Effects of Mulching on Growth and Yield in Plant Crop of Sugarcane under Rain-fed Conditions in Sevanagala, Sri Lanka

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ABSTRACT

The benefits of mulching in ratoon crops are well documented, but mulching in plant crops of sugarcane is a new concept. The objective of this study was to investigate the feasibility and benefit of using *Gliricidia* leaves and sugarcane trash as a mulch in a plant crop of sugarcane to enhance the productivity of low productive sugarcane lands. Thus, two levels of fertiliser and six types of mulching were evaluated using the variety SL 83 06 under rain-fed conditions at Sevanagala, Sri Lanka using a two-factor factorial RCBD design. Vegetative growth at early stages of the crop, cane yield, sugar yield and yield components at harvesting the plant crop were measured.

Fertilisation had a significant ($p \leq 0.05$) positive effect on the germination and tillering but not on yield and yield components. Mulching with *Gliricidia* leaves significantly ($p=0.01$) enhanced the utilisation of applied fertiliser at tillering stage. Mulching with the mixture of *Gliricidia* leaves and sugarcane trash increased cane and sugar yields by 34%, number of millable stalks by 8% and stalk weight by 21% though it reduced the germination and tillering at early stages of crop growth. *Gliricidia* fencing around sugarcane fields could produce a substantial amount of mulching material and also reduce the damage by cattle. It could be identified as a method of improving the yield of unproductive sugarcane lands in the rain-fed environments of Sri Lanka.

Key words: *Gliricidia, mulching, rain-fed, Sri Lanka, sugarcane trash*

INTRODUCTION

The productivity of sugarcane lands in Sri Lanka has decreased gradually due to soil degradation caused by soil erosion, poor crop management practices and some social reasons. The Sevanagala Sugar Industries Ltd. has identified 142 unproductive or uncultivable sugarcane allotments in D_2 and D_3 divisions in its rain-fed sector, out of total of about 2200 rain-fed allotments each of which is 1.75 ha in extent. Low soil moisture availability, soil erosion, frequent accidental fires and the damage by stray cattle and buffalos were the reasons for neglecting these sugarcane fields. Firing sugarcane lands has destroyed the cane trash and all organic materials and has led to increased soil erosion, reduced organic matter content in the soil, and ultimately to uncultivable gravely soil with low soil moisture retention ability. Maintaining a proper organic mulch would be a solution to rehabilitate and recondition such degraded sugarcane fields. Mulching reduces surface run off, soil erosion and increases the rate of infiltration (Prove *et al.*, 1986). Moreover, decomposing mulch adds organic matter to the soil and helps improve infiltration, water holding capacity and the nutrient content of the soil.

At present, only ratoon crops of sugarcane are mulched with the available trash left behind after harvesting and the benefit of it in ratoon crops is obvious as cane yield is increased by 15-16% with the conservation of soil moisture through reduction of evaporative losses by 50% (Wood, 1991; Denmead *et al.*, 1997; Chapman *et al.*, 2001). However, careful management of N fertiliser is required for achieving a higher yield with trash mulching in ratoon crops (Thornburn *et al.*, 2004). Ten tonnes of trash (about 10% by weight of a crop yield) after harvesting of about 100 t/ha cane provides about 64 kg N, 66 kg K, 40 kg Ca, 25 kg Mg, 10 kg P and 10 kg S (Mitchell and Larsen, 2000; Oliveira *et al.*, 2002). However, nutrients in the trash are initially immobilised and unavailable for plant growth. It takes several years to become available depending on the soil moisture and temperature which affect the rate of trash decomposition, and thus, the rate of nutrients release. Therefore, application of nutrients should not be reduced when rehabilitating unproductive sugarcane lands with trash mulching (Thornburn *et al.*, 2004).

Unlike in ratoon crops, organic materials to mulch plant crop fields are not easily available. On the other hand, because of its bulky nature, getting materials from outside to mulch a large block of land is a tedious exercise, and perhaps, practically impossible. *In-situ* production of mulching materials by growing suitable crops would be more appropriate under such circumstances.

Gliricidia sepium is a drought and fire tolerant deep-rooted leguminous tree adapted to a wide range of agro-climatic and soil conditions with very high rate of nitrogen fixation. It produces leaves with tender shoots of about 40 t/ha/year in fresh weight and leaf biomass of about 15 t/ha/year which can provide 40 kg/ha/year of nitrogen (Stewart *et al.*, 1996). Therefore, this study was conducted to investigate the possibility of producing *in-situ* mulching materials by growing *Gliricidia* along the boundaries of cane fields as a live fence to prevent accidental fires and cattle damage, and to investigate the benefit of using *Gliricidia* leaves and sugarcane trash as a mulch in plant crop of sugarcane to rehabilitate the unproductive lands in rain-fed sugarcane-growing environments in Sri Lanka.

MATERIALS AND METHODS

A field experiment was initiated in April 2009 in an abandoned sugarcane field (allotment number 1682) in the D_3 division of the rain-fed sector of Sevanagala Sugar Industries Ltd ($6^0$24'46"N latitude, $80^0$56'21"E longitude and 72 m altitude) where the annual average rainfall from the year 2000 to 2011 was 1407±96 mm with a distinct bimodal distribution. The average annual minimum and maximum temperatures were $22.4^0 \pm 1.0^0$ C and $32.4^0 \pm 1.1^0$ C. The evaporation from a free water surface averaged 1491.3±75 mm per annum. The average annual wind velocity, relative humidity and bright sunshine hours were 4.5±0.8 km/hr, 70±2.5% and 6.9±0.4 hr/ day respectively (Personal communication Wijayawardana, 2012). The soil is *Ranna* series of Reddish Brown Earths (RBE) and low humic gley with undulating terrain (the great group of *Rhodustalfs*, order *Alfisols* suborder *Ustalfa*) and has a sandy clay-loam texture (De Alwis and Panabokke, 1972; Anon, 1975).

A land of about 1 ha was selected and a live *Gliricidia* fence was established around the land in two rows. The fence was maintained to harvest leaves with twigs for mulching purpose. The harvested *Gliricidia* leaves with twigs in three times per year were weighted and applied equal amount as a mulch in the plots of mulching treatments. The cattle damage in the experimental plots and in the adjoining sugarcane fields in D_3 division of the Sevanagala Sugar Industries Ltd were regularly observed.

Two fertiliser levels (fertilised and un-fertilised) and six mulching treatments, i.e., blanket mulching in plant and ratoon crops with *Gliricidia* leaves and twigs (T1), blanket mulching in plant and ratoon crops with a mixture of *Gliricidia* leaves and cane trash (T2), blanket trash mulching in ratoon crops (T3), alternate-row trash mulching in ratoon crops (T4), trash burning in ratoon crops (T5) and no mulch in plant and ratoon crops (T6) were tested in the plant and ratoon crops. In the plant crop, only T1 and T2 were applied. Treatments T3, T4, T5, and T6 were applied in ratoon crops. Therefore, plots in treatments T3 to T6 were maintained without mulch as control treatments (TC) to compare the treatments T1 and T2 in plant crop yield analysis.

The experiment was conducted using the variety SL 83 06 under rain-fed conditions in a two-factor factorial Randomised Complete Block Design using three replicates in 12 treatment combinations of fertiliser levels and types of mulching. Plot size was 9 m x 8.22 m, each of which contained 6 furrows spaced at 1.37 m. The sugarcane was planted and maintained under recommended procedures (Anon, 1991). Half of the experimental plots (18) which were used as fertilised treatment were supplied with the recommended fertiliser mixture for the rain-fed sector at Sevanagala (Anon, 2007). Each experimental plot of the treatment T1 was mulched with 32 t/ha of fresh *Gliricidia* leaves with twigs. A mixture of fresh *Gliricidia* leaves of 12 t/ha with sugarcane trash of 23 t/ha was applied in each experimental plot of treatment T2.

Germination counts, 1st, 2nd and 3rd tiller counts in the inner four rows of the experimental plots were taken at 28, 75, 105 and 205 DAP. Height of the shoots from the ground surface to the point of top visible dewlap (TVD) of the leaf, number of leaves in the shoot, and leaf length and width in ten shoots in the middle cane row of each plot were taken at 205 DAP. Leaf area was measured by length and width method using a pre-calculated leaf area co-efficient of 0.8 (De Silva, 2007), and leaf area index (LAI) was calculated.

Cane yield, juice quality parameters, i.e., brix% and pol%, fibre% in cane and cane yield traits, i.e. number of millable stalks ha^{-1}, height, weight, diameter and number of internodes of the stalk, number of leaves per stalk, leaf length and leaf width and LAI were recorded at harvesting the 13-month aged plant crop. Purity and pure obtainable cane sugar (POCS) in cane juice and sugar yield were estimated based on the above-mentioned cane yield and quality parameters (Varma, 1988).

Significance of treatment differences was tested by the Proc GLM procedure of the *SAS* statistical package (2004). Means were separated using the least square means (LSmean). Interaction effects of mulching and fertilisation were compared using the Proc mixed procedure.

RESULTS AND DISCUSSION

Gliricidia fence

The *Gliricidia* plants in the fence around the one-hectare plot could produce about 5 t of fresh leaves with twigs per annum. This is sufficient to mulch about 0.05 ha of sugarcane field. It was observed that the *Gliricidia* fencing could reduce the cattle damage to some extent as compared to the existing damage caused in adjoining sugarcane fields in D_3 division of the Sevanagala Sugar Industries Ltd.

The effects of fertilisation and mulching on growth parameters of sugarcane

The results showed a significant ($p \leq 0.05$) effect of mulching on the number of germinated shoots at 28 DAP, the number of shoots per m^2 at 75 and 105 DAP, shoot height, number of leaves in the shoot and LAI at 205 DAP. Fertilisation had a significant ($p \leq 0.05$) positive effect on the number of germinated shoots at 28 DAP and the number of shoots per m^2 at 205 DAP. Moreover, the number of germinated shoots at 28 DAP showed a significant ($p=0.05$) interaction of mulching and fertilisation.

Mulching with a mixture of cane trash and *Gliricidia* leaves (T2) showed the lowest germination count at early stages of crop growth in fertilised and unfertilised plots. It could be due to the mechanical impedance of the mulch on the emerging shoots. However,

Table 1 - Germination count at 28 DAP, number of tillers per m^2 at 75, 105 and 205 DAP, and shoot height at the point of top visible dewlap (TVD) of the leaf and LAI at 205 DAP of sugarcane in different mulching treatments

	Mulched treatments		Un-mulch treatment	Mean
	T1	T2	(TC)	
Germinated shoots (no./ m^2)				
Fertilised	5.66^{a}	4.06^{b}	5.25^{a}	5.12*
Unfertilised	3.53^{b}	3.51^{b}	4.94^{a}	4.47*
Average	4.40^{ab}	3.79^{b}	5.09^{a}	4.79
No. of tillers m^{-2} at 75 DAP				
Fertilised	11.52^{a}	9.51^{a}	11.32^{a}	11.05
Unfertilised	7.99^{b}	10.27^{a}	11.06^{a}	10.42
Average	9.76^{a}	9.89^{a}	11.16^{a}	10.74
No. of tillers m^{-2} at 105 DAP				
Fertilised	10.91^{a}	10.23^{a}	12.05^{a}	11.56
Unfertilised	8.75^{b}	10.63^{a}	11.68^{a}	11.01
Average	9.83^{b}	10.43^{ab}	11.87^{a}	11.29
No. of tillers m^{-2} at 205 DAP				
Fertilised	9.71*^{a}	8.78^{b}	9.11^{ab}	9.16*
Unfertilised	8.58*^{a}	8.11^{a}	8.79^{a}	8.64*
Average	9.15^{a}	8.44^{b}	8.95^{ab}	8.90
Shoot height (cm)				
Fertilised	77.90^{b}	97.06^{a}	71.45^{b}	76.80
Unfertilised	76.3^{b}	96.07^{a}	71.74^{b}	76.55
Average	77.1^{b}	96.57^{a}	71.60^{b}	76.68
LAI				
Fertilised	1.89^{a}	2.10^{a}	1.75^{a}	1.83
Unfertilised	1.80^{ab}	2.15^{a}	1.54^{b}	1.68
Average	1.85^{ab}	2.13^{a}	1.64^{b}	1.76

Note: Means with the same letters within a variable in a row are not significantly different at 5% probability level.

* Means are significantly different at 5% probability level.

mulched sugarcane (T2) showed the greatest shoot height, number of leaves in the shoot and LAI at middle stage (205 DAP) of crop growth compared to the un-mulched treatment (Table 1).

Under un-fertilised conditions, mulching had a significant ($p \leq 0.02$) effect on germination and tillering of sugarcane at the initial 3 months of crop growth from germination to tillering. Mulched crops (T1 and T2) recorded significantly lower number of germinated shoots at 28 DAP ($p=0.02$) and number of tillers at 75 DAP ($p=0.007$) and 105 DAP ($p=0.009$). However, at 205 DAP, all treatments (T1, T2 and TC) had similar number of shoots per m^2 under un-fertilised conditions (Table 1). At the end of the cropping season, mulched plots (T1 and T2) had a greater number of millable stalks per ha.

Fertilisation had a significant ($p \leq 0.05$) positive effect on germination and tillering. It increased the germination count significantly ($P=0.02$) at 28 DAP and tiller count at 205 DAP compared to that of plants in un-fertilised plots (Table 1). Application of N increases tillering (Bonnett *et al.*, 2005) Moreover, mulching with *Gliricidia* leaves (T1) significantly ($p=0.01$) increased the tiller numbers of plants at 205 DAP in fertilised plots (Table 1). It revealed that mulching with *Gliricidia* leaves enhanced the utilisation of applied fertiliser at the stage of tillering. Increased availability of soil moisture with mulching increases tillering even with no N application, and the effect of moisture is increased by a single N application (Bonnett *et al.*, 2005). Moreover, germination count at 28 DAP showed significant ($p<0.05$) interaction effect of mulching and fertilisation. Germination count at 28 DAP in the treatment combination of fertilised and *Gliricidia* leaves mulched (F1T1) was greater than the germination count in the treatment combinations of unfertilised and *Gliricidia* leaves mulched (F0T1) (Fig. 1a).

The effects of fertilisation and mulching on yield parameters of sugarcane

There was a significant ($p<0.05$) effect of mulching on cane yield and cane yield components, i.e., number of stalks per ha, stalk weight, leaf length and sugar yield and brix% in cane juice at the time of harvesting the 13-month old plant crop of sugarcane (Table 2).

Mulching with a mixture of cane trash and *Gliricidia* leaves (T2) produced the greatest cane and sugar yields, stalk weight and leaf length when compared to treatments T1 and TC in the plant crop. Moreover, T2 recorded a 133% more cane yield (63 t/ha) than the plant crop cane yield of 27 t/ha before rehabilitation (yield records in Sevanagala Sugar Industries Ltd). Mulched treatments (T1 and T2) had a greater cane yield, number of stalks per ha and stalk weight than the un-mulched treatment (TC). However, *Gliricidia* leaves mulching (T1) recorded significantly lower brix% in cane juice than that of T2 and TC (Table 2). The decline in brix may be due to increased soil moisture and supply of N with the mulching of sugarcane (Klok *et al.*, 2003).

The effect of fertiliser levels on yields and yield components was not significant. However, cane yield, sugar yield, number of stalks per ha and stalk weight under the un-fertilised conditions, and cane yield, stalk weight, leaf

Table 2 - Cane yield (t/ha), sugar yield (t/ha) and their related parameters in plant crop of sugarcane under mulched and un-mulched conditions

	Mulched treatments		Un-mulch treatment (TC)	Mean
	T1	T2		
Cane yield (t/ha)				
Fertilised	53.44 [ab]	58.80 [a]	48.79 [b]	51.23
Unfertilised	56.23 [b]	68.13 [a]	46.04 [c]	51.42
Average	54.83 [b]	63.47 [a]	47.42 [c]	51.33
Sugar yield (t/ha)				
Fertilised	5.00 [a]	5.79 [a]	5.23 [a]	5.28
Unfertilised	5.39 [b]	7.77 [a]	4.88 [b]	5.44
Average	5.19 [b]	6.78 [a]	5.05 [b]	5.36
Number of stalks per ha				
Fertilised	78490 [a]	73128 [a]	70943 [a]	72565
Unfertilised	73443 [b]	83897 [a]	69208 [b]	72362
Average	78512 [a]	75966 [a]	70075 [b]	72463
Stalk weight (kg)				
Fertilised	0.68 [b]	0.81 [a]	0.68 [b]	0.70
Unfertilised	0.76 [ab]	0.82 [a]	0.66 [b]	0.71
Average	0.72 [b]	0.81 [a]	0.67 [c]	0.71
Leaf length (m)				
Fertilised	1.18 [a]	1.03 [b]	1.11 [ab]	1.11
Unfertilised	1.83 [a]	0.99 [a]	1.08 [a]	1.07
Average	1.13 [a]	1.01 [b]	1.00 [a]	1.09
LAI				
Fertilised	2.97 [a]	1.97 [b]	2.49 [ab]	2.49
Unfertilised	2.14 [a]	2.55 [a]	2.12 [a]	2.19
Average	2.55 [a]	2.26 [a]	2.31 [a]	2.34
Brix% in cane juice				
Fertilised	15.60 [b]	16.76 [ab]	17.66 [a]	17.12
Unfertilised	16.77 [a]	18.07 [a]	18.50 [a]	17.47
Average	16.18 [b]	17.41 [a]	17.58 [a]	17.32

Note: Means with the same letters within a variable in a row are not significantly different at 5% probability level.

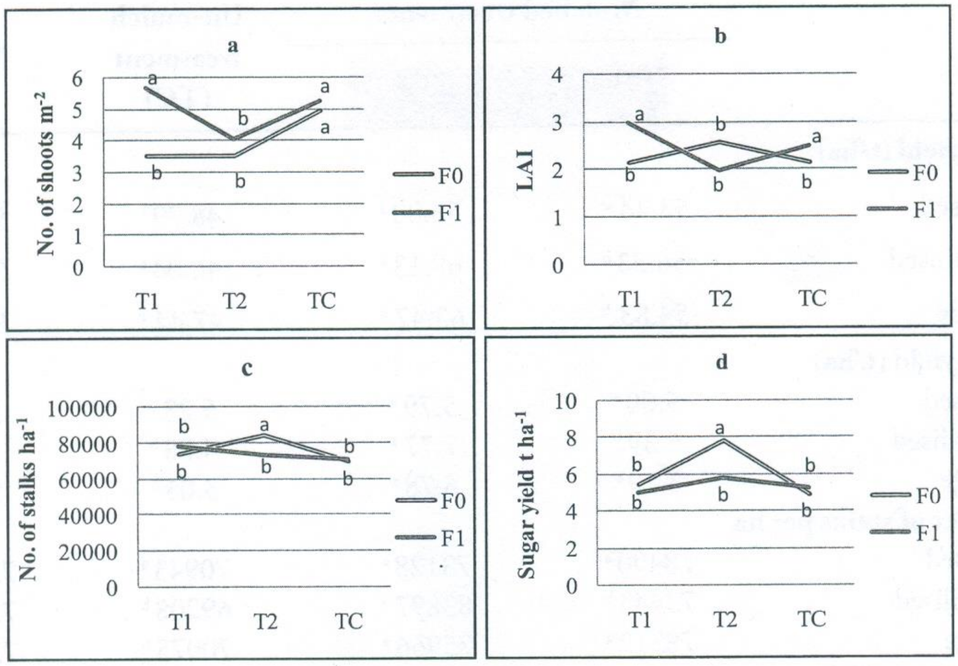

Fig. 1 - Variation of germination count at 25 DAP (a), and LAI (b), number of stalks per ha (c) and sugar yield (d) at harvesting the plant crop of sugarcane with mulching treatments (T1, T2, and TC) under fertilised (F1) and unfertilised conditions (F0). Means with the different letters are significantly different at 5% probability level.

length, LAI and brix% in cane juice under the fertilised conditions at the time of harvesting significantly ($p \leq 0.05$) varied among the tested mulched and unmulched treatments (Table 2).

There was a significant ($p<0.05$) interaction effect of fertilisation and mulching on sugar yield, number of stalks per ha and LAI at harvesting (Fig. 1b, c and d). Sugar yield in the un-fertilised and *Gliricidia* leaves with trash mulched (F0T2) plots was significantly ($P<0.05$) greater than the sugar yield in the treatment combinations of un-fertilised and *Gliricidia* leaves mulched (F0T1), un-fertilised and un-mulched (F0TC) and fertilised and *Gliricidia* leaves with trash mulched (F1T2) (Fig. 1d).

CONCLUSIONS

The study showed the substantial benefit of using *Gliricidia* leaves and sugarcane trash as a mulch in plant crop of sugarcane. Moreover, there was a possibility of producing *in-situ* mulching materials by growing *Gliricidia* along the boundaries of cane fields as a live fence and to reduce accidental firing and cattle damage. Although mulching of plant crop of sugarcane reduced the germination and tiller counts at early stages of crop growth, it significantly enhanced the cane yield and yield components except the juice quality in plant crop under rain-fed conditions. Mulching with *Gliricidia* leaves enhanced the utilisation of applied fertiliser at the tillering stage. The productivity of low productive sugarcane land can be improved by mulching which improves soil conditions and conserves soil and soil moisture. Based on these results, we recommend cultivation of organic manure crops such as *Gliricidia* in the field itself for mulching the plant crop of sugarcane to improve sugarcane-growing soils.

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