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Mucuna bracteata : Ideal cover crop for efficient soil and water management in rubber cultivation

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ABSTRACT

Data indicated that dry weights of green matter and litter production of *Mucuna* were three times higher than *Pueraria*. Similar results were observed with regard to thickness of the green matter and litter layers and the *Mucuna* exhibited 45 cm and 106 cm thick layers compared to 15 cm and 36 cm thick layers of *Pueraria*, for green matter and litter, respectively. According to data on transpiration rate indicated that *Mucuna* had significantly low transpiration rate compared to *Pueraria*. Data obtained also show that *Mucuna* had more deep rooted system compared to both rubber and *Pueraria*.

Data on soil bulk density of the 0 cm-15 cm and 15cm 30cm depths indicated that soils under *Mucuna* had the significantly low bulk density and soil resistance when compared with *Pueraria*. It was found that growing *Mucuna* resulted in a significantly higher total aggregation percentage in the region of 17% over *Pueraria*. The soils under *Mucuna* showed a significantly higher moisture content of 19.6% and 18.1% for the depths of 0-15 cm and 15-30cm respectively, in comparison to the soils under *Pueraria*. Among the two species, *Mucuna* records higher moisture profile storage capacity of 25.8 cm for a depth of 90 cm. There was an increase of 41% in the moisture storage capacity as compared to *Pueraria*. The rate of water absorption into the soil indicated a distinct variation among the different treatments. The infiltration rate was higher in the soils under *Mucuna*. Data on soil loss under two species of legumes indicated that growing *Mucuna* has minimized the soil loss significantly, compared to growing *Pueraria*. Soil analysis also indicated a build-up of organic carbon and microbes in the soil under *Mucuna* in comparison to *Pueraria*.

Key words:

INTRODUCTION

When land is cleared for replanting or new planting rubber, soil degradation can occur largely due to exposure of soil to sunlight and high intensity rainfall occurring in the rubber growing areas of Sri Lanka. Vegetative cover effectively decelerates soil degradation through interception of raindrops and promotion of better water retention and transmission characteristics (Stocking, 1988). The importance of leguminous ground covers has been emphasised by several researchers who regarded activities, which increase soil organic matter and promote biological diversity as a strategic approach in soil and water management. (Yogaratnam *et al*, 1979; Yogaratnam *et al*, 1984; Samarappuli, 1992; Samarappuli *et al*, 1999). The most widely used leguminous cover crop in Sri Lanka is *Pueraria phaseoloides*. It is apprehensive to note that this traditional leguminous cover crop do not perform successfully against the conditions like drought and shade and also do not compete successfully against weed growth. This situation leads to inefficient management of soil and moisture under rubber. Therefore, investigation on new legumes species with superior characteristics has become essential. *Mucuna bracteata* is a wild leguminous creeper found in the forest area of Tripura State, North India and is wildly grown as a cover crop in the rubber plantations in Kerala, South India (Kothanduraman, *et al*, 1997). Hence, this paper highlights the comparative efficiency of *Mucuna bracteata* in relation to traditional *Pueraria phaseoloides* in soil and moisture management under rubber.

MATERIALS AND METHODS

The experiment was conducted at Perth estate, Horana to study the effect of different cover management practices on the changes in soil characteristics and their effects on the growth of *Hevea* (clone RRIC 130). The treatments consisted with following five species of leguminous ground covers, arranged in a randomised block design with each treatment being replicated five times.

Pueraria phaseoloides (creeping type)
Mucuna bracteata (creeping type)
Flemingia macrophylla
Crotolaria micans
Tephrosia vogelli

Plots with *Pueraria* and *Mucuna* had a pure growth of the legumes and a clean- weeded circle was maintained around rubber plants for both treatments as recommended by the Rubber Research Institute of Sri Lanka). For 3rd, 4th and 5th treatments, four rows of *Flemingia, Crotalaria* and *Tephrosia* were maintained in the inter-row area, respectively. These tree legumes were lopped at a height of 1 meter from the ground, before flowering and the lopping were used as a mulch along the planting row of rubber. The type of soil in the experimental site was a shallow, gravely loam and brown to reddish yellow in colour and belonged to the *Boralu* series (Red Yellow Podzolic; ultisol).

Green matter and litter collection were done by using a 1 m^2 frame and three measurements were taken in each plot and the mean value of the three measurements was extrapolated to get the per hectare value. Similarly, thickness of the green matter and litter layers was also measured. Transpiration rate was measured using a porometer and root distribution was measured by cutting soil profiles.

The bulk density of the soil was measured by obtaining undisturbed core samples. Three measurements were done in each plot and their means are presented. The soil resistance was measured using a Proctor penetrometer at three places in each plot. For each plot, a composite bulk sample consisting of soils taken from three places were obtained for aggregate analysis. Distribution of wet-sieved aggregates and mean weight diameters were measured using mechanical sieve and a special wet sieving attachment. Dry sieved aggregation was also measured using a mechanical sieve. The neutron probe was used to monitor soil water distribution profile under different soil management practices. Access tubes were installed in each experimental plot and weekly counts for soil water content were made at depths of 10cm interval from 10 cm to 160cm. The gravimetric soil moisture content was measured by taking three samples in each plot. Moisture retention under different matric suctions and soil moisture characteristic curves were determined using the pressure plate apparatus where undisturbed core samples were obtained. The infiltration rate of the soil was measured using a double ring infiltrometer in 3 different places and their means are presented. Soil erosion under each treatment was recorded using collection tanks. Microbial population and organic carbon were also measured by collecting soil samples under each treatment

Statistical analyses of all experimental data were done by Analysis of Variance (ANOVA) followed by a mean separation procedure, Duncan's Multiple Range Test (DMRT), at the probability level of 0.05. Results with regard to *Mucuna* and *Pueraria* only were presented in this paper.

RESULTS

Data indicated that dry weights of green matter and litter production of *Mucuna* were three times higher than *Pueraria* (Table 1). Similar results were observed with regard to thickness of the green matter and litter layers and the *Mucuna* exhibited 45 cm and 106 cm thick layers compared to 15 cm and 36 cm thick layers of *Pueraria,* for green matter and litter, respectively (Table 1). According to data on transpiration rate indicated that *Mucuna* had significantly low transpiration rate compared to *Pueraria* (Table 2). Data obtained also show that *Mucuna* had more deep rooted system compared to both rubber and *Pueraria* (Table 3 and Fig. 1).

Table 1. Biomass production and cover thickness of *Pueraria* and *Mucuna*

Species	Biomass production (kg/ha) (dry wt.)		Cover thickness (cm)	
	Green matter	Litter	Green matter	Litter
Pueraria phaseoloides	2,200^a	2,000^a	36^a	15^a
Mucuna bracteata	6,250^b	6,750^b	106^b	45^b

(Means with the same letter are not significantly different)

Table 2. Transpiration rate of *Pueraria* and *Mucuna*

Species	Transpiration rate (g/cm^2/sec^2)
Pueraria phaseoloides	11.6^a
Mucuna bracteata	1.4^b

(Means with the same letter are not significantly different)

Table 3. Root distribution of *Pueraria* and *Mucuna*

Species	Depth of feeder roots (cm)
Pueraria phaseoloides	20
Mucuna bracteata	70
Rubber	30

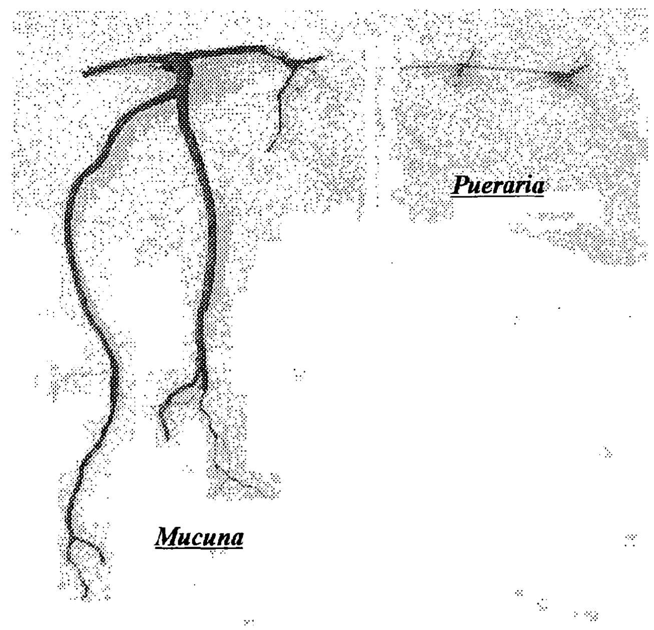

Fig. 1. Root distribution of *Pueraria* and *Mucuna*

Data on soil bulk density of the 0 cm-15 cm and 15cm 30cm depths indicated that soils under *Mucuna* had the significantly low bulk density when compared with *Pueraria*. Similar results were observed with regard to soil porosity for the 0 cm-15 cm and 15cm 30 cm depths (Table 4). There was a significant difference in penetrometer resistance and low penetrometer resistance was observed under *Mucuna* compared to *Pueraria* (Table 4).

over *Pueraria* and the amount of coarse aggregates (2mm-5 mm) and fine aggregates (<0.25mm) under different treatments is shown in Fig. 2.

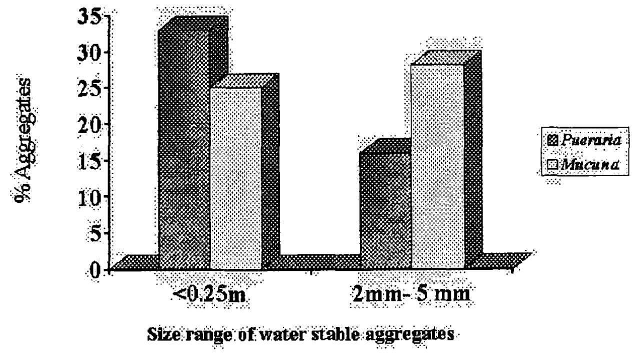

Fig. 2. Effect of growing *Pueraria* and *Mucuna* on the amount of fine and coarse aggregates

The soils under *Mucuna* showed a significantly higher moisture content of 19.6% and 18.1% for the depths of 0-15 cm and 15-30cm respectively, in comparison to the soils under *Pueraria* (Table 6). Among the two species, *Mucuna* records higher moisture profile storage capacity of 25.8 cm for a depth of 90 cm. There was an increase of 41% in the moisture storage capacity as compared to *Pueraria* (Table 6). Fig. 3 illustrates the available water storage capacity of the soils under two species of legumes over a period of 12 months. It shows an

Table 4. Effect of *Pueraria* and *Mucuna* on bulk density, soil porosity and soil resistance

Species	Bulk density (g/cm^2)		Porosity (%)		Soil resistance (g/cm^2)	
	0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
Pueraria phaseoloides	1.23^a	1.52^a	55^a	51^a	9.3^a	12.2^a
Mucuna bracteata	1.08^b	1.21^b	58^b	52^a	7.8^b	11.0^a

(Means with the same letter are not significantly different)

It was found that growing *Mucuna* resulted in a significantly higher total aggregation percentage in the region of 17% over *Pueraria* (Table 5). A significant difference was also observed for the mean weight diameter (MWD) of water stable aggregates (Table 5). Similarly, *Mucuna* had increased the amount of course aggregates by 12%

Table 5. Effect of *Pueraria* and *Mucuna* on soil aggregation and MWD of aggregates

Species	Aggregation(%)	MWD (mm)	
		Dry sieving	Wet sieving
Pueraria phaseoloides	52.8^a	1.30^a	0.70^a
Mucuna bracteata	61.9^b	2.62^b	1.21^b

(Means with the same letter are not significantly different)

Table 6. Effect of *Pueraria* and *Mucuna* on soil moisture content and soil moisture storage capacity (SMSC) for 90cm soil profile

Species	Soil moisture content (%)		SMSC (cm)
	0-15cm	15-30cm	
Pueraria phaseoloides	16.1^a	15.0^a	18.3^a
Mucuna bracteata	19.6^b	18.1^b	25.8^b

(Means with the same letter are not significantly different)

upper limit (field capacity) and a lower limit, thus indicating the available water storage capacity for a 160 cm profile, which is considered as the rooting depth of immature rubber. The amount of water retained at different soil potentials for the soils under two species of legumes is given in Table 7 and it indicates that *Mucuna* has improved the water

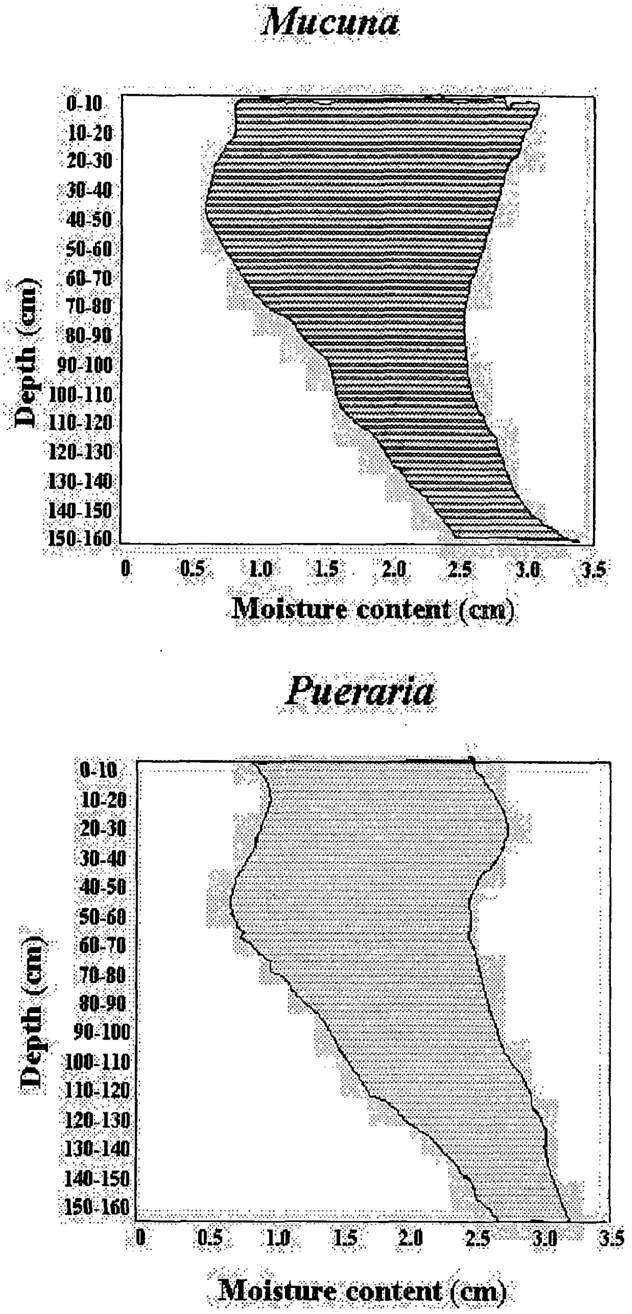

Fig. 3. Effect of growing *Pueraria* and *Mucuna* on the water storage capacity

Table 7. Effect of *Pueraria* and *Mucuna* on volumetric moisture content at different soil potentials

Species	Volumetric moisture content (%)		
	-10kPa	-500kPa	-1500kPa
Pueraria phaseoloides	16.1ᵃ	15.0ᵃ	18.3ᵃ
Mucuna bracteata	19.6ᵇ	18.1ᵇ	25.8ᵇ

(Means with the same letter are not significantly different)

retention at different soil potentials. The rate of water absorption into the soil indicated a distinct variation among the different treatments. The infiltration rate (Fig. 4) was higher in the soils under *Mucuna.* Data on soil loss under two species of legumes indicated that growing *Mucuna* has

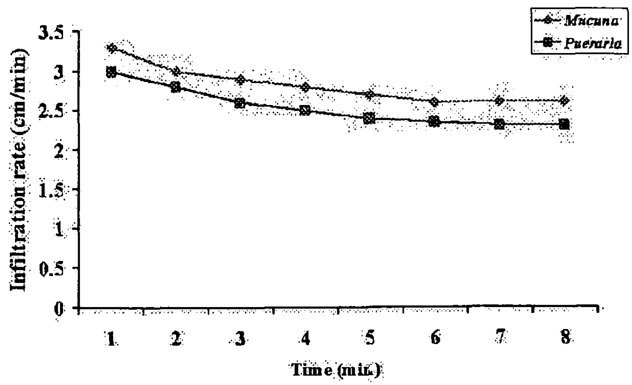

Fig. 4. Effect of growing *Pueraria* and *Mucuna* on the infiltration rate

minimized the soil loss significantly, compared to growing *Pueraria* (Table 8). Soil analysis also indicated a build-up of organic carbon and microbes in the soil under *Mucuna* in comparison to *Pueraria* (Table 9).

Table 8. Effect of growing different species of legumes on soil loss

Species	Soil loss (MT/ha)
Pueraria phaseoloides	18[a]
Mucuna bracteata	3[b]

(Means with the same letter are not significantly different)

Table 9. Effect of *Pueraria* and *Mucuna* on soil organic carbon and soil microbial population

Species	Organic C (%)		Microbes
	0-15cm	15-30cm	($x10^4$/g of dry soil)
Pueraria phaseoloides	1.1[a]	0.9[a]	62[a]
Mucuna bracteata	2.8[b]	1.9[b]	97[b]

(Means with the same letter are not significantly different)

DISCUSSION

The impact of raindrops on bare soil results in a breakdown of soil aggregates and dispersion of soil particles which seal up the soil pores in the immediate surface leading to reduced infiltration and increased run-off and thereby reducing soil moisture storage capacity and increasing soil loss. Management of ground covers is therefore, an important aspect of soil and moisture conservation in rubber cultivation (Samarappuli and Yogaratnam, 1984). It should be noted that the traditional leguminous cover crop *Pueraria* does not perform successfully against the conditions like drought and shade and also do not compete successfully against weed growth. This situation leads to inefficient management of soil and moisture under rubber. Therefore, investigation on new legumes species with superior characteristics has become essential.

Mucuna bracteata is a leguminous creeper grown as a cover crop in the rubber plantations in Kerala, South India (Kothanduraman, *et al*, 1997) and data indicated that green matter and litter production of *Mucuna* was three times higher than *Pueraria*. The importance of growing *Mucuna* in enhancing the organic matter content in the soil is shown by the experimental data. Although decomposition of organic matter is rapid under tropical conditions, organic matter tends to accumulate in the form of litter due to continuous adding of decaying leaves, stems and roots of the fast growing cover crop, *Mucuna*. The lower soil organic carbon content under *Pueraria* is probably due to the poor return of litter to the soil and greater exposure of soil under *Pueraria* owing to its susceptibility to drought and shade conditions compared to *Mucuna*. It was reported that organic matter serves as a substrate for biological activity. Polar substances resulting from decomposition of organic matter are very effective in improving cultivated soils (Kroth and Page, 1946). Microbial gums and filamentous fungi are known to thrive well under increased organic matter content and this proves by the data on microbial population under *Mucuna*. This probably contributed to an improved physical condition of soils under *Mucuna*.

Some important physical soil parameters such as soil bulk density, soil porosity and soil resistance were improved under *Mucuna*. It is possible that the higher organic matter layer on the soil surface would have prevented the direct impact of raindrops, thus preventing the breakdown of soil structure. The higher porosity under *Mucuna* may have been due to the better soil structure. An organic matter layer on the soil surface is also known to serve as a cushion against the pressure exerted by raindrops (Samarappuli, 1995).

The highest aggregation percentage and mean weight diameter of water stable aggregates were observed under *Mucuna*. There was also an increase of 17% in aggregation and a reduction of finer aggregates by 24% were observed under *Mucuna*. It appears that the loss of finer-fraction ultimately resulted in the formation of coarser (2-5 mm) water stable aggregates. The relatively higher amount of finer aggregates in soils under *Pueraria* can be attributed to structural breakdown by the impact of raindrops due to exposure of soil to rainfall. It is apparent that high organic matter content under *Mucuna* played an important role in the formation of water stable aggregates (Samarappuli, 1992). The amount of coarser aggregates assumed a dynamic role in the changes of soil structure (Zainol, 1993). The percentage aggregation is known to be a measure of ability of the soil structure to with stand the disruptive forces of erosive rain in the tropics.

The infiltration rate distinctly varied among the different treatments. It was higher under *Mucuna*. The protective action of a surface cover by intercepting and absorbing the raindrop impact prevents surface sealing and preserves the structure of the underneath soil surface. The rapid movement of water through the soil profile under *Mucuna* suggests that the unfavourable effect of the immediate soil surface may have been a limiting factor for the movement of water through the soil profile under *Pueraria* with area exposed to direct rain and sunlight. The marked increase in infiltration rate under *Mucuna* indicated that the soils have a higher water intake capacity resulting in a reduced run-off and erosion.

There may be two reasons for the effect of *Mucuna* in reducing soil erosion. Firstly, the thick organic matter layer on the surface intercepts the raindrops and dissipates their energy, thus preventing detachment of soil particles and sealing of the soil surface. Secondly, there may be a decrease in the run-off due to reduced flow rate and carrying capacity of the run-off. It is therefore, possible that growing *Mucuna* may have minimized run-off and controlled erosion. Further, on land replanted with young rubber, soon after planting, there is a loose surface layer of soil, which could easily be washed away with the run-off unless some protection is provide early (Samarappuli and Yogaratnam, 1984).

The data on soil moisture content indicates that soils under *Mucuna* had the highest moisture content of 20% and 18% for the 0-15 cm and 15-30 cm depths respectively, in comparison to soils under *Pueraria*. Among the two species, the highest moisture profile storage capacity of 25.8 cm was observed under *Mucuna* for 90 cm profile depth. There was an increase of 41% in the moisture storage capacity as compared to the soils under *Pueraria*. Similarly, at different suction, more water was retained in the soils under *Mucuna*. Thick organic matter layer would have influenced the moisture content of the soil by their effect on water intake through the immediate surface layer and also by decreasing losses due to soil evaporation probably by suppressing weed growth. Also, an improved structure decreases crusting and surface sealing and permits greater infiltration, thereby increasing the water holding capacity (Samarappuli and Yogaratnam, 1995). Moreover, the transpiration rate of *Mucuna* is ten times lower than *Pueraria* allowing more moisture to remain in the soil for a longer period of time. Any reduction in evapo-transpiration of soil moisture would be beneficial to crop growth in the same manner as additional water. Further, it was observed that *Mucuna* has a deep root system than *Pueraria*, which allows uptake of water from more deeper layers of soil reducing the competition for water with young rubber plants. Therefore, it appears possible to eliminate or at least minimize the adverse effects of moisture stress by growing *Mucuna*. The higher soil moisture content may increase the water uptake by young plants thereby increasing their growth especially during dry periods.

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