Tropical Agricultural Research and Extension 3 (1): 56- 62, 2000

Use of neutron moisture meter in soil-plant-water relation studies of rubber (*Hevea brasiliensis*)

Lalani Samarappuli, N. Yogaratnam, R.Hettiarachchi, P. Karunadasa and U. Mitrasena
Rubber Research Institute of Sri Lanka, Dartonfield, Agalawatta, Sri Lanka.

Accepted 30 September1999

ABSTRACT

Volumetric moisture content data obtained from 12 positions in relation to planting points over a period of 12 months indicate that the distances varying from 0-120 cm from the trunk of young rubber tree are suitable for assessing the water content of the soil profile. Feeder root density was significantly different at different depths with the highest percentage of roots being in the surface soil layers, 0-10cm and 10-20cm, in the region of 120 cm circle. These findings were further confirmed by the co-efficient of variation of volumetric moisture content data obtained at different depths in relation to planting points. Therefore, it is evident that a clear relationship exists between the rooting density of rubber and the moisture readings. Based on the soil moisture data under different management practices, it is possible to overcome the adverse effects of soil moisture deficit by growing appropriate rubber clones, with the use of mulch preferably paddy straw and higher levels of potassium, during the immature period of rubber plants.

Keywords: *Hevea brasiliensis*, soil moisture, neutron moisture meter, mulch, potassium, clones, root density

INTRODUCTION

In Sri Lanka, rubber cultivation is traditionally confined to the low country wet zone. Yet, both productivity and total land area under rubber has shown a declining trend. In view of the decline in productivity and diversification of rubber lands into other alternative ventures, greater emphasis is now being placed on improvement of crop productivity and expansion of rubber cultivation into marginal areas.

Young rubber plants like any other crop, suffer from moisture stress during dry periods, which is a common feature in marginal dry areas. Moreover, inter-row ground cover vegetation can also compete with the immature rubber plants for moisture (Samarappuli 1992a). Soil moisture deficit retards latex flow and thereby reduces yield of rubber. It is therefore necessary to understand the effect of soil moisture stress on the performance of rubber tree and to device suitable agronomic practices such as ground cover management, fertilizer programme, clone selection and field establishment practices to overcome the adverse effects of soil moisture stress.

In this connection, moisture content of the soil profile under rubber has to be monitored regularly and repeatedly in a given site. The neutron moisture meter measures the volumetric water content of the soil in a manner that satisfies the ideal requirements of agronomists. This method of measuring soil water content is a non-destructive field method based on the slowing down of fast neutrons emitted by a radioactive source by water. Some of the advantages of this method are greater precision, non-destructive attribute, ability of repetition in the same place and speedy sampling (Van Bavel 1961; Kristensen 1973; Greacen 1981).

Therefore, the objective of this study was to monitor soil water content under rubber in relation to plant response and make use of these data in devicing suitable agronomic practices to overcome the adverse effects of soil moisture stress.

Abbreviations: AWSC - available water storage capacity; LDR - leaf diffusive resistance; SMSC - soil moisture storage capacity

MATERIALS AND METHODS

Experiment 1

A first experiment was conducted to determine the most suitable position in relation to the rubber plant for the installation of access tubes. Trees were selected at random in a 3-year old plantation and access tubes were installed at distances 60, 120 and 180 cm from the trunk of each plant in four directions, north, south, east and west, making in all 12 positions. Moisture readings were recorded weekly using neutron moisture meter from 10 to 90 cm at 10 cm intervals. This area generally covers the rooting zone of immature rubber plants. Soils samples were collected from same places to determine the rooting pattern of rubber plants.

Experiment 2

Three pot experiments were conducted to study the effects of four levels of soil moisture on the performance of Rubber plants of five different clones, using five different establishment practices and three levels of potassium. These were tested in a fully randomized design with single tree plots replicated four times. The four levels of moisture (M) were: M_0 - Watering at 90% depletion of available water; M_1 -Watering at 70% depletion of available water; M_2 - Watering at 50% depletion of available water and M_3- Watering at 30% depletion of available water. The five different rubber clones (C) used were: C_1 - PB 86; C_2 - RRIC 100; C_3 - RRIC 102; C_4 - RRIC 110 and C_5 - RRIC 121. Five different establishment practices were: E_1 - Brown budded bare roots; E_2 - Green budded bare roots; E_3 - Brown budded poly bags; E_4 - Green budded poly bags; E_5 - Young budded poly bags. The potassium levels (K) were; K_0 -no potassium added; K_1- Recommended dosage (33g of K/plant/year); K_2 -Double the recommended dosage (66g of K/plant/year).

The maintenance of the four levels of moisture throughout the experiment was done using a neutron moisture meter.

Experiment 3

A field experiment was established to study the effects of different soil management practices on the performance of rubber plants. Three ground cover management practices were studied in a randomized block design with six replicates. The three ground covers used were natural cover (unweeded), mixedl legumes (*Pueraria phaseoloides* and *Desmodium ovalifolium*) and mixed legumes + dead mulch in the form of rice straw around the base, at the rate of 5kg per plant once in 6 months. The neutron moisture meter was used to monitor profile soil water distribution 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 to 160 cm. Plant physiological measurements, growth and yield were recorded periodically.

RESULTS

Variation in soil moisture content (co-efficient of variation) of volumetric moisture content data obtained from 12 positions in relation to planting points over a period of 12 months indicated the highest variation at 60 cm from the tree. No significant difference was seen in relation to the direction from the base of the rubber plant (Fig. 1).

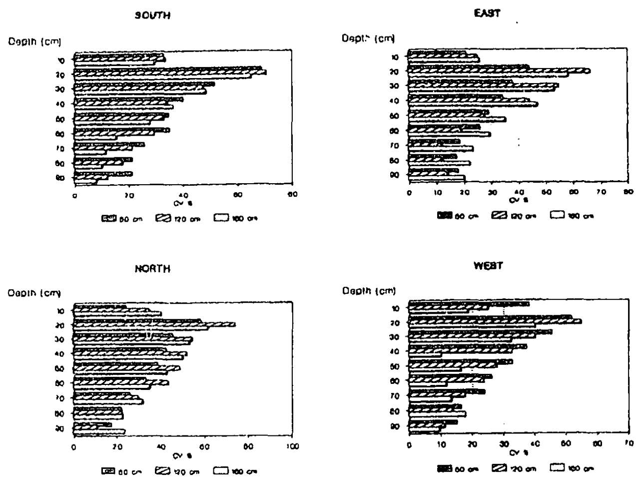


Fig. 1. Coefficient of variation of moisture content at Different depths and distances

Volumetric moisture content data obtained from different depths over the same period indicate that 10-20 cm and 20-30 cm depth had the highest variation, (Table 1).

Table 1. Co-efficient of variation (CV) of moisture content at different depths

Depth(cm)	CV(%)
0-10	29.33
10-20	70.48
20-30	47.11
30-50	32.95
50-70	21.25
70-90	15.14

No significant difference in the density of feeder roots were found between different distances from the base of the rubber plant. One-year old rubber plants had more feeder roots in the region of 120 cm circle. A significant difference in the density of vertical distribution of feeder roots was also found, with the highest percentage of roots in the surface soil layers at 0 - 10 cm and 10 - 20cm (Table 2).

Table 2. Feeder root densities at various soil depths (mg/1000cc). at 3 distances from the base of rubber plant

Distance (cm)	Depth (cm)					
	0-10	10-20	20-30	30-50	50-70	70-90
60	215.5^a	289.9^a	95.1^a	28.0^a	13.9^a	6.0^a
120	213.5^a	293.7^a	93.5^a	20.0^b	10.0^b	3.4^b
180	208.7^b	281.4^b	84.6^b	8.2^c	2.6^c	0.7^c

The values having different letters in each column are significantly different at 0.05 probability level

Fig 2 illustrates the available water storage capacity (AWSC) of the experimental area over a period of 12 months.

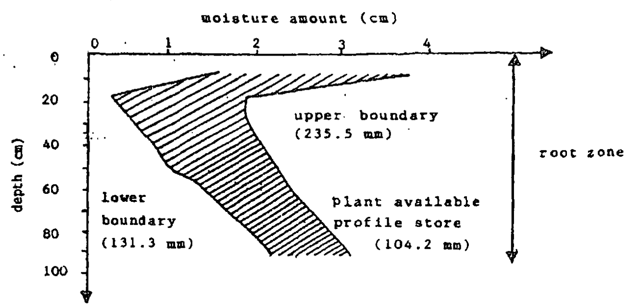


Fig.2 The available water storage capacity

It showed an upper limit of 235.5 mm (field capacity) and a lower limit of 131.3 mm thus yielding an AWSC of 104.2 mm. Fig 3 illustrates the available soil water in relation to the total rainfall over a period of 12 months for a 90 cm profile, which is generally the rooting depth of immature rubber. A clear relationship exists between available soil water and total rainfall during this period.

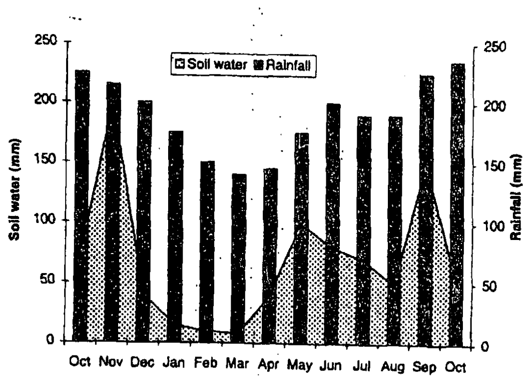
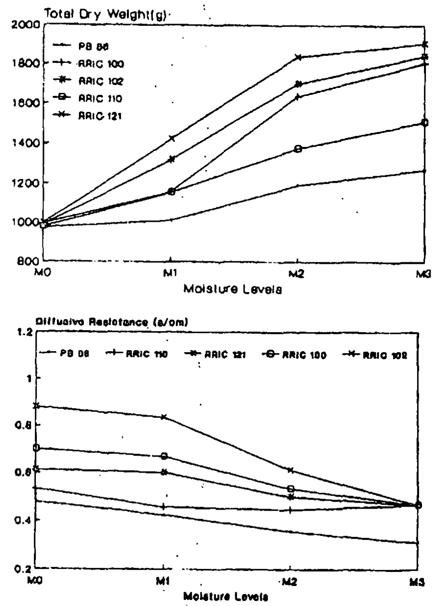


Fig.3 Available soil water in relation to rainfall

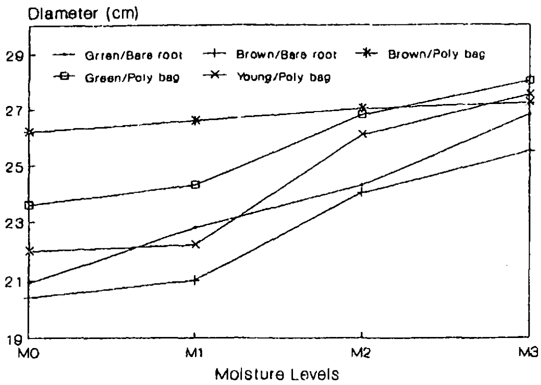
In experiment 2, total dry weight accumulation data showed that there was a significant interaction ($P<0.001$) between different clones and soil moisture regimes (Fig 4). At 30% field capacity level, clones RRIC 121 and RRIC 102 showed higher total dry weights compared to other three clones. At 70% field capacity level, clones RRIC 121, RRIC 102 and RRIC 100 showed higher total dry weights compared to other clones. Leaf Diffusive Resistance (LDR) showed a significant interaction ($P<0.05$) between different clones and soil moisture regimes (Fig 4). At low soil moisture regimes i.e. 10% and 30% available water levels, clone RRIC 102 showed the highest LDR compared to other clones.



M_0 - Watering at 90% depletion of available water
M_1 - Watering at 70% depletion of available water
M_2 - Watering at 50% depletion of available water
M_3 - Watering at 30% depletion of available water

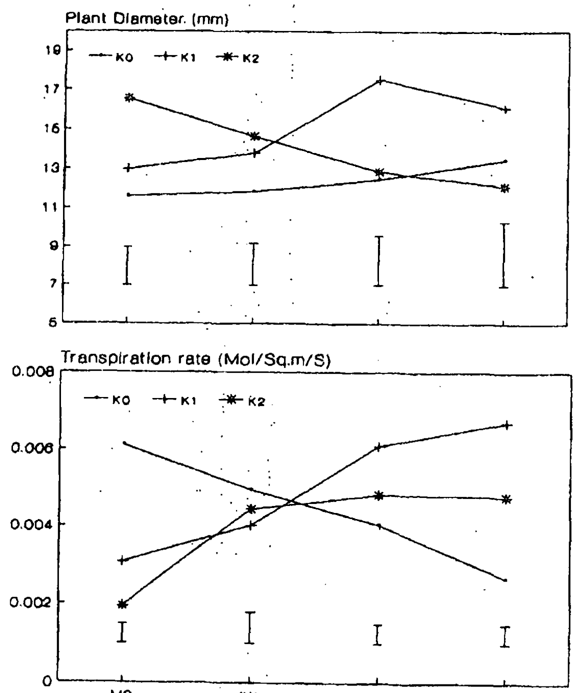
Fig 4. Effect of different soil moisture regimes on total dry weight and diffusive resistance of different clones

Plant diameter measurements made at 12 months after planting showed that there was a significant interaction ($P<0.01$) between different establishment practices and soil moisture regimes (Fig. 5). At low soil moisture levels, brown budded poly bag plants showed the highest plant diameter in comparison with the other establishment practices. Plant diameter recorded a significant interaction ($P<0.001$) between applied potassium and soil moisture content (Fig 6). The plant diameter at M_2 level with K_1 (recommended level) was almost equal to the diameter at M_0 level in combination with the K_2 level. There was also a significant interaction ($P<0.001$) between applied potassium and different levels of soil moisture on transpiration rate (Fig. 6).



M_0 - Watering at 90% depletion of available water
M_0 - Watering at 70% depletion of available water
M_0 - Watering at 50% depletion of available water
M_0 - Watering at 30% depletion of available water

Fig.5 Effect of different soil moisture regimes and establishment practices on plant diameter



M_0 - Watering at 90% depletion of available water
M_0 - Watering at 70% depletion of available water
M_0 - Watering at 50% depletion of available water
M_0 - Watering at 30% depletion of available water

Fig.6 Effect of different soil moisture regimes and potassium levels on stem diameter and transpiration rate of rubber plants

In experiment 3, among the different soil management practices that were tested for their effects on moisture conservation in rubber plantations, dead mulch exhibited the highest soil moisture storage capacity of 27.6 cm in comparison with other practices such as growing leguminous covers or naturals. Similar results were observed with regard to leaf water potential, girth and yield of rubber plants (Table 3). Figure 7 illustrates the available water storage capacity of the soils under different soil management practices. It shows an upper limit 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.

Table 3. Effect of different soil management practices on soil moisture storage capacity (SMSC), leaf water potential (LWP), girth and yield of rubber plants

Treatment	SMSC(cm)	LWP(-Mpa)	Girth(cm)	Yield(kg/ha/yr)
Naturals	21.7^a	2.57^a	40.0^a	1166^a
Legumes	23.3^b	2.07^b	44.5^b	1193^a
Dead mulch	27.6^c	1.83^b	50.0^c	1419^b

The values having different letters in each column are significantly different at 0.05 probability level

DISCUSSION

It appears that during dry period, distances varying from 0-1.2 m from the trunk of the tree are suitable for assessing the water content of the soil profile. This is in line with the previous reports based on the use of radiotracers, that root activity in immature plantations is more towards the tree trunk than away from it (Liu Chong Qun 1984; Samarappuli *et al.* 1992a). In this study, it is possible that on wet days when the soil is saturated with water, daily changes due to transpiration losses may not have caused much fluctuation in the soil water content. But on dry days, the process of depletion and recharging from the moist layers may be continuous in the profile close to the trunk.

The available soil water storage capacity of 104.2 mm with the upper and lower limits of 235.5 and 131.3 mm, respectively, is likely to be the amount of water that is available to both rubber and leguminous covers over a period of 12 months. Clearly these upper and lower limits are somewhat arbitrary, yet in practical terms it has been possible to obtain a useful estimate of the profile water store and the available water storage capacity for *Boralu* series soils receiving a total rainfall of 2800 mm. This is further elaborated by the data on available

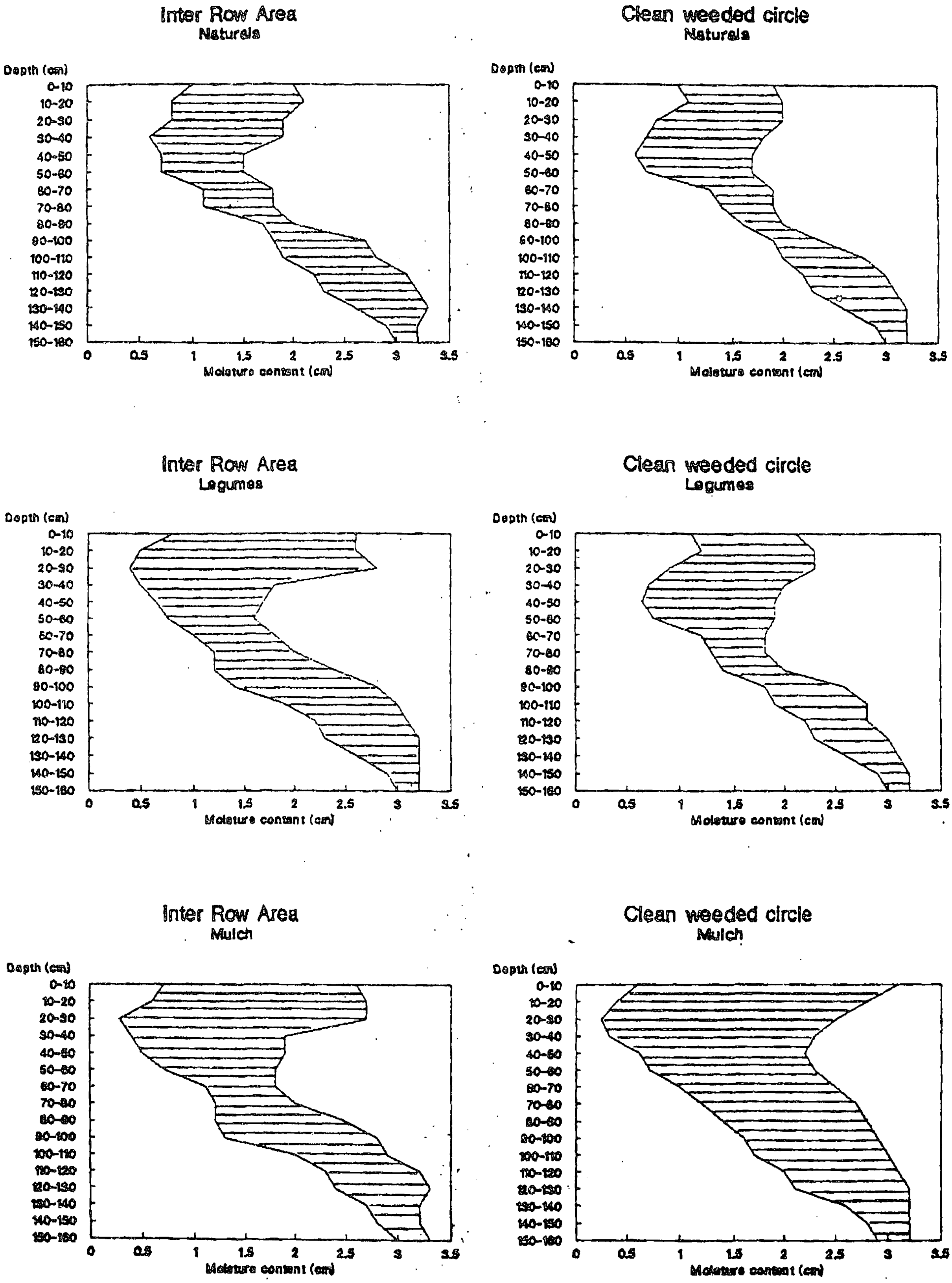


Fig. 7 Effect of different soil management practices on the available water storage capacity

This is further elaborated by the data on available soil water in relation to precipitation where a clear relationship exists between these two variables. It is evident that even during the most dry periods in January, February and March the available soil water has been in the region of 140 to 175 mm, with the lowest value of 140 mm in February. Total precipitation in the preceding 3 months i.e. in October, November and December of the previous year, had been around 1000 mm. These results therefore seem to suggest that if there had been approximately 1000 mm of rain during the north east monsoon in the previous year, there will be an adequate amount of water in the soil during the dry periods of January to April in the following year.

In general, development and distribution of the root system in the soil are expected to influence the growth, yield and nutrition of any plant. Assessing the rooting pattern of a perennial tree like rubber is rather difficult because of the laborious sampling involved in this process (Samarappuli *et al.* 1996a). The results obtained in this study clearly show that there were significant differences in feeder root development between various directions from the base of the rubber plant with south direction having more feeder roots. The density of feeder roots at different depths also showed that there was a significant difference in their vertical distribution, with the highest percentage of roots being in the surface soil layers, 0-10cm and 10-20cm. These findings were further confirmed by the statistical calculations (co-efficient of variation) of volumetric moisture content data obtained from 12 positions at different depths in relation to planting points over a period of 12 months. The distance 60 cm from the tree at depths 10-20 cm and 20-30 cm recorded the highest variation indicating the greatest root activity. Therefore, it is evident that a clear relationship exists between the rooting density of rubber and the moisture reading. Thus, the neutron moisture meter could be used to assess the rooting pattern of rubber trees.

Dry spells and prolonged drought periods which lead to soil moisture deficit appear to be a major limiting factor for growth and tapability of rubber trees (Samarappuli *et al.* 1996b). This study has shown that the growth of RRIC 121 and RRIC 102 were superior to other clones tested even at the very low soil moisture level of 10% available water. Moreover, leaf diffusive resistance data indicated that clone RRIC 102 had the highest leaf diffusive resistance which could result in a comparatively higher water use efficiency value (Kozlowski 1975; Samarappuli *et al.* 1992b). Therefore, clone RRIC 102 may perform better compared to other clones i.e. RRIC 100, RRIC 110, RRIC 121 and PB 86, under low soil moisture conditions.

The growth of one whorled brown budded poly bag plants was found to be superior to other establishment practices such as one whorled poly bagged green buddings and young buddings, brown budded bare roots and green budded bare roots at the very low soil moisture level of 10% available water (Samarappuli *et al.* 1993a). According to the results, in the absence of potassium, stomatal conductance was greater at 10% field capacity, losing more water from the plant. Thus it may be possible that K sufficient rubber plants close stomata and reduce transpiration more readily than the K deficient plants. These results also suggest that plants fertilized with higher levels of K (Treatment K_2) maintain a higher water use efficiency and a higher growth rate under water stress, compared to K deficient plants.

Among the different soil management practices, dead mulch exhibited the highest soil moisture, storage capacity. Application of straw as a mulch reduces the rate of evaporation of soil moisture, thus allowing moisture to remain in the soil for a longer period Samarappuli *et al.* 1992c; 1992d). Mulches also would influence the moisture content of the soil by their effect on water intake through the immediate surface layer and due to improved soil structure by higher organic matter content, which decreases crusting and surface sealing,thereby allowing greater infiltration and increasing the water holding capacity. Any reduction in evaporation of soil moisture would be beneficial to crop growth in the same manner as additional water intake by the soil. Therefore, it is possible to eliminate or at least minimize the adverse effects of moisture stress by mulching (Samarappuli & Yogaratnam 1984; Samarappuli 1992b). The higher soil moisture content increases the water uptake and along with the water, nutrients are also taken up, thereby increasing the growth of rubber plants under dry climatic conditions. Thus it should be possible to extend rubber growing areas to marginal lands by choosing the appropriate clone such as RRIC 102, with the use of dead mulch, preferably paddy straw, and higher levels of potassium during the early stages of growth.

This study clearly establishes the effectiveness of neutron moisture meter in monitoring soil water balance in the root zone forsoil-plant-water relation studies in rubber.

REFERENCES

Greacen, E.L. (1981) Soil water assessment by the neutron method. CSIRO Australia,.1-2.

Liu Chong Qun 1984 Radiotracer studies on root activity and foliar spray of rubber trees (*Hevea brasiliensis*).ICOSANP (M.S.S.S.), Kuala Lumpur, Pp1-27.

Kozlowski TT 1975 Water relations and tree Improvement. pp. 27-43. In: Cannel MGR and Last FT (ed.) Tree Physiology and Yield Improvement. Academic Press, London.

Kristensen KJ 1973 Depth intervals and top soil moisture measurement with the neutron depth probe. Nordic Hydrology. 4: 77-86.

Samarappuli Lalani and Yogaratnam N 1984 Some aspects of moisture and soil conservation in rubber plantations. Proc. Int. Rubb. Conf. 1984 1(II): 529-543.

Samarappuli Lalani 1992a Effects of some soil management practices and moisture regimes on the performance of *Hevea*. PhD thesis, University of Peradeniya, Peradeniya, Sri Lanka.

Samarappuli Lalani 1992b Some agronomic aspects in overcoming moisture stress in *Hevea brasiliensis*. Indian J. Nat. Rubber Res. 5: 127-132.

Samarappuli Lalani, Yogaratnam N, Karunadasa P and Mitrasena U 1992a Preliminary studies on the use of Neutron Probe in some rubber growing soils. J. Rubber Res. Inst. Sri Lanka. 72: 39-48.

Samarappuli Lalani, Yogaratnam N, Samarappuli IN, Karunadasa P and Mitrasena U 1992b Towards shorter immaturity and improved yields by mulching with rice straw. J. Rubber. Res. Inst. Sri Lanka. 72: 27-38.

Samarappuli Lalani, Karunadasa P an Mitrasena U 1992c Effects of potassium and moisture stress on the performance of young *Hevea brasiliensis*. Proc. Int. Conf. on Fertilizer Usage in the Tropics. 87-96.

Samarappuli Lalani, Yogaratnam N and Hettiarachchi R 1993a Effect of soil moisture on establishment success at different planting techniques in rubber. J. Rubber. Res. Inst. Sri Lanka. 73: 58-71.

Samarappuli Lalani, Yogaratnam N, Karunadasa P and Mitrasena U 1996a Root Development in *Hevea brasiliensis* in relation to management practices. J. Rubber. Res. Inst. Sri Lanka. 77: 93-111.

Samarappuli Lalani, Dharmakeerthi S, Perera AMA, Hettiarachchi R, Karunadasa Pand Mitrasena U 1996b Possibilities of growing rubber in marginal dry areas. Proc. IRRDB Seminar on Agronomy, Farming Systems and Technology. 31-43.

Van Bavel CHM, Nielsen DR and Davidson JM 1961 Calibration and characteristics of two Neutron Moisture Probes. Proc. Soil Sci. Soc. Amer. 25:329-334.