its tip and causing it to branch as it grows as observed by Dobson (1995).

data is presented in Table 3. Annual Report (2001) showed that *Acacia mangium* provenance 2 had significantly higher ( $P < 0.05$ ) leaf litter content in the year 2001. *Acacia auriculiformis*, *Swietenia macrophylla* and *Bridelia moonii* had the lowest ( $P < 0.05$ ) leaf litter content compared to *Acacia mangium* provenance 2 (Annual Report 2001). The leaf litter content in *Acacia mangium* provenance 1, *Macaranga peltata*, *Gliricidia sepium* and *Tectonagrandis* were similar. However, by the year 2016 (Table 4) leaf litter content of *Tectonagrandis* was higher ( $P < 0.05$ ) than *Acacia* species, *Swietenia macrophylla*, *Bridelia moonii* and *Macaranga peltata* but not different from *Gliricidia sepium* (Bandara et al., 2017). Lugo et al., (1991) observed that the floor litter content in a tropical plantation having indigenous tree species ranges from 500 to 2800 g per m<sup>2</sup>. Further, supporting the above finding, Stanley and Montagnini, (1999) stated that leaf litter accumulation in soils varies within a year depending on tree species supporting the findings of the present study.

Table.2: Tree diameter (cm) measurements of the forest tree species

Forest tree species	Year			
	2000		2016	
	Diameter at 30 cm	Diameter at 130 cm	Diameter at 30 cm	Diameter at 130 cm
1 <i>Acacia</i> species	13.18 <sup>b</sup> ± 0.86	11.11 <sup>b</sup> ± 0.86	40.33 <sup>d</sup> ± 0.91	35.74 <sup>d</sup> ± 0.86
2 <i>Macaranga peltata</i> (Kenda)	12.59 <sup>b</sup> ± 0.86	10.63 <sup>b</sup> ± 0.86	30.31 <sup>c</sup> ± 0.86	28.44 <sup>c</sup> ± 0.86
3 <i>Gliricidia sepium</i>	6.93 <sup>a</sup> ± 0.86	5.86 <sup>a</sup> ± 0.86	27.25 <sup>b</sup> ± 0.86	22.89 <sup>ab</sup> ± 0.86
4 <i>Swietenia macrophylla</i> (Mahogany)	4.97 <sup>a</sup> ± 0.86	3.83 <sup>a</sup> ± 0.86	24.43 <sup>a</sup> ± 0.86	21.10 <sup>a</sup> ± 0.86
5 <i>Bridelia moonii</i> (Ketakela)	5.11 <sup>a</sup> ± 0.86	4.19 <sup>a</sup> ± 0.86	25.40 <sup>ab</sup> ± 0.89	22.91 <sup>ab</sup> ± 0.86
6 <i>Tectonagrandis</i> (Teak)	6.97 <sup>a</sup> ± 0.86	4.08 <sup>a</sup> ± 0.86	27.32 <sup>b</sup> ± 0.86	24.28 <sup>b</sup> ± 0.86

Different superscripts within columns differ significantly (a,b,c,d:  $P < 0.05$ )

Table.3: Leaf litter content, weed biomass level and Light availability at ground level and soil organic matter levels in the experimental site during the early stages of growth.

Forest tree species	2001 <sup>(1)</sup>	2002 <sup>(2)</sup>	2002 <sup>(2)</sup>	2005 <sup>(3)</sup>
	Leaf litter (Dry Weight basis (g/m <sup>2</sup> ))	Weed biomass (g/m <sup>2</sup> )	Light availability at ground level (lumen/m <sup>2</sup> )	Soil organic matter (%)
1 <i>Acacia auriculiformis</i>	92 <sup>a</sup>	63	13	2.3
2 <i>Acacia mangium</i> – provenance 1	327 <sup>bc</sup>	20	16	2.9
3 <i>Acacia mangium</i> – provenance 2	488 <sup>c</sup>	27	18	2.4
4 <i>Macaranga peltata</i> (Kenda)	188 <sup>ab</sup>	13	6	2.3
5 <i>Gliricidia sepium</i>	156 <sup>ab</sup>	16	3	3.4

6	<i>Swieteniamacrophylla</i> (Mahogany)	90 <sup>a</sup>	282	44	2.8
7	<i>Brideliamoonii</i> (Ketakela)	120 <sup>a</sup>	197	10	3.0
8	<i>Tectonagrandis</i> (Teak)	175 <sup>ab</sup>	258	25	3.3
	Level of significance	***	*	***	n.s.
	LSD (P=0.05)		85	11	

Note: Data in this table was obtained from the Annual Reports published by the Coconut Research Institute,<sup>(1)</sup> and Annual Report (2001),<sup>(2)</sup> Annual Report (2002) and<sup>(3)</sup> Annual Report (2005)

\*\*\* P=0.05 \*P=0.01

Table.4: Leaf litter content at different forest tree species at the experimental site in 2016

Treatment	Leaf litter(g/m <sup>2</sup> )	Soil Organic Carbon percentage (%)
<i>Acacia spp</i>	2085 <sup>a</sup> ± 415	1.89 <sup>c</sup> ± 0.09
<i>Brideliamoonii</i>	2011 <sup>a</sup> ± 415	1.55 <sup>a</sup> ± 0.09
<i>Swieteniamacrophylla</i>	2040 <sup>a</sup> ± 415	1.78 <sup>abc</sup> ± 0.09
<i>Tectonagrandis</i> ,	3321 <sup>b</sup> ± 415	1.61 <sup>bc</sup> ± 0.09
<i>Macarangapeltata</i>	2050 <sup>a</sup> ± 415	1.83 <sup>ab</sup> ± 0.09
<i>Gliricidia sepium</i>	2374 <sup>ab</sup> ± 415	1.77 <sup>abc</sup> ± 0.09

Different superscripts within columns differ significantly (a,b,c: P<0.05)

Source: Bandara et al.,(2017)

It had been noted that the weed growth was lower (P<0.05) in the plots with *Acacia* species and *Macarangapeltata* in 2000 (Annual Report, 2000). However, by the year 2002, weed biomass per m<sup>2</sup> (Table 3) were higher (P<0.05) in *Swieteniamacrophylla*, *Tectonagrandis* and *Brideliamoonii* compared to *Macarangapeltata*, *Gliricidia sepium* and *Acacia* species (Annual Report, 2002). Thus, higher the light availability at ground level, higher the weed biomass allowing favourable conditions for the growth of weeds (Table 3). This is also supported by the slower growth rates of these forest tree species (*Swieteniamacrophylla* and *Brideliamoonii*). Similarly, *Swieteniamacrophylla* has a higher (P<0.05) weed density than *Acacia auriculiformis* which in turn had a higher (P<0.05) weed density than *Tectonagrandis* (Annual Report, 2004). Weed density in other forest tree species were significantly lower (P<0.05). Lowest weed density was observed in plots with *Gliricidia sepium* (Annual Report, 2004). It may be due to the lower light availability at ground level (Table 3) restricting the growth of weeds in the *Gliricidia* plots.

Soil organic matter content in the year 2005 (Table 3) was not significantly different among treatments (Annual Report, 2005). However, by the year 2016 (Table 4) *Acacia* species had a higher (P<0.05) soil organic carbon percentage (SOC%) compared to *Brideliamoonii*. It was observed that accumulation of leaf litter has not directly influenced on the SOC%. This may be because depending on the forest tree species the rate of decomposition varies along the year as suggested by Stanley and Montagnini

(1999). According to the above Authors even though *Pithecellobium elegans* and *Vochysia ferrinaea* producers a larger amount of floor litter content with higher organic matter content, both species have different decomposition rates. *P. elegans* has a higher decomposition rate whereas, species such as *V. ferrinaea* has a slower decomposition rate (Stanley & Montagnini, 1999).

#### IV. CONCLUSION

*Calophyllum elatum* and *Grewia tiliifolia* did not survive beyond year 2002 could be due to the hard laterite soils being not their naturally favourable soils, susceptibility for drought and competition from other forest tree and weed species. *Acacia* species had the fastest growth during the time period (1999-2016) followed by *Macarangapeltata*, *Gliricidia sepium* and *Tectonagrandis*. In contrast, *Swieteniamacrophylla* had the lowest growth during the same period. Further, *Brideliamoonii* had a lower growth compared to *Acacia* species and *Macarangapeltata* but not different from other species. Thus *Acacia* species, *Macarangapeltata*, *Gliricidia sepium* and *Tectonagrandis* could be selected as better agro-forest tree species for medium term basis to be grown in hard laterite soils in Andigama soil series Shallow Phase.

#### ACKNOWLEDGEMENT

Authors wish to acknowledge present and past Directors of the Coconut Research Institute, Sri Lanka for funding the research. The research group Dr K.B. Dassanayake, Agronomist and Mr H.A. Abeysona, Technical Officer of

the Agronomy Division who initiated this long term research in 1999 are acknowledged. Presently, Mr W.M. Nuwan, Technical Officer and Mr Arosh Ranganath Field Assistant from the Agronomy Division are acknowledged for their assistance in the Data collection.

#### REFERENCES

- [1] Annual Report. (2000). Report of the Agronomy Division. Coconut Research Institute, Lunuwila, Sri Lanka.
- [2] Annual Report. (2001). Report of the Agronomy Division. Coconut Research Institute, Lunuwila, Sri Lanka. 32-33.
- [3] Annual Report. (2002). Report of the Agronomy Division. Coconut Research Institute Lunuwila, Sri Lanka. 44-45.
- [4] Annual Report. (2004). Report of the Agronomy Division. Coconut Research Institute, Lunuwila, Sri Lanka. 38-39.
- [5] Annual Report. (2005). Report of the Agronomy Division. Coconut Research Institute, Lunuwila, Sri Lanka. 29-30.
- [6] Bandara U. M. S. A. M., F.Nadheesha M. K., Somasiri S. C., Amarashinghe K. G. A. P. K. (2017). Assessment of Soil Organic Carbon Levels in Hard Laterite Coconut Growing Soil Having Medium Rotation Agro Forestry Trees. *Proceedings of the 16th Agricultural Research Symposium* 1-5.
- [7] CRI Advisory Circular No. 1. (2008). CRI Advisory Circular No. 1. Use of fertilizer for cultivation of coconuts and land suitability.
- [8] Dahanayake Kapila. (1982). Laterites of Sri Lanka—a reconnaissance study. *Mineralium Deposita***17**: 245-256.
- [9] Dobson M. (1995). Tree Root Systems. Arboricultural Advisory and Information Service, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, Gu104 LH
- [10] Eldridge K., Davidson J., Harwood C., Wyk G. van. (1994). Eucalypt Domestication and Breeding. Clarendon Press. Oxford.
- [11] Lugo A.E., Cuevas E., SaÂnchez M.J. (1991). Nutrients and mass in litter and top soil of ten tropical tree plantations. *Plant and Soil***125**: 263-280.
- [12] Parrotta John A., Turnbull John W., Norman J. (1997). Catalyzing native forest regeneration on degraded tropical lands. *Forest Ecology and Management***99**: 1-7.
- [13] Punniyawardena B.V.R. (2008). Rainfall pattern in Sri Lanka and agro-ecological zones. Department of Agriculture: pp. 25-75.
- [14] SAS (2002) 'SAS 9.1.' (SAS Institute Inc.: Cary, NC).
- [15] Somasiri L.L.W., Nadarajah N., Amarasinghe L., Gunathilake H.A.J. (2006). Land suitability assessment of coconut growing areas in the coconut triangle. Coconut Research Institute of Sri Lanka, Lunuwila.
- [16] Stanley William G., Montagnini Florencia. (1999). Biomass and nutrient accumulation in pure and mixed plantations of indigenous tree species grown on poor soils in the humid tropics of Costa Rica. *Forest Ecology and Management***113**: 91-103.