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Agronomic performance and industrial yield of sugarcane under water-saving irrigation in cerrado soil

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The objective of this study was to evaluate the growth and gross yield of sugar and ethanol of first-year sugarcane with water-saving irrigation via hose-drawn traveller using a line of sprinklers. The experimental design was randomized blocks, analyzed in a split plot scheme with four replications. The factors evaluated in the plots consisted of five levels water-saving irrigation applied after planting (0, 30, 45, 60 and 75 mm). The subplots were represented by four evaluation periods (90, 170, 250 and 330 days after planting - DAP). The sugar yield and gross alcohol yield were evaluated punctually at the end of the cycle to 330 DAP. In the central lines of the subplots, the morphological characteristics relative to plant height, culm diameter, internodes length, number of sugarcane plants, number of leaves, leaf area, leaf length and leaf width, were evaluated. The gross yields of sugar and alcohol were calculated using the raw sugar value determined by technological analysis of the broth from a sample with 12 culms per experimental unit. Water-saving irrigation provides a positive effect on leaf length, leaf area, plant height and number of sugarcane plants. Water-saving irrigation of 75 mm definitely promotes an increase of 30% in gross sugar and alcohol yield.

Key words: *Saccharum officinarum* L., hose-drawn traveller, alcohol yield, water deficit.

INTRODUCTION

Currently, increases in productivity of sugarcane have been achieved combined with a higher quality and gross yield of sugar and alcohol from sugarcane raw material, in large part due to the use of irrigation (Simões et al., 2015).

The use of irrigation in the culture of sugarcane is essential for growth, development and increased crop productivity (Souza et al., 2015). Irrigation provides productivity expectation well above the minimum required for renewal of the area favoring much greater potential of longevity of sugarcane (Silva et al., 2014).

There is a strong correlation between levels irrigation

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and the variables that define the quality of the raw material of sugarcane, mainly the content of total recoverable sugars, the total soluble solids (Brix°), the pol, the purity and the pol percent cane (PCC) increased in proportion with the irrigation water levels (Farias et al., 2009).

In the sugarcane culture, different types of irrigation are used, including irrigation by mechanized spraying, self-propelled, center pivot and subsurface drip irrigation (Quintana, 2010).

In self-propelled irrigation systems currently available in the domestic market, there are two distinct forms of water spray for crops: Irrigation bar or hydraulic cylinder (Prado, 2008). The use of self-propelled spraying with an irrigation bar is highlighted. The irrigation bar can replace the cylinder spray in lower slope areas, with the advantage of a more uniform distribution of water and droplets with a smaller diameter (Marouelli et al., 2013).

From the different investments aiming to increase the yield of sugarcane, water-saving irrigation should be highlighted, as it may result in an increased production without expanding the agricultural area (Dalri et al., 2008; Dalri and Cruz, 2002, 2008; Quintana, 2010). Thus, water-saving irrigation of sugarcane is one of the technological alternatives that pursue the increase in production in areas previously marginalized by water deficit (Teixeira et al., 2012).

Throughout its growth, sugarcane needs good soil moisture conditions to express all its productive potential (Silva et al., 2008). Consequently, the yield and the production of sugar and ethanol from irrigated sugarcane depend on the amount of water applied and on the irrigation management (Dantas Neto et al., 2006). Therefore, the hypothesis is that water-saving irrigation promotes a greater efficiency in the culture of sugarcane.

The objective of this study was to evaluate the growth and gross yield of sugar and ethanol of first-year sugarcane with water-saving irrigation via hose-drawn traveller using a line of sprinklers.

MATERIALS AND METHODS

The experiment was carried out in July 2013, during the crop cycle of the cane plant of the variety SP83-5073 in the Boa Vista mill located in the municipality of Quirinópolis – GO, which has a soil classified as distroferric Red Latosol cerrado phase, according to Embrapa (2013). The climate is () classified according to Köppen and Geiger (1928) climate classification as tropical savanna with dry winter and rainy summer (Aw), with an annual rainfall between 1430 and 1650 mm, and drought period well defined between May and October.

The experimental design was randomized blocks, analyzed in a split plot scheme with four replications. The factors evaluated in the plots consisted of five levels water-saving irrigation (WSI) applied after planting (0, 30, 45, 60 and 75 mm). The subplots were represented by four evaluation periods (90, 170, 250 and 330 days after planting - DAP).

The experimental plots, in virtue of the proportion of the area wetted by the irrigation equipment, were 50.0 m long and 50.0 m wide (33 crop lines with 1.5 m spacing), with a total area of 2500.0 m^2. The subplots were composed of 5.0 m of 2 lines, located in the center of the plot.

The application process was made according to the management adopted in every area of commercial cultivation of the mill. During soil preparation, spread fertilization was carried out with incorporation by average grade for the layer 15 cm deep. The planting fertilizer used was according to the soil analysis (Table 1) in accordance with the recommendations of Sousa and Lobato (2004). The recommendation was 200 kg ha^{-1} of P_2O_5 in the form of simple superphosphate. As for the K and N sources, the concentrated stillage enriched with urea, totaling 180 kg ha^{-1} K_2O and 100 kg ha^{-1} nitrogen was used. For micronutrients, the dose of 100 kg ha^{-1} in the form of granulated Fritted Trace Elements (FTE), being 4 kg ha^{-1} zinc, 2 kg ha^{-1} boron and 2 kg ha^{-1} copper was used. The nitrogen coverage fertilization was performed 60 days after planting, where 120 kg ha^{-1} N (urea) were applied on both sides of the lines.

Water-saving irrigation was carried out by a self-propelled reel winder, model 140/GSV/350-4RII, coupled to an irrigation bar, model 48/54; MDPE tube with 140 mm outer diameter and length of 350 m; wall thickness of 10.3 mm, with lattices 24.5 m long on each side, totaling 49.0 m of adjustable structure, allowing the irrigation of sugarcane to 4.0 m high, with height compensation system through telescopic wheels installed along the lattices, the central car of the bar was operated with 3.0 m width. The emitters spaced at 1.85 m were used, totaling 26 emitters; the working pressure in the bomb was 10 Kgf cm^{-2} and in the reel was 5 Kgf cm^{-2}; the reel was operated with an average wind speed of 14.5 m s^{-1}. The application of the water volume was located between the lines of the varieties of sugarcane, but the wetness of the experimental area was total.

During the crop cycle, variety SP83-5073, weather data were collected daily, obtained by the meteorological station of the mill; being the reference evapotranspiration (ET_0) calculated according to the equation of Penman-Monteith-FAO/56 (Allen et al., 1998) (Table 2).

The number of leaves was determined by counting the fully expanded leaves with a minimum of 20% of green area, counted from the +1 leaf; the leaf area was determined by counting the number of green leaves (fully expanded leaf with minimum of 20% green area, counted from the +1 leaf) and the measurements on +3 leaves, being obtained the leaf length and width in the middle portion, according to the methodology described by Hermann and Câmara (1999):

$$\mathrm{LA} = 0.75 \times \mathrm{L} \times \mathrm{W} \times (\mathrm{NF} + 2) \quad (1)$$

Where, L = length of the +3 leaf; W = width of the +3 leaf; 0.75 = correction factor for the leaf area of the culture; NF = number of expanded leaves with at least 20% green area.

The number of sugarcane plants was determined by counting all plants in the parcel containing more than six fully expanded leaves. The sugar yield and gross alcohol yield were evaluated punctually at the end of the cycle to 330 DAP.

The gross yields of sugar and alcohol were calculated using the raw sugar value determined by technological analysis of the broth from a sample with 12 culms per experimental unit. Equations 2 and 3 according to the methodology described by Caldas (1998) were used:

$$YSu = \left(\frac{\mathrm{PCC} \times \mathrm{PC}}{100} \right) \quad (2)$$

Where: YSu = sugar yield in t ha^{-1}; PCC = percentage of raw sugar contained in the culms and determined in the laboratory; PC = culm production in t ha^{-1}.

Table 1. Physical, water and chemical characteristics of the soil in the experiment area.

Physical and water characteristics								
Layer	FC	PWP	Micro	Macro	TP	PD	Sd	PR
m	---------------%---------------				cm^3	-------g cm^{-3}-------		MPa
0.00-0.20	66.5	45.39	67.28	24.30	42.97	2.24	1.28	5.04
0.10-0.20	70.75	41.14	71.16	23.68	47.47	2.39	1.25	3.17
0.20-0.40	56.5	34.92	56.84	13.33	43.51	2.27	1.28	5.19

Granulometry				
	Clay	Silt	Sand	Textural class
	----------%----------			
0.00-0.20	27.50	6.90	65.60	Sandy
0.20-0.40	45.06	4.04	50.90	Sandy

Chemical characteristics											
Layer	pH	O.M	P	K	Ca	Mg	Al	H+Al	SB	CTC	V
m	in H_20	g kg^{-1}	mg dm^{-3}	-------------(mmol dm^{-3})-------------							(%)
0.00-0.20	6.1	60.4	8.2	3.0	21.3	15.7	0.0	55.7	45.8	95.5	45.9
0.20-0.40	6.3	45.5	2.1	4.2	15.4	14.2	0.0	45.5	35.7	75.2	40.5

FC, Field capacity; PWP, permanent wilting point; Micro, microporosity; Macro, macroporosity; TP, total porosity; PD, particle density; Sd, soil density; PR,penetration resistance; pH in distilled water. P and K, extractor Mehlich^{-1}. O.M, organic matter; T, Cation exchange capacity; SB, sum of bases; V, saturation per base.

Table 2. Monthly data of temperature (maximum, minimum and average), relative humidity, Rainfall and reference evapotranspiration.

Year	Month	Temperature (ºC)			RH	Rainfall	ET_0
		Maximum	Minimum	Average	%	mm	mm day^{-1}
2013	6	31.08	17.94	24.51	66.91	11	4.12
	7	29.11	13.94	21.53	60.90	0	3.99
	8	31.12	14.02	22.57	45.47	0	4.61
	9	33.41	18.60	26.00	58.44	13	5.05
	10	33.47	20.92	27.20	55.66	121	5.18
	11	32.20	21.07	26.64	79.25	105	4.88
	12	32.52	22.30	27.41	84.13	235.6	5.00
2014	1	29.4	20.4	23.21	77.99	206.0	5.3
	2	30.4	19.7	23.64	74.39	376.0	5.1
	3	28.7	19.14	23.11	82.54	315.0	4.8
	4	27.9	18.8	23.20	81.37	165	4.7
	5	26.7	18.4	21.37	70.49	40	4.5

In the central lines of the subplots, the morphological characteristics relative to plant height (PH); culm diameter (CD); internodes length (IL); number of sugarcane plants (NSP); number of leaves (NL); leaf area (LA); leaf length (LL) and leaf width (LW). The plant height was measured, with the aid of a tape measure, from the ground to the collar of the +1 leaf (+1 leaf is that in which the collar can be completely visualized), and expressed in cm; the culm diameter was determined with the aid of a caliper rule in the middle third of the plant, and expressed in mm.

$$Ay = ((PCC \times F) + ARL) \times Glf \times 10 \times PC \quad (3)$$

Where: Ay = gross alcohol yield in liters per ton of sugarcane in m^3 ha^{-1}; PCC = percentage of raw sugar contained in the culms and determined in the laboratory; F = stoichiometric conversion factor of glucose to a sucrose molecule plus another fructose molecule, equal to 1.052; ARL = percentage of free reducing sugars, whose values range from 0.7 to 0.85% (the distillery uses 0.7 for a high PCC); GLf = Gay Lussac factor of 0.6475; PC = culms production in t ha^{-1}.

The data were submitted to analysis of variance by F test at 5% probability, and in cases of significance, regression analysis was performed to the water-saving irrigation depths and the evaluation dates, using the statistical software SISVAR (Ferreira, 2011).

Table 3. Summary of ANOVA of number of leaves (NL), leaf length (LL), leaf width (LW) and leaf area (LA) of sugarcane in different times of evaluation with water-saving irrigation, Quirinópolis - GO, 2013/14.

SV	DF	MS[1]			
		NL	LL	LW	LA
WSI	4	0.354^{ns}	403.35*	0.035^{ns}	1,016,979.1**
Block	3	0.361^{ns}	342.36^{ns}	0.259^{ns}	91,181.3^{ns}
Residue (a)	12	0.442	112.13	0.219	78,320.7
DAP	3	16.76**	3,775.5**	5.287**	19,385,684.7**
WSI *DAP	12	0.529^{ns}	343.36*	0.243^{ns}	52,316.6^{ns}
Residue (b)	45	0.284	164.03	0.354	55,598.7
CV_1 (%)	-	10.24	7.52	11.02	7.39
CV_2 (%)	-	8.21	9.10	13.99	6.23

[1]Water-saving irrigation (WSI); Days after planting (DAP). Source of variation (SV), Degree of freedom (DF), mean square (MS) and coefficient of variation (CV). ** and * - significant at 1 and 5% probability, respectively; ^{ns} not significant by F test at 5% probability.

RESULTS AND DISCUSSION

In the summary of analysis of variance, it is observed that there was a significant interaction between the factors water-saving irrigation (WSI) and days after planting (DAP) for the variable leaf length, and there was a significant isolated effect for leaf area regarding WSI and DAP. Concerning the number of leaves and leaf width, there was a significance only for DAP (Table 3). Silva et al. (2015) also found that there were no significant effects of irrigation on number of leaves in the early stage of sugarcane, while for leaf area they found an effect of irrigation at all stages of sugarcane. Farias et al. (2007) also noted that there was a great influence of irrigation on leaf area index during the growing season.

The number of leaves of sugarcane plants at every 80 days had an increase of 9.1% (Figure 1A). The maximum leaf width sugarcane plants was observed at 225 days after planting (approximately five leaves), which is 21.7, 3.6, 0.72 and 12.9% higher than that observed at 90, 170, 250 and 330 DAP, respectively (Figure 1B). Silva et al. (2012) observed that the maximum area of individual leaves respond to the length of the leaves as soon as the width tends to stabilize.

Leaf length and leaf area adapted to linear growth in function of water-saving irrigation in sugarcane plants. According to the regression equation obtained, there was an increase of 4.9 and 3.2% for each 15 mm increase for leaf length (at 90 DAP) and leaf area of sugarcane by using water-saving irrigation (Figure 2A and C). The leaf area had an increase of 14.7% every 80 days in function of days after planting (Figure 2D).

The maximum leaf length found in water-saving irrigation (0, 30, 45 and 60 mm) was virtually equal. It was an average of approximately 1.54 m, which was observed at 276, 240, 222 and 229 days after planting, respectively. The maximum leaf length showed a difference of 39.7, 12.9, 0.78 and 3.3% (0 mm water-saving irrigation), 16.9, 3.7, 0.07 and 6.1% (30 mm water-saving irrigation), 16.9, 2.6, 0.74 and 11.2% (45 mm water-saving irrigation) and 17.9, 3.3, 0.39 and 9.3% (60 mm water-saving irrigation), compared to leaf length observed at 90, 170, 250 and 330 DAP, respectively (Figure 2B).

The water-saving irrigation in general, provided a major growth of leaves, mainly in length; when compared the treatments with and without water-saving irrigation it was verified accented differences in relation to the size of the leaves, resulting in lower leaf area which occurred preferentially in the initial stages. For better productivity, yields of sugar and alcohol to sugarcane needs a shoot well-developed, for this is very important that the differences in leaf size (initial stages) with respect to the maximum leaf growth will be smaller, the longest time possible, thus obtaining a major rate development of shoot.

The culture yield of sugarcane and the expansion of its leaf area are directly related because rapid growth of leaf area maximizes the interception of solar radiation and accumulation of biomass, increasing the yield of sugarcane (Inman-Bamber, 1994; Hanauer, 2011).

The water-saving irrigation in sugarcane plants was significant at 1% probability for plant height and number of sugarcane plants, as well as days after planting. There was a significant effect at 1% probability in relation to DAP for internode length and culm diameter (Table 4). Souza et al. (2015) found a significant effect of irrigation on plants' growth in height and on culm phytomass of sugarcane (variety SP 79-1011). Silva et al. (2009) found in this variety that the sugarcane growth parameters values, related to the number of culms, culm length, culm diameter, number of internodes and culm weight, responded significantly to irrigation.

The number of sugarcane plants and plant height with water-saving irrigation indicated a total increase of 19.8 and 18.7% compared to 0 and 75 mm water-saving irrigation (Figure 3A and C). Farias et al. (2008) verified lower values of plant height (1.53 m) and increase of only

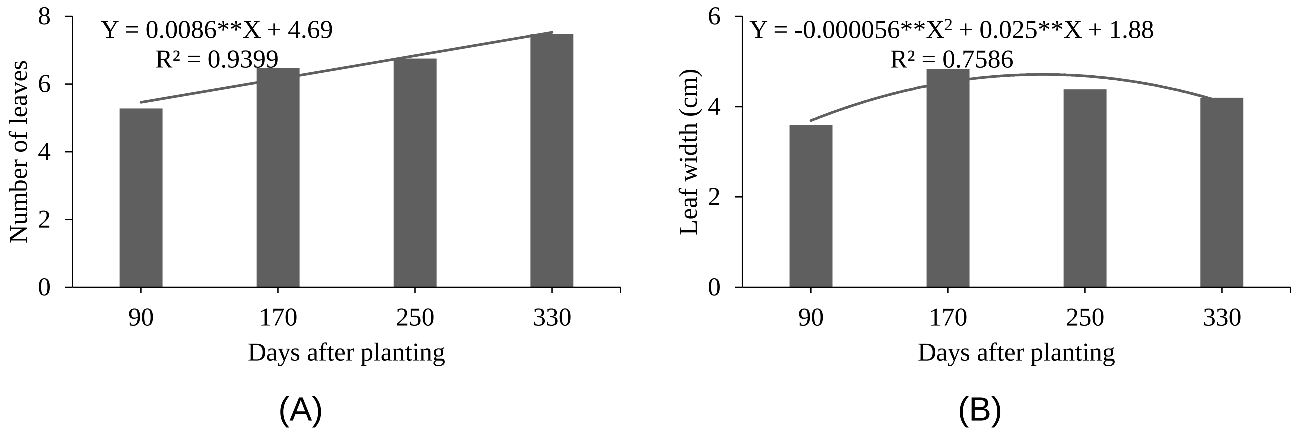

Figure 1. Number of leaves (A) and leaf width (B) of sugarcane in function of days after planting, Quirinópolis - GO, 2013/14. ** and *, significant at 1 and 5% probability, respectively by F test at 5% probability.

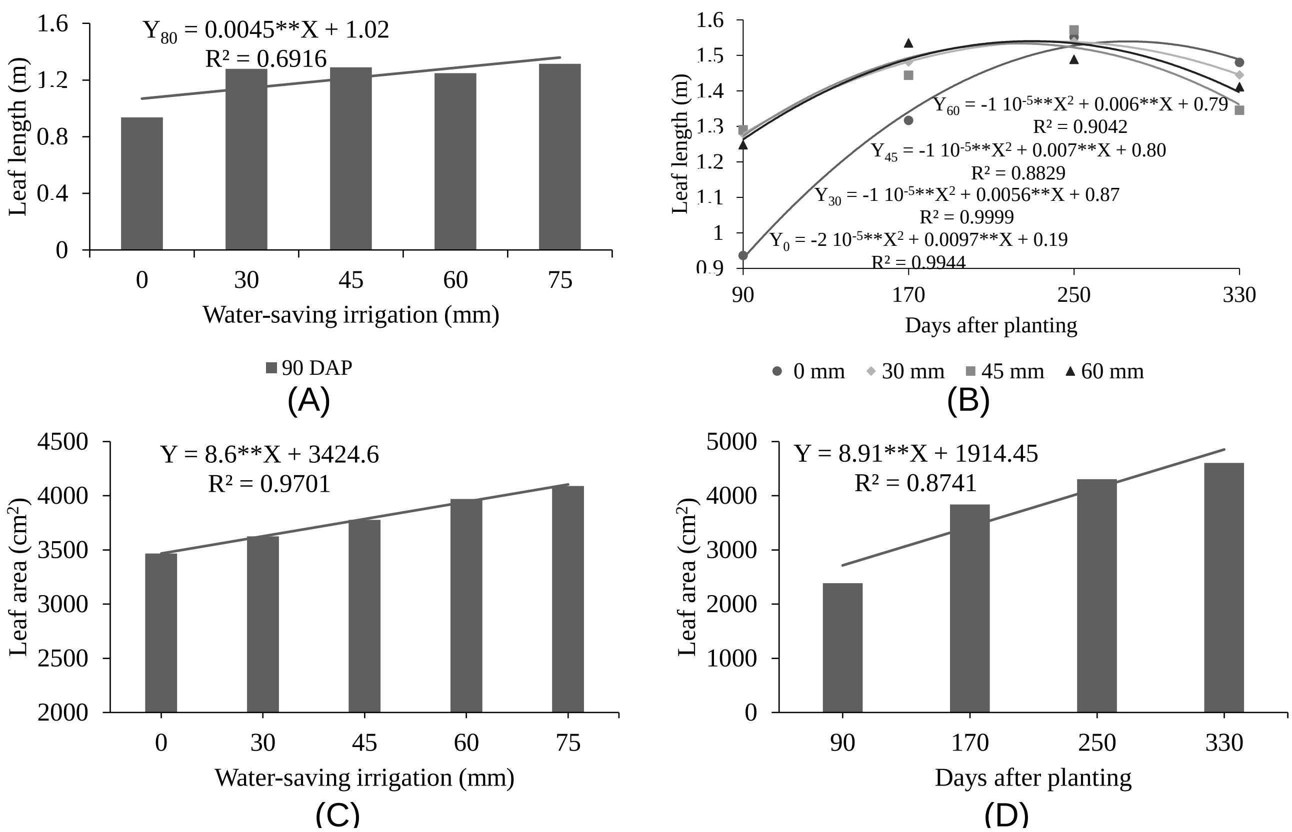

Figure 2. Leaf length and leaf area of sugarcane in function of water-saving irrigation (A and C) and of days after planting (B and D), Quirinópolis - GO, 2013/14. ** and *, significant at 1 and 5% probability, respectively by F test at 5% probability.

4 cm in plant height compared with cultivation rainfed. The number of plants and plant height in function of days after planting in sugarcane plants adapted to a linear model, indicating an increase of 11.4 and 24.2% every 80 days (Figure 3B and D).

The internode length increased by 6.4% every 80 days. Thus, a total increase of 19.3% between 90 and 330 days after planting can be seen (Figure 4A). Culm diameter in function of days after planting adapted to a quadratic model with R^2 = 98.8%. There was an increase in culm

Table 4. Summary of ANOVA of plant height (PHe), internode length (IL), culm diameter (CD) and number of sugarcane plants (NSP) in different times of evaluation with water-saving irrigation, Quirinópolis - GO, 2013/14.

SV	DF	MS[1]			
		PHe	IL	CD	NSP
WSI	4	3,422.46**	7.295^{ns}	6.43^{ns}	533.52**
Block	3	913.552*	0.612^{ns}	4.96^{ns}	310.00*
Residue (a)	12	195.2121	2.957	5.09	77.18
DAP	3	124,357.6**	21.29**	32.6**	4,026.52**
WSI *DAP	12	74.7027^{ns}	1.433^{ns}	3.78^{ns}	65.16^{ns}
Residue (b)	45	345.6377	3.511	4.59	100.01
CV_1 (%)	-	8.84	12.17	8.25	11.48
CV_2 (%)	-	11.76	13.26	7.83	13.07

[1]WSI, Water-saving irrigation; DAP, days after planting; SV, source of variation; DF, degree of freedom; MS, mean square; CV, coefficient of variation (). ** and * - significant at 1 and 5% probability, respectively; ^{ns} not significant by F test at 5% probability.

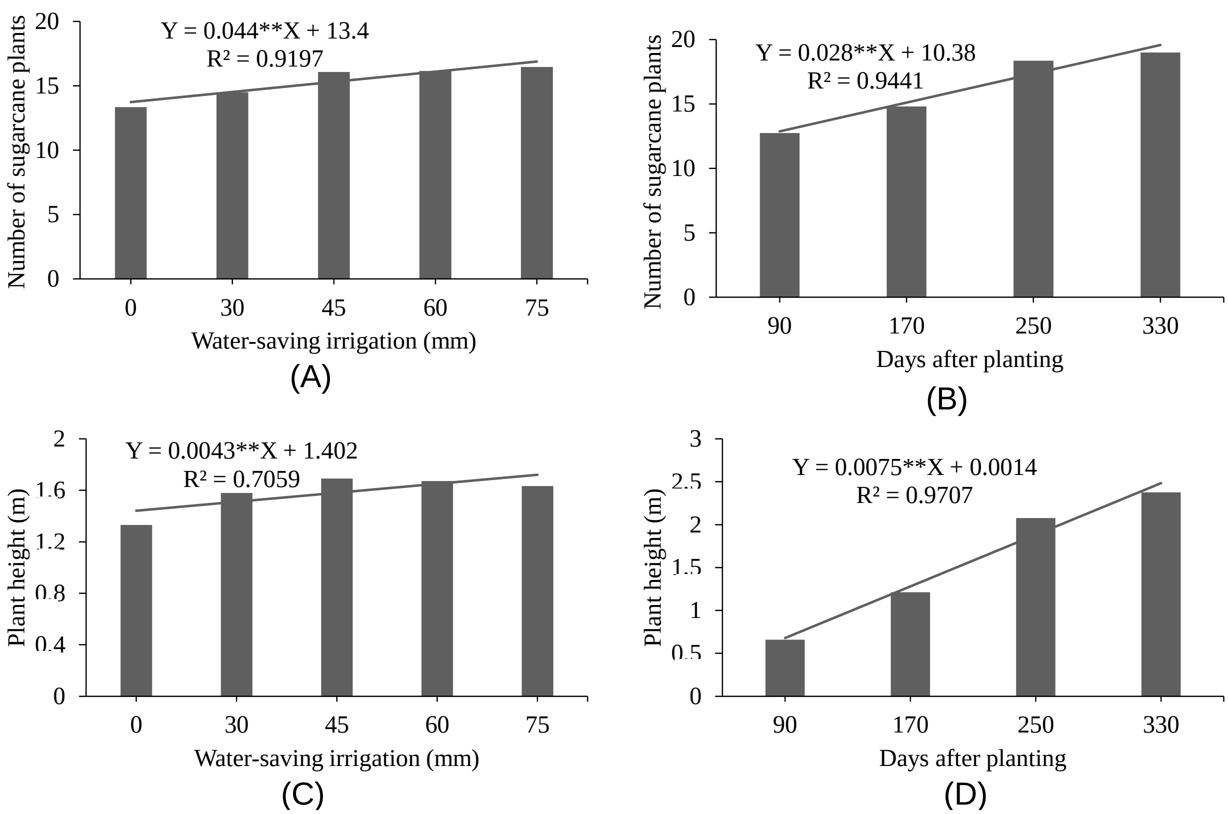

Figure 3. Number of sugarcane plants and plant height in function of water-saving irrigation (A and C) and of days after planting (B and D) of sugarcane, Quirinópolis - GO, 2013/14. ** and *, significant at 1 and 5% probability, respectively by F test at 5% probability.

diameter up to 256 DAP. In this period, a culm diameter of approximately 28.4 mm was reached. The maximum culm diameter verified at 256 DAP was 10.2, 2.7 and 2% larger than the culm diameter observed at 90, 170 and 330 DAP, respectively (Figure 4B). Silva (2007) and Oliveira et al. (2010) observed culm diameter of approximately 27 mm in the RB867515 and RB72454 varieties.

With water-saving irrigation, it was verified a major number of sugarcane plants. Water-saving irrigation did not influence the culm diameter; however, it should be highlight that the plant height has a major effect on

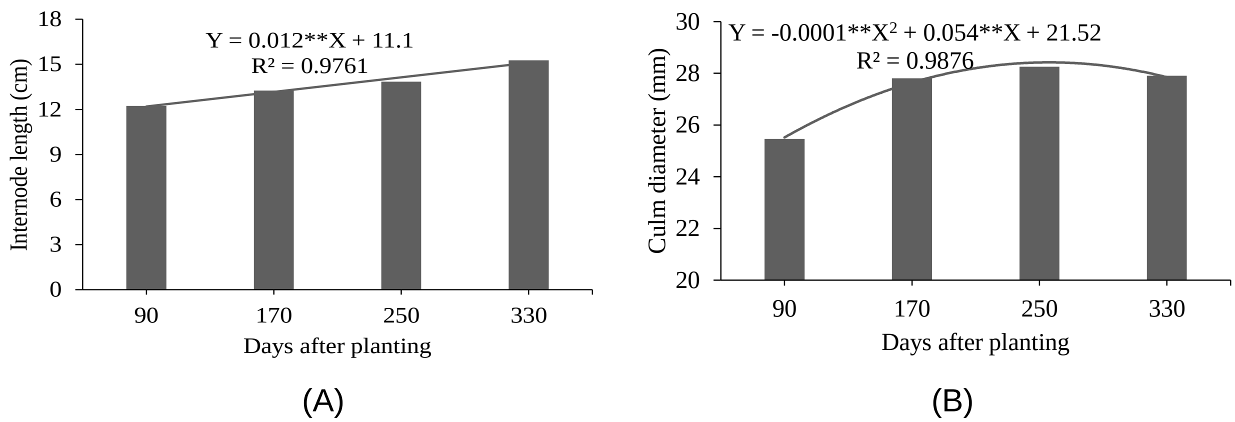

Figure 4. Internode length (A) and culm diameter (B) of sugarcane in function of days after planting, Quirinópolis - GO, 2013/14. ** and *, Significant at 1 and 5% probability, respectively by F test at 5% probability.

Table 5. Summary of ANOVA of gross alcohol (GAY) and sugar yield (GSY) of sugarcane plants with water-saving irrigation (WSI), Quirinópolis - GO, 2013/14.

SV	DF	MS[1]	
		GSY	GAY
WSI	4	19.59*	9.884*
Block	3	15.09[ns]	7.583[ns]
Residue	12	5.144	2.601
CV (%)	-	14.30	14.33

[1]SV Source of variation; DF, degree of freedom; MS, mean square; CV, coefficient of variation. ** and *, significant at 1 and 5% probability, respectively; [ns] not significant by F test at 5% probability.

productivity and yield of sugar and alcohol of sugarcane than the culm diameter, being responsible for increments quite considerable consequently verified that plants of sugarcane with water-saving irrigation demonstrated best performance in this variable.

The water-saving irrigation was significant at 5% probability for gross sugar yield and gross alcohol yield in sugarcane plants (Table 5). Carvalho et al. (2009) also observed a significant influence of irrigation on yield of sugar and alcohol.

The regression analysis showed a linear behavior for gross sugar and alcohol yield in function of water-saving irrigation (R^2 > 91%) for first-year sugarcane plants. Consequently, the maximum gross yield of sugar and alcohol was obtained with a 75 mm water-saving irrigation, indicating a difference of 30% in average yield in relation to absence of water-saving irrigation (Figure 5A and B).

Campos et al. (2014), evaluating varieties of sugarcane submitted to water-saving irrigation in the Cerrado of Goiás, concluded that water-saving irrigation of sugarcane in the Cerrado proved to be generally highly practicable, with a great response by most varieties, verified increases in average productivity of culms.

The gross sugar yield found in 60 and 75 mm water-saving irrigation was 17.2 and 18.3 t ha^{-1}. The gross sugar yield, according to the regression equation, obtained a 6.1% increase for each 15 mm increase of water-saving irrigation, thus demonstrating an increase in gross sugar yield of 0.07 t ha^{-1} for every 1 mm increase in water-saving irrigation in sugarcane plants (Figure 5A).

The gross alcohol yield observed in the 60 and 75 mm water-saving irrigation was 12.2 and 12.98 m^3 ha^{-1}, soon verifying an increase of 6%, due to the 15 mm increase, which shows an increase in gross alcohol yield of approximately 0.05 m^3 ha^{-1} for each 1 mm increase in water-saving irrigation in sugarcane plants (Figure 5B). Carvalho et al. (2009) noted that the increase in irrigation levels resulted in increases in the production of culm, the gross income of sugar and alcohol in gross income.

Conclusion

Water-saving irrigation provides a positive effect on leaf length, leaf area, plant height and number of sugarcane plants. Water-saving irrigation of 75 mm definitely promotes an increase of 30% in gross sugar and alcohol

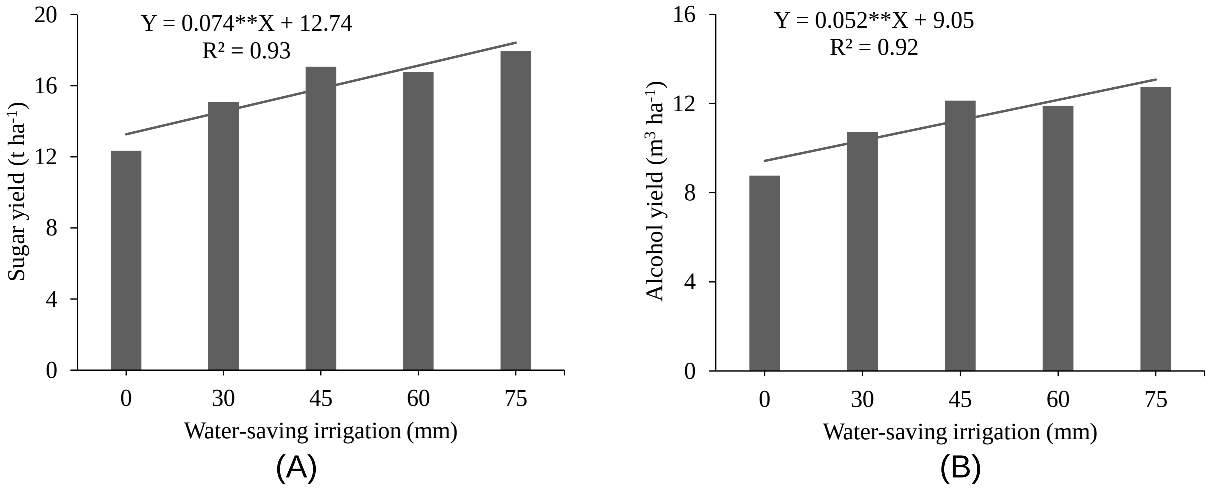

Figure 5. Yield of sugar (A) and alcohol (B) of sugarcane in function of water-saving irrigation, Quirinópolis - GO, 2013/14. ** and *, significant at 1 and 5% probability, respectively by F test at 5% probability.

yield. The results of this study demonstrate the viability of adopting the practice of water-saving irrigation. This suggests the need of more studies in the conditions edaphic and climatic of the region of southwest Goiano.

Conflict of Interests

The authors have not declared any conflict of interests.

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REFERENCES

Allen RG, Pereira LS, Raes D, Smith M (1998). Crop evapotranspiration,guidelines for computing crop water requirements. FAO Irrigation and drainage. Food and Agriculture Organization, Rome.

Caldas C (1998). Manual de análises selecionadas para indústrias sucroalcooleiras. Maceió: Sindicato da Indústria e do Álcool do Estado de Alagoas. 424p.

Campos PF, Alves Júnior J, Casaroli D, Fontoura PR, Evangelista AWP (2014). Variedades de cana-de-açúcar submetidas à irrigação suplementar no cerrado goiano. Eng. Agríc. Jabotic. 34(6):1139-1149.

Carvalho CM, Azevedo HM, Dantas Neto J, Farias CHA, Silva CTS, Gomes Filho RR (2009). Rendimento de açúcar e álcool da cana-de-açúcar submetida a diferentes níveis de irrigação. jan.-mar., Recife, PE, UFRPE. Rev. Bras. Ciênc. Agrár. 4(1):72-77.

Dalri AB, Cruz RL (2002). Efeito da freqüência de irrigação subsuperficial por gotejamento no desenvolvimento da cana-de-açúcar (*Saccharum* spp.). Irrig. Botucatu. 7(1):29-34.

Dalri AB, Cruz RL (2008). Produtividade da cana-de-açúcar fertirrigada com N e K via gotejamento subsuperficial. Engen. Agríc. Jaboticabal 28(3): 516-524.

Dalri AB, Cruz RL, Garcia JB, Duenhas LH (2008). Irrigação por gotejamento subsuperficial na produção e qualidade de cana-de-açúcar. Irrig. Botucatu. 13(1):1-11.

Dantas Neto J, Figueredo JLC, Farias CHA, Azevedo HM, Azevedo CAV (2006). Resposta da cana-de-açúcar, primeira soca, a níveis de irrigação e adubação de cobertura. Rev. Bras. Engen. Agríc. Ambient. 10(1):283-288.

Embrapa (2013). Sistema brasileiro de classificação de solos. Centro Nacional de Pesquisa de Solos. 3 ed. Brasília: Embrapa Produção de Informação; Rio de Janeiro: Embrapa Solos.

Farias CHA, Dantas Neto J, Fernandes PD, Gheiy HR (2007). Índice de área foliar em cana-de-açúcar sob diferentes níveis de irrigação e zinco na paraíba. Revista Caatinga -Mossoró Brasil 20(4):45-55.

Farias CHA, Fernandes PD, Azevedo HM, Dantas Neto J (2008). Índice de crescimento da cana-de-açúcar irrigada e de sequeiro no Estado da Paraíba. Rev. Bras. Engen. Agríc. Ambient. 12(4):356-362.

Farias CHA, Fernandes PD, Gheyi HR, Dantas Neto J (2009). Qualidade industrial de cana-de-açúcar sob irrigação e adubação com zinco, em Tabuleiro Costeiro paraibano. Rev. Bras. Engen. Agríc. Ambient. 13(4):419-428.

Ferreira DF (2011). Sisvar: a computer statistical analysis system. Ciênc. Agrotecnol. 35(6):1039-1042.

Hanauer JG (2011). Crescimento, desenvolvimento e produtividade de cana-de-açúcar em cultivo de cana-planta e cana-soca de um ano Santa Maria, RS. Universidade Federal de Santa Maria, Centro de Ciências Rurais, Santa Maria, RS, Brasil. 81 p.

Hermann ER, Câmara GMS (1999). Um método simples para estimar a área foliar de cana-de-açúcar. Revista STAB, Piracicaba 17(1):32-34.

Inman-Bamber NG (1994). Temperature and seasonal effects on canopy development and light interception of sugarcane. Field Crop Res. Amsterdan 36(1):41-51.

Köppen W, Geiger R (1928). Klimate der Erde. Gotha: Verlag Justus Perthes.

Marouelli WA, Braga MB, Guimarães TG (2013). Irrigação na cultura da batata. Ministério da agricultura, pecuária e abastecimento - MAPA. Embrapa, Brasília, DF Dezembro. 20 p.

Oliveira ECA, Oliveira RI, Andrade BMT, Freire FJ, Lira Júnior MA, Machado PR (2010). Crescimento e acúmulo de matéria seca em variedades de cana-de-açúcar cultivadas sob irrigação plena. Rev.

Bras. Eng. Agríc. Ambient. 14(9):951-960.
Prado G (2008). Modelagem da aplicação de água com canhões hidráulicos sob diferentes condições de vento. Tese. Universidade Federal de Lavras (UFLA), Lavras, MG. 121 p.
Quintana KA (2010). Irrigação e fertirrigação por gotejamento para cana-de-açúcar na presença e ausência de boro. Universidade Estadual Paulista "Júlio de Mesquita Filho" Câmpus de Jaboticabal. Tese. Jaboticabal,São Paulo,Brasil 70p.
Silva CTS, Azevedo HM, Azevedo CAV, Dantas Neto J, Carvalho CM, Gomes Filho RR (2009). Crescimento da cana-de-açúcar com e sem irrigação complementar sob diferentes níveis de adubação de cobertura nitrogenada e potássica. Revista Brasileira de Agricultura Irrigada Fortaleza CE INOVAGRI. 3(1):3-12.
Silva LC (2007). Análise de crescimento e acúmulo nutrientes de sete cultivares de cana-de-açúcar na Região de Coruripe. Maceió: UFAL. 127p.
Silva MA, Arantes MT, Rhein AFL, Gava GJC, Kolln OT (2014). Potencial produtivo da cana-de-açúcar sob irrigação por gotejamento em função de variedades e ciclos. Rev. Bras. Engen. Agríc. Ambient. 18(3):241-249.
Silva MA, Silva JAG, Enciso J, Sharma V, Jifon J (2008). Yield components as indicators of drought tolerance of sugarcane. Sci. Agric. 65(1):620-627.
Silva NF, Cunha FN, Teixeira MB, Soares FAL, Moura LC (2015). Crescimento vegetativo da cana-de-açúcar submetida a lâminas de irrigação e fertirrigação nitrogenada via gotejamento subsuperficial. Rev. Bras. Agric. Irrig. 9(2):79-90.
Silva TGF, Moura MSB, Zolnier S, Carmo JFA, Souza LSB (2012). Biometria da parte aérea da cana soca irrigada no Submédio do Vale do São Francisco. Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE. Rev. Ciênc. Agron. 43(3):500-509.
Simões WL, Calgaro M, Coelho DS, Souza MA, Lima JA (2015). Respostas de variáveis fisiológicas e tecnológicas da cana-de-açúcar a diferentes sistemas de irrigação. Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE. Rev. Ciênc. Agron. 46(1):11-20.
Sousa DMG, Lobato E (2004). Cerrado: Correção do solo e adubação. 2.ed. Brasília, Embrapa Informação Tecnológica 416p.
Souza JKC, Mesquita FO, Dantas Neto J, Silva MBR, Farias CHA, Lima YB (2015). Crescimento da cana-de-açúcar submetido a diferentes lâminas de irrigação e adubação com zinco. UFCG - Universidade Federal de Campina Grande. Revista agropecuária científica no semiárido ACSA. 11(1):114-119.
Teixeira EN, Mantovani EC, Vieira GHS, Coelho MB, Fernandes ALT (2012). Interceptação de água pelo dossel da cana-de-açúcar. Irrig. Botucatu. 17(1):71-84.