Feeder Roots Distribution of Component Crops in the Tea (*Camellia sinensis*, (L.) O.Kuntze), Rubber (*Hevea brasiliensis*) Intercropping System

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ABSTRACT

The study was aimed to determine the horizontal and vertical distribution of feeder roots of component crops of tea (*Camellia sinensis, L.*) rubber (*Hevea brasiliensis*) intercropping system and carried out in the Rubber Research Institute, (sub station) at Kuruwita. The trenches were dug out (45cm wide and 45cm deep) and soil samples from 0-5cm, 5-15cm, 15-30cm and 30-45cm depths were taken from the profile wall of both intercropped and sole cropped rubber plots. The root length density (mm/cc) and bulk density (g/cc) were calculated in each sample. The feeder roots of rubber were concentrated mainly in the upper layer of the soil (0-5cm depth) and had a shallow distribution. The greater proliferations of rubber feeder roots were near to the tea bushes than between tea rows and also sole rubber cropped. The feeder roots of tea were distributed both in 0-5cm and 5-15cm depths and mainly concentrated near to the tea bushes. The bulk density of the soil was not a limiting factor for the feeder roots distribution in the soils of the study.

KEY WORDS: - *Camellia sinensis* (L.) O.Kuntze, *Hevea brasiliensis*, Feeder Root Distribution, Root Length Density, Soil Bulk Density

INTRODUCTION

Intercropping, which involves growing two or more crops simultaneously on the same piece of land, has a very long history. This has been practised in many parts of the world, one of the earliest examples being that of shifting cultivation, locally referred to as chena cultivation (Anon, 2001).

Intercropping systems are particularly attractive in areas of high population and absolute land shortage (Papendick etal, 1976). In developed countries however, intercropping is uncommon. and monocropping is generally practised for the convenience in mechanization and commercial production. Therefore at present, intercropping systems are found, with few exceptions in the developing tropical and sub-tropical zones where they potentially provide a range of cultural and economic benefits (Iqbal, 2003).

The cultivation of rubber (*Hevea brasiliensis*) within an intercropping system is not a new concept, the practice having been introduced at the inception of rubber production in Sri Lanka. After rubber was introduced to Sri Lanka in 1876, it was inter planted with tea (*Camellia sinensis, L.*) and cocoa (*Theobroma cacao*) on large estates (Anon 2001). The rubber/tea intercropping is well suited to the wetter regions where both component crops are grown. This fits well with the social context of the smallholder farming community. Under normal circumstances, rubber cannot be tapped very often during the rainy season and farmers can still obtain an income from tea harvests. Also on large estates, this intercrop secures more job opportunities for estate workers. Moreover, rubber/tea intercropping has proven to be economically sustainable under conditions where the market price of one of the component crops falls. The rubber crop also provides a shelter for tea during drought resulting in significantly fewer casualties than that occur with sole tea (Anon 2000). Beside these benefits, there are some problems with intercropping. Reasons for the wide-scale lack of adoption of intercropping among rubber farmers in Sri Lanka have been investigated. Indifference, lack of knowledge, problems of security, lack of suitable lands and pest and disease problems have been quoted as reasons why farmers did not adopt intercropping (Iqbal, 2003).

Potentially intercropping may increase land use efficiency and productivity due to a more efficient use of resources such as light, water and nutrients than sole cropping. Numerous experimental findings have indicated that intercropping may provide greater and better economic returns (Haymes and Lee, 1999). An improvement in the efficiency of nutrient capture from different zones of the soil profile in intercropping systems has been reported by Noordwijk et al., (1996).

Soong (1976) indicated that maximum feeder root development in rubber occurred in February/March immediately after defoliation and minimum growth was in August to December and coincided with the onset of leaf senescence. Cover management also exerted a large influence on root development. In young rubber trees, it was found that leguminous creeping cover enhanced better rooting than grass or Mikania (Soong, 1976).

Therefore when considering interactions of above and below ground, the below ground interactions may considerably influence growth and yield. The root distribution is very important considering the below ground interactions. Many studies have been done on above ground interactions of various crop combinations and also tea/rubber intercropping system

But few studies have been done on below ground interaction and not a single study has been reported on below ground interactions of tea/rubber intercropping system.

Thus the main aim of this study was to determine the horizontal and vertical distribution of feeder roots of component crops under tea/rubber intercropping system. Because of these fine roots are the main active absorbing zones of the root system (Guha and Yeow, 1966).

MATERIALS AND METHODS

The study was carried out in the Rubber Research Institute; sub station at Kuruwita locates in the administrative district of Rathnapura, in the low country wet zone during the period of December 2004 to May 2005. The soil type at the trial site belonged to the Rathnapura series, which is of sandy clay-loam texture, and yellowish brown in colour. Clones (genotypes), which had been used for rubber and tea, were RRIC 121 and TRI 2025, respectively. Rubber was planted at a spacing of 2.4m*12m (8ft*40ft) with seven rows of tea interplanted between rubber rows at spacing of 1.2m*0.6m (4ft*2ft). The first row of tea was 2.4m (8ft) away from the rubber. The spacing of sole rubber plots was 3.6m*5.4m (12ft*18ft). Three plots each from rubber/tea intercropping and rubber sole crop were selected as replicates. The rubber trees in all plots were planted in 1990, hence had the same age. Trenches, 45cm wide and 45cm deep, were dug using the mammoty and alavangu. Soil samples from 0-5cm (D1), 5-15cm (D2), 15-30cm (D3), 30-45cm (D4) depths were taken from profile wall by using hand spade. The sample sizes were 1125cm^3(5*15*15cm), 2250cm^3(10*15*15cm), 3375cm^3(15*15*15cm), 3375cm^3(15*15*15cm) at depths D1, D2, D3 and D4 respectively. In each sampling unit of intercrop, twelve sampling points were chosen, with eight points being sampled between tea rows (R) and four points being sampled near to tea bushes (L) as shown in Figure 1.

In each sampling unit of sole rubber plot, 5 sampling points were chosen (Figure2). These were taken only for a comparison with rubber feeder roots in intercropped.

Roots were separated from soil by hand sorting, and then wash with water. Both tea and rubber feeder roots were distinguished by outer appearance (colour, size, and branching pattern) from other types of roots without much difficulty. Observations made on rubber feeder roots showed that they were unsuberised and pale yellowish in colour with a diameter of 1.06± 0.21mm (Soong, 1976). Feeder roots of tea were tough and pale pink in colour. For the convenience, roots below 1.5mm diameter were considered as feeder roots. During the sorting of roots, living roots were distinguished and separated from dead roots.

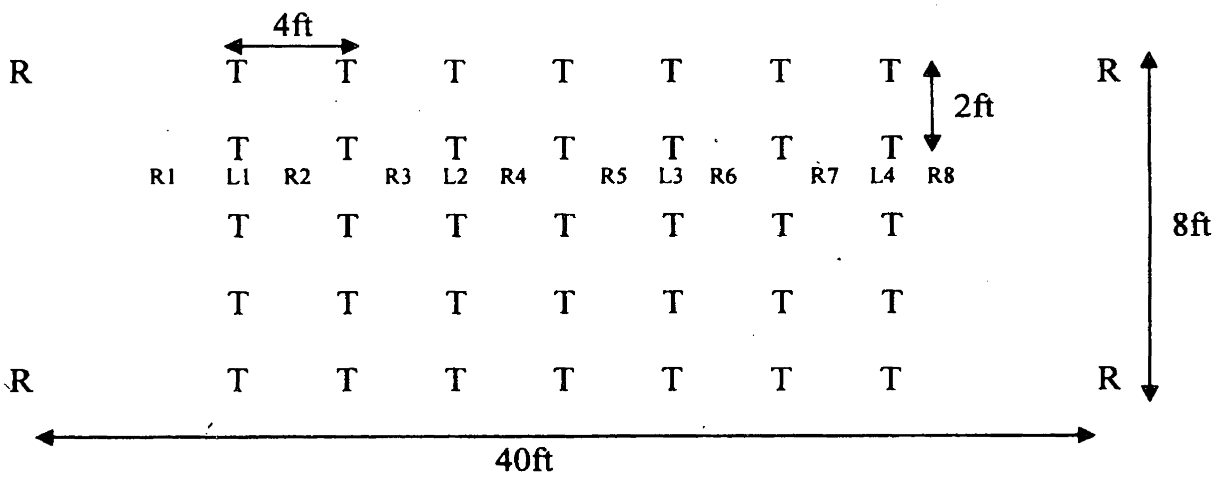


Figure 1. Sampling unit for rubber/ tea intercrop.
R-Rubber rows, T- Tea rows, R1...R8- Eight points being sampled between tea rows, L1...L4- Four points being sampled near to tea bushes

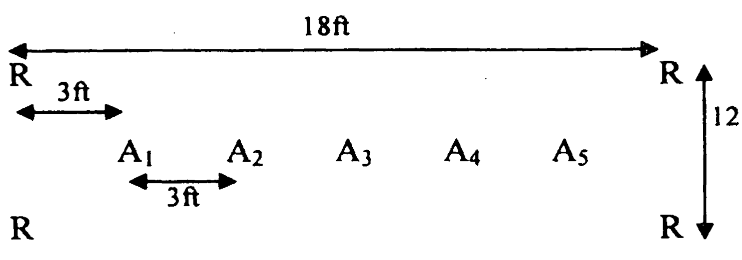


Figure 2. Sampling unit for sole rubber crop
A1...A5 – Five sampling points

Dead roots were far less elastic and darker in colour than living roots. The following parameters were measured.

1. Area of feeder roots: the LI-3000 leaf area meter was used for this purpose.
2. Diameter of roots: vernier calliper was used to measure the diameter.
3. Soil fresh weight: both bulk and sub soil sample (about 105g) were taken insitu.
4. Soil dry weight: sub soil samples were kept in an oven for about 48 hrs at 105°C till samples reached constant weight.

Since there were large numbers of feeder roots, it was difficult to measure root diameter of all. Therefore the median value (0.75mm) was taken as the representative value. By using the above assessments, root length density and bulk density were calculated as follows:

$$\text{1. Root length (mm)} = \frac{\text{Area of feeder roots (mm}^2\text{)}}{\text{Average diameter of roots (mm)}}$$

$$\text{2. Root length density (mm/cc)} = \frac{\text{Total root length (mm)}}{\text{Volume of particular soil sample (cc)}}$$

$$\text{3. Bulk density (gcm}^{-3}\text{)} = \frac{\text{Dry weight of soil (g)}}{\text{Volume of bulk soil sample (cc)}}$$

ANALYSIS

Valid statistical analysis of data such as root length density and bulk density within replicated field experiments is often difficult. The pattern of changing root length density and bulk density with depth and distance was much the same in all three intercrop replications and also in three sole crop replications. Therefore we can have confidence that the mean, across replications represents the real trend. The mean root length density and the mean bulk density over the all replicates were used to interpret the results. For better understanding, matrix tables were prepared for mean root length density.

RESULTS AND DISCUSSION

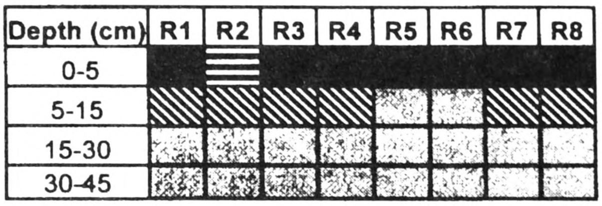
Distribution of rubber feeder roots

Between tea rows

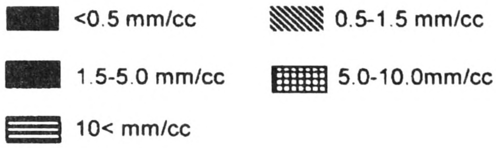
The mean root length density of rubber feeder roots of three replications were higher in depth of 0-5cm (Table 1).

The greatest proliferation and distribution of rubber feeder roots in between tea rows were in the surface soil layer (0-5cm). Between 5-15cm depth few feeder roots were found with the mean root length density of 0.5-1.5mm/cc. According to Table1 only very few roots were found below 15cm of soil depth as root length density was very low (<0.5mm/cc).

Table 1 Distribution of mean root length density (mm/cc) of rubber feeder roots between the tea rows in rubber/tea intercropping at different soil depths and rows.



R1...R8- Eight points being sampled between tea rows



There is no marked variation of horizontal distribution of rubber feeder roots in between tea rows (R1 to R8). A distinct decrease in root length density with horizontal distance from a tree is typical for isolated trees (Van Noordwijk et al., 1996), but the trend in horizontal root distribution can be less pronounced in plantations where roots of adjacent trees can overlap (Ruhigwa et al., 1992).

The low root length density at intermediate depths and lowest layers presumably resulted from unknown restrictions to rooting. Veihmeyer and Hendrikson (1948) obtained some threshold bulk density values that limited root penetration and they were 1.75g/cc for sands and 1.46g/cc to 1.65g/cc for clays. Table 2 shows that the bulk density (g/cc) in between the tea rows did not exceed the threshold values of Veihmeyer and Hendrikson (1948).

Table 2. Mean soil bulk density (g/cc) between the tea rows.

Depth (cm)	R1	R2	R3	R4	R5	R6	R7	R8
0-5	1.55	1.46	1.44	1.63	1.45	1.24	1.31	1.46
5-15	1.49	1.42	1.37	1.47	1.20	1.37	1.52	1.46
15-30	1.38	1.42	1.49	1.38	1.23	1.44	1.65	1.45
30-45	1.66	1.54	1.75	1.39	1.42	1.52	1.56	1.53

R1...R8- Eight points being sampled between tea rows

Near tea bushes

Distribution of mean root length density of rubber feeder roots near the tea bushes at different depths is given in Table 3.

Though, no marked variation of horizontal distribution was observed, higher feeder root length accumulated in the surface soil near tea bushes (Table 3). However the root length density in 0-5cm depths near tea bushes (>10mm/cc) is higher than that of between tea rows (5-10mm/cc). This proved that the nutrient and water absorption by rubber is more prominent near to the tea bushes.

This high feeder root distribution and proliferation of rubber may be due to competition for fertilisers applied to tea bushes. There was almost same vertical and horizontal distribution pattern of rubber feeder roots in 15-30cm and 30-45cm depths, near to tea bushes and between tea rows.

Table 3 Distribution of mean root length density (mm/cc) of rubber feeder roots near to the tea bushes at different depths and rows.

Depth (cm)	L1	L2	L3	L4
0-5	10< mm/cc	10< mm/cc	1.5-5.0 mm/cc	10< mm/cc
5-15	<0.5 mm/cc	0.5-1.5 mm/cc	0.5-1.5 mm/cc	0.5-1.5 mm/cc
15-30	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc
30-45	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc

L1...L4- Four points being sampled near to tea bush

<0.5 mm/cc 0.5-1.5 mm/cc
1.5-5.0 mm/cc 5.0-10.0mm/cc
10< mm/cc

The mean soil bulk density values in all four depths were less than the threshold values obtained by Veihmeyer and Hendrikson (Table 4).

Table 4 Mean soil bulk density (g/cc) near tea bushes

Depth (cm)	L1	L2	L3	L4
0-5	1.47	1.68	1.42	1.41
5-15	1.62	1.70	1.34	0.98
15-30	1.35	1.21	1.40	1.45
30-45	1.53	1.47	1.45	1.39

L1...L4- Four points being sampled near to tea bush

Therefore some other soil properties may have influenced to limit root distribution of rubber in intermediate (15-30cm) and deep soil layers (30-45cm) between tea rows and near tea bushes. However, it is not the purpose of this study to investigate in detail the effects of soil physical and chemical properties on root distribution of rubber and tea.

Rubber mono crop

The mean feeder root length densities of rubber mono crop were also higher in 0-5cm depths than that of other root depths (Table 5). But values were less (1.5-5mm/cc) than, those recorded in intercrops (Table1 and Table5), (Table3 and Table5). There were almost same horizontal distribution patterns in each depth. In mono crop, bulk densities were higher in 15-30cm depth and 30-45 cm depth (Table6).

So the bulk density may influence the vertical limitation of root penetration. Other than the bulk density other soil properties (porosity, ped density, etc.) may also have influenced the limitation of root penetration.

Distribution of tea feeder roots

Between tea rows

The root length densities of tea feeder roots in all depths, between the tea rows were less than 0.5mm/cc (Table 7) which indicated that there was no considerable amount of tea feeder roots distributed between tea rows.

Due to this very low root length densities of tea feeder roots, very limited absorption (water and nutrients) possible in this region. As in the case of rubber roots, soil bulk density may not have been responsible for this type of root distribution, as the bulk densities were not markedly different in the surface and deep soil layers (Table 2).

Near tea bushes

The root length densities of tea feeder roots, near the tea bushes were higher in 0-5cm and 5-15cm depths than in between tea rows (Table 7 and 8).Near the tea bushes, the feeder root density of tea was also very low (<0.5mm/cc) below 15cm of soil depth (Table 8).

Table 5 Distribution of mean root length density (mm/cc) of rubber feeder roots in rubber mono crop.

Depth (cm)	A1	A2	A3	A4	A5
0-5	5.0-10.0mm/cc	5.0-10.0mm/cc	5.0-10.0mm/cc	5.0-10.0mm/cc	5.0-10.0mm/cc
5-15	<0.5 mm/cc	0.5-1.5 mm/cc	0.5-1.5 mm/cc	0.5-1.5 mm/cc	0.5-1.5 mm/cc
15-30	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc
30-45	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc

A1...A5 – Five sampling points of sole rubber crop

<0.5 mm/cc 0.5-1.5 mm/cc
1.5-5.0 mm/cc 5.0-10.0mm/cc
10< mm/cc

Table 6. Mean soil bulk density (g/cc) in rubber mono crop

Depth (cm)	A1	A2	A3	A4	A5
0-5	1.60	1.76	1.64	1.42	1.59
5-15	1.53	1.61	1.54	1.55	1.62
15-30	1.68	1.82	2.00	1.86	1.81
30-45	2.03	1.98	2.03	2.27	2.00

A1...A5 – Five sampling points of sole rubber crop

Table 7 Distribution of mean root length density (mm/cc) of tea feeder roots between the tea rows in different depths and rows.

Depth (cm)	R1	R2	R3	R4	R5	R6	R7	R8
0-5	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc
5-15	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc
15-30	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc
30-45	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc

R1...R8- Eight points being sampled between tea row

<0.5 mm/cc 0.5-1.5 mm/cc
1.5-5.0 mm/cc 5.0-10.0mm/cc
10< mm/cc

Table 8 Distribution of mean root length density (mm/cc) of tea feeder roots near to the tea bushes at different depths and rows.

Depth(cm)	L1	L2	L3	L4
0-5	5.0-10.0mm/cc	0.5-1.5 mm/cc	0.5-1.5 mm/cc	0.5-1.5 mm/cc
5-15	0.5-1.5 mm/cc	0.5-1.5 mm/cc	0.5-1.5 mm/cc	0.5-1.5 mm/cc
15-30	0.5-1.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc
30-45	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc	<0.5 mm/cc

L1...L4- Four points being sampled near to tea bush

<0.5 mm/cc; 0.5-1.5 mm/cc; 1.5-5.0 mm/cc; 5.0-10.0mm/cc; 10< mm/cc

CONCLUSIONS

The root study conducted in the tea-rubber intercropping system showed that there were significant differences in feeder root distribution of tea and rubber. The feeder roots of rubber had shallow distribution pattern and mainly concentrated in the upper layer of the soil (0-5cm). However the root distribution near the tea bush was higher and a considerable amount was found even between tea rows. The greater proliferations of rubber feeder roots were observed for rubber/tea intercropping systems than in the mono crop. The feeder roots of tea were distributed mainly in the upper and intermediate soil layers (0-5cm and 5-15cm depths) and also concentrated only near the tea bush. However rubber showed higher root proliferation and distribution when compared to tea.

Since the bulk density values obtained were below the threshold values of Veihmeyer and Hendrikson, it can be safely concluded that the bulk density was not the limiting factor to root development and distribution in the soils under the study.

The above findings provided useful information for further studies on below ground interactions of tea/rubber intercropping and also for the fertiliser placements of tea and rubber.

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