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Fine roots in mixed plantations of *Hevea* (*Hevea brasiliensis* H.B.K. Müll. Arg.) and cacao (*Theobroma cacao* L.).

Jochen Kummerow[1] *and Silvana Lages Ribeiro*[2]

Abstract

Rootlet distribution in mixed plantations of *Hevea* (*Hevea brasiliensis* H.B.K. Müll. Arg.) and cacao (*Theobroma cacao* L.) was analyzed. Fine roots of both species occupy preferentially the upper 15 cm of the soil. Two to nine times more *Hevea* than cacao rootlets were found in all soil samples. *Hevea* rootlets are three times thicker (0.73 mm) than cacao rootlets (0.22 mm). Thus, 1 g dry weight of cacao rootlets extends over 36 m vs. 6.7 m of *Hevea* rootlets. Nevertheless, the rootlet surface area (2 ¶ r x length of rootlets) of *Hevea* reached 1 $m^2.m^{-2}$ vs. 0.5 $m^2.m^{-2}$ in cacao. These observations suggest that fertilizing in mixed *Hevea*-cacao plantations of the conventional 7 x 3 m spacing would benefit preferentially the *Hevea* trees. This would result in higher leaf area indexes of *Hevea* and consequently produce light limitations for the shaded cacao trees.

Key words: Theobroma cacao, Hevea brasiliensis, rootlets, phytomass

Radicelas em plantações consorciadas de seringueira (*Hevea brasiliensis* H.B.K. Müll Arg.) e cacau (*Theobroma cacao* L.)

Resumo

Foi analisada a distribuição de radicelas em plantações consorciadas de seringueira (*Hevea brasiliensis* H.B.K. Müll. Arg.) e cacau (*Theobroma cacao* L.). As raízes finas de ambas as espécies ocuparam, preferencialmente, a camada do solo de até 15 cm de profundidade. Em todas as amostras do solo foram encontradas duas a nove vezes mais radicelas de seringueira do que de cacau. As radicelas de seringueira foram três vezes mais espessas (0,73 mm) do que as de cacau (0,22 mm). Em conseqüência, 1 g do peso das radicelas de cacau estende-se por 36 m contra 6,7 m das radicelas da seringueira. Contudo, a área superficial (2 ¶r x comprimento das radicelas) das radicelas de seringueira atinge 1 m^2 por m^{-2} do solo, ao passo que, para o cacau, seu valor é de 0,5 $m^2.m^{-2}$ Essas observações sugerem que a adubação em plantações consorciadas de seringueira e cacau, no espaçamento convencional de 7 x 3 m, beneficia preferencialmente a seringueira. Isso estimula a formação de um maior índice de área foliar para a seringueira, limitando a intensidade de luz para o cacaueiro.

Palavras-chave: Theobroma cacao, Hevea brasiliensis, radicelas, fitomassa

[1] *Centro de Pesquisas do Cacau, Caixa Postal 7, 45.600, Itabuna, BA, Brasil and Botany Department, San Diego State University, San Diego, California 92182, U.S.A.*

[2] *Divisão de Botânica, Centro de Pesquisas do Cacau, Caixa Postal 7, 45.600, Itabuna, BA, Brasil e Universidade Federal de Viçosa, 46570, Viçosa, MG, Brasil.*

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Introduction

Both the root systems of *Hevea* and cacao are characterized by large conical tap roots and extensive, yet shallow lateral roots (Himme, 1959; Bouychou, 1963, Cadima, 1970). Likewise, the bulk of the fine roots (= rootlets) in both the species has been found close to the soil surface (Rubber Research Institute of Malaya, 1962; 1969; Kummerow, Kummerow and Alvim, 1981). The phenomenon of surface close fine roots has been reported for many of the Amazon forests (Klinge 1973), the origin of *Hevea* and cacao.

The surge of interest in growing *Hevea* for shading and production in combination with the smaller cacao tree in the southern Bahia triggered the following study. It is intended to demonstrate that the fine roots of these species occupy the same soil layers and that *Hevea* fine roots in mixed stands form the larger part of the total rootlet biomass. The data presented here are limited and do not intend to provide answers to all questions. However, they should help in designing more comprehensive studies.

Material and Methods

Main research site is the block F' of the Centro de Pesquisas do Cacau, 22 km west of the port of Ilheus in Bahia (lat. 14° 7'S, long. 39° 16'W, 86 m a.s.l.). The sampling was confined to a small yet representative area of about 100 m^2 with slightly irregular rows of 5 yr *Hevea* and 2.5–yr cacao trees between these rows. The soil is a deep, fertile Alfisol with high loam content throughout the profile which had been analized in detail by Silva and Melo (1970). The rubber trees were 5–7 m tall and did not show a closed canopy at sampling time in January, 1981. The cacao trees were 1.5 – 2.0 m tall. In addition, some soil cores were collected from commercial *Hevea*-cacao stands in the municipality of Una, Bahia. Here all rubber trees were in production, 10 years old, 9–11 m tall, and 7 x 3 m spaced. The cacao trees varied between 10 months and 3.5 years. These plantations showed a closed *Hevea* canopy.

Soil cores were extracted with a 30 cm long and 5.5 cm wide steel pipe. The extracted cores were subdivided into three 5 cm long soil cylinders, thus allowing for root density analysis of the 0–5, 5–10, and 10–15 cm depth layers. The core processing followed the same procedure as described recently by Kummerow, Kummerow and Alvim (1981). Basically, the method consists in washing the soil through 0.5 mm soil sieves and transferring the individual fine root clusters and single rootlets by means of fine forceps into petri dishes. Rootlet lengths per sample were estimated by the line intersect method (Newman, 1966; Tennant, 1975). Finally, dry weights were recorded after drying for 72 hr at 78°C.

Results and Discussion

According to the sampling scheme (Fig. 1) the cores 1 – 4, collected close to a vigorous *Hevea*, contained about nine times more *Hevea* than cacao rootlets. Samples 5 – 8, from the vicinity of a healthy cacao tree, showed about twice

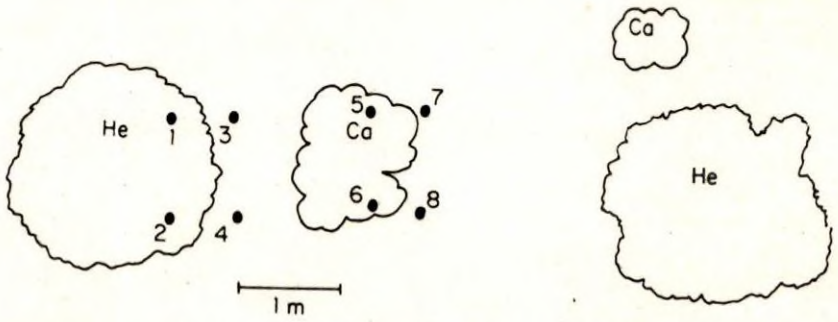

Figure 1 – Position of soil cores n.º 1 – 8 in a mixed *hevea*-cacao plantation. He = 5-yr *Hevea* and Ca =2.5-yr cacao trees.

the amount of *Hevea* than cacao fine roots (Table 1). More data would be desirable, however, the results are supported by a few samples collected on an exploratory visit in mixed *Hevea*-cacao plantations in the municipality of Una, Bahia. Although all the cores were extracted from the cacao crown area where the highest cacao rootlet concentration could be expected, significantly larger quantities of *Hevea* than cacao roots were found in all samples (Table 2). Since it does not seem feasable to plant *Hevea* and cacao at the same time because of the shade requirement of the young cacao, the predominance of *Hevea* roots in *Hevea*-cacao plantations may have to be accepted.

An analysis of the rootlet distribution in the uppermost 15 cm of the soil was based on the samples 1 – 8 (Table 1). The data show that rootlets of both the species were represented with about the same frequency in the soil profile. The observed differences are not significant (Table 3).

The fine root biomass values found in these soil cores match well those observed in *Hevea* plantations in Malaysia. In a mature stand with leguminous ground cover, 44 g.m^{-2} were found in

Table 1 - Dry weight in g.m^{-2} of rootlets sampled from 0-15 soil depth in a mixed *Hevea*-cacao plantation. Samples 1-4 collected close to a *Hevea* stem and 5-8 close to a cacao stem. For precise position of samples 1-8 see Figure 1. SE = Standard error. Differences between *Hevea* and cacao significant (P = 0.05).

No.	*Hevea*	Cacao	No.	*Hevea*	Cacao
1	60.4	2.1	5	36.5	40.3
2	75.2	0.3	6	46.5	22.5
3	64.6	17.2	7	79.8	28.0
4	32.9	12.3	8	72.6	9.8
$\bar{X}$	58.3	8.0		58.9	25.1
SE	9.01	4.05		10.32	6.32

Table 2 - Rootlet biomass in g.m^{-2} of *Hevea* and cacao trees in mixed plantations. Soil depth from surface to 15 cm. Cacao between the *Hevea* rows. All samples 0.3-0.9 m distant from cacao stems. Values are means from two samples.

Hevea	Age	Cacao	Age	Biomass ratio *Hevea*/cacao
117.3	10 yr	20.2	10 mo	5.0
220.7	10 yr	24.6	3.5 yr	9.0

Table 3 - *Hevea* and cacao rootlet distribution with soil depth from surface to 15 cm. The total fine root biomass was considered 100 %. Values in $g.m^{-2}$. Means from eight cores. SE = Standard error.

	Hevea			Cacao		
Depth in cm	0-5	5-10	10-15	0-5	5-10	10-15
Rootlet biomass	27.6	14.5	14.1	10.9	6.6	5.1
SE	6.33	5.12	4.09	3.15	2.0	1.99
%	49.1	25.9	25.0	48.2	29.2	22.6

the upper 8 cm of the soil (Rubber Research Institute of Malaya, 1962). In a later report (Rubber Research Institute of Malaya, 1969) 136 g pro m^2 from surface to 15 cm depth were recorded. Likewise, the cacao rootlet density of 35 $g.m^{-2}$ is similar to the 33 $g.m^{-2}$ reported earlier from a cacao plantation with *Erythrina glauca* shade trees (Kummerow, Kummerow and Alvim (1981). Thus, the presence of *Hevea* rootlets did not reduce the cacao rootlet biomass.

Limiting the comparison of rootlets of the two species to the biomass values would be misleading. The 0.73 mm diameter of *Hevea* rootlets was more than three times greater than that of cacao (0.22 mm). Consequently, 1 g of *Hevea* rootlets extended over 6.7 m while the thinner fine roots of cacao reached a length of 36.4 m per g dry weight. In addition, we found evidence for a substantial fraction of mostly unsuberized *Hevea* roots (sometimes as high as 40%) with a mean diameter of 1.6 mm, thus confirming earlier observations of a mostly unsuberized category of fine roots with 2.3 ± 0.6 mm diameter (Rubber Research Institute of Malaya, 1969). Nevertheless, based only on our main 0.73 mm rootlet population it was calculated that the rootlet surface of the rubber trees was nearly double that of cacao (Table 4). Our observations in 10–yr *Hevea* stands with cacao between the rows indicate an even larger *Hevea:* cacao

Table 4 - Rootlet surfaces of 5-yr *Hevea* and 2.5-yr cacao in a mixed stand. Rootlets from 0-15 cm soil depth. Standard error in parenthesis. Rootlet dry weights are means of eight samples.

	Hevea	Cacao
Rootlet diameter (mm)	0.73 (0.026)	0.22 (0.014)
Rootlet specific length ($m.g^{-1}$ dry weight)	6.7	36.4
Rootlet biomass ($g.m^{-2}$)	61. (7.95)	21 (6.13)
Rootlet lenght ($m.m^{-2}$)	409	764
Rootlet surface ($m^2.m^{-2}$) (2 πr x length)	0.937	0.528

rootlet surface ratio. Keeping our limited data base in mind we may conclude that in mixed stands the potential for nutrient absorption of *Hevea* roots appears to be higher than that of cacao. This conclusion is supported by the observation of a relatively low shoot growth rate but an aggressive development of the root system in *Hevea* vs. a fast shoot and slower root growth of cacao seedlings in nutrient solution (Alvim, Grangier and Santana, 1966?). Fertilizer addition to the crown area of the cacao in a mixed plantation with 7 m row distance between rubber trees, will probably benefit preferentially the rubber trees and thus produce higher leaf area indexes. The increased shade could further limit cacao productivity.

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