

ROOT DEVELOPMENT IN *HEVEA BRASILIENSIS* IN RELATION TO MANAGEMENT PRACTICES

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ABSTRACT

Feeder root density was shown to be significantly different between distances from the base of the rubber plant and in their vertical distribution with the highest percentage of roots being in the surface soil layers, 0-10 cm and 10-20 cm in the region of 120 cm circle. The amount of feeder roots in the surface soil was more than 75% of the total feeder roots and only 17.2% and 1.9% of the total root weights were found in the lower soil layers, 20-50 cm and 50-90 cm, respectively. Statistical calculations (coefficient of variation) of volumetric moisture content data indicated that the distance 60 cm from the tree at surface soil layers would appear to give the highest variation.

Significant positive correlations were found between fine sand content (<200 μ diameter) and root density, while clay content was negatively correlated to root density. Root density had the tendency to decrease with increasing soil bulk density, but to increase with increasing soil organic carbon content.

There was a significant difference in root density between clones. Vigorous clones like RRIC 102, RRIC 121, RRIC 100 and RRIC 110 had more feeder roots than a less vigorous clone like PB 86. Feeder root development also significantly differed between different establishment practices.

Differences in the development of feeder roots were also shown to be significant with different soil moisture levels and potassium levels. Moreover, data obtained show that there was more vigorous feeder root development under mulching than under legume cover or natural cover.

INTRODUCTION

The rubber tree possesses an extensive root system that is adopted for exploiting large volume of soil. It has both a well developed tap root and lateral roots and also large numbers of fine rootlets that help to increase the tree's absorptive capacity for moisture and nutrients. Studies made on these fine rootlets show that they are the main active absorbing zones of the root system (Soong, 1976). This indicates that their development and distribution in the soil have a great influence on the growth, yield and nutrition of the rubber tree.

Root developments in Hevea brasiliensis

Information concerning the rooting habit of crops is required especially with respect to its development and distribution in relation to environmental changes and management practices. This paper presents results obtained on the effects of some environmental factors and management practices on development of roots in rubber trees. These information could be useful in better understanding of some growth and nutritional problems encountered in rubber cultivation.

MATERIALS AND METHODS

Experiment 1

A pilot study was conducted to determine the rooting pattern of 3-year old rubber plants in the field. Trees were selected at random in a 3-year old replanting and undisturbed soil samples were taken at distances 60, 120 and 180 cm (2,4 and 6 ft.) from the trunk of each plant in four directions, north, south, east and west, making in all 12 positions, at depths of 10 cm intervals from 10 to 90 cm. Roots were separated from soil by hand sorting, then washed clean and dried at 80 °C for 48 hours before weighing. Access tubes were also installed at the above 12 positions and moisture readings were recorded weekly using neutron probe at depths of 10 cm intervals from 10 to 90 cm. Soil bulk density, soil organic carbon and soil texture were also determined at depths of 10 cm intervals from 10 to 90 cm.

Experiment 2

Three pot experiments were done to study the effects of four levels of moisture on root growth of *Hevea* plants in relation to five different clones, 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) are:

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

Lalani Samarappuli *et al.*

The five different clones (C) are:

C ₁	-	PB 86
C ₂	-	RRIC 100
C ₃	-	RRIC 102
C ₄	-	RRIC 110
C ₅	-	RRIC 121

Five different establishment practices are:

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

Three levels of potassium (K) are;

- K₀ - Nil potassium
- K₁ - Recommended dosage (33 g of K/plant/year)
- K₂ - Double the recommended dosage (66 g of K/plant/year).

Root length, root spread, root density, root fresh and dry weights were recorded at the end of the experiment. Maintenance of the four levels of moisture throughout the experiment was done using a neutron meter.

Experiment 3

Eight different mulching materials were tested on root growth of *Hevea* plants in a fully randomized design with single tree plots replicated four times.

Eight different mulching materials are:

C ₀	-	No mulch (control)
C ₁	-	Rice Straw
C ₂	-	Coir dust
C ₃	-	<i>Pueraria phaseoloides</i>
C ₄	-	Guatamala grass
C ₅	-	Vetiver grass
C ₆	-	<i>Tephrosia vogellie</i>
C ₇	-	<i>Sesbania aculeata</i>

Root developments in Hevea brasiliensis

Mulching was done three times during the experimental period at four monthly intervals, and each time one kilogram of fresh material per pot was used. Root length, root spread, root density, root fresh and dry weights were recorded at the end of the experiment.

Experiment 4

A field experiment was started in 1982 at Dorset Division, Clyde State Plantation, Tebuwana to study the effects of different soil management practices on the performance of PB 86 plants. Three ground cover management practices that were studied in a randomized block design with six replicates are

- a. Natural cover (weeds)
- b. Mixed legumes (*Pueraria phaseoloides* and *Desmodium ovalifolium*)
- c. Mixed legumes + Dead mulch (rice straw) around the base, 5kg/plant/application, once in 6 months.

Root development under different soil management practices was studied by repeated sampling of selected trees at different stages.

RESULTS

The results clearly show that there was a significant difference in feeder root development towards south direction from the base of the rubber plant at 0-10 cm depth (Table 1).

Table 1. *Effect of different directions on the root densities of Hevea at 0-10 cm depth*

Directions	Root Density (mg/1000 cc)
South	218.8 ^a
West	211.6 ^b
East	210.6 ^b
North	209.2 ^b

Differences in the density of feeder roots were also shown to be significant 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 (Table 2).

Table 2. *Effect of distance from the base of rubber plants on feeder root densities at various soil depths (mg/1000cc)*

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
160	208.7 ^b	281.4 ^b	84.6 ^b	8.2 ^c	2.6 ^c	0.7 ^c

The density of feeder roots at different depths showed that there was a significant difference in their vertical distribution with the highest percentage of roots being in the surface soil layers, 0-10 cm and 10-20 cm. The amount of feeder roots in the surface soil was 34.4% to 46.6% of the total feeder roots and only 17.2% and 1.9% of the total root weight were found in the lower soil layers, 20-50 cm and 50-90 cm, respectively (Table 3).

Table 3. *Effect of soil depth on feeder root development of rubber plants*

Depth (cm)	Root Density (mg/1000 cc)	Percentage Distribution (%)
0-10	212.8 ^a	34.4 ^a
10-20	288.4 ^b	46.6 ^b
20-30	87.7 ^c	14.2 ^c
30-50	18.8 ^d	3.0 ^d
50-70	8.8 ^e	1.4 ^e
70-90	2.8 ^f	0.5 ^f

Root developments in Hevea brasiliensis

Statistical calculations (coefficient of variation) of volumetric moisture content data obtained from 12 positions in relation to planting points over a period of 12 months indicate that distance 60 cm (2 ft.) from the tree would appear to give the highest variation. No significant difference was seen in relation to the direction from the base of the rubber plant (Fig. 1). Volumetric moisture content data obtained from different depths over the same period indicate that depths 10-20 cm and 20-30 cm had the highest variation, *i.e.* 70.48% and 47.11% (Table 4).

Table 4. *Coefficient 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

Significant positive correlations were found between fine sand content (<200 μ diameter) and root density. In general, soils with higher fine sand content had higher root density (Fig. 2). Clay content was negatively correlated to root density, resulting lower root density with higher clay content (Fig. 2).

Root density had the general tendency to decrease with increasing bulk density in soil, but to increase with increasing soil organic carbon content (Fig. 3).

Root density data obtained in experiment 2 showed that there was a significant difference in root density between clones (Table 5). Vigorous clones like RRIC 102, RRIC 121, RRIC 100 and RRIC 110 had more feeder roots than a less vigorous clone like PB 86.

Root length, root spread and root dry weight data obtained showed that there were significant differences ($P < 0.001$) between different soil moisture levels on root length, root spread and root dry weight (Table 6).

There were significant differences ($P < 0.001$) in feeder root development between different establishment practices (Table 7).

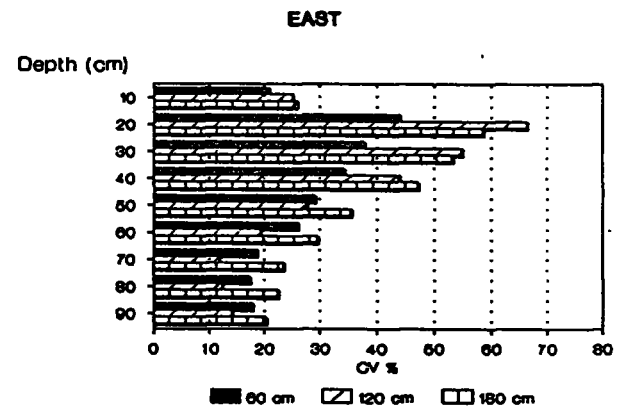
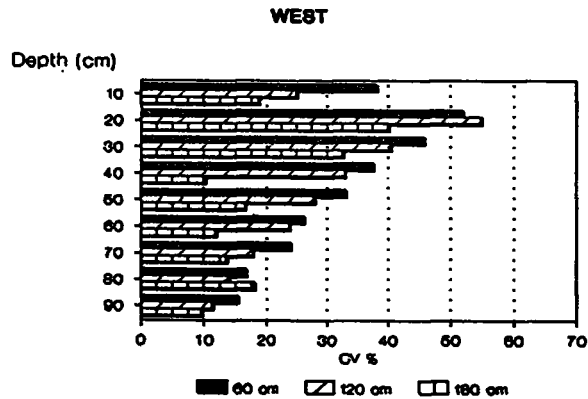
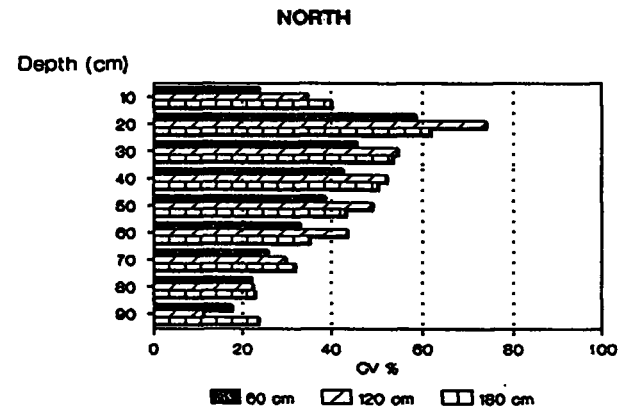
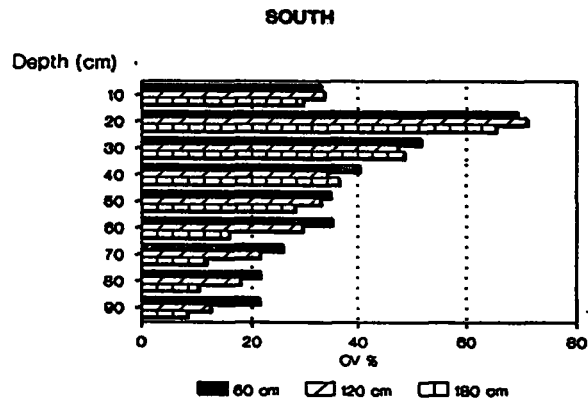


Fig.1 Coefficient of variation of moisture content at different depths and distances

Root developments in Hevea brasiliensis

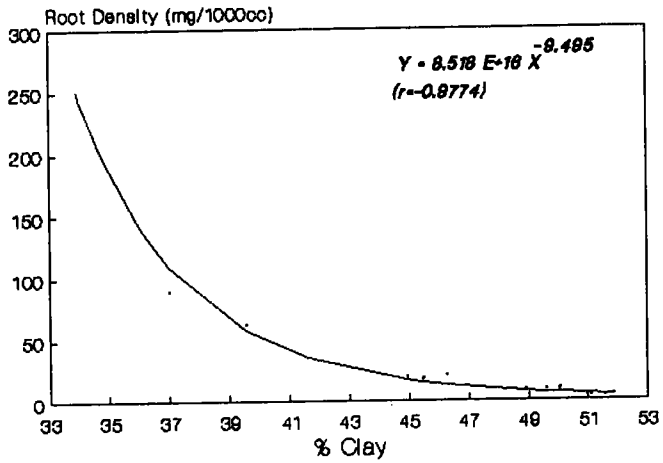
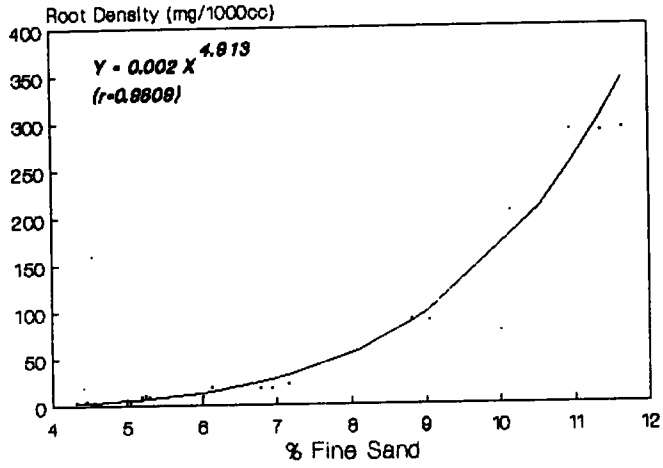


Fig. 2 Relationship between root density and percentage of sand and clay in soil

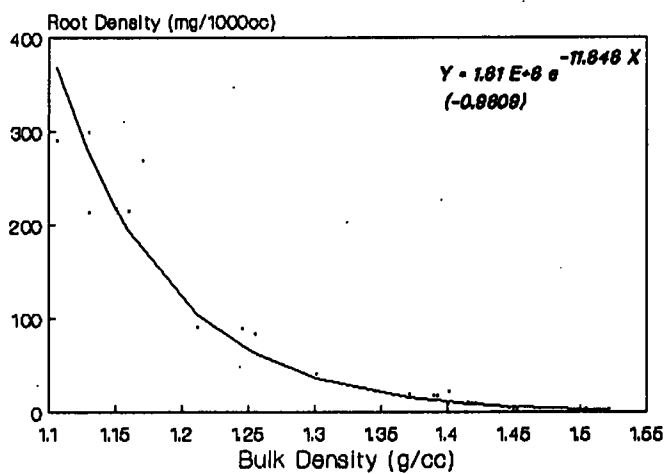
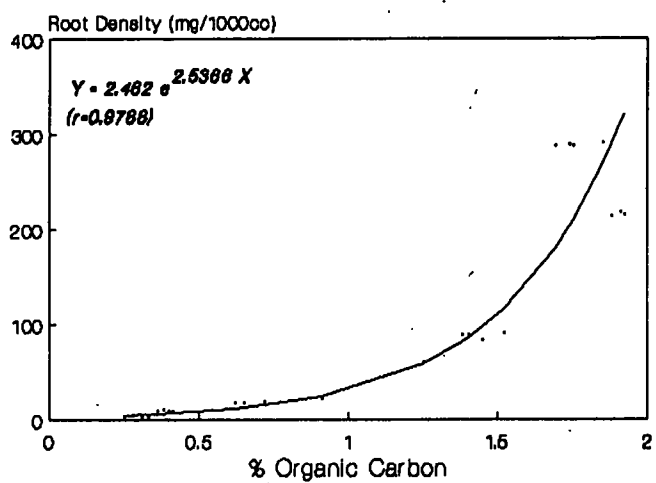


Fig. 3 Relationship between root density and soil characteristics

Root developments in Hevea brasiliensis

Table 5. *Effect of different clones on feeder root density*

Treatment	Root Density (mg/1000 cc)
RRIC 102	467.2 ^a
RRIC 121	409.8 ^b
RRIC 100	384.7 ^b
RRIC 110	380.3 ^b
PB 86	291.6 ^c

Table 6. *Effect of different soil moisture regimes on root length, root spread and root dry weight*

Treatment	Root length (cm)	Root spread (cm)	Root dry weight (g)
M ₃	115.5	44.8	624.9
M ₂	117.4	46.1	824.0
M ₁	110.5	44.6	461.2
M ₀	97.5	42.3	398.2
LSD	2.3	1.2	43.2

Assessment of root length made at the end of 12 months after commencement of the K and moisture experiment, showed a significant interaction ($P < 0.001$) between applied potassium and soil moisture content. It appears that increasing the level of applied potassium to double the recommended level would tend to decrease the root length under no stress conditions. However, under water stress conditions, application of K has improved the root growth (Fig. 4). Moreover, the root length at M₂ level with K₁ were almost equal to the root length at M₀ level in combination with the K₂ level (Fig. 4).

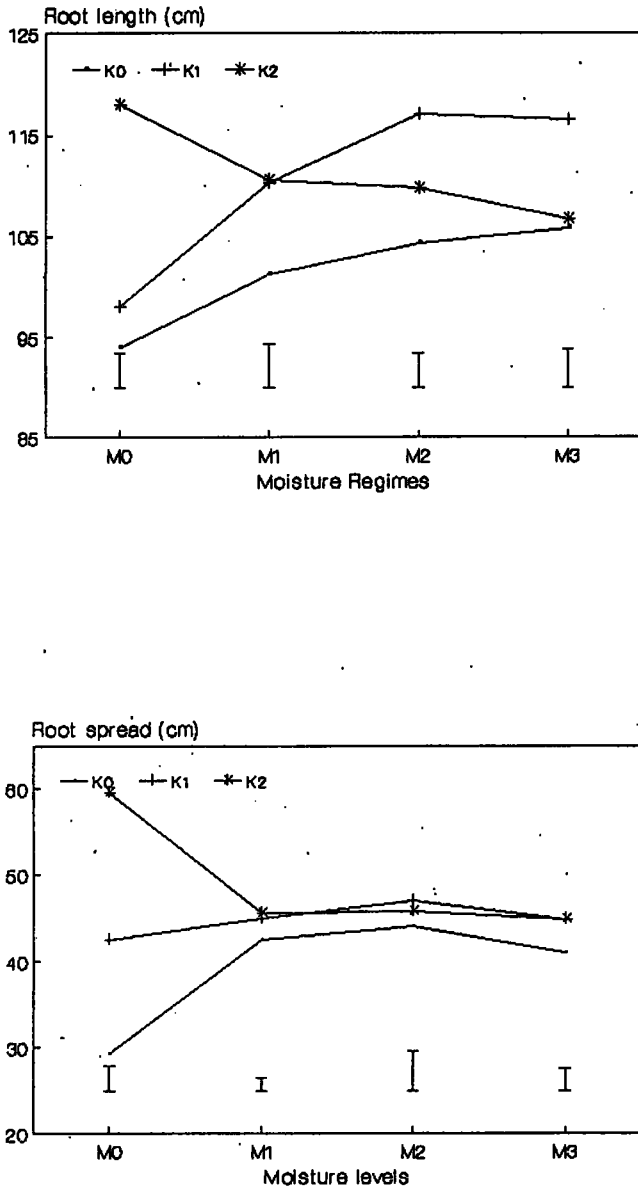


Fig. 4 Effect of different soil moisture regimes and potassium levels on root length and root spread

Root developments in Hevea brasiliensis

A significant interaction ($P < 0.001$) was also observed between applied potassium and soil moisture content on root spread where the effect of K at no stress condition was not significant. Nevertheless, under soil moisture stress condition, application of potassium has increased the root spread significantly ($P < 0.001$) (Fig. 4). It appears that the root spread at M_0 level with K_2 was highest while with K_0 root spread was lowest at the M_0 level (Fig. 4).

Table 7. *Effect of different establishment practices on feeder root development*

Treatment	Root Density (mg/1000 cc)
Young budded poly bags	420.3 ^a
Brown budded poly bags	409.9 ^b
Green budded poly bags	395.0 ^b
Brown budded bare roots	283.1 ^c
Green budded bare roots	280.2 ^c

Root fresh and dry weight data also showed that there is a significant interaction ($P < 0.001$) between applied K and moisture contents. At both K_0 and K_1 levels, a linear effect was observed on root fresh weight with the increase in soil moisture levels. But with K_2 level the effect was quadratic (Fig. 5). At the same time, at both K_0 and K_1 levels, root dry weights were significantly ($P < 0.001$) increased with the increase in the level of moisture, but at K_2 level a significant ($P < 0.001$) reduction in root dry weight was observed (Fig. 5). Further, the effect of potassium on both fresh and dry weights of roots, at M_3 , M_2 and M_1 levels of soil moisture were quadratic, where the increases in both fresh and dry weights were significant ($P < 0.001$) at K_1 level and with a further increase in potassium to K_2 level showed a significant ($P < 0.001$) reduction in weights. However, at M_0 level of soil moisture, application of potassium has increased both fresh and dry weights of roots significantly ($P < 0.001$) (Fig. 5). Assessment of root length, root spread and root dry weight made at the end of 12 months after commencement of experiment 4 showed a significant difference ($P < 0.001$) between different mulching materials. Root length was highest under *Tephrosia* mulch and root spread and root dry weight were highest under rice straw compared to other mulching materials (Table 8).

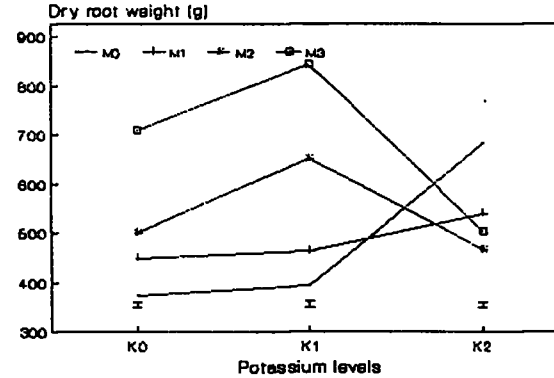
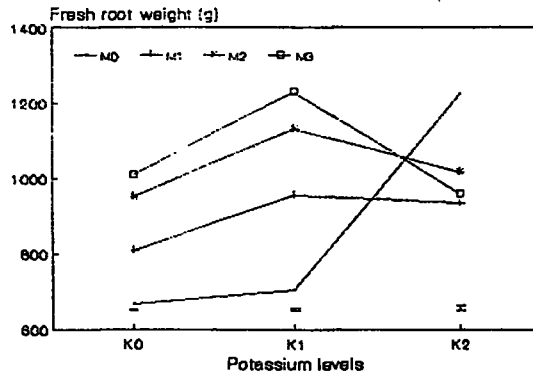
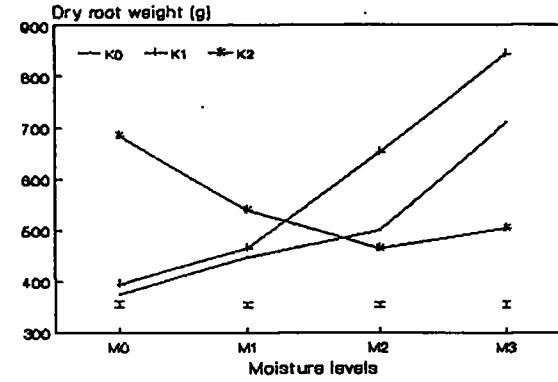
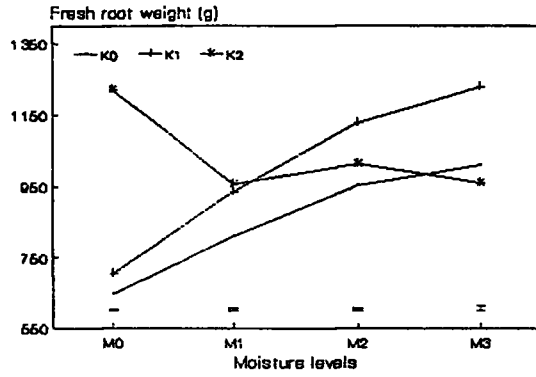
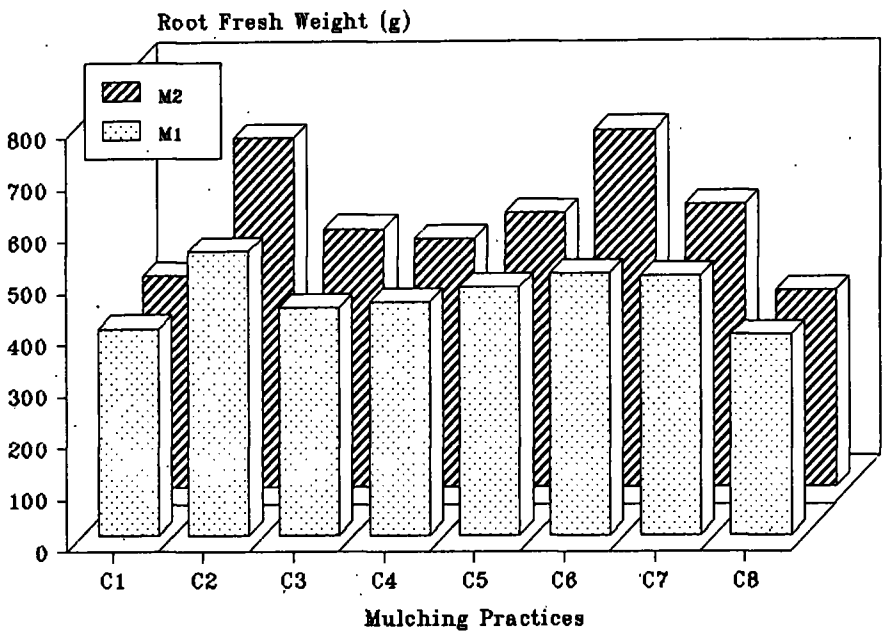


Fig. 5 Effect of different soil moisture regimes and potassium levels on fresh and dry root weights

Root developments in *Hevea brasiliensis*

Root fresh weight data showed significant interaction ($P < 0.01$) between different mulching materials and soil moisture content (Fig. 6).

Data obtained show that there was more vigorous feeder root development under mulching than under legume cover or natural cover (Table 9).



C0 - No mulch
C1 - Rice straw
C2 - Coir dust
C3 - *Pueraria*

C4 - Guatamala
C5 - Vetiver
C6 - *Tephrosia*
C7 - *Sesbania*

Fig. 6 Effect of different mulching materials and soil moisture regimes on root fresh weight

Table 8. *Effect of different mulching materials on root length, root spread and root dry weight*

Treatment	Root length (cm)	Root spread (cm)	Root dry weight (g)
<i>Tephrosia</i>	101.5 ^a	84.9 ^a	255.5 ^{abc}
<i>Pueraria</i>	87.1 ^b	76.5 ^b	225.5 ^{bcd}
Guatamala	84.5 ^{bc}	76.0 ^{bc}	257.5 ^{ab}
Rice straw	84.3 ^{bc}	87.5 ^a	285.0 ^a
<i>Sesbania</i>	83.1 ^{bc}	72.8 ^{bc}	199.0 ^d
<i>Veriver</i>	78.3 ^{bc}	71.0 ^{bc}	219.0 ^{cd}
Coir dust	75.1 ^c	68.3 ^c	220.0 ^{cd}
No mulch (control)	64.1 ^d	52.4 ^d	199.0 ^d

Table 9. *Effect of different soil management practices on feeder root development*

Treatment	Root Density (mg/1000cc)
Naturals	294.8 ^a
Legumes	300.1 ^a
Dead mulch	502.6 ^b

DISCUSSION

In general, development and distribution of the root system in the soil are expected to influence the growth, yield and nutrition of any plant. 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. This could be due to the fact that as the land slope in this study area is towards south direction, more soil nutrients and moisture may have accumulated in this direction. Differences in the density of feeder

Root developments in Hevea brasiliensis

roots were also shown to be significant within different distances from the base of the rubber plant. The major lateral roots which arise from the tap root in a whorl within 30 cm of the soil surface may grow horizontally, or only slightly downwards. Further, laterals may be commonly produced at a depth of 40-80 cm, but they do not extend horizontally as far as those nearer the surface. Results of this study clearly shows that one year old rubber plants had more feeder roots in the region of 60 cm circle. The feeder root concentration in the 60 to 90 cm depth in the soil, close to the tree, is also considerably greater than in the centre of the inter row area. These findings provide useful information for guiding the method of fertilizer application. The lower feeder roots close to the trees are important in absorbing nutrients that have been leached out of the top soil. Very few such lower feeder roots were present in the centre of the inter row area. To secure the most efficient use of fertilizers they must be applied in such a way that they are in contact with most roots. The above results confirm that the present method of fertilizer application in the weed free circle is acceptable for young rubber plants as the feeder roots have been found to be concentrated close to the tree.

The density of feeder roots at different depths showed that more than 75% of the total root weight was in the top 20 cm of the soil. Therefore, the bulk of nutrient and moisture uptake is likely to occur in the top 20cm of the soil. Another very important feature of the rooting habit of rubber is the observation of some feeder roots well below the soil surface. Their existence well below the surface shows that the soil conditions where such root growth was possible, it would be possible to exploit nutrients and moisture even at lower soil depths.

These findings were further confirmed by the statistical calculations (coefficient 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. These results indicate that the distance 60 cm (2 ft.) from the tree at depths 10-20 cm and 20-30 cm would appear to give the highest variation indicating the highest root activity.

Physical factors like soil texture, soil structure etc. have also important influences on root growth and development. Significant positive correlations were found between fine sand content ($<200 \mu$ diameter) and root density. In general, soils with higher fine sand content had higher root density and this could be due to the formation of more favourable soil structure, resulting in better aeration for root growth; or, it could be the reaction of the trees to a soil with low moisture retention. Clay content was negatively correlated to root density. Since soil texture is an inherent property of a soil, and cannot be altered easily by management practices, the above relationships could indicate the potential of soils for rubber cultivation. Soils with high clay contents will inhibit root development. Unless the soils contain sufficient amounts of sesquioxides and organic matter to offset this inhibition by generating good soil structure the growth of rubber trees will be affected.

In general, root density had the tendency to decrease with increasing bulk density in soil, but to increase with increasing soil organic carbon content. The value of mulching in enhancing the organic carbon content and in decreasing the bulk density of the soil was clearly shown by Samarappuli, 1992(a). Root growth measurements, indicate that the density, length and spread of roots were improved with mulching than under legume cover or natural cover. Such differences in feeder root development of *Hevea* under different soil management practices could be attributed to the higher organic matter content of the soil under mulching, competition for moisture and nutrients by roots of legumes and the release of toxic substances from the natural cover. Allmaras & Nelson (1971) and Chaudhary & Prihar (1974) reported that mulch induced changes in the hydrothermal regime of soil, increased the density of rooting and caused greater lateral spread of roots. This may also would have contributed to the better crop-growth and nutrient uptake with mulching.

It was found that in soils with higher moisture content (70% field capacity) plants have less feeder root density than those grown in similar but less moist (50% field capacity) soils. Soils with higher moisture contents will inhibit root development (Samarappuli, 1993). Unless the soils have a good soil structure to offset this inhibition by draining off the excess water the growth of rubber trees will be affected. It was further noted that soil water deficit also caused a reduction in root growth, thereby decreasing the efficiency with which the plants would absorb soil water and nutrients. Clemens & Jones (1978) reported that drought caused no change in plant performance but caused a significant reduction in root dry weight. Taylor & Gardner (1983) have also reported that increasing root penetration is associated with increasing soil moisture, and roots are shorter and thinner under high soil moisture stress conditions.

There were significant differences in feeder root development between various clones of *Hevea brasiliensis*. Vigorous clones like RRIC 102, RRIC 121, RRIC 100 and RRIC 110 had more feeder roots than a less vigorous clone like PB 86. Data from RRIM also showed that vigorous clones like RRIM 605 and RRIM 623 had more feeder roots than a less vigorous clone like RRIM 513 (Soong, 1976). It appears, therefore, that the better growth of some clones, over others, on a wider range of soils may be due to a larger amount of feeder roots available for absorption of moisture and nutrients. This, to some extent, has been confirmed in various commercial areas where a less vigorous clone like PB 86 has grown poorly and has shown symptoms of nutrient deficiency in areas where more vigorous clone like Tjir 1 has been healthy and strong (RRIM, 1958). Furthermore, RRIC 102 clone has shown that it can withstand moisture stress conditions when compared to PB 86 under Sri Lankan conditions (Samarappuli, 1992b). Thus, it is likely that if a clone has the ability to produce a vigorous root system it would be suited for planting over a wide range of soil and climatic conditions.

Root developments in Hevea brasiliensis

Data on the influence of soil moisture on root growth of differently budded plants indicates, that young budded polybag plants had significantly higher root density compared to other establishment practices. It appears that root growth in relation to density may have had greater effect in the performance of rubber plants in the first 12 months of its growth. Young plants are less likely to survive in soils with inadequate supply of moisture at the surface; this is particularly so during the dry periods. Young budded polybag plants with more efficient root system would enable the young plants to tap on a larger reservoir of moisture beneath the surface, thereby increasing the efficiency with which the plants would absorb soil water and nutrients. Moreover, the deeper penetration of tap root in young budded poly bag plants is obviously advantageous in providing sufficient anchorage, where wind is considered a problem.

Root growth measurements made in experiment 2, indicated that the root penetration was improved with added potassium. It also seems to suggest that adequate nutrient supply encourages root proliferation and deeper penetration so that water can be taken up from lower depth which is obviously advantageous under stress condition. Edward (1981) found that maize roots penetrated 60 cm deeper when receiving K fertilizer, giving access to an extra 10 cm of water. It has been suggested that efficient water uptake from the soil and its transport upwards are more important than stomatal conductance in determining drought resistance by sorghum and cotton (Ackerson & Krieg, 1977). It was also clearly evident that root growth due to the increase in soil moisture content is always greater with more potassium. It was further noted that the root growth at 50% field capacity with recommended level of potassium were almost similar to the root growth at 10% field capacity in combination with double the recommended level of potassium would tend to retard the root growth of plants.

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Lalani Samarappuli *et al.*

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