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Growth of Cocoa as Function of Fertigation with Nitrogen

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Abstract: The effect of irrigation and nitrogen fertilization on the growth characteristics of cocoa (*Theobroma cacao* L.), specifically the clone CCN-51, was evaluate in a field experiment conducted on the period from August 2010 to June 2011 in Jequié city, Bahia State, Brazil. The experimental area, approximately 0.18 ha with the planting of cocoa clonal CCN- 51 in Yellow Oxisol was irrigated drip emitters. The statistical experimental design was randomized blocks with four replications where the factors water level and nitrogen level were factorial combined resulting in the 16 treatments. During the experimental period were measured plant height and stem diameter during six periods. The analysis of variance showed a significant effect of water and N levels in plant height and stem diameter. The biometric variables responded to treatments. The water level used in this study negatively affected the plant growth. The nitrogen level used in this study positively influenced the plant growth. The relative growth rate in relation to the plant height and stem diameter, on average, corresponded to about 14% and 15%, respectively.

Key words: Drip irrigation · Fertigation · *Theobroma cacao* L.

INTRODUCTION

Cocoa (*Theobroma cacao* L.), Sterculiaceae family, native of Amazon region is a perennial plant of great economic importance, which usually begins to bear fruit at three years old. The brazilian plantations face damage caused mainly by biological conditions such as "vassoura-de- bruxa" and "podridão-parda" disease caused by fungi *Crinipellis perniciosa* and *Phytophthora palmivora,* which occur respectively in the States Amazon and Bahia, the largest producers of cocoa in Brazil.

Brazil was the world's largest producer of cocoa with about 40% of this production, currently occupies the seventh position with an estimated harvest in August 2011 of 237000 tonnes. One of the new alternatives to recover cocoa production in Brazil will be production of cocoa irrigated in the semi-arid region. Recent results with cocoa crop grown in Linhares-ES, Brazil, showed that the introduction or adaptation of technologies contributed to a significant increase in production in the state. Cocoa tree requires moisture for its growth throughout the year and regular irrigation is required [1].

Siqueira *et al*. [2] concluded that fertigation cocoa is a new technology that has proven profitable for the producer and soluble fertilizers have a greater influence on productivity. Nitrogen is the mineral nutrient required most by plants. There are, however, no studies on N fertilization calibration for cocoa production and frequent irrigation. According Borges and Silva [3], urea is the source most used in fertigation in function to the lower price and lower salt index/unit of nutrient. The use of soluble fertilizers in irrigation water has been one of the practices adopted by producers of cocoa in the semi-arid region of Bahia, especially urea and potassium sulfate as a nitrogen and potassium source, respectively.

The objective of this study was to analyze the vegetative growth in the field clonal cocoa CCN-51 subjected to irrigation and nitrogen levels applied through irrigated water.

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MATERIALS AND METHODS

The field experiment with cocoa was carried out from August 2010 to June 2011 on the Farm Vale do Sol, in Jequié County, BA (State of Bahia), Brazil (Latitude 13° 51' 28" South; Longitude 40° 05' 02" West, 199 m ASL). According to Köppen's classification, the climate is Aw; average annual temperature is 24°C and minimum and maximum relative humidity of air is 58.3 % and 72.9 %, respectively. The experimental area was approximately 0.18 hectares cultivated with rooted clonal cocoa tree cuttings CCN-51 in holes of 0.40 x 0.40 x 0.40 m at a spacing of 3.5 x 2.0 m, irrigated with located drip system. The soil was classified as a Yellow Oxisol with the following physical and chemical characteristics: sand = 683.8 g kg^{-1}; silt = 228.8 g kg^{-1}; clay = 87.4 g kg^{-1}; bulk density = 1.57; porosity = 43.12 %; field capacity = 10.63 %; permanent wilting point = 3.63 %; pH (H_2O) = 6.48; Ca = 2.53 $cmol_c$ kg^{-1} ; Mg = 1.81 $cmol_c$ kg^{-1} ; Na = 0.03 $cmol_c$ kg^{-1}; K = 0.28 $cmol_c$ kg^{-1}; H + Al = 0.84 $cmol_c$ kg^{-1}; OM = 1.0 g kg^{-1} ; P = 11.2 mg kg^{+} .

In the experimental field were applied four irrigation regimes, based on the gross irrigation depth (GD) 0.60; 0.80; 1.0 and 1.2 GD, corresponding to water level W1= 1146.35mm; W2= 1335.66 mm; W3= 1525.58 mm; W4= 1717.58 mm, respectively, inferred from a Class "A" Evaporation Pan installed on the farm. The fertilizer doses applied were 70, 100 130 and 160% of the recommended nitrogen for the cocoa cultivation corresponding to nitrogen doses N1=249.30 kg ha^{-1}; N2= 307.20 kg ha^{-1}; N3= 365 kg ha^{-1} and N4= 422,9 kg ha^{-1}. The statistical experimental design was a 4 x 4 factorial, randomized blocks with four replications, where the water depths and nitrogen factors were combined resulting in 16 treatments with 64 plants in each block, totaling 256 plants.

The rooted cocoa tree cuttings were transplanted on August 2010. In each hole were applied 70 g/hole of FTE BR 12, 140g/hole of MAP (52% P_2O_5 and 11% N) and 3 L of goat manure. Fertigation was performed weekly; injection of urea (% 45 N) as a nitrogen source was applied in the suitable proportions according to standard dose of weekly application of 3 g N $plant^{-1}$ considered as N2 (100%) and other levels N1 (70%), N3 (130%) and N4 (160%) compared to standard dose. Potassium fertilizer was applied weekly by fertigation keeping 2 g K $plant^{-1}$ of potassium sulphate. These mixtures were diluted with ten liters container discharge time of five minutes.

During the experimental period, on six occasions, was measured plant height (PH) and stem diameter (SD): 265 days after transplantation (DAT); 325 DAT; 385 DAT; 445 DAT; 505 DAT and 565 DAT. The last data were submitted to analysis of variance and comparison between means by Tukey test.

RESULTS AND DISCUSSION

An increase in nitrogen levels (N) led to significant increase ($p < 0.01$) in growth traits, i.e., plant height and stem diameter, were significantly affected by nitrogen levels. Likewise, increasing nitrogen levels there was a significant difference ($p < 0.01$) on the growth length of wheat [4]. Plant height and stem diameter were significantly ($0.01< p< 0.05$) affected by the water levels (W). The results of the interaction between the factors W and N were not significantly affected (Table 1). According to Tarighaleslami *et al*. [5], studying the effects of drought stress and different nitrogen levels on growth of corn, the results for plant height was positively affected by nitrogen fertilizer application and water.

Likewise, increasing doses of nitrogen have a significant effect on the growth of wheat Table 1.

Table 1: Analysis of variance for experimental growth trait [plant height (PH) and stem diameter (SD)]

Treatment	DF	Mean Square PH	Mean Square SD
Blocks	3	87,09^{ns}	6,60^{ns}
Water levels (W)	3	318,26*	40,84*
Nitrogen levels (N)	3	980,48**	78,24**
W x N	9	139,66^{ns}	18,69^{ns}
W linear regression	1	848,78**	116,27**
N quadratic regression	1	1488,32**	54,04*
Error	45	79,74	11,92
C.V.	%	5.5	6.63
		Mean	
		--cm--	--mm--
W1 (1146.35 mm)		165.84	53.55
W2 (1335.66 mm)		166.00	53.14
W3 (1525.58 mm)		161.07	51.58
W4 (1717.58 mm)		156.66	50.05
N1 (249.3 kg ha^{-1})		160.62	50.63
N2 (307.2 kg ha^{-1})		156.22	51.29
N3 (365.0 kg ha^{-1})		158.93	51.03
N4 (422.9 kg ha^{-1})		173.82	55.37

ns, * and **; Non significant and significant at the 5 ($0.01< p< 0.05$) and 1% ($p < 0.01$) levels of probability, respectively

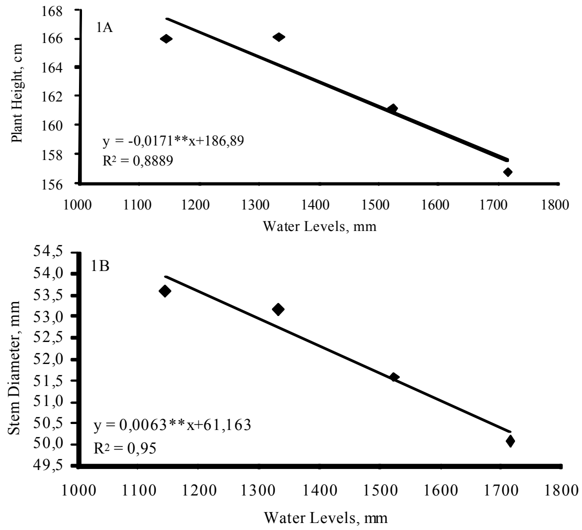

Fig. 1: Plants height (1A) and stem diameter (1B) according to the water levels

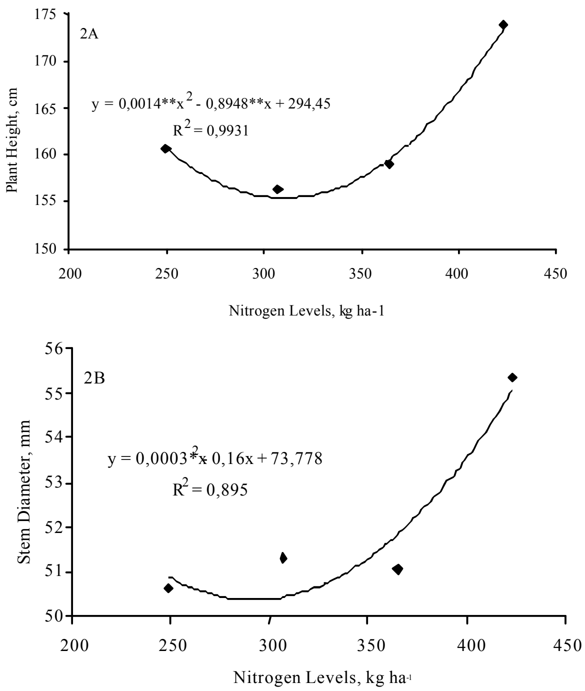

Fig. 2: Plants height (2A) and stem diameter (2B) according to the nitrogen levels

Plant height and stem diameter were significantly affected by water levels described by a linear equation (Figure 1A and 1B). Abdoellah and Notoradiningrat [6] also found a significant linear regression in the growth of stem diameter of the cacao tree to analyze the influence of Al / K + Ca + Mg in plant growth. However, the values of plant height as a function of the water levels ranging from 165.86 cm to 156.66 cm (Figure 1A), i.e., the increased quantity of irrigation water from 1146.35 mm to 1717.58 mm there was a reduction in plant height at 5.5%. In the same way, the increase in the irrigation water decreased the stem diameter (Figure 1B), i.e., the largest to the smallest amount of water decreased by 6.54 %. The cocoa plantation in irrigated semi-arid region is an innovation, for it has not yet precise information about the irrigation and management of production. Irrigation effect on cocoa yield depends mostly on the amount and distribution of rainfall. Therefore, the results of this study showed that irrigation, on average, had a significant effect but negative in plant height and stem diameter.

According to Purdy and Schmidt [7], the height of cocoa may vary from 5 to 8 m having a precipitation ranging from 1250 to 2800 mm per year. PROAMAZONIA [8] and Gramacho *et al*. [9] cites similar values of precipitation for maximum growth of the plant. Dias [10] and Abdul-Karimu *et al*. [11] found that the cocoa plant with two years of age, in the regions of the traditional cultivation of coca presents the average values of stem diameter and plant height of 32.7 mm and 150 cm, respectively.

According to literature, the cocoa is susceptible to stress caused by a lack of moisture in the soil [12], therefore, several authors concluded that irrigation in the semi-arid conditions of Brazil can be supplementary in character, provided optimal soil moisture levels are secured for the cocoa growth and development. However, the application of too much water in the soil affects cocoa development.

A polynomial relationship between nitrogen levels and plant height and stem diameter represents the contribution of N fertilizer on experimental growth trait (Figures 2A and 2B).

Nitrogen is the mineral nutrient required most by plants and Chepote *et al*. [13] agreed that this is the basis of nutrient fertilization of cocoa.

The results of this study showed that increasing nitrogen level increased plant height and stem diameter. Plant height ranged from 160.62 to 173.82 cm (Figure 2A) and stem diameter ranged from 50.63 to 55.37 cm (Figure 2B) with application of 249.31 and 422.9 kg ha^{-1} of nitrogen. There was an increase in plant height and stem diameter of 8.22 % and 9.36 %, respectively, in relation to the increase of 69.63 % of nitrogen, corroborating Souza Junior and Carmello [14]. These authors studying the effects of nitrogen fertilization on the production of cocoa seedlings observed that plant height and stem diameter significantly responded to a quadratic addition of nitrogen. Instead, Leite [15], studying the growth in

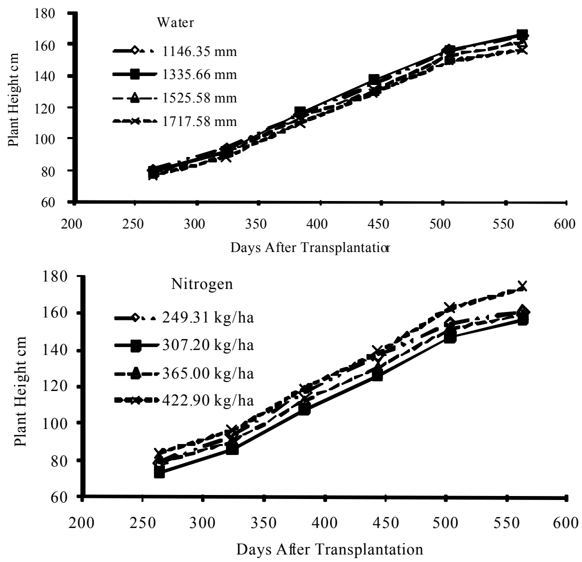

Fig. 3: Development of plant height in function of days after transplantation for water and nitrogen levels

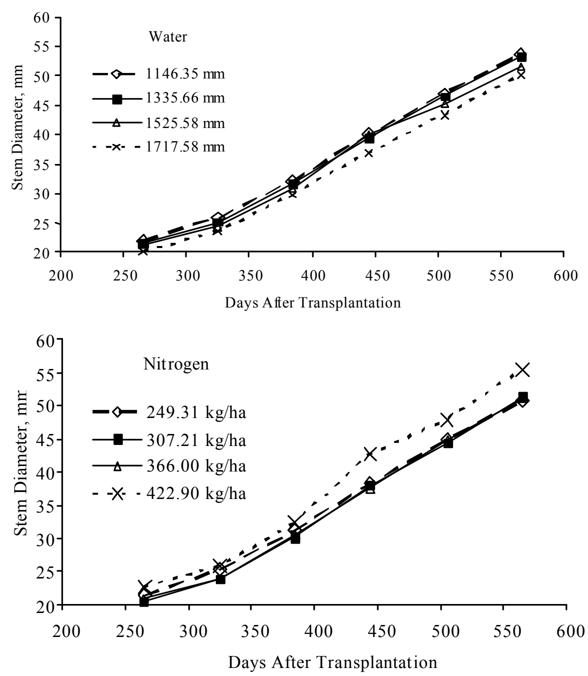

Fig. 4: Development of stem diameter in function of days after transplantation for water and nitrogen levels

average diameter and height of cocoa to 630 days submitted to irrigation found that both showed a linear increasing from the third month after planting, with the value of stem diameter and height of the plant 35.8 mm and 190.6 cm, respectively. This probably due to the requirement of nitrogen in certain environments, such as poor soils.

Chepote *et al*. [13], studying cocoa plant with 24 months of age and applying a fertilization of 240 kg ha^{-1} of the formula 30-90-30, found a diameter of 28.5 mm and a height of 181.7 cm. These values were the lowest and highest found in this study, respectively. Probably the smallest stem diameter is due to the increase of plant height.

The sigmoid profiles for the variable plant height as a function of days after transplantation (DAT) are shown in Fig. 3 corroborating [16], which found a similar profile.

From 265 to 565 DAT, the relative growth rate, on average, corresponded to about 14%. However, the growth rate of 325 to 385 DAT was 25% and the final period of 505 to 565 DAT was 5.58%, i.e., the growth rate was reduced to coincide with the early flowering and fruiting cocoa corroborating [15]. In general, in the period prior to flowering and fruiting, due to the large cell division and cell elongation, the plants grow quickly. After this period, the relative growth rate decreases because the plants require a higher accumulation of nutrients for the formation of flowers and consequently fruits.

The sigmoid profiles for the variable stem diameter as a function of days after transplantation (DAT) are shown in Figure 4.

From 265 to 565 DAT, the relative growth rate, on average, corresponded to about 15%. However, the growth rate of 325 to 445 DAT was 25%. The explanation for the relative growth rate, in relation to the stem diameter, is similar to the behavior of plant height. The highest growth rate occurs in the period of flowering and fruiting.

CONCLUSION

The biometric variables did not respond to treatment interaction.

The water level used in this study negatively affected the plant growt.

The nitrogen level used in this study positively influenced the plant growth.

The relative growth rate in relation to the plant height and stem diameter, on average, corresponded to about 14% and 15%, respectively.

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