Evapotranspiration and CROP COEFFICIENTS of a Coffee Plantation in Southern Brazil 1

F ábio Ricardo Marin 2 ; Luiz Roberto Angelocci 3 ; Evandro Zanini Righi 3 and Paulo César Sentelhas 3,

INTRODUCTION

Coffee plants have been cultivated in Brazil since 1727 and have a great importance for the economy of the country. Brazil has more than 2,400,000 ha of commercial plantations of coffee, and in the last 15 years they have been expanded to regions where drought is more intense and normally coincides with fruit expansion, what became irrigation very important and somewhat essential in such regions (Camargo, 1985). Currently, it is estimated that about 200,000 ha of coffee plantations are being grown under irrigation in the country.

In spite of great advances in technologies for water supply and the economic importance of coffee crop, irrigation management have been made inadequately in the most Brazilian coffee regions due to the large amount of water applied, which normally exceeds the crop needs (Camargo, 2002). Regarding this point, Carr (2001) postulated that estimates of water requirements for irrigation purposes are still imprecise for this crop and, probably, subject to large errors depending on the local circumstances and the system of irrigation used.

The objective of this study was to assess the water use by a drip-irrigated coffee plantation in Southern Brazil using different measurement techniques in order to determine the two components of crop coefficients (Kc), i.e. basal (Kcb) and evaporative (Kce) components. The study also evaluated the micrometeorological factors affecting transpiration, crop and reference evapotranspiration relationships and its implications on actual rates of water use and on irrigation management.

MATERIAL AND METHODS

The study was carried out in a coffee plantation at the experimental area of the Agricultural College "Luiz de Queiroz", University of São Paulo, Piracicaba, State of São Paulo, Brazil (lat. 22 ° 42'S; long. 47 ° 30'W; 546m a.m.s.l.) from August to October, 2002. The experimental field had 0.25 ha of 5-year-old plants of *Coffea arabica* 'Mundo Novo' grafted on stock *Coffea canephora* 'Apoatã', growing in hedgerow system oriented predominantly from NW-SE. Spacing at planting was 1 m between plants and 2.5 m between rows and during the experiment average plants' dimensions were 2.5 m height and 1.8 m width.

Net radiation (Rn) was measured with a net radiometer (NR Lite, Kipp & Zonen, Inc.) mounted 4 m above the soil surface. Soil heat flux (G) at the surface was measured using three heat flux plates (HTF3, REBS).

The overall crop evapotranspiration (ETc) was determined by the surface energy balance using the Bowen ratio method. Meteorological data from an automatic standard weather station (CR10X, Campbell Scientific, Inc.) located 200 m away from the experimental field were used to compute daily values of reference evapotranspiration (ETo), based on Penman-Monteith equation as parameterized by FAO-56 Bulletin (Allen et al., 1998).

The stem heat balance method (Baker & van Bavel, 1987) was used to estimate the transpiration rate of coffee plants. Commercially available stem sap flow gauges (three SGB50 and one SGB35, Dynamax, Inc.) were installed on the stem of four coffee plants around the micrometeorological tower. Transpiration rates were normalized dividing them by the plant's leaf area to obtain transpiration rate on a leaf area unit basis. The crop transpiration was scaled to a ground area unit basis multiplying the average transpiration rate of the four plants by the average leaf area index of them. The plants' leaf area ranged from 6.0 to 13.9 m^2 .

Diurnal courses of stomatal conductance (gs) were also measured during 5 days along the experimental period with a steady state porometer (LI 1600, Li-Cor, Inc.) on exposed and shaded leaves in the upper, middle and bottom canopy layers. The measurements were done in 20 leaves at seven times in each day from 9 h to 16 h (local time).

The decoupling factor (W) for a hipostomatous leaf was calculated following McNaughton & Jarvis (1983) and Jarvis (1985a).

RESULTS AND DISCUSSION

The relations between crop evapotranspiration and transpiration with ETo are showed in Figure 1, being the slope of the straight lines the Kc (Fig. 1A) and Kcb (Fig. 1B) values. In Hawaii, Gutiérrez & Meinzer (1994) found an mean Kc value of 0.66 for *Coffea arabica* , var. Catuaí with IAF ranging from 1.4 to 7.5. Although Kc and Kcb obtained in this study are within of a range proposed by Allen et al. (1998), they were 44% and 23%, respectively, higher than those found by Gutiérrez & Meinzer (1994). Variety, root-stock, coffee plants' age, and management system can be listed as causes for differences in Kc and Kcb between two studies. However, the main cause for low values of Kc observed at Hawaii seems to be the differences in the micrometeorological conditions in relation to them observed under our conditions, especially that one related to the atmospheric water demand. This reason was also mentioned by Gutiérrez & Meinzer (1994) to explain the variation of Kc between two years with different values of ETo.

This hypothesis can be inferred from the non-linear relationship between T and ETo (Fig. 1B). The non-linearity between these variables may be explained by the high inner resistances to water transport of coffee plants when submitted to conditions of high atmospheric water demand, such as verified for other horticultural species (Syvertsen & Lloyd, 1994; Tardieu & Simonneau, 1998), what is due to an opposite tendency of transpiration and stomatal movement in relation to increasing air vapor pressure deficit (McNaughton & Jarvis, 1983). For coffee, several works had been carried out to investigate the relationship of leaf conductance with environmental variables. Butler (1977) and Barros et al. (1995) verified a large dependence of stomatal conductance on air temperature and VPD, with a trend of stomatal closure with the increase of these variables. Fanjul et al. (1985) also observed a reduction in stomatal conductance with increase in photosynthetic photon flux density.

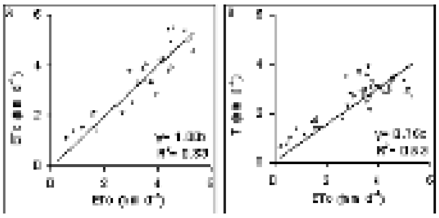

Figure 1 – Relationship between crop (ETc) and reference (ETo) evapotranspiration (A), and relationship between crop transpiration (T) and ETo (B).

In order to diagnose the causes of the non-linear relationship observed in Figure 1B, it was calculate the decoupling factor (W) with data obtained in Brazil and in Hawaii (Gutiérrez & Meinzer, 1994). The W values ranged from 0.04 to 0.23 in both places, indicating that there was a great influence of wind speed and VPD in the determination of ETc and T of both coffee plantations, i.e. crop transpiration was conditioned by aerodynamic rather than radiation conditions and imposed evapotranspiration rates tends to be larger and increase crop evapotranspiration (Jarvis, 1985a). As McNaughton & Jarvis (1983) and Jarvis (1985b) postulated, in tall horticultural crops with discontinuous ground cover W tends to be gradually lesser due to a reduction of aerodynamic resistance of canopy, caused by a vigorous air mixing and a high crop roughness. Therefore, in conditions of high available energy, high wind speed, and low VPD, what are normally found when ETo surpasses 4.0 mm day -1 , it may be expected that tall horticultural species with high inner resistances to water flow do not respond directly to the atmospheric water demand. This is the case of coffee fields analyzed here since high atmospheric water demand, represented by ETo rates, have caused the stomatal closure by the leaves and consequently a reduction in the ratio between T and ETo.

Thus, it seems inadequate to adopt a unique value of Kcb (and Kc) for tall horticultural crops with discontinuous ground cover that normally shows low W . Alternatively, it could be used two or three values of Kcb for different ranges of ETo, considering the crop skill to response to the environment, such as show Figure 2. Besides, proposed values of Kcb (and Kc) might be theoretically defined as function of plant population density, presence of vegetation between rows, LAI, and ranges of ETo.

Regarding the linear relationship observed between ETc and ETo (Figure 1A), different from that one found for T and ETo (Figure 1B), one may infer that the fall in transpiration rate when in high atmospheric demands was compensated by a direct response in evapotranspiration rates of interrow (i.e. soil evaporation plus grass transpiration). This compensation is based on the fact that evapotranspiration of short vegetation is normally strongly coupled to Rn, specially when under conditions of low wind and some isolation of overhead conditions, like was verified in the coffee plantation (McNaughton & Jarvis, 1983; Jarvis, 1985b). The different patterns of response between interrow vegetation and coffee plants indicate that orchards similar to this one studied here are complex and takes into account two distinct micrometeorological components, especially about aerodynamic aspects. From this observation, one infers that horticultural crops should be differentiated in relation to the management systems, named: irrigation system and interrow ground cover.

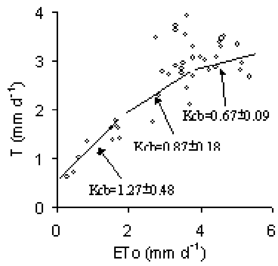

Figure 2 – Relationship between daily transpiration (T) and reference evapotranspiration (ETo) rates and mean Kcb values for different ranges of ETo.

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2 Embrapa Monitoramento por Satélite, Av. Júlio Soares de Arruda, 803. 13088-300. Campinas, SP, Brasil. fabio@cnpm.embrapa.br

3 USP/ESALQ/DCE. Av. Pádua Dias, 11, 13418-900, Piracicaba, SP, Brasil.