Available soil water in *Coffea arabica-Erythrina poeppigiana*, *C. arabica-Eucalyptus deglupta* and *C. arabica* monoculture plantations

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Introduction

Management of competition for water, light and nutrients between trees and crops, for the farmer's benefit, is the biophysical determinant for the success of agroforestry systems (Sanchez, 1995). In areas with a limited rainfall, competition for water is of higher relevance than the above-ground interactions (Jiménez, 1998). Shading has been widely used in several parts of the world where coffee (*Coffea arabica*) is grown. In Central America, shade is used in most coffee plantations (Perfecto et al. 1996). Shade trees diminish coffee stress, but they can also compete for the resources available (Beer et al., 1998). In seasonally dry areas, root competition for water may be a constraint to the use of shade trees in coffee plantations (Franco, 1951). In Sao Paulo, Brazil, Franco and Inforzato (1950) estimated that total transpiration of coffee with tree shade exceeded rainfall during the six months of the dry season. On the other hand, in Central America, where coffee is frequently grown under shade, available water in the soil may be greater than the permanent wilting coefficient, even after four months of drought (Franco, 1951). In Pernambuco (Northeastern Brazil) Matiello et al. (1985) reported that coffee under shade always maintains a better vegetative condition, even during the driest years, than coffee without shade. Similar results are reported by Suárez de Castro et al. (1961) in El Salvador. In Costa Rica, the Central American country where coffee plantations without shade were widely promoted in the 80's, it is presently common to see eucalyptus trees (mainly *Eucalyptus deglupta*) and other timber trees, in coffee plantations previously without shade or coffee plantations with a low economic value (Galloway and Beer, 1997). There are no comparative studies on available soil moisture in coffee plantations with different tree species or without shade in areas with long dry periods. The aim of this study was to evaluate available soil moisture in a coffee plantation without shade and under shade of *E. deglupta* or *Erythrina poeppigiana* in the Central Valley of Costa Rica.

Methodology

The study was carried out on the Sacramento Farm, located in Naranjo, Alajuela, Costa Rica (10° 04'N, 84° 23'O, 1020 masl) between December 1997 and July 1998. Mean annual rainfall is 2225 mm and mean temperature is 20°C. The dry season extends from December 15 to May 15, approximately. The deep soils are volcanic, classified as Andisol and are of sandy-clay-silt texture. The study site included three plots: coffee without shade; coffee associated with *E. deglupta*; and coffee associated with *E. poeppigiana* (no repetitions could be established). Soil conditions, slope, management, variety and weather conditions are similar in the three plots. Measures were carried out every 25 days, approximately, for a total of eight sampling dates. On each date, four soil samples were taken using a soil corer, in four sampling sites in each plot: in the middle of the space between two coffee rows at 1, 2 and 3 m from the nearest shade tree along the coffee rows at four depths: 0-15, 15-30, 30-45 and 45-60. The four sampling sites in each plot were selected at random. All trees are planted at 8x8 m, and had their foliage during the whole period of study. Eucalyptus trees had an average height of 10.6 m, 16.5 cm stem diameter at breast height (DBH) and a crown diameter of

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6 m. On the other hand, *Erythrina* trees had an average height of 6.2 m, a 16.4 cm DBH and an average crown diameter of 3.7 m. From December 10, 1997 to May 20, 1998 there was no rain. Furthermore, six samples were taken at each depth, in order to determine apparent density, field capacity (0.33 bars) and permanent wilting point (15 bars). Determination of dry weight was carried out in ovens (105°C during 48 hours). Maximum water content available at each depth was determined as the difference between volumetric water content at field capacity and wilting point.

Results and Discussion

During the dry season (December 10 to May 20) the amount of plant available water in the soil was higher in the coffee-poró system, followed by coffee without shade, and always lower for the coffee-eucalyptus system (Table 1). This behavior continued until May 29 when the amount of rain was not enough to restore the soil's maximum water retention capacity. In the evaluation carried out once the rainy season was established (July 10), available water was similar in the three coffee growing systems. According to the data from the evaluations carried out on March 5, March 26 and April 16, no water was available for the plants at depths 30-45 and 45 to 60 cm. Similar behavior was observed on March 26 and April 16 at 0-15 cm depth for the coffee-eucalyptus and coffee without shade. As the dry period continued, available soil moisture diminished to levels lower than the permanent wilting coefficient, except at depth 15-30 cm; hydric stress was always greater for the coffee-eucalyptus system. The observations carried out during these dates on the apparent status of the plants, clearly showed the effects of hydric stress, such as wilted leaves, loss of foliage, yellowish leaves, very small young leaves with a rolling leaf layer, as well as dead superficial fine roots (under litterfall) or near to the soil's surface, for coffee as well as for Eucalyptus and poró. In some coffee plantations located near to the site of study, coffee plants died due to hydric stress.

The results obtained for the coffee-poró and coffee without shade systems are similar to the ones reported by Suárez de Castro et al. (1961) in El Salvador, who carried out measures on soil moisture at different depths between 0 and 40 cm, in coffee plantations without shade and under *Inga* sp. and *Leucaena glauca* shade, during the dry season. They are different to the ones reported by Franco (1948, 1942) who concluded that a lack of water, caused by the competition of shade trees, was the factor responsible for several failures in shade trials established in coffee plantations in Sao Paulo. Franco's results lead to supported the general belief that soil moisture is higher in coffee without shade. In the coffee-eucalyptus system, water available during the period of hydric deficit was lower than for coffee without shade, which suggests a greater competition for water in the coffee-shade system, similar to the results found by Franco (1948, 1952). However, in the studies carried out by Franco, soil samples were taken at depths ranging between 0.5 and 2.0 m (most coffee roots are found in the first 30 to 40 cm); this situation makes data comparison difficult. Anyway, these results show that no generalizations can be made on coffee-tree competition. Meteorological, weather and soil conditions, tree species and spatial arrangements, tree and coffee planting and management practices, and the interactions of many of these factors, can influence the results; thus more research and information are required to make any general conclusion.

Low retention rate of available water at the 30-60 cm soil strata, in the study site, suggests the importance of preserving top soil as an option for coffee plant survival during the dry season.

Table 1. Means of available soil water (mm) in different coffee plantation systems and dates during the period December 1997-July 1998. Naranjo, Alajuela , Costa Rica.

Evaluation date	System	Depth (cm)			
		0-15	15-30	30-45	45-60
December 23	*Coffea-Erythrina*	23.7	30.0	11.8	10.5
	Coffea-Eucalyptus	10.4	13.5	3.6	2.7
	Coffea	23.2	27.1	10.6	9.1
January 13	*Coffea-Erythrina*	17.9	23.0	8.8	6.3
	Coffea Eucalyptus	6.2	6.9	0.1	0.0
	Coffea	15.2	20.6	6.4	6.7
February 02	*Coffea-Erythrina*	10.2	13.9	5.1	2.7
	Coffea-Eucalyptus	1.4	3.5	0.0	1.7
	Coffea	9.8	14.3	1.1	0.0
March 05	*Coffea-Erythrina*	3.1	7.9	0.3	0.7
	Coffea Eucalyptus	0.3	2.2	0.0	0.0
	Coffea	4.2	7.8	0.0	0.0
March 26	*Coffea-Erythrina*	1.1	10.4	0.8	0.0
	Coffea-Eucalyptus	0.0	3.2	0.0	0.0
	Coffea	0.0	6.4	0.0	0.0
April 16	*Coffea-Erythrina*	0.8	6.2	0.0	0.0
	Coffea-Eucalyptus	0.0	2.1	0.0	0.0
	Coffea	0.2	5.4	0.0	0.0
May 29	*Coffea-Erythrina*	20.2	26.7	8.6	3.3
	Coffea-Eucalyptus	10.0	15.5	2.9	0.4
	Coffea	19.2	21.2	3.7	0.0
July 10	*Coffea-Erythrina*	25.5	34.0	12.0	11.2
	Coffea-Eucalyptus	24.3	32.1	12.0	11.2
	Coffea	25.5	34.0	12.0	11.2

Conclusions

During the dry season, available water in the soil was always higher in the coffee-poró and coffee without shade systems than in the coffee-eucalyptus system. At 30-60 cm depth, soil moisture decreased to levels close or under the permanent wilting coefficient. Conservation of available water in the first 30 cm of the soil, mainly in the 15-30 cm stratum, prevented coffee plants, whose root system as demonstrated in different areas and soils is mostly found in the first 30 to 40 cm, did not die due to hydric stress. The highest and fastest depletion of water in the coffee-eucalyptus system suggests greater competition for water in this system, and the need to develop a more extensive study in order to better define the ecological impact of this tree species, as a shade tree for coffee, in areas with a severe seasonal hydric deficit.

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