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FINE-ROOT GROWTH AND LONGEVITY IN A CACAO (*Theobroma cacao* L.) PLANTATION

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In the humid tropical rainforests, fine roots frequently grow at the soil-litter interface, a fact which makes it possible to carry out observations more directly. The purpose of this research was to answer two questions through direct evaluation in the field. Firstly, are growth rates of fine roots of tropical trees substantially different from the rates shown by species which grow in subtropical or temperate regions; and, secondly, is the functional lifespan of fine roots in humid tropical regions particularly short? Answers to these questions could make an important contribution to the understanding of the dynamics of tropical ecosystems. Growth and longevity measurements were carried out on fine-roots (less than 1 mm in diameter) directly at the soil-litter interface on a cacao (*Theobroma cacao*) plantation, in Bahia, Brazil. The rates of growth in the length of the fine roots were, on average, 3.7 and 1.8 mm per day for first and second order fine-root branches respectively. The average life span of these roots was three days, with variations within a range of one to ten days. Observations related to the growth in biomass of the fine roots, made by using of an ingrowth core technique, provided evidence to confirm and support the existence of rapid root replacement in the cacao ecosystem. Fine-root growth was closely related to rainfall frequency. The results were contrasted with those of ecosystems with seasonal climates, where elongation rates of fine roots appeared to be faster and their lifespan much greater.

Key words: *Theobroma cacao*, fine root, growth, longevity, turnover

Crescimento e longevidade de raízes finas em uma plantação de cacau (*Theobroma cacao* L.). Nas florestas tropicais úmidas raízes finas crescem freqüentemente na interface solo-folhedo. Isto faz com que seja possível a realização de observações de raízes mais diretamente, sob condições de campo. O propósito deste estudo é de responder duas questões através de avaliações diretas no campo. Taxas de crescimento de raízes finas em uma árvore tropical diferem substancialmente daquelas taxas obtidas em espécies que se desenvolvem em regiões subtropicais ou temperadas? O período de vida funcional de raízes finas nos trópicos úmidos é especialmente curto? Respostas a estas questões podem propiciar uma importante contribuição ao entendimento da dinâmica de ecossistemas tropicais. Foram realizadas medições de crescimento e longevidade de raízes finas (diâmetro < 1,0 mm) diretamente na interface solo-folhedo, em uma plantação de cacau (*Theobroma cacao*) na Bahia, Brasil. As taxas de alongamento das raízes finas foram, em média, 3,7 e 1,8 mm pôr dia, para as ramificações de primeira e segunda ordem, respectivamente. O período médio de vida funcional destas raízes foi de três dias, com variações dentro de uma faixa de um a dez dias. Observações relacionadas ao incremento da biomassa das raízes finas, utilizando-se uma técnica específica, corroboraram com evidências que apoiam a existência de rápida renovação de raízes no ecossistema cacaueiro. O crescimento de raízes finas foi estreitamente correlacionado com a freqüência das chuvas. Os resultados foram contrastantes com aqueles de ecossistemas com climas sazonais, onde taxas de alongamento de raízes finas apresentam-se mais rápidas e longevidade destas raízes são muito maiores.

Palavras-chave: *Theobroma cacao*, raízes finas, crescimento, longevidade, reciclagem

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Introduction

The sensitivity of the tropical rainforest to perturbations and the increasing need to incorporate these landscapes into non-destructive agricultural production (Alvim, 1978) have triggered intensive ecosystem research in the wet tropics. Substantial information is available on root biomass production (Berish, 1982; Klinge, 1973; Kummerow et al., 1981; Santantonio et al., 1977), nutrient uptake and cycling (Stark and Spratt, 1977; Stark and Jordan, 1978), and mycorrhizal associations (St. John, 1980). However, information on fine root growth dynamics and longevity is rather sketchy.

Fine root growth rates for temperate and subtropical plant species have been obtained from root observation tunnels, rhizotrons and simple root observation boxes. Moreover, fibre optics have been used to directly measure fine root growth rates *in situ* (for a literature review on root growth see Böhm, 1979). Although all these studies involved some degree of environmental modification, a broad base of information on fine root growth rates and longevity is available (Head, 1973; Lyford, 1975).

In the humid tropical rainforests, fine roots frequently grow at the soil-litter interface, a fact that makes direct observations possible. The purpose of this study was, based on data obtained by direct field observations, to answer the following two questions. Do fine-root growth rates in a tropical tree differ substantially from those in subtropical and temperate regions? Is the lifespan of fine root in the wet tropics especially short? Answers to these questions may help to improve the understanding of the dynamics of tropical ecosystems.

Material and Methods

Research site - All observations were made in an 11-year-old cacao plantation of the "Centro de Pesquisas do Cacau" 22 Km west of the Port of Ilhéus, in the State of Bahia, Brazil. The 4 - 5 m tall cacao trees grew in the frequently planted 3 x 3 m pattern and had developed a closed canopy. These cacao trees were shaded by 15 m tall *Erythrina glauca* (Fabaceae), planted 24 m distant from each other. Such a system simulates the dense tropical rainforest with a closed canopy and a well developed overstory from the shade trees. The last fertilizer applications occurred 9 months prior to our studies. The ground, covered by a 3 - 10 cm litter layer, was nearly free of weeds with only a few *Tradescantia* plants on small areas with relatively high light penetration. The fertile soil (Alfisol, series São Miguel) has an effective depth of 1.5 m. The well formed A-horizon is underlain by a deep B-horizon. The yellowish clay of the latter is neutral and becomes slightly acid with depth (Silva and Melo, 1970).

Climate - The mean annual temperature of the research area was 23.3° C, with mean annual maxima and minima of 28.6 and 19.4° C respectively, based on 12 years of observations. Average rainfall is about 1700 mm with a relatively even distribution throughout the year. The humid character of the area is shown by a mean annual relative humidity of 84%, ranging from 83% in January to 87% in June (CEPLAC, 1979).

Fine root growth and longevity - Eleven 10 x 10 cm wire squares were randomly distributed beneath the canopy. They were placed on the surface of the A-horizon after careful removal of the litter in such a way as not to disturb the layers of dead leaves in progressive stage of decomposition. The length and location of some fine roots in the 100 cm^2 area of each of the eleven squares were recorded by scale drawings on millimeter paper. The cream colored fine roots contrasted strongly with the dark humus of the A-horizon. Generally, sketches were made within 3 minutes. Relative root activity was estimated on a scale of 0 - 6, where 0 indicated no root growth and 6 indicated abundant fine root growth in the 100 cm^2 area observed. After measurements of individual fine roots, the undisturbed block of litter was returned to the original position until the next observation one or two days later. Root lengths and observations on their longevity were followed over a month period. Death of a fine root was recognized by a color change from cream-white to dark brown and a shriveled appearance.

Ingrowth cores - About 6 kg of soil from the cacao stand were collected to a depth of 10 cm. Roots were removed by hand and, after six days of drying at 80° C, the soil was passed through a 2 mm mesh soil sieve. Thirty soil cores of 10 cm length each were extracted with a galvanized steel pipe (5.5 cm diameter) from random positions under the canopy. A minimum distance of 1 m from the cacao and 6 m from the *Erythrina* stems was maintained. The holes were filled immediately with the root-free, dried and sieved soil, which had been prepared previously. Rings from galvanized steel wire (5.5 cm wide) marked the precise position of each hole that was filled with the root-free soil. Flagging aided in relocating the wire rings after they had been covered with the original litter layer.

After 4, 6 and 8 weeks, 10 of these soil cores were removed with a 5.5 cm wide steel pipe. The precise position for the extraction was determined by the above mentioned wire rings and careful vertical placement of the steel pipe. The soil from these cores was washed through a 1 mm mesh soil sieve. Roots were separated into live and dead fractions by means of a dissection microscope. Live roots were sorted into cacao and *Erythrina*, an easy task because of the lack of weeds. The coarse, white *Erythrina* rootlets were rapidly distinguished from the 0.2 to 0.5 mm thick cream-coloured cacao roots.

Results

Morphology - A representative fine root system on the surface of the A-horizon was selected and its growth, branching pattern and longevity are shown in Figure 1. The unsuberized roots appeared to be healthy and, initially, the main axis showed only four small branchlets. During the following two weeks the main rootlet did not elongate but became the source of nine additional branchlets. Three weeks after the first observation, all the rootlets appeared to show reduced activity, as judged by their dark brown and shrivelled aspect.