AVAILABLE SOIL WATER IN A *Coffea arabica-Erythrina poeppigiana, C. arabica-Eucalyptus deglupta* AND *C. arabica* MONOCULTURE PLANTATIONS

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Resumen
Se evaluó el agua disponible en el suelo de 0-15, 15-30, 30-45 y 45-60 cm de profundidad, en parcelas de café sin sombra y con sombra de *Eucalyptus deglupta* o *Erythrina poeppigiana*, durante la estación seca en el Valle Central de Costa Rica. El agua disponible para las plantas fue siempre mayor en los sistemas café-*E. poeppigiana* y café sin sombra en comparación con el sistema café-*E. deglupta*. En el estrato de 30-60 cm, la humedad descendió hasta niveles cercanos o inferiores al coeficiente de marchitez permanente (15 bares) en todos los sistemas. La permanecia de agua disponible en los 30 cm más superficiales, donde se encuentran la mayor parte de raíces absorbentes del café, evitó la muerte de las plantas por estrés hídrico.

Palabras claves: Coffee shade systems, Costa Rica, hydric stress, water competition

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 limited rainfall, competition for water is of higher relevance than the above-ground interactions (Jiménez, 1998). Shade trees can diminish coffee (*Coffea arabica*) 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 the total transpiration of coffee with shade trees exceeded rainfall during the six months of the dry season. On the other hand, in Central America, where coffee is frequently grown under shade (Perfecto et al., 1996), 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 maintained a better vegetative condition, even during the driest years, than coffee without shade. Similar results are reported in El Salvador (Suárez de Castro et al.,1961). 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 planted in coffee plantations previously without shade or in coffee plantations with shade trees of low economic value (Galloway and Beer, 1997). The aim of this study was to evaluate available soil moisture in coffee plantations without shade or under shade of eucalyptus (*E. deglupta*) or poró (*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'W, 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

mid-December to mid-May. The deep soils are volcanic (Andisols) and are of sandy-clay-silt texture. The study site included three plots: coffee without shade; coffee associated with eucalyptus and coffee associated with poró (no repetitions were available on this commercial farm). Soil conditions, slope, management, coffee variety and weather conditions were similar in the three plots. Measurements were carried out approximately every 25 days for a total of eight sampling dates. On each date, soil samples were taken using a soil corer, in four sampling sites in each plot: i.e. 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, and at four depths (0-15, 15-30, 30-45 and 45-60 cm). The four sampling sites in each plot were selected at random. All trees were 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 6 m. The poró had an average height of 6.2 m, DBH of 16.4 cm and an average crown diameter of 3.7 m. There was no rain between December 10, 1997 and May 20, 1998. Six soil samples were also taken at each depth, in order to determine apparent density, field capacity (0.33 bars) and permanent wilting point (15 bars). Maximum plant available water content 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 the amount of plant available water in the soil was higher in the coffee-poró system, followed by coffee without shade, and was always lower for the coffee-eucalyptus system (Table 1). This difference was maintained until May 29, the period during which the amount of rain was not enough to restore the soil's maximum water retention capacity. In the evaluation carried after the rainy season was established (July 10), available water was similar in the three coffee 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 45-60 cm. Similar results were found 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 the depth 15-30 cm. Hydric stress was always greater for the coffee-eucalyptus system. The observations carried out during this period on the physiological 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 the litter layer), or near to the soil surface, for coffee as well as for eucalyptus and poró. In some coffee plantations located near to the study site, coffee plants died from hydric stress during the same period.

The results obtained for coffee-poró and coffee without shade are similar to those reported by Suárez de Castro et al. (1961) in El Salvador, who carried out measurements during the dry season on soil moisture at different depths between 0 and 40 cm in coffee plantations without shade and under coffee with *Inga* sp. or *Leucaena glauca* shade trees. The present results are different to those reported by Franco (1948, 1952) who concluded that a lack of water, caused by shade tree competition, was responsible for failures of shaded coffee plantations in Sao Paulo, Brazil. Franco's results lead to the general belief that soil moisture remains higher in coffee without shade. In the present study, in the coffee-eucalyptus system water available during the period of hydric deficit was lower than for coffee without shade, which suggests greater competition for water in coffee-shade systems, as 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, but most coffee roots are found in the first 30 to 40 cm; this situation makes data comparison difficult. The present results show that no generalizations should be made on coffee-tree competition for water since this depends on the characteristics of the tree species, the way they are managed (e.g. pruning regime) and many site factors (Beer et al., 1998).

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

Evaluation date	System	Depth (cm)			
	A.	**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
	B. 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
	C. Coffea	15.2	20.6	6.4	6.7
February 02	*Coffea-Erythrina*	10.2	13.9	5.1	2.7
	D. 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
	E. Coffea Eucalyptus	0.3	2.2	0.0	0.0
	Coffea	4.2	7.8	0.0	0.0
March 26	*F. 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

Plant available water in the soil during the dry season 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 to 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 is mostly found in the first 30 to 40 cm, from dying due to hydric stress. The higher and faster depletion of soil water in the coffee-eucalyptus system suggests greater competition in this system, and the need to develop a more extensive study in order to define the ecological impact of this tree species when it is used as a shade tree for coffee in areas with a severe seasonal hydric deficit.

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