WATER RELATIONS IN A COFFEE GROVE PLANTED WITH GREVILLEAS IN VITÓRIA DA CONQUISTA, BAHIA, BRAZIL

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(received: october 27, 2005; accepted: december 12, 2005)

ABSTRACT: This study was carried out in order to evaluate the physiological effects of silk-oak plants (*Grevillea robusta* A. Cunn.) arranged in rows within coffee groves (*Coffea arabica* L.) at Capinal, a village near the city of Vitória da Conquista, BA, Brazil. Four treatments were defined by distances of zero, four, eight, and twelve meters between coffee plants row and silk-oak plants, with six replicates in a randomized block design. The following traits were evaluated: specific leaf area (SLA), relative water content (RWC), leaf proline (PRO), and soil moisture (SM). Samplings were made every two months from 1999 to 2002. Leaves from the middle part of coffee plants in each plot were collected to evaluate PRO, RWC, and SLA. Soil samples were collected at 0-10, 10-20, 20-30cm deep, on the crown projection area, and between coffee rows for SM analysis. Data obtained were submitted to the analysis of variance and regression analysis. Linear decreases in SLA were observed in the periods evaluated according to the distances among coffee and silk-oak plants. No model was estalished for RWC during 1999-2000 and 2001-2002 periods. There was a direct relation between PRO and the distances from the silk-oak trees row on all periods evaluated. SM decreased in all depths between coffee plant rows, as a function of the distances between coffee plants and silk-oak plants.

Keyword: *Coffea arabica* L., *Grevillea robusta* A. Cunn., tree planting¸ agroforestry systems, silk oak.

RELAÇÕES HÍDRICAS EM CAFEZAL ARBORIZADO COM GREVÍLEAS NO MUNICÍPIO DE VITÓRIA DA CONQUISTA, BAHIA

RESUMO: *Com o objetivo de avaliar os efeitos fisiológicos da arborização com grevíleas (Grevillea robusta A. Cunn.) dispostas em renques em cafezais (Coffea arabica L.), foi realizado este estudo no povoado Capinal, município de Vitória da Conquista, Ba, Brasil. Foi utilizado o delineamento em blocos casualizados, com quatro tratamentos, definidos por distâncias entre cafeeiros e grevíleas de zero, quatro, oito e doze metros, com seis repetições. Foram avaliadas as seguintes características: área foliar específica (AFE), teor relativo de água (TRA), prolina foliar (PRO) e umidade do solo (US). As amostragens foram realizadas a cada dois meses no período de 1999 a 2002. Para avaliar PRO, TRA e AFE, foram coletadas folhas da parte mediana de plantas de café de cada parcela. Para análise de US, foram coletadas amostras nas profundidades de 0-10, 10-20, 20-30 cm, na projeção da copa e nas entrelinhas de plantas de cafeeiros. Os dados foram submetidos à análise de variância e de regressão. Diminuições lineares de AFE foram observadas nos períodos avaliados em função das distâncias entre cafeeiros e grevíleas. Quanto ao TRA, não foi possível o ajustamento de modelos nos anos de 1999-2000 e 2001-2002. Para os três períodos avaliados, PRO aumentou em função das distâncias a partir do renque de árvores de grevíleas. A US, em todas as profundidades nas entrelinhas dos cafeeiros, decresceu em função das distâncias entre cafeeiros e grevíleas.*

Palavras-chave: Coffea arabica L., Grevillea robusta A. Cunn., arborização¸ sistemas agroflorestais, silk-oak.

1 INTRODUCTION

Coffee cropping in Brazil is one of the country's most important agricultural activities, with 2,405,253 hectares of planted area (IBGE, 2004). As coffee cropping expands, a coffee park of 50,000 hectares has been formed in the State of Bahia, distributed through the following regions: Plateau (Vitória da Conquista, Chapada Diamantina, Jequié, Itiruçu, Brejões, Santa Inês), Cerrado (Western Bahia), and Coastal Strip (South, Lower South, and Extreme South) (SOUZA et al., 2002). The development of coffee farming at the Conquista Plateau in the 1970's generated jobs and income. Presently, coffee farming still has an important participation in the economy, providing 50,000 direct and 100,000 indirect jobs (DUTRA NETO, 2001). An average 900m elevation and a mean annual temperature of 21°C (ESMET, 2004), characteristic in Vitória da

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Conquista, provide favorable conditions for coffee cultivation. However, great seasonal precipitation variability occurs in the area, both within a given year and year after year. The presence of trees promotes an effective stomatal control of coffee trees by increasing air humidity and reducing transpiration, with, resulting optimization of water use by the plants (RENA & MAESTRI, 2000). A lot of research has been done in order to provide an understanding of the effects of the association of other tree species with coffee plantations, however, field studies are scarce and only provide qualitative parameters (SOTO-PINTO et al. 2000). The aim of this project was to evaluate water relations in a coffee grove planted with grevilleas arranged in rows, in Vitória da Conquista, Bahia, Brazil.

2 MATERIAL AND METHODS

The experiment was carried out in a 18-year-old coffee plantation, located in the village of Capinal, Vitória da Conquista – BA, Brazil. Catuaí Amarelo Cultivar coffee plants (*Coffea arabica* L.), arranged in a 1.5 × 4.0m spacing, were clearcut in September of 1998. The soil in the experimental area was classified as a medium-textured, Typic Xanthic Dystrudox, with a flat topography. Monthly precipitation distribution was determined by daily readings from three pluviometers installed at the experimental area. Grevileas dendrometric evaluation performed at the begininig of the experiment showed that grevilleas crown projection area, trunk diameter and height were, respectivelly, 19.7m , 0.33 and 13,3m. A randomized block design with four treatments defined by distances of zero, four, eight, and 12m between coffee plants and silk-oak (grevillea) plants and six replicates, was used. Each experimental plot consisted of seven plants, three of which were usable. Soil moisture (SM) percentage in each plot was determined by collecting soil samples at 0-10, 10-20, and 20-30cm depths at the crown projection area (CPA), and between coffee rows (USR), Samples were collected in the period from August 1999 to April 2000, on five months: August (SE1/99), October (SE2/99), December (SE3/99), February (SE4/00), and April (SE5/00). In the period from July 2000 to May 2001, new samples were collected in six other months: July (SE1/00), September (SE2/00), November (SE3/00), January (SE4/01), March (SE5/01), and May (SE6/01). In the period from July 2001 to May 2002, five months were analyzed: July (SE1/01), September (SE2/01), November (SE3/01), March (SE4/02), and May (SE5/02). Gravimetric soil moisture content was determined according to Embrapa/CNPS (1997) methodology. Moisture at field capacity and permanent wilting point were determined using air-dried soil samples submitted to pressures of, repectivelly, 0.3 bar (FC) and 15 bar (PWP) (EMBRAPA, 1997) (Table 1).

Coffee plant evaluations were performed during three years. In the first year (1999/2000), five months were discriminated: July (SE1/99), October (SE2/99), December (SE3/99), February (SE4/00), and April (SE5/00). In the second (2000/2001) and third (2001/2002) years, another six months were evaluated: July (SE1/00 and SE1/01), September (SE2/00 and SE2/01), November (SE3/00 and SE3/01), January (SE4/01 and SE4/02), March (SE5/01 and SE05/02), and May (SE6/01 and SE6/02). The methodology described by Catsky (1960) was used for relative water content (RWC) determination. The 3rd or 4th pairs of leaves from middle portion of coffee plant were collected, and 10 disks (7 mm in diameter) were removed from the blade of each leaf, totaling 20 disks per plot. The specific leaf area (SLA) was obtained from the relation between the areas of the 20 disks removed for RWC determination. In order to evaluate proline contents, the 3rd or 4th pairs of leaves were removed starting at the branch apex, in the middle part of the plant, according to the methodology proposed by Bates (1973), without introduction of toluene. Statistical analysis was run using the SAEG version 9.0 software, including analysis of variance, regression analysis, and Pearson correlations. The regression models were selected based on the significance of the "F" test adopting the 5 and 1% levels, on the coefficient of determination, and on the phenomenon under study.

Table 1 – Gravimetric soil water content at field capacity and permanent wilting point for 0-10, 10-20, and 20-30cm depths.

	0-10cm (%)	10-20cm (%)	20-30cm (%)
Field capacity	22.21	21.31	26.74
Permanent wilting point	15.48	15.62	16.03

3 RESULTS AND DISCUSSION

A homogeneous behavior, characterized by linear specific leaf area (SLA) reductions, occurred in all months evaluated during the three years of study, as a function of increased distances between coffee plants and grevillea plants (D) (Figure 1). According to Morais et al. (2003), the decrease of light incidence in coffee plants provided by the proximity of coffee plants to grevilleas, may change leaf anatomy by reducing leaf thickness. Auxin synthesized in young leaves and shoots apices is diverged to root by conducted sieves by a polar transport. When light is restricted, auxin flux to roots is reduced and is diverged to lateral routes, resulting in enlargement of foliar epidermis and cortical cells (MORELLI & RUBERTI, 2000). This can promote a greater foliar area for coffee plants under shading by grevilleas, resulting in rising of SLA values. Simultaneous area increase and thickness reducction is a plant strategy to maximize foliar exposition and absorption of light (KITAJIMA, 1996). In field assays, Rodriguéz et al. (1999) verified higher SLA in coffee plants (*Coffea arabica* L.) near grevillea trees.

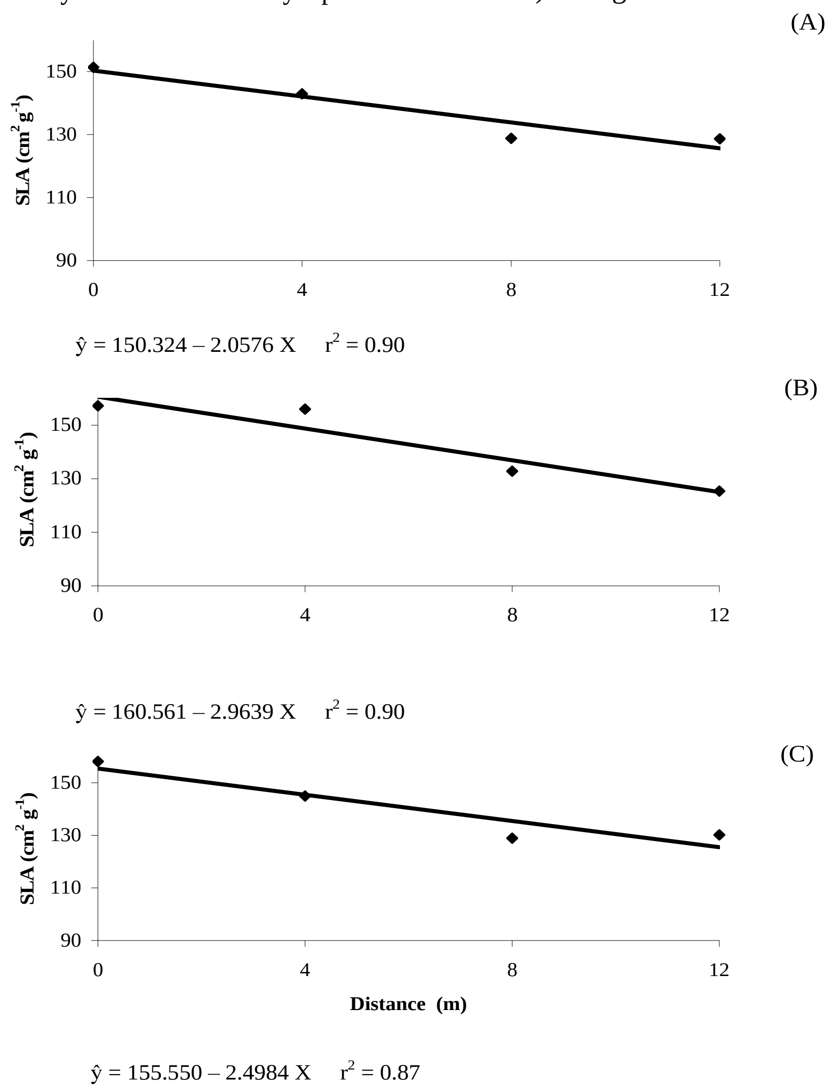


Figure 1 – Specific leaf area (SLA) estimate for coffee plants evaluated in the years from 1999-2000 (A), 2000-2001 (B), and 2001-2002 (C) as a function of distance from grevillea rows. Vitória da Conquista, 2005.

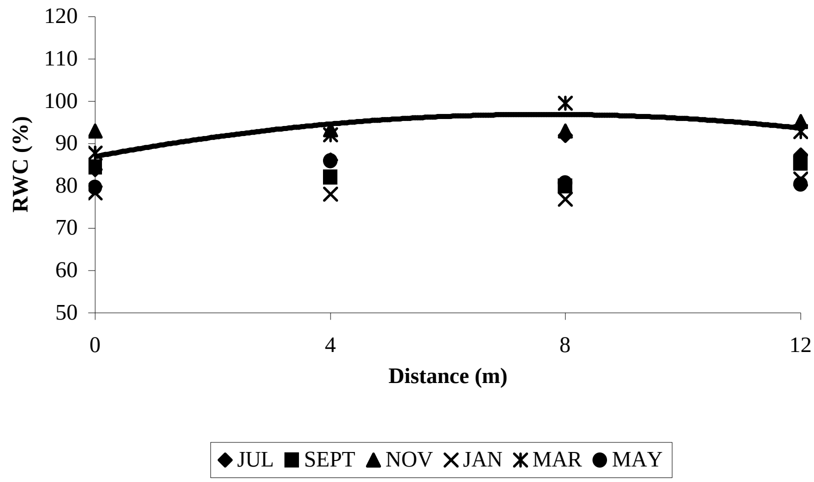
During the 2000-2001 period, a quadratic model was fitted only for March; RWC increased as D increased, up to 7.64m, and at that point a maximum value of 96.9% RWC was obtained (Figure 2).

In March, soil moisture (SM) between rows was higher in coffee plants near the grevillea row (Figure 5B). According to Sanchez, 1995, the litterfall accumulated by trees constitutes a barrier against soil water loss. Furthermore, the presence of planted trees could maintain SM in areas within the reach of the grevillea canopy, establishing a direct relation between SM and leaf RWC, as observed by Carelli et al. (1999). However, a quadratic model similar to the model fitted for RWC was only verified during the 2000-2001 period for SM at a 20-30cm depth, evaluated under the crown projection area (Figure 7B), resulting in a correlation of 0.2 at 1% probability by the **t** test. Increasing linear models were verified for proline contents (PRO) as a function of distances from the grevillea row (Figure 3). However, no interaction occurred between D and months evaluated (SE) in the 1999-2000 period (Figure 3A).

In the years from 2000-2001 and from 2001-2002, there was an interaction between D and SE, with a PRO variation from 2.36 to 19.47 ìM g^{-1}DM (Figures 3B and 3C). In 2000-2001, it was verified that in July the linear model was defined by higher values than in other months. Greater variation was also observed in July between PRO contents for coffee plants under the grevillea canopy and those located farther away. In July of the 2001-2002 period, the greater slope of the fitted straight line indicated a marked effect of **D** (Figure 3C, although PRO contents were constant between evaluation seasons. The reduced rainfall index observed in those periods was a factor associated with the PRO rise (Figure 4).

According to Rodrigues (1988), for PRO accumulation to represent a sensitive indicator of dehydration, a limiting water deficit condition must occur. The relation between the effect of light on PRO accumulation in plants submitted to water stress, verified in previous experiments, must be taken into consideration within the context of this study. Martinez et al. (1995) conducted a study about leaf PRO content fluctuations on hybrid potatoes submitted to water restriction, and verified that PRO accumulation ocurred currently with an increased incidence of radiation, remaining constant during the night. The effect of light on PRO accumulation was attributed to greater availability of substrates and energy from photosynthesis or to some light-induced process. Therefore, coherent conclusions can only be considered based on studies that relate PRO accumulation with radiation availability. It was observed during the three years of study that SM values at the 0-10cm depth remained near the permanent wilting point (Material and Methods, Table 1). Greater water evaporation at the soil surface layer and the presence of a greater amount of roots were factors that determined low SM values at 0-10cm (CAMPANHA, 2001). In 1999-2000, a linear model was fitted for SM and D under coffee plant crown projection, at a 0-10cm depth, but no interaction occurred between D and SE. A quadratic model was fitted for the SM evaluations between coffee rows in the 1999-2000 period (Figure 5A). A decrease in SM was observed up to 7.63m away from the grevillea row, reaching a minimum SM value of 18.99%. A slight rise was observed farther away. Similar results were observed by Matsumoto et al. (2003), in Barra do Choça, BA, Brazil. A decreasing linear model was verified for the 2001-2002 period; however, there was no interaction between D and SE (Figure 5C). There was an interaction between D and SE (Figure 5B) in the 2000-2001 period, and decreasing linear models were fitted for the months of July, September, March, and May.

Based on the precipitation analysis for the three years evaluated, a difference was observed for the 2000-2001 period in relation to the others, due to a marked reduction and irregularity in precipitation (Figure 4). This water condition allowed the positioning of the linear models to be differentiated; higher SM levels were observed in the months of July and September, in relation to March and May. In September, a steeper slope was verified for the linear model, indicating greater SM reduction in relation to D between coffee rows at 0-10cm depth (Figure 5B).



MAR $\hat{y} = 86.961 + 2.6043\,X - 0.1705\,X^2$ $R^2 = 0.78$

Figure 2 – Relative water content (RWC) estimate for coffee plants evaluated in the 2000-2001 period as a function of distance from grevillea rows. Vitória da Conquista, 2005.

In the three periods evaluated, no model was fitted for SM and D on the crown projection area at the 10-20 cm depth. The maximum SM value at 10-20 cm depth between coffee rows was 23.80%, while the minimum value was 15.43%, with greater concentration of values near the SM, corresponding to its field capacity (Figure 6). Values lower than the permanent wilting point were verified only in May, at distances higher than 11.19m (Figure 6B). SM reductions in relation to D were verified based on the linear models, at the 10-20 cm depth between coffee rows (Figure 6). There were no interactions between D and SE in 1999-2000 and 2001-2002 (Figures 6A and 6C). Neves (2001) observed higher SM values between coffee rows at 0-10cm depth in coffee groves planted with trees during the dry period, as compared to coffee trees maintained unshaded. Interactions between D and SE were not observed in any of the three study periods, when SM at the crown projection area was evaluated at 20-30cm depth (Figure 7). A linear model was fitted for SM and D in the periods from 1999-2000 and from 2001-2002 on the crown projection area at 20-30cm depth (Figures 7A and 7C). D value increases were related to SM increases, but small variations at distances between 0 and 12m between grevillea and coffee plants were observed (Figure 7 A and 7C).

An interaction between coffee plants and grevillea roots could be involved in the process. Lot et al. (1996) verified from root sap flux determinations that grevilleas could absorb a substantial water portion from two meters away from its trunk. However, Ong et al. (2000) observed that in a corn field associated with grevilleas there was reduction in grevillea trunk sap flux. The homogeneous SM values observed in the association between coffee plants and grevilleas could be related to soil sample depth and the major influence in SM of self shading promoted by crown projection of coffee plants maintained far away from grevilleas row. In the 1999-2000 and 2000-2001 periods, interactions were observed between D and SE (Figures 8A and 8B). For 1999-2000, a quadratic model was fitted for the months of October, December and April. No SM differences were observed among evaluated Ds in September, November, and May. The higher monthly precipitation index observed in November and December determined increased SM in December as compared to other months (Figure 4). The uniformity of rainfall distribution observed in the 1999-2000 period contributed toward the similarity of values observed in October and April (Figures 4 and 8A). In the 1999-2000 and 2000-2001 periods, minimum SM values of 19.79% and 17.84%, respectively, were discriminated at 20-30cm depth.

In the months of July, September, November, and March 2000-2001, a linear model was fitted for SM at 20-30 cm depth between coffee rows, with decreased SM values in relation to D (Figure 8B). The litterfall accumulation of grevillea could be related to major SM values observed in this study. According to Clowes and Logan (1985) the litterfall reduces evaporation of soil superficial layer and maximizes water infiltration. Despite the benefits of the association between trees and coffee plants, water use efficiency and availability depends mainly of tree water utilization and local environmental conditions.

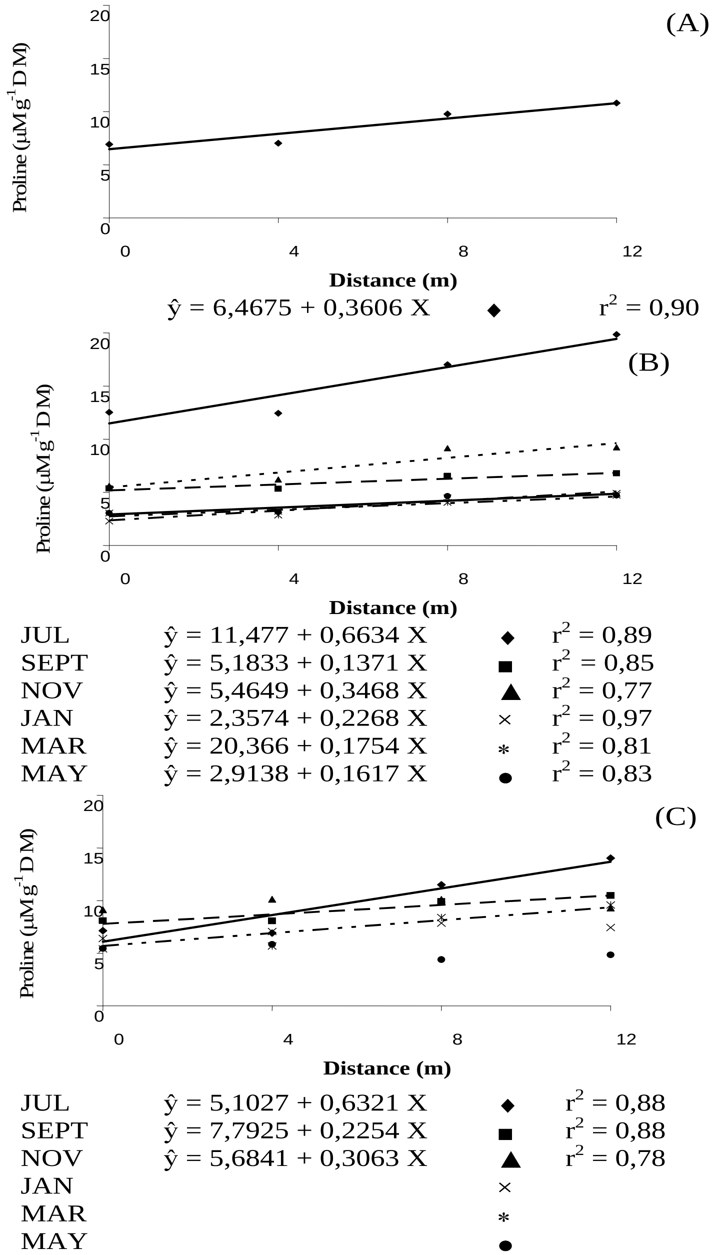


Figure 3 – Leaf proline content estimate for coffee plants evaluated in the years from 1999-2000 (A), 2000-2001 (B), and 2001-2002 (C) as a function of distance from grevillea rows. Vitória da Conquista, 2005.

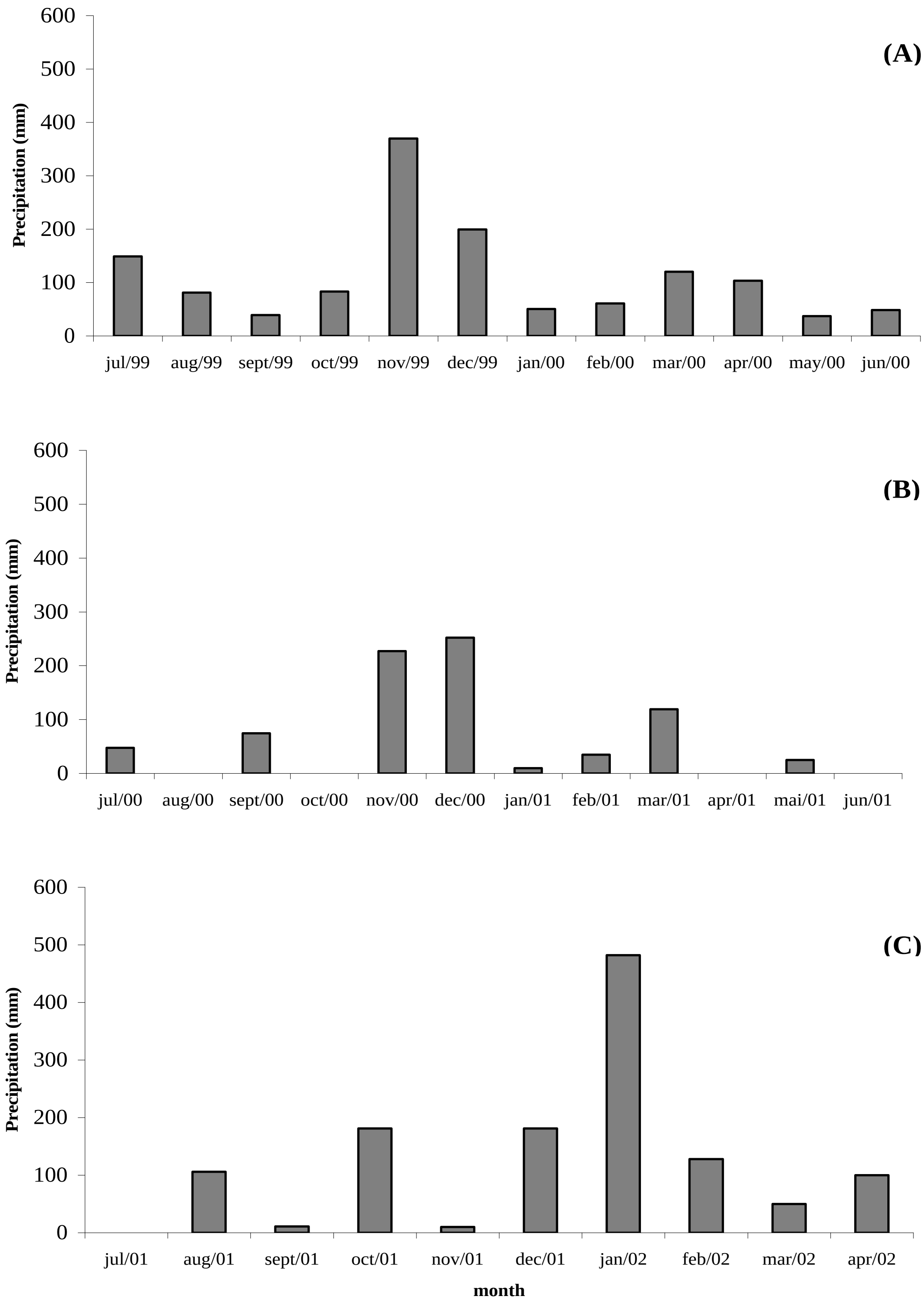
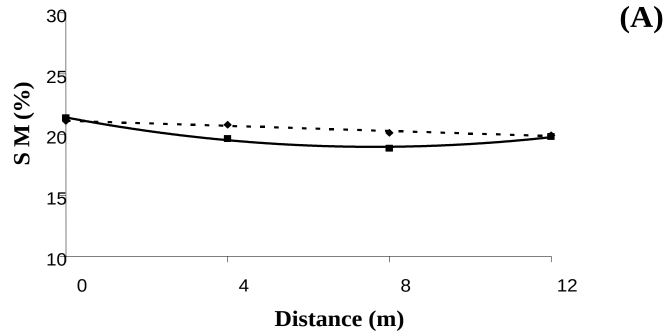
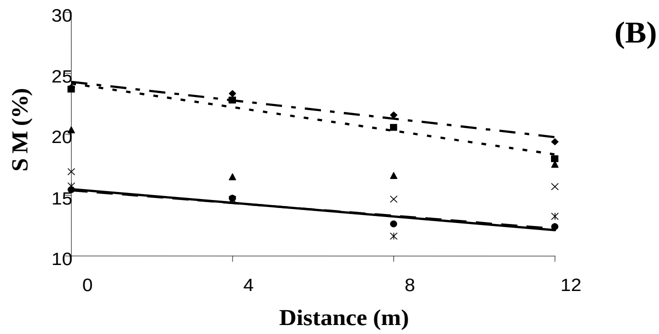


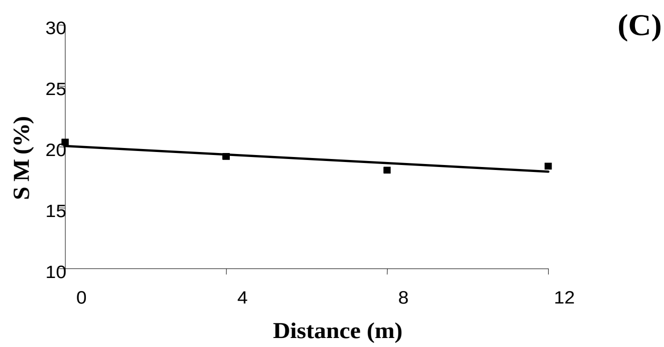
Figure 4 – Monthly precipitation (mm), observed in Capinal village in the years from 1999-2000 (A), 2000-2001 (B), and 2001-2002 (C). Vitória da Conquista – BA, 2005.



CROWN $\hat{y} = 21.137 - 0.1052\ X$ ◆ $r^2 = 0.96$
B.R. $\hat{y} = 21.418 - 0.635\ X + 0.0416\ X^2$ ■ $r^2 = 0.99$

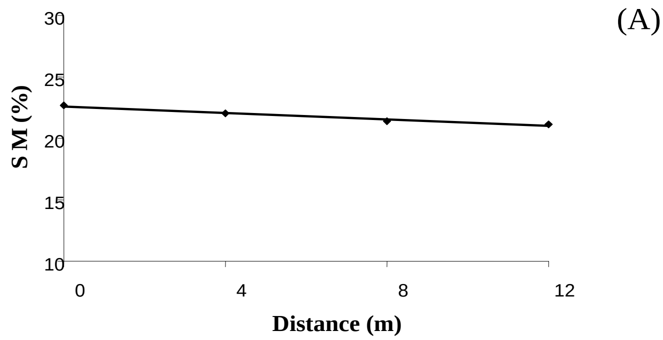


B.R.
JUL $\hat{y} = 24.293 - 0.3775\ X$ ◆ $r^2 = 0.94$
SEPT $\hat{y} = 24.158 - 0.4844\ X$ ■ $r^2 = 0.96$
NOV ▲
JAN ×
MAR $\hat{y} = 15.380 - 0.2620\ X$ * $r^2 = 0.58$
MAY $\hat{y} = 15.490 - 0.2810\ X$ ● $r^2 = 0.92$

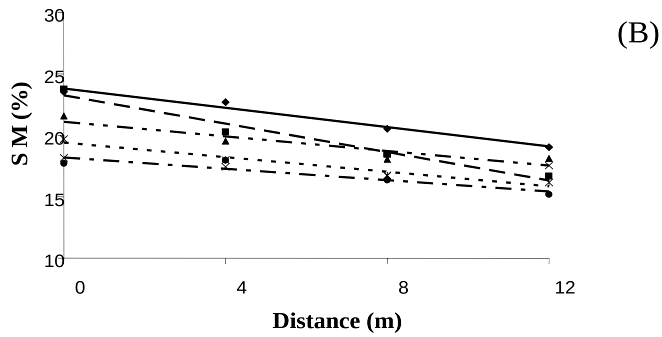


B.R. $\hat{y} = 20.0830 - 0.1759\ X$ ■ $r^2 = 0.79$

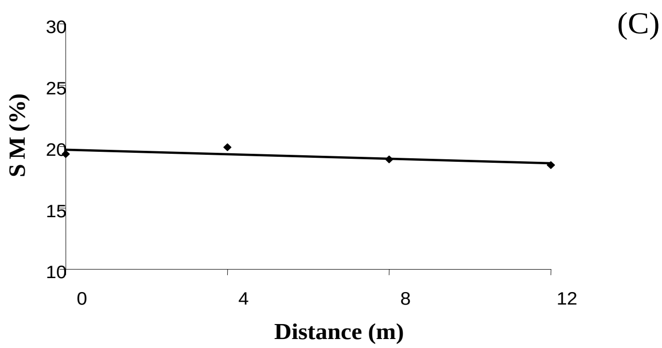
Figure 5 – Soil moisture (SM) estimate at 0-10cm depth, on the crown projection area (CROWN) and between coffee plant rows (B.R.), evaluated in the years from 1999-2000 (A), 2000-2001 (B), and 2001-2002 (C) as a function of distance from grevillea rows. Vitória da Conquista, Bahia, 2005.



ŷ = 22.592 – 0.1311 X ♦ r^2 = 0.97

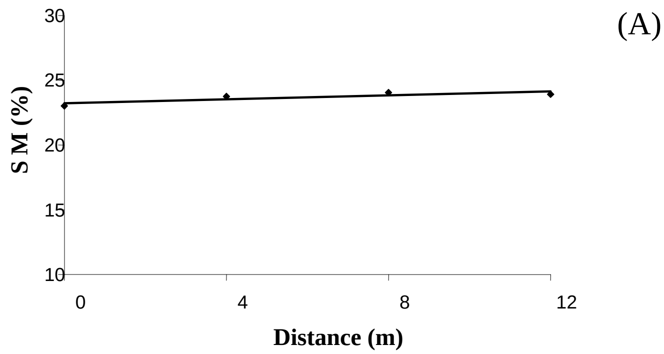


JUL	ŷ = 23.796 – 0.3918 X	♦	r^2 = 0.98
SEP	ŷ = 23.244 – 0.5762 X	■	r^2 = 0.96
NOV	ŷ = 21.084 – 0.2954 X	▲	r^2 = 0.86
JAN		×	
MAR	ŷ = 19.407 – 0.2963 X	*	r^2 = 0.95
MAY	ŷ = 18.187 - 0.2297 X	●	r^2 = 0.85

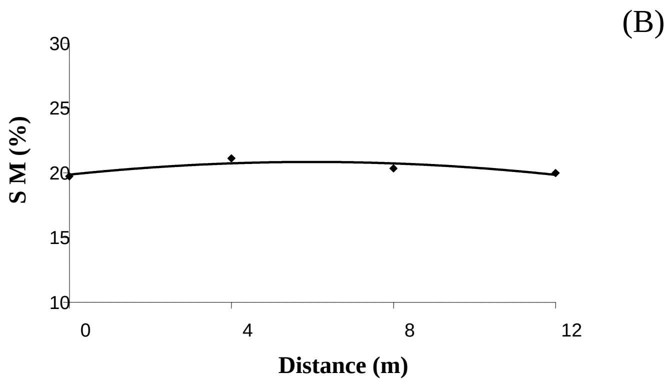


ŷ = 19.742 – 0.0917 X ■ r^2 = 0.79

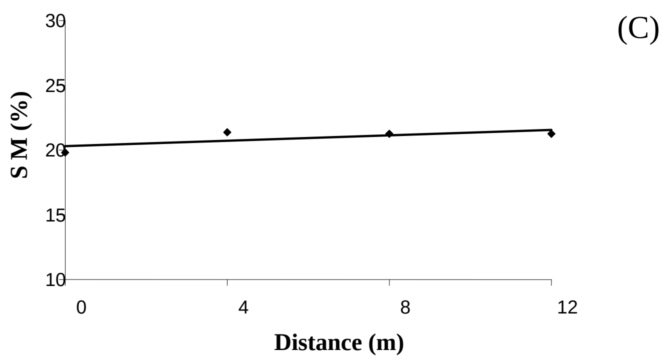
Figure 6 – Soil moisture (SM) estimate at 10-20cm depth, between coffee plant rows, evaluated in the years from 1999-2000 (A), 2000-2001 (B), and 2001-2002 (C) as a function of distance from grevillea rows. Vitória da Conquista, Bahia, 2005.



$\hat{y}$ = 23.2361 – 0.0749 X ♦ r^2 = 0.70

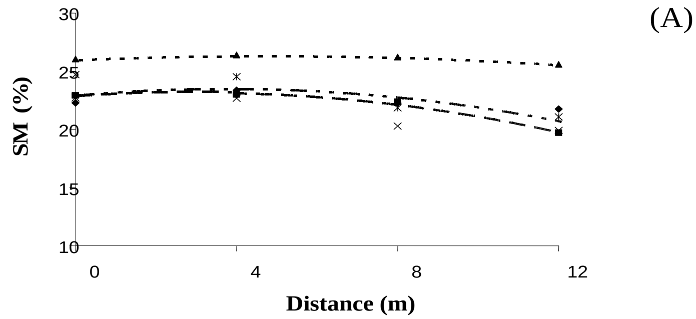


$\hat{y}$ = 19.867 + 0.3273 X – 0.0274 X^2 ♦ r^2 = 0.70



$\hat{y}$ = 20.293 + 0.1054X ♦ r^2 = 0.53

Figure 7 – Soil moisture estimate at 20-30cm depth, on the crown projection area of coffee plants, evaluated in the years from 1999-2000 (A), 2000-2001 (B), and 2001-2002 (C) as a function of distance from grevillea rows. Vitória da Conquista, Bahia, 2005.



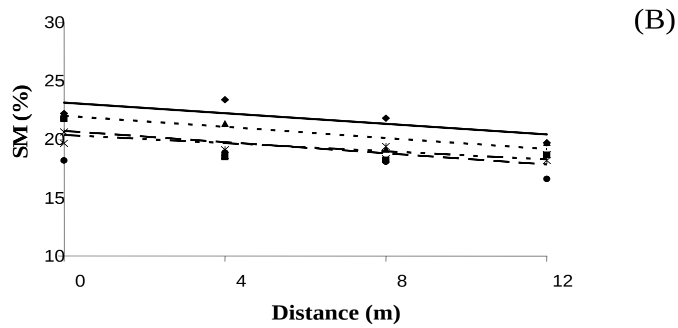
AUG ◆

OCT $\hat{y} = 22.849 + 0.2600\ X - 0.0429\ X^2$ ■ $r^2 = 0.99$

DEC $\hat{y} = 26.050 + 0.1446\ X - 0.0152\ X^2$ ▲ $r^2 = 0.99$

FEB ×

APR $\hat{y} = 23.020 + 0.3017\ X - 0.0409\ X^2$ * $r^2 = 0.69$



JUL $\hat{y} = 23.128 - 0.2270\ X$ ◆ $r^2 = 0.58$

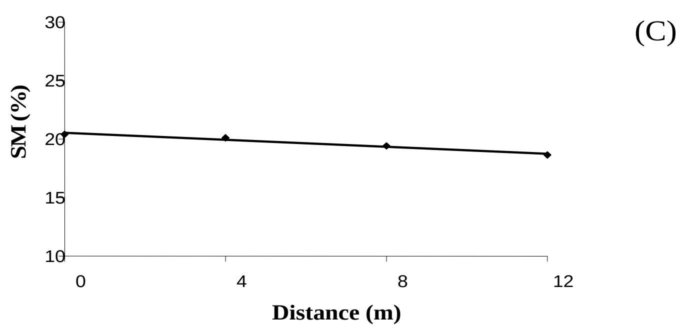
SEP $\hat{y} = 20.705 - 0.2388\ X$ ■ $r^2 = 0.55$

NOV $\hat{y} = 22.008 - 0.2380\ X$ ▲ $r^2 = 0.77$

JAN ×

MAR $\hat{y} = 20.366 - 0.1754\ X$ * $r^2 = 0.81$

MAY ●



$\hat{y} = 20.537 - 0.1496\ X$ ◆ $r^2 = 0.97$

Figure 8 – Soil moisture estimate at 20-30cm depth, between coffee plant rows, evaluated in the years from 1999-2000 (A), 2000-2001 (B), and 2001-2002 (C) as a function of distance from grevillea rows. Vitória da Conquista, Bahia, 2005.

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