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Contour and East-West row planting systems of rubber (*Hevea*) for intercropping Part II. Distribution of fine roots in the inter row space

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Abstract

Root competition is one of the main sources of interference in rubber based inter cropping systems. This needed investigation and the growth and distribution of roots were studied in an inter cropping system where rubber was planted in east-west oriented rows and in contours and coffee, cinnamon and grass were planted in the inter-row. Root length density (RLD) of rubber and of the intercrops in the inter-row was studied over a period of 7 years. RLD in between two rubber trees in a row was high initially. Whole of the inter-row was gradually invaded by the rubber roots by the end of the 6th year in both planting systems and were not reduced due to the presence of intercrops. Cinnamon as the intercrop however has favored the growth of rubber roots. Intercrop root length densities declined with time and was reduced to low levels by the end of the 7th year. This decline was severe and rapid in case of grass that had a very high density initially. Cinnamon had low RLD through out and the decline was not high as observed for Grass or Coffee.

Key words : *Brachiaria brizantha, Cinnamom verum, Coffea arabica* , inter cropping, light availability, root length density

Introduction

One of the main sources of interference in intercropping systems apart from the competition for light is the root competition, mainly from the tree component of the system that leads to depression of yields (Conner, 1983, Rao *et al.*, 1991, Ruhigawa, 1992).

Shade from the tree component of the system also affect the root development in the under growth (Jackson & Cladwell, 1992) due to the poor allocation of dry matter to the roots.

To alleviate the problem of competition among component crops in intercropping systems, various methods such as alley cropping combined with compatible crops (Ong *et al.*, 1999), plant manipulation (Rao *et a.l*, 1991), changes in plant population densities (Cannel, 1983) spacing (Schroth, 1999) planting trees in east west oriented rows to increase light availability during the day (Allen, 1974) have been discussed. The type of component crops in an

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intercropping system also influences the distribution of roots resulting in complementary effects (Ruhigawa, *et al.*, 1992 and Akinnifesi *et al.*, 1999).

In this experiment rubber was planted in contours and in east west oriented rows and were intercropped. The growth and distribution of roots of rubber and of the intercrops in the inter-row space were examined during a period of seven years after establishment to understand any influence of the rubber planting system and of the rubber/intercrop combinations on the development and consequent effects on growth and yield of component crops. The data on the yield of component crops and the availability of light in the inter-row are published elsewhere (Pathiratna & Perera, 2002 and Pathiratna & Perera, 2003 a).

Materials and methods

Site

The experiment was located in a 3.0 ha. block of land in an estate in the Kalutara district. The mean annual rainfall in the area was about 2300 mm, well distributed during most part of the year and receiving rains in both monsoons. The land was flat to undulating and the soil belonged to the red yellow podzolic group.

Experimental design

A split plot design with two spatial arrangements *i.e.* contour planting and east west oriented row planting was developed as the main treatments. Contours were in different directions with respect to the path of the sun. Each main treatment was split to accommodate three intercrops and a control. These treatments were replicated four times. The intercrop plots were 70 m^2 on either side of the effective rubber row consisting of 8 rubber plants.

Crops

Rubber

Polybagged plants of the rubber clone RRIC 100 were planted with a spacing of 8.1m × 2.4m.

The intercrops were selected on the basis that (1) grasses, requiring high irradiance for light saturation (2) coffee, a shade tolerant species and (3) cinnamon, a species which can grow under moderate shade yielding satisfactorily (Pathiratna & Perera, 1998).

Cinnamon

Cinnamon was planted as six months old poly bagged seedlings with a spacing of 1.2m × 0.91. There were five rows of cinnamon within the inter-row giving about 8000 plants/ha intercropping.

Coffee

Six months old coffee seedlings of the variety robusta in four rows were planted with a spacing of 2.4 × 1.8 m. This gave about 2000 plants/ha intercropping. Single stem plant training method was practiced.

Grass

The species of grass was *Brachiaria brizantha* planted as tillers spaced 30cm x 30cm.

All intercrops were planted leaving a space of 1.5 m to the rubber row. The control plots had *Pueraria* cover with a mixture of weeds/naturals established according to RRISL recommendations. The planting of crops was done in July 1992.

Agro-management practices

Plots of cinnamon and coffee were kept weed free throughout. Weeds were also removed from grass plots but those present along with *Pueraria* in control plots were not removed. All leaves and twigs of cinnamon that remained after harvests amounting to about 8000 kg/ha were returned to the same plots annually. Entire grass crop was removed every two months.

Fertilizer

Rubber was fertilized as recommended throughout up to the 7th year at the rate of 400 kg/ha with a mixture containing 12 14 14 NPK.

The fertilizer for cinnamon was a 14:11:14 NPK mixture applied at the rate of 15.0g per bush in the first year, 30.0g per bush in the 2nd year, and 60.0g per bush (480 kg /ha) there after and after the 2nd year this amount was applied as two split doses.

Grass was given a 14:11:14 NPK fertilizer mixture every two months at the rate of 800 Kg/ha/year.

Coffee was fertilized at the rate of 120 g/bush in the first year and 240 g/bush (480 kg/ha) there after with a mixture consisting of 14:11:14 NPK applied in two doses.

Measurement of root length density

Root length densities (RLD) were determined by taking 15.0 cm diameter soil cores to a depth of 30.0 cm at 4 positions in the plot and were repeated in two replicates only. The positions used were; (1) in between two rubber trees in the row; (2) 1.5m away from the rubber tree; (3) 2.9 m away from the rubber trees and (4) 4.3m away from the rubber tree in the direction of the inter- row and positions 1,2,3,4 were repeated twice in each plot.

Soil cores were taken by driving a steel barrel into the soil and the resulting soil cores were divided into three 10 cm depths. All roots collected, roots of different crops were separated, washed and the lengths were measured by the Grid line intersect method (Marsh, 1971). Dry weights were taken and the total root length at different depths were determined.

Results

Root length density

Roots of rubber and other crops in the inter-row space were measured as RLD in a 3700 cm^3 soil core and is presented as RLD per 1000 cm^3. The roots collected from the soil cores were mainly feeder roots in rubber and all roots below 2.0 mm diameter in other crops. RLD measurements were first taken 3 years after the establishment of

crops. Most of the feeder roots were found in the first 30 cm of the core and was not considered separately for different depths.

The influence of intercrops on rubber root density

There was a continuous increase in rubber RLD in all intercrop plots under both planting systems up to the 5th year after which the effect of different intercrops showed some variation. The greater RLD of rubber seen in cinnamon plots compared to those of grass and coffee in the 6th year in the row system and the greater root length densities seen in cinnamon compared to grass in the 6th year and grass and coffee in the 7th year in the contour system were significant (Figs. 1&2).

The influence of rubber on the intercrop root length density

There was a general decline in intercrop RLD during the 7 year period in both planting systems (Figs. 3 & 4). The RLD of grass under the row planted rubber was significantly higher than in all other treatments in the 3rd,4th and 5th years except with that of coffee in the 4th and 5th years. RLD's of all intercrops in the 6th 7th yeas were low and was not different. At this stage most of the *B. brizantha* has perished and other types of grass were present and no distinction between these roots could be made (Fig. 3).

Under contour planted rubber, RLD of grass was similarly higher and was significantly higher than that of cinnamon in the 3rd 4th and 5th years. Weeds/cover in the control plots also

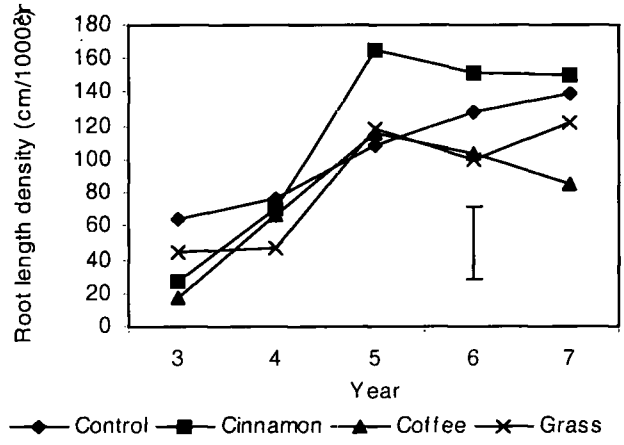

Fig.1. The effect of inter crops on the root length density of rubber in row planting system during the 7 year period (vertical bars= LSD)

had higher RLD in the 3rd year. RLD of Cinnamon was the lowest throughout in both systems and showed no difference to that of coffee (Fig. 4).

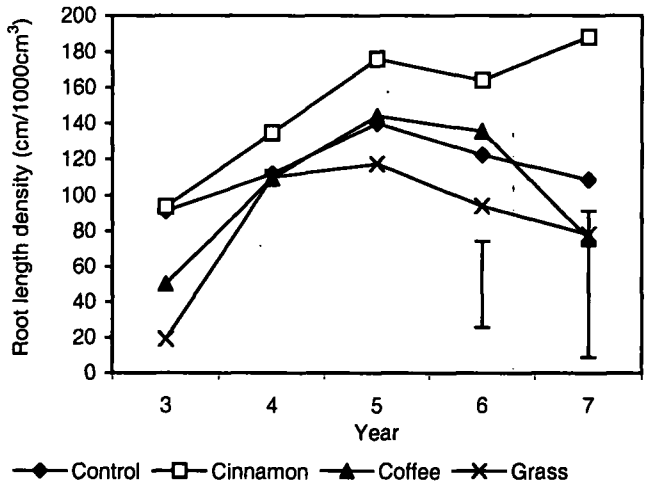

Fig. 2. The effect of inter crops on the root length density of rubber in the contour planting system during the 7 year period (vertical bars = LSD values)

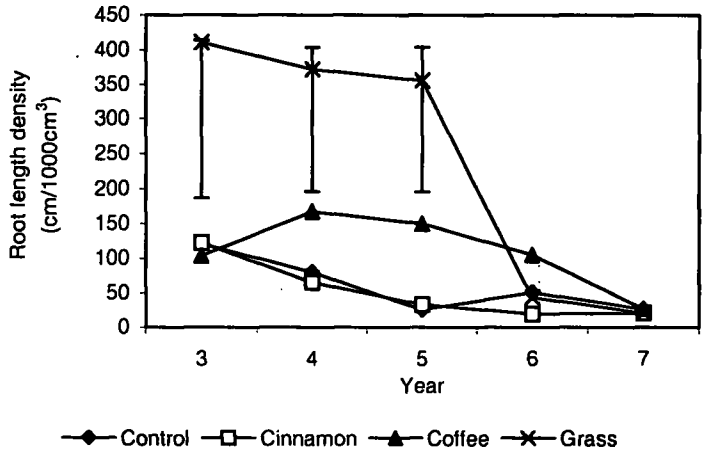

Fig. 3. The effect of rubber on the intercrop root length density in the inter row under row planting system (vertical bars =LSD values).

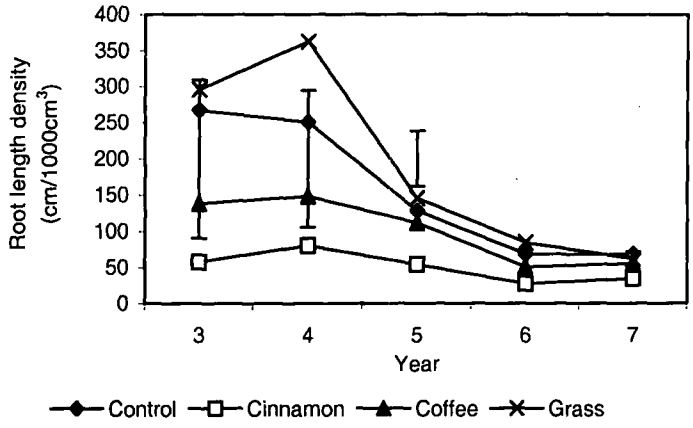

Fig. 4. Effect of rubber on the intercrop root length density in the inter row of contour planting system (vertical bars =LSD values)

Rubber root density in the four positions in the inter-row

The spread of rubber roots into the inter row space is considered here. In the row planting system there was a continuous increase in the RLD in all positions except for the reduction in the 6th and 7th years at position 1 (between two rubber trees in a row). At the same time there were significantly more rubber roots in position 1 than in other positions during the 3rd, 4th, 5th and 6th years. In the 7th year RLD's were similar in all positions (Fig. 5).

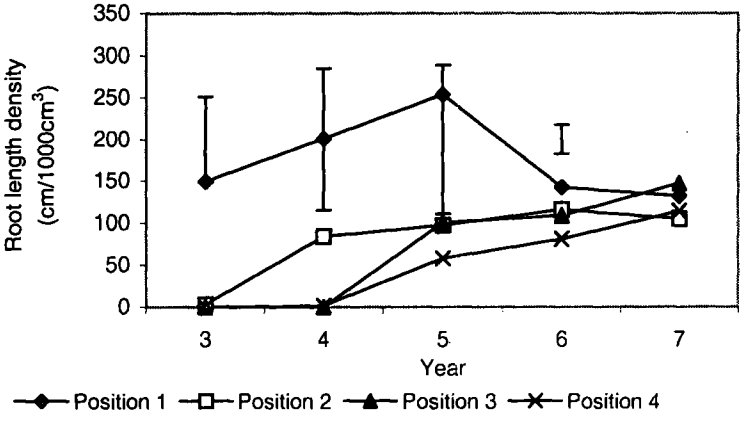

Fig. 5. Rubber root length density in different positions in the inter row in the row planting system (vertical bars =LSD values)

In the contour system the same pattern was there in the 3rd and 4th years. In the 5th year RLD at position 4 (middle of the inter row) was significantly lower than in all other positions. RLD in the 6th and 7th years showed similarity in all positions indicating the uniform spread of rubber roots (Fig 6).

Discussion

The development of feeder roots is a dynamic process and their proliferation changes during the year depending on the availability of favorable conditions (Snoog, 1976, Schroth & Zech, 1995). Apart from the environmental factors, other agronomic practices such as the return of residues of cinnamon after harvesting and clean weeding are factors that could have affected their growth in this experiment. However the overall out come gives an understanding of their behavior in different treatments during the period under study.

Most of the feeder roots in all crops in this experiment were found in the first 30 cm of soil and RLD only up to this depth was measured. This was considered to be fair as earlier report too confirms this (Ruhigwa *et al.*, 1992). No attempts were made to separate the RLD into different depths.

RLD of rubber in between two trees in a row was high initially and their growth into the inter row space was gradual. By the 7th year all four positions *i.e.* the whole of the inter row space seems to be invaded by the roots of the two rubber rows from either side and their distribution seems to be even in both rubber planting systems by the 6th year (Figs 5 & 6).

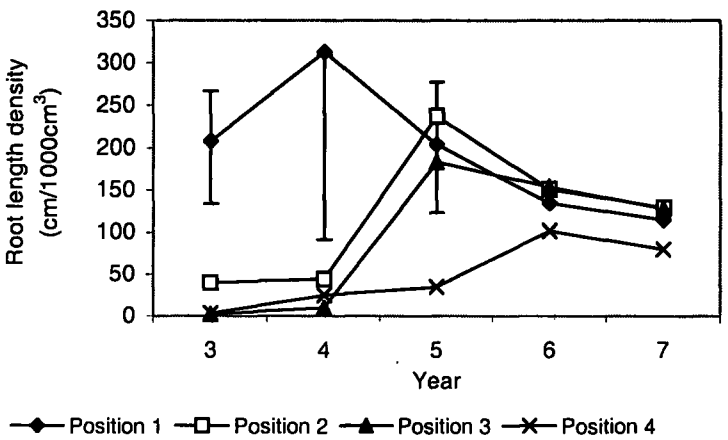

Fig. 6. Rubber root length density in different positions in the inter row in contour planting system (vertical bars =LSD values)

Rubber being the tree crop component of the system always had the advantage of exerting competition to overcome any influence of the intercrops and facilitate the growth of its roots, a situation that implicates more competition for the intercrop (Scroth, 1999). This is mainly by the spread of the canopy, limiting light to the intercrops (Pathiratna & Perera, 2003a). The continuous increase of rubber RLD in the inter row space substantiates this observation (Fig 2).

It is also seen that cinnamon has favored their growth in both planting systems particularly in contour planting system (Fig.2). The reason for this could be the soil enrichment due to the addition of plant residues.

The general trend of decline in the root length densities of all intercrops after about 4 years in both planting systems implies competition from rubber (Fig.3 & 4) and is due to the spread of the roots and the canopy of rubber into the inter row space (Pathiratna & Perera, 2003a). The largest drop in root length density was in *B. brizantha,* which is a high irradiance requiring species and was also influenced by regular defoliation (harvesting) and continuous reduction of light availability. Consequences of the combined effect of the removal of photosynthetic biomass and shading have been considered to be very severe on root development (Kandiah *et al.*1984, Schroth, 1999).

In cinnamon, that also was subjected to defoliation annually (Pathiratna & Perera, 2003a) the root length density remained unchanged from its low levels that existed from the 3rd year. It may be that an intensive feeder root system is not produced in cinnamon, a feature observed with some woody multipurpose tree species too (Akinifessi *et al.,* 1999).

The behavior shown by coffee even without such defoliation is similar to that of cinnamon but shows a greater reduction of root length densities possibly due to competition which is also reflected in coffee yields in the 2nd and 3rd harvests (Pathiratna & Perera, 2002 and Pathiratna & Perera, 2003a). Spatial displacement of roots due to competition is also another possibility in such instances (Schroth, 1999). The data as a whole shows that competition from rubber has reduced the root length density of all inter crops in the inter row in both treatments. The growth and the spread of rubber roots into inter row space was unaffected by the presence of intercrops during the first five years. But after five years there was an increase of root growth in cinnamon plots in both treatments. The RLD of high irradiance requiring grass was greater initially but was more vulnerable to the competition from rubber. The effect on those crops with a less dense feeder root system however did not seem to be great.

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References

Akinifesi, E K, Tang, B K and Ladipo, D O (1999). Structural root form and fine root distribution of some woody species evaluated for agroforestry systems. *Agroforestry System* **42**, 121-138.

Allen, L H Jr (1974). Model of light penetration into a wide row crop. *Agronomy Journal* **66**, 41-47.

Cannel, M G R (1983). Plant Management in agroforestry; Manipulation of trees, population densities and mixtures of trees and herbaceous crops. In: *Plant Research in Agroforestry*. pp 455-486 (Ed. P.A. Huxley) ICRAF, Nairobi.

Connor, D J (1983). Plant stress factors and their influence on production of agroforestry plant association. In: *Plant Research in Agroforestry* pp. 401-425 (Ed. P A Huxley) ICRAF, Nairobi, PP.407.

Jackson, R B and Caldwell M M (1992). Shading and capture of localized soil nutrients: Nutrient contents, carbohydrates and root uptake kinetics of a perennial tussock grass. *Oecologia* **91**, 457-462.

Kandiah, S, Wettasinghe, D T and Wadasinghe, A (1984). Root influences on shoot development in tea (*Camellia sinensis*) (L) O Kuntze) following shoot pruning. *Journal of Horticultural Science* **59**. 581-587.

Marsh, B A B (1971). Measurement of length in random arrangement of lines. *Journal of Applied Ecology* **8**. 265-270.

Ong, C K, Deans, J D, Wilson, J, Mutua, J, Khan, A A H and Lowson, E M (1999). Exploring below ground complementarity in agroforestry using sap flow and root fractal techniques. *Agroforestry System* **44**, 87-103.

Pathiratna, L S S and Perera, M K P (1998). Effect of shade on the bark yield components of cinnamon (*Cinnamomum verum*. J. Pres) intercropped with rubber (*Hevea brasiliensis* Muell Arg.). *Journal of Plantation Crops* **26**, 70-74.

Pathiratna, L S S and Perera, M K P (2002). Contour and east west row planting systems of rubber (*Hevea*) for inter cropping. Part I. Effects on growth and yield of component crops. *Journal of the Rubber Research Institute of Sri Lanka* **85**, 53-61.

Pathiratna, L S S and Perera, M K P (2003a). Contour and east west row planting systems of rubber (*Hevea*) for inter-cropping. III. Light availability in the inter row space. *Journal of the Rubber Research Institute of Sri Lanka* **86**, 11-22.

Rao, M R, Ong, C K, Pathak, P and P Sharma, M M (1991). Productivity of annual cropping and agroforestry systems on a shallow alfisol in semi-arid India. *Agroforesty Systems* **15**, 51-63.

Ruhigwa, B A, Gichuru, M P, Mambani, B and Tariah, N M (1992). Root distribution of *Acioa barteri, Alchornea codifolia, Cassia siamea* and *Gmelina orborea* in an acid Ultisol. *Agroforestry Systems* **19**, 67-78.

Schroth, G (1999). A review of below ground inter actions in agroforestry, focusing on mechanisms and management options. *Agroforestry Systems* **43**, 5-34.

Schroth, G and Zech, W (1995). Root length dynamics in Agroforestry with *Gliricidia sepium* as compared to sole cropping in the semi–deciduous rainforest of West Africa. *Plant and Soil* **170**, 297-306.

Snoog, N K (1976). Feeder root development of *Hevea brasiliensis* in relation to clones and environment. *Journal Rubber Research Institute of Malaysia* **24**, 283-298.

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