J. Rubb. Res., **2(1)**, 50–61

Effects of Mulching with Rice Straw on Some Physical Properties of Soils under Rubber

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The value of mulching with rice straw in improving some physical properties of soil during the immature period of rubber plants was studied. Data on the influence of different soil management practices indicated that soil bulk density, soil porosity and soil resistance were improved with mulching in the clean weeded circle around the rubber plants. The highest aggregation percentage was also observed under mulch. There was an increase of 20% in aggregation and a reduction of finer aggregates by 45% over the clean weeded circle in the legume plots. A significant difference was also observed in the mean weight diameter of water stable aggregates. Also, the soils under mulch had the highest moisture content. The moisture profile distribution and available water storage capacity of the soils under different soil management practices over a period of 12 months were also studied for a 160 cm profile depth, which is considered as the rooting depth of immature rubber. Mulching has improved water retention at different soil potentials. Similarly, at different suctions more water was retained in the soils under mulch as compared to soils in the clean weeded circles of legume plots and natural plots which have a growth of natural vegetation. The infiltration rate showed a distinct variation among the different treatments.

When forests are cleared for agriculture, changes detrimental to the environment can occur largely due to alterations in the hydrological cycle, micro-climate, biological population and soil physical properties[1]. Similar effects can operate in rubber plantations in a tropical country like Sri Lanka with poor soil characteristics and high rates of precipitation[2]. When an old stand of rubber is cleared, it results in bare patches of soil where surface run-off can be serious. Also, during the early years after planting, young rubber plants provide very little protection to the soil mainly due to poor canopy cover. The impact of rain drops on bare soil results in a breakdown of the soil aggregates and a dispersion of soil particles which seal up the soil pores in the immediate surface leading to reduced infiltration. Under these conditions there could be an increased runoff and soil losses depending on the slope of land, length of slope and erodibility of soil and rainfall characteristics[3]. Many soils, particularly those that have carried two planting cycles of rubber and which are due for replanting, have low reserves of organic matter and are of poor

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structure As a result of their low permeability to rainfall such soils are susceptible to erosion[2]

Leguminous ground covers are known to preserve soil fertility and conservation of soil[4] Yet, most of the legume covers take at least 6 to 12 months to provide sufficient protection to the soil However, at the same time ground covers may also compete for the nutrients and moisture with young rubber plants A circle of about one meter radius around each rubber plant should therefore be clean weeded to avoid competition with young rubber plants But, this can lead to soil degradation due to the exposure to adverse climatic conditions It may, therefore, be important to adopt some agronomic practices, that may improve the physical properties of soil Mulching with rice straw on the bare soil patches and around the base of the rubber plants may be a possible and effective agronomic practice Therefore, a study was undertaken to investigate the effect of mulching with rice straw on changes in soil physical properties under rubber, as hardly any work has been done on the use of paddy straw in rubber plantations

MATERIALS AND METHODS

The experiment was conducted at Dorset Division, Clyde Estate, Tebuwana, Kalutara for a period of 6 years The experimental layout consisted of three ground cover management practices, arranged in a randomised block design with each treatment being replicated six times Treatments consisted of

a Natural vegetation (weeds)

b Mixed legumes (*Pueraria phaseoloides* and *Desmodium ovalifolium*)

c Mixed legumes + Mulch (rice straw) around the base, 2 kg–5 kg/plant/application, once in 6 months

The plot size was 0 10 ha consisting of 25–30 effective rubber trees of clone PB 86 Each plot was surrounded by a common single guard row on all four sides Plots with natural cover had common weeds The weeds were periodically slashed for prevention of overgrowth The leguminous plots had a mixed growth of *P phaseoloides* and *D ovalifolium* A clean weeded circle was maintained around the rubber plants for both treatments as recommended by the Rubber Research Institute of Sri Lanka For the 3rd treatment, *P phaseoloides* and *D ovalifolium* were maintained in the inter-row and within-row areas as in treatment (b), but the clean weeded circle around the base of the plant was mulched with rice straw at the rate of 2 kg–5 kg per application once in 6 months during the experimental period The type of soil in the experimental site was a shallow, gravelly loam and brown to reddish yellow in colour[5] and belonged to the *Boralu* series (Red Yellow Podzolic, Rhodudults)

The bulk density of the soil was measured by obtaining undisturbed core samples Three measurements were done in each plot in the inter-row and in the clean weeded circle on three different days (2, 4 and 6 months after application of straw) and their means are presented The soil resistance was measured using a Proctor Penetrometer at three places in each plot in the inter-row and in the clean weeded circle For each plot, two composite bulk samples from the inter-row and weed free circle consisting of soils taken from three places were obtained for aggregate analysis Distribution of wet-sieved aggregates and mean weight diameters were measured using a mechanical sieve and a special wet sieving attachment Dry-sieved aggregation was also measured using a mechanical sieve The

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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 10 cm interval from 10 cm to 160 cm. The gravimetric soil moisture content was measured by taking three samples from two depths 0 cm–15 cm and 15 cm–30 cm in each plot in the inter-row and in the clean weeded circle. 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 on 3 different days (2, 4 and 6 months after application of straw) and their means are presented.

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

Data on soil bulk density of the 0 cm–15 cm and 15 cm–30 cm depths indicated that soils under mulch had the significantly lowest bulk density when compared with other treatments. The clean weeded circle in the plots with natural vegetation recorded significantly the highest bulk density of 1.45 g/cm^3 for the 0 cm–15 cm depth and 1.61 g/cm^3 for the 15 cm–30 cm depth in comparison with 1.02 g/cm^3 for the 0 cm–15 cm depth and 1.18 g/cm^3 for the 15 cm–30 cm depth under mulch (*Table 1*). Similar results were observed with regard to soil porosity for the 0 cm–15 cm and 15 cm–30 cm depths (*Table 1*). There was a significant difference in penetrometer resistance among the treatments. The lowest penetrometer resistance was observed under mulch while the highest was observed in the bare weed free circle around the rubber plants in natural plots (*Table 1*).

It was found that mulch resulted in a significantly higher aggregation percentage. There was an increase of 20% in the total aggregation over the legumes in the clean weeded circle around the rubber plants (*Table 2*). Similarly, mulching had reduced the amount of finer aggregates by 45% over the clean weeded circle around the rubber plants in the legume plots (*Table 2*). The size distribution of the water stable aggregates for soil samples obtained from the clean weeded circle around the rubber plants under different soil management practices is shown in *Figure 1*. A significant difference was also observed for the mean weight diameter (MWD) of water stable aggregates (*Table 3*). The amount of coarse aggregates (2 mm–5 mm) and fine aggregates (<0.25 mm) under different treatments is shown in *Figure 2* and the changes in the amount of water stable aggregates with time over the six year period is shown in *Figure 3*.

The soils under mulch showed a significantly higher moisture content of 20.8% and 19.1% for the depths of 0 cm–15 cm and 15 cm–30 cm respectively, in comparison to the practices such as growing leguminous covers or naturals or leaving the soil bare (clean weeded circle)(*Table 1*). Among the different soil management practices, mulching recorded the highest moisture profile storage capacity of 27.6 cm for a depth of 90 cm. There was an increase of 43% in the moisture storage capacity as compared to the clean weeded circle in legume plots (*Table 4*). *Figure 4*

TABLE 1. EFFECT OF DIFFERENT SOIL MANAGEMENT PRACTICES ON SOIL BULK DENSITY, SOIL POROSITY, SOIL RESISTANCE AND SOIL MOISTURE CONTENT FOR TWO DIFFERENT DEPTHS, SIX YEARS AFTER PLANTING

Treatment	Bulk density (g/cm^3)				Soil porosity (%)				Penetrometer resistance (kg/cm^2)				Soil moisture content (%)			
	Inter-row area		Clean weeded circle		Inter-row area		Clean weeded circle		Inter-row area		Clean weeded circle		Inter-row area		Clean weeded circle	
	0–15cm	15–30cm	0–15cm	15–30cm	0–15cm	15–30cm	0–15cm	15–30cm	0–15cm	15–30cm	0–15cm	15–30cm	0–15cm	15–30cm	0–15cm	15–30cm
Naturals	1.27[a]	1.33[a]	1.45[a]	1.61[a]	52.1[a]	49.8[a]	45.3[a]	39.2[a]	10.3[a]	13.3[a]	12.5[a]	15.1[a]	15.3[a]	13.9[a]	12.5[a]	12.1[a]
Legumes	1.09[b]	1.29[b]	1.31[b]	1.51[b]	58.9[b]	51.3[b]	50.6[b]	43.0[b]	8.1[b]	12.9[b]	11.3[b]	14.5[a]	18.1[b]	16.9[b]	14.3[b]	13.5[a]
Mulch	1.08[b]	1.28[b]	1.02[c]	1.18[c]	59.2[b]	51.7[b]	61.5[c]	55.5[c]	8.3[b]	12.8[b]	7.8[c]	9.1[b]	18.7[b]	16.8[b]	20.8[c]	19.1[b]

[a,b,c]The values in each column are significantly different at the 0.05 probability level.

TABLE 2. EFFECT OF DIFFERENT SOIL MANAGEMENT PRACTICES ON SOIL AGGREGATION, SIX YEARS AFTER PLANTING

Treatment	Aggregation (%)			
	Inter-row area		Clean weeded circle	
	Total	<0.25 mm	Total	<0.25 mm
Naturals	56 3[a]	23.4[a]	52.8[a]	35 6[a]
Legumes	60 4[b]	17 2[b]	54 4[b]	27 6[b]
Mulch	61.0[b]	17.9[b]	65.3[c]	15.2[c]

[a,b,c]The values in each column are significantly different at the 0 05 probability level.

TABLE 3. EFFECT OF DIFFERENT SOIL MANAGEMENT PRACTICES ON MEAN WEIGHT DIAMETER OF AGGREGATES, SIX YEARS AFTER PLANTING

Treatment	Mean weight diameter (mm)			
	Inter-row area		Clean weeded circle	
	Dry sieving	Wet sieving	Dry sieving	Wet sieving
Naturals	1.71[a]	0.92[a]	1 25[a]	0 58[a]
Legumes	2 72[b]	1.09[b]	1.31[b]	0 73[b]
Mulch	2.98[b]	1.13[b]	3.14[b]	1.37[c]

[a,b,c]The values in each column are significantly different at the 0 05 probability level.

TABLE 4. EFFECT OF DIFFERENT SOIL MANAGEMENT PRACTICES ON MOISTURE STORAGE CAPACITY FOR 90 CM SOIL PROFILE, SIX YEARS AFTER PLANTING

Treatment	Soil moisture storage capacity (cm)	
	Inter-row area	Clean weeded circle
Naturals	21.7[a]	19 1[a]
Legumes	22.9[b]	19.3[a]
Mulch	23.3[b]	27 6[b]

[a,b,c]The values in each column are significantly different at the 0.05 probability level

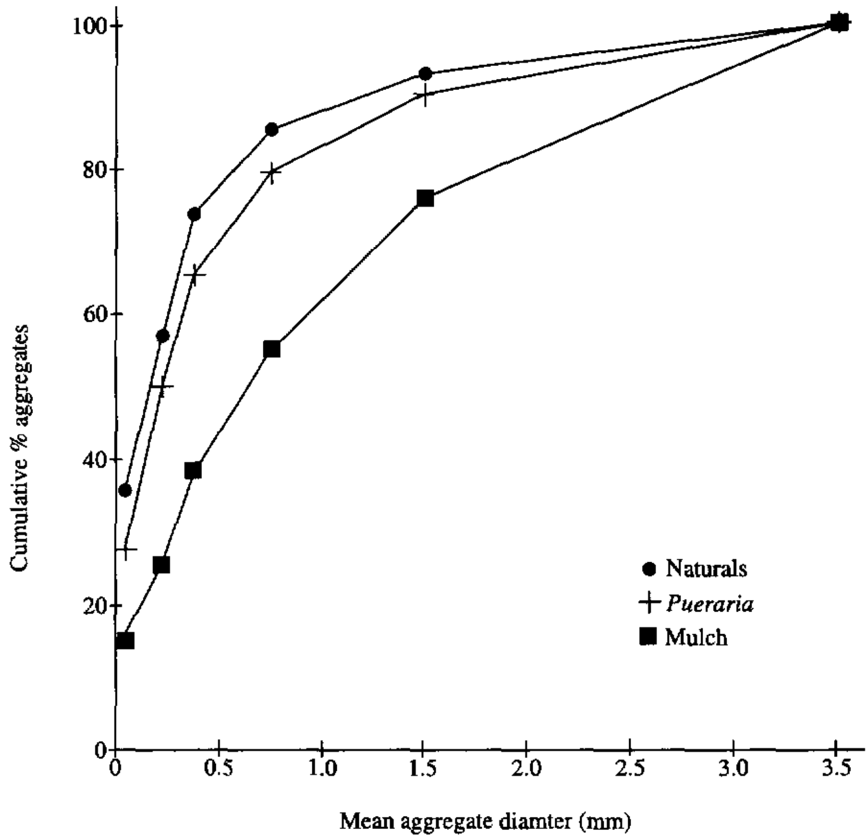

Figure 1. Effect of different soil management practices on size distribution of water stable aggregates.

illustrates the available water storage capacity of the soils under different soil management practices over a period of 12 months. It shows an 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 different management practices is given in *Table 5*. In general, a significantly higher amount of water was retained at –10 kPa. Also, mulching improved the water retention at different soil potentials. Similarly, at different suctions, more water was retained in the soils under mulch as compared to soils in the clean weeded circles of legume and natural plots. There were no significant differences in water retention among the other treatments (*Figure 5*). The rate of water absorption into the soil indicated a distinct variation among the different treatments. The infiltration rate (*Figure 6*) was highest in the soils under mulch. Similarly, the soils of the clean weeded areas in legume plots also had a higher infiltration rate as compared to the soils in the clean weeded areas in plots with natural vegetation.

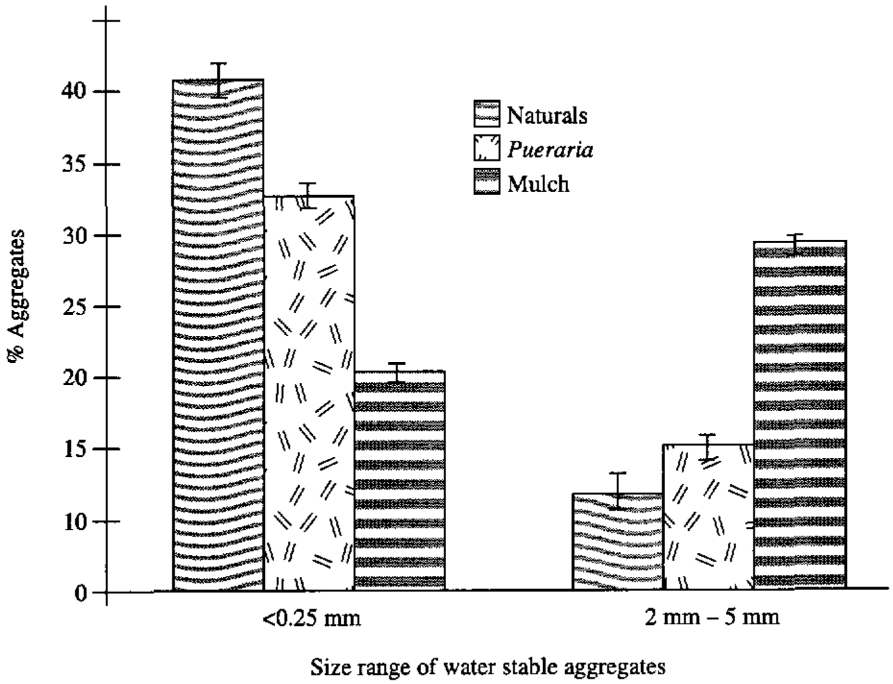

Figure 2. Effect of different soil management practices on the amount of fine and coarse aggregates.

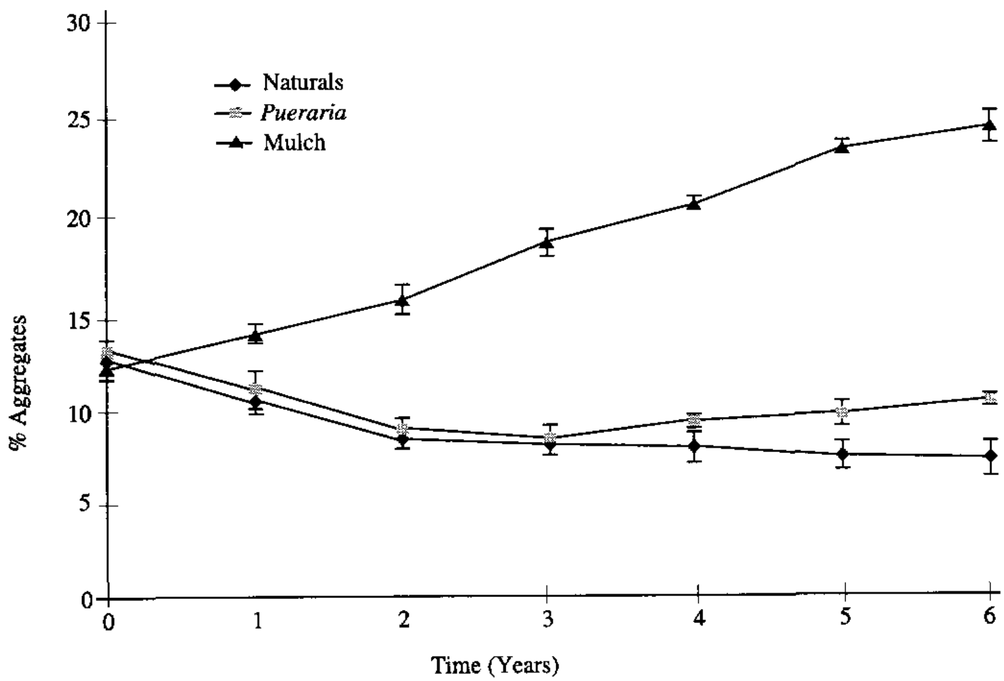

Figure 3. Changes in water stable aggregates in soil during the immature period of rubber.

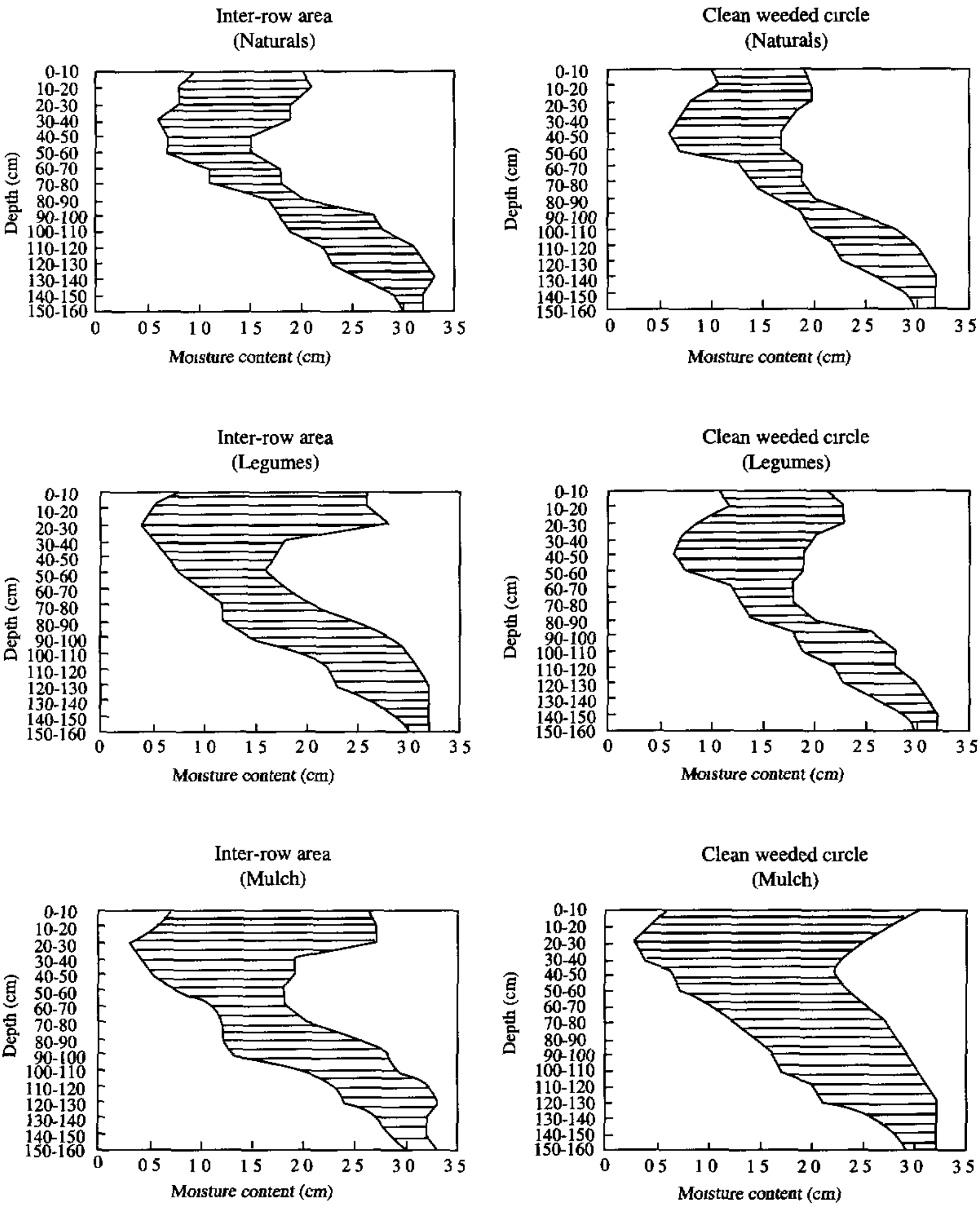

Figure 4 Effect of different soil management practices on the available water storage capacity (AWSC)

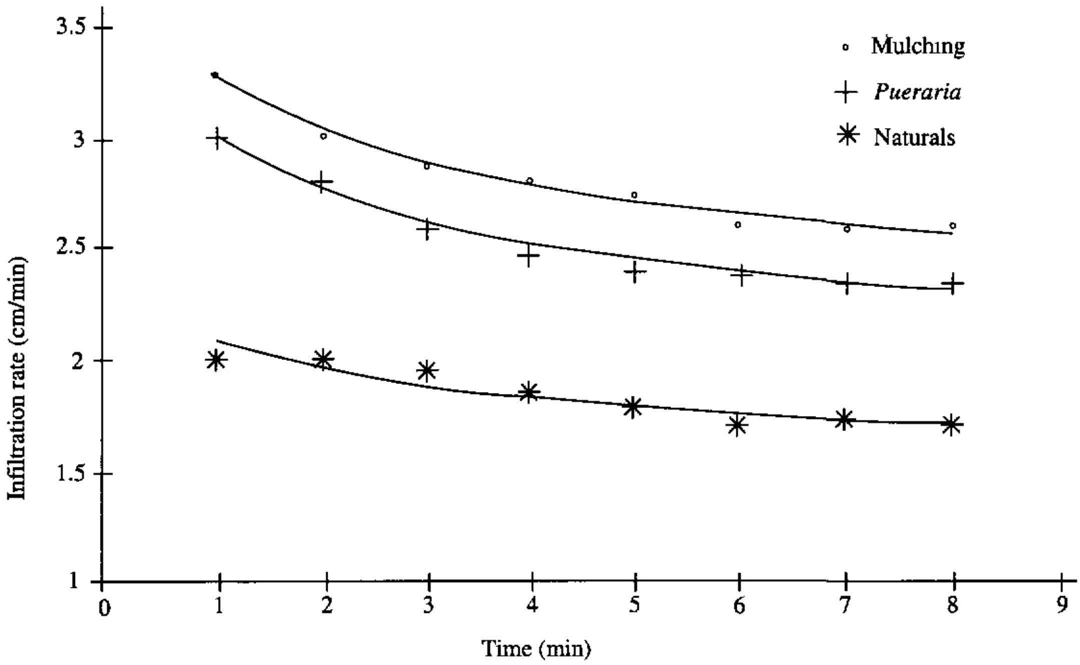

Figure 5. Effect of different soil management practices on the infiltration rate.

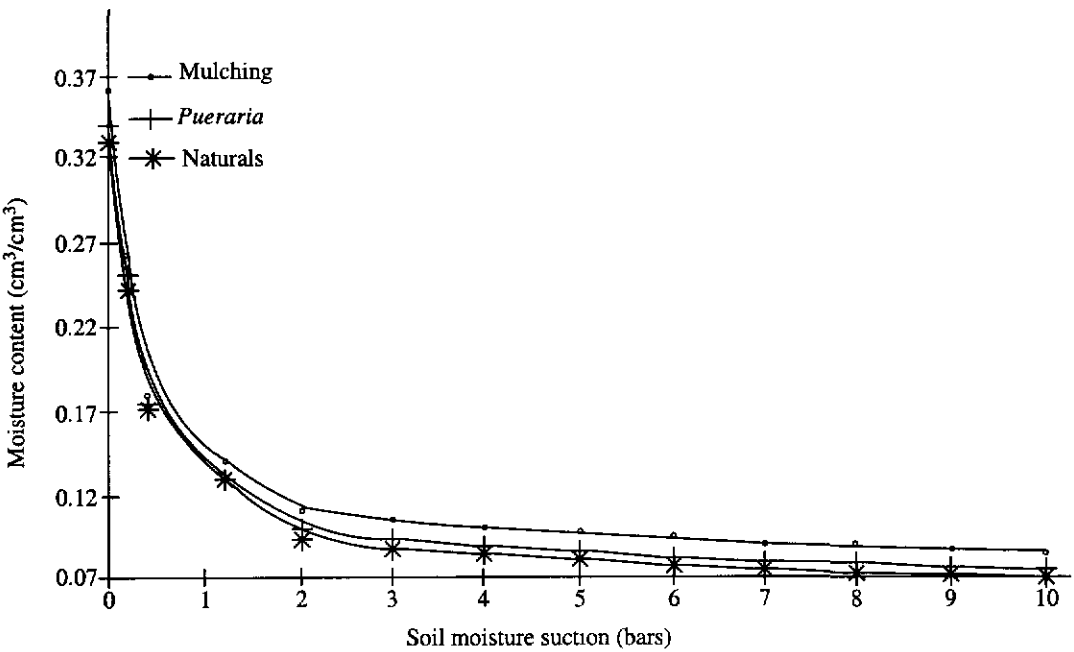

Figure 6. Effect of different soil management practices on moisture retention.

TABLE 5 EFFECT OF DIFFERENT SOIL MANAGEMENT PRACTICES ON VOLUMETRIC MOISTURE CONTENT AT DIFFERENT SOIL POTENTIALS, SIX YEARS AFTER PLANTING

Treatment	Volumetric moisture content (%)					
	Inter-row area			Clean weeded circle		
	−10 kPa	−500 kPa	−1500 kPa	−10 kPa	−500 kPa	−1500 kPa
Naturals	38.3[a]	33.9[a]	32.7[a]	35.4[a]	32.5[a]	32.1[a]
Legumes	43.1[b]	34.5[a]	32.9[a]	36.9[b]	33.1[a]	32.8[a]
Mulch	43.7[b]	35.0[a]	31.8[a]	45.9[c]	34.3[b]	31.8[a]

[a,b,c]The values in each column are significantly different at the 0.05 probability level.

DISCUSSION

The impact of raindrops on bare soil results in a breakdown of soil aggregates and a dispersion of soil particles which seal up the soil pores in the immediate surface leading to reduced infiltration and increased run-off. Management of ground covers is therefore, an important aspect for the preservation of soil fertility and soil conservation in rubber cultivation[6]. At the same time, as ground covers may compete with young rubber plants for nutrition and moisture, a circle of about one meter radius around each rubber plant was clean weeded to avoid competition. This can lead to some degree of soil degradation around the base of the rubber plants due to the exposure of soil to adverse climatic conditions.

Some important physical soil parameters such as soil bulk density, soil porosity and soil resistance were improved under mulching in the clean weeded circle around the rubber plants. It is possible that the layer of mulch on the soil surface would have prevented the direct impact of raindrops, thus preventing the breakdown of soil structure. The higher porosity under mulch may have been due to the better soil structure. A mulch surface is also known to serve as a cushion against the pressure exerted by raindrops[2].

The highest aggregation percentage and mean weight diameter of water stable aggregates were also observed under mulch. There was an increase of 20% in aggregation and a reduction of finer aggregates by 45% over the legumes in the clean weeded circle under mulch. It appears that the loss of finer-fraction ultimately resulted in the formation of coarser (2 mm–5 mm) water stable aggregates. The relatively higher amount of finer aggregates in the clean weeded circle can be attributed to structural breakdown by the impact of raindrops. It is apparent that mulching played an important role in the formation of water stable aggregates. The amount of coarser aggregates assumed a dynamic role in the changes of soil structure[7]. The percentage aggregation is known to be a measure of ability of the soil structure to withstand the disruptive forces of erosive rain in the tropics. A higher percentage aggregation under mulching may be due to a higher organic matter content[8]. It was reported that organic matter serves as a substrate for biological activity[9]. Polar substances resulting from decomposition of organic matter are very effective in aggregating cultivated soils[10]. Microbial gums and filamentous fungi are known to thrive well under increased organic matter content and this probably contributed to an increased percentage of aggregation.

The infiltration rate distinctly varied among the different treatments. It was higher under mulching. 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 straw mulch 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 in the clean weeded circle. The marked increase in infiltration rate with mulching 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 mulch in reducing soil erosion. Firstly, the mulch on the surface intercepts the rain drops 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 mulching may have minimised 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 provided earlier[11]. In this respect, mulching has the advantage over the establishment of cover crops, because mulch can be applied immediately after planting to give a suitable cover to protect the soil[3].

The influence of soil management practices on soil moisture content indicates that soils under mulch had the highest moisture content of 21% and 19% for the 0 cm–15 cm and 15 cm–30 cm depths respectively, in comparison with the other practices such as growing leguminous covers or naturals or leaving the soil bare (clean weeded circle). Among the different soil management practices, the highest moisture profile storage capacity of 27.6 cm was observed under mulch for a 90 cm profile depth. There was an increase of 43% in the moisture storage capacity as compared to the clean weeded circle around the rubber plants in legume plots. Similarly, at different suction, more water was retained in the soils under mulch as compared to soils in the clean weeded circles of legume plots and natural plots which have a growth of natural vegetation. Mulches would influence the moisture content of the soil by their effect on water intake through the immediate surface layer and also by decreasing losses due to evaporation and probably by suppressing weed growth[12]. Also, an improved structure decreases crusting and surface sealing and permits greater infiltration, thereby increasing the water holding capacity. Mulches also tend to reduce the rate of evaporation of soil moisture thus allowing moisture to remain in the soil for a longer period of time[13]. Any reduction in evapo-transpiration of soil moisture would be beneficial to crop growth in the same manner as additional water. Therefore, it appears possible to eliminate or at least minimise the adverse effects of moisture stress by mulching with rice straw. The higher soil moisture content may increase the water uptake by young plants thereby increasing their growth specially during dry periods

Mulching with rice straw during the immature period of rubber plants not only improves the physical properties of soil, it is also important for the recycling of crop residues which are otherwise discarded

ACKNOWLEDGEMENT

The authors wish to thank Mrs Wasana Wijesuriya, Biometrician for her valuable assistance in statistical analysis

Date of receipt November 1998
Date of acceptance March 1999

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