

Influence of Long Term Application of Green Manure on the Productivity of Coconut Cultivated in Reddish Brown Latosolic Soils in Sri Lanka

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Abstract

Organic matter contributes in maintaining soil fertility in agriculture. Green leaf biomasses of *Gliricidia sepium* and *Tithonia diversifolia* are high in plant nutrients and recognized as potential green manure sources for many crops. In a field experiment carried out in a coconut plantation with Reddish Brown Latosolic soil, two green manure crops were grown to study their abilities and establishment in coconut avenues and to evaluate their effect on nut yield. *In situ* green manuring, especially with legumes, had the most beneficial effect on soil improvement. The use of green biomass alone has improved soil properties. The biomasses of *Gliricidia* and *Tithonia* decomposed rapidly after application to the soil, and incorporated biomass would be an effective source of N, P and K for crops. Results showed that, coconut yields were significantly increased with the incorporation of green biomass of *Gliricidia* and *Tithonia* than with commercial inorganic fertilizer application. Mean nut yield for five years in the green manure applied plots was (37-46%) significantly ($P < 0.05$) higher, compared to that of the inorganic fertilizer applied plots towards the latter part of the experiment. Addition of green manure has significantly ($P < 0.05$) improved the soil parameters i.e. soil N (by 75%), organic C content (by 86%) and soil microbial activity (by 52%). Soil bulk density has been reduced by 20% which enhances the root growth. The improvement of soil moisture content by 92% is of great importance for coconut in withstanding the frequent dry spells which are on increasing trend with the present climatic change situations. There was no significant effect of green manures on soil pH and P but P content was improved with the use of green biomasses of *Gliricidia* and *Tithonia*.

Key words: *Gliricidia*, *Coconut*, *Tithonia*, *green manure*, *soil amendment*

Running title: Influence of green manures on coconut land productivity

Introduction

Crop productivity in coconut farming system is achieved by a combination of management strategies, among which the development of an efficient and effective nutrient recycle plays an important role. This is due to the large-scale export of nutrients through produce and stubble, which in conventional systems is replaced by chemical fertilizers. In contrast, *exsitu* or *in situ* green manures, animal manure, cover crops or different types of organic matter are used individually or in combination to replenish exported nutrients in organic systems (Stokdale *et al.*, 2000). In the tropics, where soil fertility is generally low (Hartemink, 2003; Zingore *et al.*, 2003), the decline in crop yields, even in conventional cropping systems due to excess soil mining calls for the inclusion of organic matter to maintain soil fertility (Gachengo *et al.*, 1999; Eilitta *et al.*, 2004). Nutrient replenishment and quality enhancement of tropical soils could be achieved by the addition of inorganic- fertilizers, organic

matter or both. While short-term benefits could be gained by inorganic fertilizers, harmful effects could develop in the long term (Nosengo, 2003). Green manures are the ideal method of sustaining soil fertility in the tropics (Joergensen, 2002; Fageria, 2007), for both soil fertility and microbial activity (Palm *et al.*, 2001). The organic matter status of the soil can be maintained by the addition of green leaves, compost or farm yard manure. However, in many coconut plantations, growers are unable to apply the required quantities of compost or farm yard manure because of inadequately supply. Different types of organic materials can be added to the soil to improve the soil conditions (Nagarajah and Amarasiri, 1977). Plant species for use in biomass transfer must accumulate large amounts of nutrients in their biomass, and these nutrients must be readily released in plant available forms when the biomass is applied to crop growing areas (George *et al.*, 2001). Hence, cultivation of green manure crops *in situ* and their incorporation were considered to be a viable alternative. This is practiced by the farmer as it is the most convenient and economic method of enhancing the organic matter status of the soil. *Tithonia diversifolia* (Hemsley) A. Gray has been identified as a useful resource for biomass transfer (Niang *et al.*, 1996; Gachengo *et al.*, 1999). It has been used successfully to improve soil fertility and crop yields in Kenya (Jama *et al.*, 2000), Malawi (Ganunga *et al.*, 1998), Nigeria (Ayeni *et al.*, 1997). It is a common plant abundantly in upcountry areas of Sri Lanka. Concentration of nitrogen (N), phosphorus (P) and potassium (K) in its green leaf biomass are relatively high (Jama *et al.*, 2000). Leguminous green manure crops can be used to improve the soil structure and nitrogen status of the soil. The most common green biomass source in coconut plantations has been *Gliricidia sepium* due to its abundance. It's a fast growing tropical legume tree and leaf manuring improves physical, chemical and biological properties of the soil (Sangakkara, 1989). *Gliricidia* is widely used as green manure in different cropping systems and is reported as a substitute for synthetic nitrogen fertilizers (Okogun *et al.*, 2000; Chirwa, 2006). However, the suitable types of materials to be added to the

soil and their long-term effects in increasing the productivity are not known with certainty in Sri Lanka.

Some areas of the intermediate zone of Sri Lanka are characterized by the presence of Reddish Brown Latasolic soils. Since soil fertility of this soil group is comparatively much lower to its counterpart the Reddish Brown Earth (Rhodudalfs), the need for either improving or at least maintaining the organic matter status was identified as prime importance of the great soil group. However, the impact of green biomass applied as mulch or incorporated on soil development and productivity of coconut palms in Reddish Brown Latasol soils has not been clearly identified especially in field studies on coconut farming systems. The objectives of this study were to monitor the long term effects in coconut land productivity due to the addition of different green biomass materials and the inorganic fertilizer in coconut plantations in Reddish Brown Latasol soils in this region.

Materials and methods

This experiment was carried out at the Ridigama Estate, Dodangaslanda, in the Low country Intermediate Zone of North Western Province of Sri Lanka from January 2007 to December 2012. The area is characterized by bimodal pattern of rain fall with an annual mean precipitation of 1500 mm. Approximately 65% of the annual rainfall is received from September to February (Maha). There is a smaller peak of rainfall from March to May (Yala), but the rainfall is erratic. Higher ambient air and soil temperatures (about 28⁰C- 32⁰C) and bright sunshine hours (about 6 – 8 hours per day) are more common especially during the dry periods from May to September. The soil at the site is a Reddish Brown Latasolic (RBL) (USDA soil taxonomy - Rhodudalfs fine loamy, non-calcareous, isohyperthermic), (FAO/UNESCO soil taxonomy - RhodicCutanicLuvisols) soil. Soils are very deep and well drained. Surface soil is dark brown in colour with a sandy clay loam texture. The sub surface soil is dark reddish brown to dark red in colour and texture ranges from clay loam to clay. Structure of the sub surface soil is moderately developed coarse sub

angular blocky with patchy cutans on ped faces. However, during the dry season ground water table remains at 10 – 12 m below the ground surface. Reaction of the soil is slightly acidic (pH 6.0 – 6.5) throughout the soil profile (Mapa *et al.*, 2005).

Age of the coconut plantations was 50 years and trees were planted at a spacing of 8 m × 8 m (giving a density of 137 trees/ha). Fifteen centimeter long well matured *Tithonia* stem cuttings and 3.5 feet long well matured *Gliricidia* sticks were used for planting the trials. The cuttings of both species were established separately as treatments with rains in 2007. Double rows of *Tithonia* and *Gliricidia* cuttings were planted in between two rows of coconut palms, at a spacing of 1m x 2m (2250 cuttings ha⁻¹). The distance between coconut palms and green biomass species (*Tithonia* and *Gliricidia*) was 3m. Each experimental plot was 384m² (consisting six coconut squares) in size and plots were separated by a single row of coconut. Experimental treatments were arranged in a Randomized Block Design with three replicates. Both green manure species were left to grow during the first 18 months without pruning. The first pruning was done on May 2009 in both treatments. In *Tithonia* treatment, all the plants initially were cut back to the designated cutting height of 0.6m. At each subsequent cutting, all coppice sprouts on the *Tithonia* stumps were cut back to within 1cm of the stump. *Gliricidia* treatment, all the coppice sprouts were cut back to within 4cm of the stump. Both species were cut two times per year with onset of monsoon rains. Pruned green biomass was thatched around the coconut palms 2.5m radius within each treatment plots. This management allowed the establishment of a vigorous stand of *Gliricidia* and *Tithonia*.

Before starting the experiment, all the coconut palms were applied with 3 kg of adult palm fertilizer mixture (800g Urea, 600g Rock Phosphate and 1600g Muriate of Potash) with 1000g of Dolomite/palm/ year. However, in control treatment palms were regularly fertilized with adults palm mixture. Coconut palms in T₁ and T₂ treatments, 50kg of *Gliricidia* and 35kg of *Tithonia* green biomass were applied

respectively. (The quantity biomass application was determined by the nutrient contents of the green biomass species). Green biomass applied palms were fertilized with 50% of the fertilizer mixture.

Soil Sampling and analysis

From the commencement of the experiment, Soil samples were randomly collected 2.5m away from the effective root zone of the coconut palms at 0-30cm depth for determination of available and exchangeable plant nutrients in the soil. Simultaneously, an undisturbed soil sample was collected using a core-sampler at depths of 0-15cm and 15-30cm. Samples were processed under laboratory conditions by air drying separately at room temperature for 48-72 hours without any contaminations. Air dried soil samples were crushed and sieved through 2 mm sieve. In addition, undisturbed soil samples were collected from same locations to determine microbial activity.

Soil moisture content

Soil samples were collected from four random points from the 2.5m away from the effective coconut palms a depth 0.3m, to determine treatment effects on soil moisture content during dry period following IAEA (2008) gravimetric method.

Data analysis

Experimental data were analysed following Analysis of Variance (ANOVA) procedure using the statistical software SAS (SAS reference) and the significance of the differences between means was tested using Least Significant Differences (LSD) at P=0.05 (SAS Institute 1999).

Results and Discussion

Effect of green manuring on soil physical properties (soil moisture and bulk density)

During the experimental period, soil moisture content was measured and it was significantly changed (P<0.05) during the last two years of the experimental period (Table 1). However, green manuring treatments have

Table 1. Effect of different green manures on soil moisture content (%)

Treatments	Soil moistures content (%)				
	2008	2009	2010	2011	2012
T ₁ - Gliricidia green manure	2.76	3.62	1.44	4.56	2.98
T ₂ - Tithonia green manure	2.85	3.53	1.47	4.28	3.04
T ₃ - Control (APM)	3.15	3.13	1.27	2.98	1.58
Significance	ns	ns	ns	*	*
LSD (P<0.05)	-	-	-	0.403	0.307

* Significantly different at P=0.05; NS- not significant

Table 2. Effect of different green manures on soil bulk density (g/cm³)

Treatments	Soil bulk density (g/cm ³)				
	2008	2009	2010	2011	2012
T ₁ - Gliricidia green manure	1.63	1.58	1.49	1.42	1.36
T ₂ - Tithonia green manure	1.68	1.58	1.47	1.45	1.46
T ₃ - Control (APM)	1.71	1.64	1.68	1.73	1.69
Significance	ns	ns	*	*	*
LSD (P<0.05)	-	-	0.18	0.19	0.18

* Significantly different at P=0.05; NS- not significant

Table 3. Effect of different green manures on soil microbial activity (mg/day)

Treatments	Microbial activity (mg/day)				
	2008	2009	2010	2011	2012
T ₁ - Gliricidia green manure	77.5	91.9	109.8	116.2	116.4
T ₂ - Tithonia green manure	71.9	86.2	113.9	111.4	119.8
T ₃ - Control (APM)	71.5	74.7	68.3	84.5	76.4
Significance	ns	ns	*	*	*
LSD (P<0.05)	-	-	23.2	12.8	22.3

* Significantly different at P=0.05; NS- not significant

Table 4. Effect of different green manures on soil pH

Treatments	Soil pH				
	2008	2009	2010	2011	2012
T ₁ - Gliricidia green manure	5.42	5.73	5.56	5.37	5.59
T ₂ - Tithonia green manure	5.58	5.68	5.68	5.28	5.43
T ₃ - Control (APM)	5.41	5.71	5.70	5.91	5.65
Significance	ns	ns	ns	ns	ns
LSD (P<0.05)	-	-	-	-	-

* Significantly different at P=0.05; NS- not significant

Table 5. Effect of different green manures on soil available P (ppm) content

Treatments	Soil P (ppm)				
	2008	2009	2010	2011	2012
T ₁ - Gliricidia green manure	11.32	12.41	13.42	14.94	15.34
T ₂ - Tithonia green manure	12.50	14.61	14.30	13.26	13.38
T ₃ - Control (APM)	11.45	10.98	11.48	12.85	12.01
Significance	ns	ns	ns	ns	ns
LSD (P<0.05)	-	-	-	-	-

* Significantly different at P=0.05; NS- not significant

shown a quantitatively higher content of soil moisture compared with the control treatments. Soil moisture content was not significantly changed between green manure treatments T₁ and T₂. In contrary T₂ recorded quantitatively higher moisture content in year 2012.

T₁ showed higher moisture content in 2011 compared to other treatments. Interestingly, control treatment (T₃) recorded the lowest moisture content during the whole experimental period. Increased soil moisture content might be due to the application of green manures which might have improved soil physical properties. Further the higher organic carbon content of the soil which resulted in increased water holding capacity of the soil (Ji and Under, 2001). Soil organic matter is responsible to a great extent, directly or indirectly for making the good physical environment of the soil suitable for the growth of plant roots (Jeyamala and Soman, 1999). Application of green manures reduced bulk densities of soil (Table 2), which is a vital soil characteristic for successful root development (Kuchenbuch and Ingram, 2004). There were no significant differences in the bulk densities of soils to which the two green manures were added during the first two years. However, there was a significant effect of treatments on soil bulk density at the end part of the experimental period. The lowest bulk densities were observed in T₁ and T₂ during the last three years of the experimental period. A high level of organic matter in the soil indicates reduced bulk density, improved soil structure, aeration and high water holding capacity all of which are attributes of a productive soil (Hsieh and Hsieh, 1990).

Effect of green manuring on soil biological properties (microbial activity)

There was a significant effect of treatments on soil microbial activity during the last three years of the experimental period (Table 3). The highest soil microbial activities were recorded in green manure applied treatments (T₁ and T₂) when compared with control treatment (T₃). The lowest soil microbial activity was observed in control treatment during the whole period of the experiment (Table 3). The

application of green manures to the soil is considered as a good management practice because stimulate soil microbial growth and activity with subsequent mineralization of plant nutrients (Eriksen, 2005); and therefore increase soil fertility and quality (Doran *et al.*, 1988).

Effect of green manures on soil chemical properties (soil pH, organic C, available P, total N and exchangeable K)

Green manure applications have no significant impact on soil pH and soil available phosphorus content during the whole period of the experiment (Tables 4 and 5). However soil available P content increased with time during the experimental period and the highest value was given by *Gliricidia* green manuring treatment (T₁) (Table 5).

In this study, there was a significant effect of green manure treatments on soil N and K contents when compared with control treatments during the last three years of the experimental period (Tables 6 and 7). The highest total N content was given by T₁ and T₂. Green manures improves the nutrient availability of the soil (Seiter and Horwath, 2004), a phenomenon observed under field conditions of this study (Table, 6). The mean increment in soil N due to application of green manures (*Gliricidia* and *Tithonia*) was 76.7% and 76.5% respectively when compared to the soils that did not receive green manures (T₃). The both green manures increased the total N content of the soil (Table, 6). Soil nitrogen plays an important role in improving the productivity and sustainability of these farming systems which is also a simultaneous effect of using high quality organic manures (i.e. organic manures with low C: N ratio) (Six *et al.*, 2002). However, in tropical regions, low availability of soil organic carbon and nitrogen and incorporation of insufficient quantities of organic matter leads to poor-quality soil and low sustainability (Egodawatta *et al.*, 2012). George *et al.*, (2001) also recorded that short fallows of *T. diversifolia* increased total soil N, thus *T. diversifolia* is not N₂-fixing, the increase in total N due to a transfer of N from deeper soil horizons to the topsoil, or due to fallow-associated non-symbiotic N₂- fixation.

Table 6. Effect of different green manures on soil total N (ppm) content

Treatments	Soil N (ppm)				
	2008	2009	2010	2011	2012
T ₁ - Gliricidia green manure	287.2	324.4	332.4	495.0	581.7
T ₂ - Tithonia green manure	301.0	315.3	346.8	510.7	580.9
T ₃ - Control (APM)	311.8	315.7	265.2	322.1	329.1
Significance	ns	ns	*	*	*
LSD (P<0.05)	-	-	22.7	39.7	29.4

* Significantly different at P=0.05; NS- not significant

Table 7. Effect of different green manures on soil exchangeable K (meq/100g)

Treatments	Soil K (meq/100g)				
	2008	2009	2010	2011	2012
T ₁ - Gliricidia green manure	0.068	0.082	0.108	0.116	0.296
T ₂ - Tithonia green manure	0.072	0.082	0.113	0.129	0.328
T ₃ - Control (APM)	0.061	0.077	0.091	0.087	0.102
Significance	ns	ns	*	*	*
LSD (P<0.05)	-	-	0.008	0.02	0.03

* Significantly different at P=0.05; NS- not significant

Table 8. Effect of different green manures on soil organic C content (%)

Treatments	Soil organic C (%)				
	2008	2009	2010	2011	2012
T ₁ - Gliricidia green manure	1.08	1.18	1.38	1.78	1.98
T ₂ - Tithonia green manure	1.12	1.45	1.47	1.95	2.12
T ₃ - Control (APM)	1.04	1.12	1.09	1.11	1.06
Significance	ns	ns	ns	*	*
LSD (P<0.05)	-	-	-	0.58	0.84

Generose *et al.*, in 1998 has identified that *Tithonia* is a high quality organic source in terms of nutrient release and supplying capacity.

The similar phenomenon also observed with soil exchangeable K content; mean value of soil K were enhanced by 190% and 221% when *Gliricidia* and *Tithonia* green biomass were applied treatments (Table 7). However, soil K contents were increased by *Tithonia* which is generally high in these nutrients (Jama *et al.*, 2000). The results clearly highlight the importance of organic materials in improving soil quality and fertility. Incorporation develops greater benefits confirming the reports (Schjonning *et al.*, 2004) under divers' range of ecological conditions. Generose *et al.*, in 1998 has identified that *Tithonia* is a high quality organic source in terms of nutrient release and supplying capacity. According to the Olabode *et al.*, in 2007 Lower C/N ratio of *Tithonia* compared to *Chromolaena* and *Panicum* indicates a faster rate of decomposition.

The results indicate the green manure application increased soil organic carbon content of manure amended soils. There was a significant effect of treatments on soil organic C content during the last two years of the experimental period (Table 7). The highest soil organic C content was recorded in green manure applied treatments (T₁ and T₂) when compared with control treatment (T₃). Similar results was observed by Follett *et al.*, (2007). From several studies it has been found that the addition of organic residues increases the soil organic carbon level initially and with the course of time organic carbon content decreases in soil up to a certain period (Gulser *et al.*, 2010 and Manivannan *et al.*, 2009).

Effect of green manures on coconut yield (nuts/palm/year)

Application of green manuring practices significantly increased (P<0.05) nut yield over the control treatment. This increase in nut yield commenced from the fourth year after the first application of all treatments and the trend continued. The mean increment nut yield due to application of green manures (T₁ and T₂) (*Gliricidia* and *Tithonia*) was 47% and 37%

respectively when compared to the soils that did not receive green manures (T₃). This could be explained in terms of increased soil fertility due to application green manures for coconut palms.

It is interesting to note that there was no significant difference between the *Gliricidia* and *Tithonia* green manure application treatments (T₁ and T₂) (Table, 9). Green manure like *Gliricidia sepium* helped the establishment of 2-month old poly bagged seedlings at 100% survival rate and the nut production increased by 42% while copra production by 45% at the end of the 5th year (Mahindapala, 1989). However, there are reports of contrasting influences in field studies with long duration green manure applications. The influence of green manures on crop yields of maize and several other crops has been tested in the context of agroforestry systems. The results of green manure treatments and crops yields were diverse, and some studies illustrated more pronounced long-term beneficial influences (Sileshi and Mafongoya, 2006; Kimaro *et al.*, 2007) or short-term influences (Sangakkara *et al.*, 2004; Reddy *et al.*, 2008 and Silva *et al.*, 2008).

Conclusion

This study highlighted the importance of green manuring for coconut farming systems. It demonstrate the possibility of *in situ* cultivation of two green manure crops (*Gliricidia sepium* and *Tithonia diversifolia*) in coconut plantation and their green biomass incorporation into the palm manure circle soil to increase organic matter content of the soil which ultimately adds soil macro and micronutrients besides improving soil physical and chemical properties. It stimulates soil biological activities which is necessary for soil health and fertility. It has positive effect on coconut yield and it is environment friendly and economical. It concluded that may be the use of *in situ* green manures along with chemical fertilizers, is essential to suppress any possible negative impact of fertilizers on the soil and to sustain soil productivity in coconut plantations.

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