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Response of sugarcane varieties to deficit irrigation in Brazilian Savanna

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Abstract: Goias state is the second largest producer of sugarcane in Brazil. However, it still has low productivity, mainly due to lack of varieties adapted to the region and the typical water deficit. This study was carried out with the objective to evaluate the performance of sixteen sugarcane varieties submitted to deficit irrigation in the "Cerrado" (Brazilian Savanna). The experiment was carried out in Goianesia-GO (Brazil), in a distrophic Red - Yellow Latosol (Oxisol), from April 2012 to May 2013 in randomized block design with treatments formatted for sixteen sugarcane varieties: CTC2, CTC4, CTC9, CTC11, CTC15, CTC18, IAC87-3396, IAC91-1099, IACSP94-3046, IACSP94-2094, IACSP94-2101, IACSP95-5000, RB857515, RB92579, Rb966928 and SP860042 and four replications. The deficit irrigation was of 50% water requirement using a sprinkler system. Performance of varieties was evaluated through tillering and productivity. The results showed significant differences among the varieties. The best results were obtained for varieties IAC91-1099, CTC15, CTC11, SP86-0042, IAC87-3396, RB92579, CTC2, CTC4, RB867515 and IACSP94-2094, with yield varying from 165.28 to 136.53 t ha^{-1}, and these can be recommended for cultivation under "Cerrado" with deficit irrigation of 50% of ETc.

Keywords: *Saccharum officinarum*, water stress, sprinkler

Resposta de variedades de cana-de-açúcar à irrigação com déficit no Cerrado

Resumo: Goiás é o segundo estado com maior produção de cana-de-açúcar do Brasil. Entretanto, ainda apresenta uma baixa produtividade, devido principalmente à falta de variedades adaptadas a esta região e ao déficit hídrico típico. Assim, objetivou-se avaliar o desempenho de dezesseis variedades de cana-de-açúcar submetidas à irrigação suplementar no Cerrado. O experimento foi conduzido em Goianésia-GO, em um Latossolo Vermelho-Amarelo Distrófico, de textura argilosa de abril de 2012 a maio de 2013 (cultivo de 1ª soca). O delineamento foi em blocos casualizados, com 16 tratamentos (variedades): CTC2, CTC4, CTC9, CTC11, CTC15, CTC18, IAC87-3396, IAC91-1099, IACSP94-3046, IACSP94-2094, IACSP94-2101, IACSP95-5000, RB857515, RB92579, RB966928 e SP86-0042; e com quatro repetições. A irrigação com déficit, por aspersão, correspondeu a uma reposição de 50% da ETc. Os resultados, da colheita de primeira soca, apresentaram diferenças significativas em produtividade entre as variedades avaliadas. As variedades destaques foram IAC91-1099, CTC15, CTC11, SP86-0042, IAC87-3396, RB92579, CTC2, CTC4, RB867515 e IACSP94-2094, com produtividades variando de 165,28 a 136,53 t ha^{-1}. Assim, estas variedades podem ser recomendadas para o cultivo no Cerrado, com reposição de apenas 50% da ETc.

Palavras-chave: *Saccharum officinarum*, déficit hídrico, aspersão

Introduction

Sugarcane is considered as one of the most produced crops in the world, more than one billion tons are being harvested per year (Conab, 2013). It is responsible for 70% of sugar production in the world, more than sugar from the sugar beet crop. Sugarcane is also used as a power source. Therefore, the cultivation of sugarcane has been growing, especially in regions with tropical and subtropical climates. Given that drought reduces significantly the yield of sugarcane, the development of varieties adapted to this condition will be a key factor to increase production and expansion of new agricultural areas (Henry, 2010).

India was, 30 years ago, the biggest producer of sugarcane in the world. Currently, Brazil is the country with the largest production, responsible for 23% of sugarcane production in the world. For the 2012/2013 harvest, the estimated area for sugarcane sector is about 8.52 million hectares. Brazilian production is concentrated in the São Paulo State (the largest national producer), with a planted area of 4.4 million hectares (51.87%) and an average yield of 73.1 t ha^{-1}, followed by 0.726 million hectares in the Goiás State (8.52%) and 70.7 t ha^{-1} productivity, and Minas Gerais with 0.722 million hectares (8.47%) and yield of 74.2 t ha^{-1} (CONAB, 2013).

The Vale do São Patrício region is the major sugarcane producing in Goias State (Centre of Brazil), especially in the municipality of Goianésia. This municipality has the third largest planted area of 45,000 ha, behind only of Quirinopolis (58,500 ha) and Turvelândia (45,300 ha) (CANASAT, 2013). As sugarcane crop requires a cumulative rainfall above 1,000 mm yr^{-1} (Marin &Nassif, 2013), water availability in soil in this region, can be considered the main factor of production variability in each crop cycle. This is one factor that limits to increase productivity in the Vale do São Patrício region, although annual rainfall is about 1,540 mm in this region, it is concentrated in the months of October to March, and there is a strong water deficit from April to September, different from the São Paulo region.

For maximum yields in sugarcane stalks, soil water content and air temperature must be appropriate in all vegetative stages of plant. The growth and development of sugarcane are directly proportional to water transpired, because there is a linear relationship between the evapotranspiration of sugarcane and sugar productivity (Leal, 2012). Damage caused by water deficit on leaf expansion and crop productivity depends on the intensity and duration of rain in this period, the stage of crop development and the variety cultivated (Machado et al., 2009).

Irrigation is a beneficial agricultural practice, because it provides adequate soil water content during the crop cycle, if it is conducted with technical and suitable system. Increases in the sugar cane productivity, when irrigated fully (without water stress) are easily found in the literature (Farias et al., 2008; Dalri & Cross, 2008). However, this irrigation management recommendation is not common to sugarcane, because in Brazil there are extensive sugarcane areas, requiring large investments. The use of resistant or tolerant water stress varieties will be another alternative to minimize reduction in productivity associated with drought.

The sugarcane is the crop with the largest irrigated area in Brazil (1.7 million hectares) of the total of 5.4 million hectares, and with great potential for expansion (ANA, 2012). So, the objective of this study was to evaluate the performance of varieties of sugarcane irrigated with déficit irrigation in the 'Cerrado' (Brazilian Savanna, Vale do São Patrício, Goiás state).

Material and Methods

The study was carried out in Goianesia-GO, Brazil (15° 12' S; 48º 59' W; and 580 m elevation). According to classification of Köppen, the climate of the region is an Aw, tropical savanna (winter dry and rainy summer). The annual mean rainfall is 1,540 mm, with well-defined periods of drought between May and October (Figure 1). Plants were cultivated in Oxisol Hapludox, corresponding to a Red Yellow Latosol distrophic

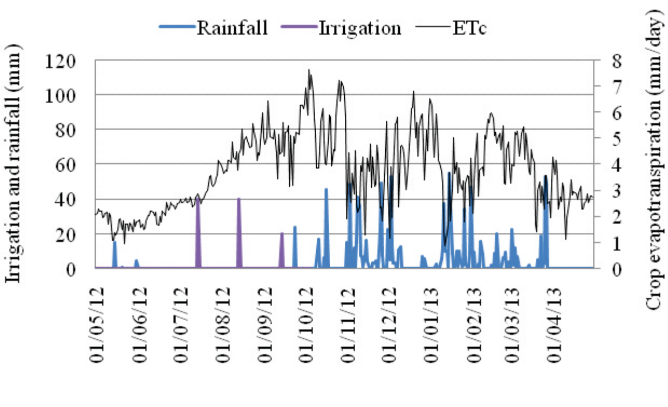

Figure 1. Water balance in sugarcane crop (2nd. harvest), with monthly rainfall, daily crop evapotranspiration and irrigation at Goianésia-GO, Brazil (May 2012 to April 2013).

(EMBRAPA, 2006).

The area was prepared six months before the installation of the experiment. Soil chemical analysis was made in the following layers: 0-0.25 and 0.25-0.50 m; and soil physical analysis for: 0-0.30 and 0.30-0.60 m. Dolomitic limestone was used in order to reach base saturation of 50%. Further, agricultural gypsum (2,250 kg ha^{-1}) and P_2O_5 (100 kg ha^{-1}) were also applied.

Soil tillage was based on a heavy harrow, for the incorporation of dolomitic limestone. After that, an intermediate ploughing was performed for incorporation of phosphate and breaking of clods and then, preparation of topsoil was done with leveling disk harrow before planting.

At the bottom of the furrow, 0.35 m deep, 115 kg P_2O_5 ha^{-1} (triple super phosphate) was distributed. Sugarcane planting was done manually (29/04/2011), where stalks with three vegetative buds were used. The Phipronil insecticide 800 WG was applied (0.050 kg ha^{-1} PC) for termites prevention. Water depth of 40 mm was applied to stimulate sugarcane growth.

The experiment was conducted in randomized block design. The treatments consisted of 16 varieties of sugarcane: CTC2, CTC4, CTC9, CTC11, CTC15, CTC18, IAC87-3396, IAC91-1099, IACSP94-3046, IACSP94-2094, IACSP94-2101, IACSP95-5000, RB857515, RB92579, RB966928 and SP86-0042; with four replications. The experimental plots were formed by four rows, 1.5 m apart, and 15 m of length, totalizing 90 m².

The crop coefficient (Kc) was used for irrigation management, the following values were used for each growth stage, measured in days after the planting (DAP): 0.5 (germination, 30 DAP); 0.8 (development, 140 DAP); 1.25 (full development, 145 DAP) and 0.8 (maturity, 181 DAP) (Dalri & Cross, 2008). Reference evapotranspiration (ETo) was estimated by Penman-Monteith Model (FAO 56). The weather data were obtained through automatic station of the National Meteorological Institute of Brazil (INMET), which is located in the Jalles Machado Mill, near the experimental area (Figure 1). Irrigation levels were estimated through water balance (irrigation, effective rainfall and crop evapotranspiration - ETc), in each growth stage, considering an application efficiency of 83%.

During the crop cycle a necessity of 100 mm of irrigation was estimated to complement the rain (1,212.50 mm), according to (50% of ETc) crop water requirement (Figure 1). Irrigation equipment self-propelled reel type Turbomaq (140/GSV/350-4RII model) was used, which has an application range of 54 m. DLD type sprinkler spray nozzle was used with Senninger®#21 (flow 109,90 L h^{-1} and a service pressure of 36 m water column) and Senninger pressure regulator 20 psi.

Agricultural management done during the sugarcane cycle consisted of: planting systematization (leveling soil); application of fertilizer after the planting (05-00-12 B + 0.3% Zn + 0.3% in 1,200 kg ha^{-1}); weed control.

The experimental analysis corresponded at the second cycle of sugarcane. The plants were harvested with 336 days after 1st harvest (29/05/2012), using the mechanical harvest machine.

The variables evaluated were the following: i) number of tillers: counted the number of tillers per meter in the two central rows of each plot; ii) yield, determined in ton per hectare; and iii) technological variables: ATR (Total sugar per ton), POL (% sugar), TPH (Total sugar per hectare), Purity and Fiber.

Data were submitted to variance analysis and the means were compared by Tukey test at 0.05 probability level.

Results and Discussion

For the variable number of tillers per meter of crop row, analysis of variance showed significant differences among the varieties analysed. Of the 16 varieties evaluated, 3 varieties were with higher number of tillers per meter: IACSP94-2094, CTC11 and SP86-0042 with 18.11, 16.32 and 15.65 tillers per meter, respectively. While the lower values were obtained in varieties RB867515, RB966928, RB92579 and CTC18 with 11.38, 11.97, 12.08 and 12.21 tillers per meter, respectively (Table 1).

Bennet et al. (2011) reported that tillering is linked to genetic potential of each variety, a fundamental factor in the production of sugarcane as height and stalk diameter. The effect of drought on tillering is fairly controversial, being connected directly to the stage of crop development (Machado et al., 2009). However, reductions in tillering rates up to 20% are reported for the variety RB867515 (Bennet et al., 2011), 68% for IACSP94-2101 and CTC2 (12.16 tillers m^{-1}) varieties and 10% for RB867515 (12 tillers m^{-1}) (Santin et al. (2009), corroborating with the results of this study, where groups of varieties have different tillering, probably due to genetic deficit tolerance of each variety.

The good tillering promotes the maintenance of the final plant population over the harvests. Moreover, varieties with low rate of tillering need an extra weed control between the rows. For productivity, analysis of variance also showed significant differences among varieties. Of the 16 varieties evaluated, 10 show higher results, and their mean productivity did not differ significantly among themselves by Tukey test at 0.05 level of probability. The varieties were IAC91-1099, CTC15, CTC11, SP86-0042, IAC87-3396, RB92579, CTC2, CTC4, RB867515 and IACSP94-2094, with yields ranging from 165.28 to 136.53 t ha^{-1} of sugarcane. The worst results were obtained for varieties IACSP94-2101 and CTC18 with 117.92 and 115.00 t ha^{-1}, respectively (Table 1).

The highest mean productivity of varieties is associated with better performance in number of tillers per meter, except for RB867515 and RB92579 varieties which showed high productivity with low average tillering. This probably should have compensated the low tillering with good growth in diameter and length of stems.

When the productivity of the second harvest (Table 1) was compared with first harvest, there was a small change of positions between best varieties group and an intermediate group. The IAC91-1099 variety, for example, remained with productivity above 160 t ha^{-1} (Table 1), and CTC15 that was one of the best productivity in the first harvest, showed intermediate productivity in second harvest, with productivity above 140 t ha^{-1} integrating, the varieties group with, IAC87 - 3396, RB92579 and SP86 - 0042 (yield > 140 t ha^{-1}). The CTC11 variety that had not featured in productivity in the first harvest (Campos et al., 2013) presented at the second harvest, as one of the varieties with best productivity (yield > 140 t ha^{-1}, Table 1). The CTC9 and RB867515 varieties in the second harvest, show productions between 120 and 140 t ha^{-1}, integrating the group of varieties CTC4, IACSP94-2094, IACSP93-3046, RB966928 and IACSP95-5000. Even so, these yields (120 and 140 t ha^{-1}) can be considered good for the region (Conab, 2013).

Variety CTC18 repeated in the second harvest, low tillering and low productivity (Table 1), the same was found in the first harvest (Campos et al., 2013). It shows little adaptation of this variety in this region, even with déficit irrigation. Similar results were observed for IACSP962042 variety (Machado et al., 2009), and hybrid HV-241 elephant grass (*Pennisetum purpureum* Schum) (Barreto et al., 2001) in relation to water deficit.

The CTC18 presented the variety of lower productivity (Table 1). The water deficit negatively impacted tillering and biomass accumulation of this variety. The stress due to water deficiency is regarded as the biggest factor restricting the production and stability of crop productivity in many regions of the world (Heinemann, 2010). The déficit irrigation for not to attend to evapotranspirometric phenological demand, affects the productivity of various crops.

Tolerance to drought stress is related to morpholo-gical, physiological, biochemical and metabolic factors

Table 1. Yield, tillering (n° of tillers) and technological analysis of sugarcane in second harvest

Treatment	N° tillers (m^{-1})	Yield (t ha^{-1})	ATR (kg)	POL (%)	TPH t ha^{-1}	Purity (%)	Fiber (%)
CTC2	13.54bcd	142.36 abcde	167.19ab	16.83 ab	23.96ab	87.54 ab	10.58de
CTC4	13.64 bcd	137.36 abcde	167.71 ab	16.90 ab	23.20ab	88.02 ab	10.18e
CTC9	13.20 cd	126.67bcde	172.63ab	17.44 ab	22.08ab	88.87 a	10.58de
CTC11	16.32ab	153.89 abc	171.20 ab	17.26 ab	26.55ab	87.61 ab	11.08cde
CTC15	13.10 cd	154.86 ab	169.49ab	17.13 ab	26.53ab	89.59 a	10.58de
CTC18	12.21 d	115.00 e	164.74ab	16.43 ab	18.88ab	82.15b	10.38e
IAC87-3396	13.59 bcd	152.50 abc	160.31b	16.08 b	24.51b	85.96 ab	10.98cde
IAC91-1099	15.12bc	165.28 a	163.01 ab	16.39 ab	27.07ab	86.68 ab	12.48abcd
IACSP93-3096	13.99 bcd	130.28 bcde	161.48ab	16.23 ab	21.14ab	86.22 ab	13.44 a
IACSP94-2094	18.11a	136.53 abcde	164.80ab	16.67 ab	22.76ab	89.86 a	13.38 a
IACSP94-2101	13.84bcd	117.92 e	162.69ab	16.45 ab	19.40ab	89.84 a	13.10 ab
IACSP95-5000	12.97 cd	122.22 de	172.99ab	17.53 ab	21.41ab	90.27 a	12.58 abc
RB867515	11.38 d	137.78 abcde	164.83ab	16.63 ab	22.90ab	88.41 ab	12.08 abcde
RB92579	12.08 d	150.83 abcd	171.98ab	17.40 ab	26.24ab	89.73 a	11.88 abcde
RB966928	11.97 d	125.55 cde	171.46ab	17.34 ab	21.77ab	89.61 a	11.28bcde
SP86-0042	15.65abc	152.64 abc	178.39 a	18.07 a	27.57a	89.93 a	11.18 bcde
CV %	7.91	83.16	4.09	4.43	4,41	2.92	6.61

[1]Means followed by the same letter in the column do not differ by Tukey test at 0.05 probability level

(Larcher, 2000). Thicker cuticles prevent water loss by transpiration (Castro et al., 2009). Increase in the synthesis of proline, superoxide dismutase, catalase, peroxidase and abscisic acid act as messengers in the process of perception and action responses in the process of growth in situations of water stress and other environmental stresses (Sharma et al., 2011). Guimarães et al. (2008) found that the variety RB72454, under water stress, had higher levels of proline associated with higher dry matter accumulation and growth of stems. Oliveira et al. (2011) found that the RB763710, IACSP813250, RB92579, RB72454, RB867515, IACSP801816 and RB85-5453 varieties had higher yields in irrigated systems.

The varieties showed significant differences for all technological variables: ATR, POL, Purity and Fiber (Table 1). The highest values of ATR and POL were observed in variety SP86 - 0042 (178.39 kg and 18.07%) and lowest in the variety IAC87 - 3396 (160.31 kg and 16.08%), which differed significantly (P>0.05), and other varieties showed intermediate values. The values found in this work of ATR ranged from 160.31 to 178.39 kg among varieties. These values were higher (25% more) than the values found in the first harvest in this same area in the previous year, from 106.14 to 146.12 kg (Campos et al., 2013), offsetting the mean reduction of 6% in sugarcane productivity. The IAC87 - 3396 variety despite having one of the highest yields of sugarcane, showed low value of ATR. This probably was due to the high moisture content. The opposite occurred with CTC9, IACSP94-2101 and RB966928 varieties, which showed low yields of sugarcane and high values of ATR. This was probably due to the greater purity of the sugarcane brought from the field to industry.

The general mean fiber was 11.61%, similar to that obtained by Maschio (2011) of 11.3% for varieties with déficit irrigation of 70% of ETc. The IACSP93-3096, IACSP94-2094, IACSP94-2101, IACSP95-5000, IAC91-1099, RB867515 and RB92579 varieties were, respectively, 13.44, 13.38, 13.10, 12.58, 12.48, 12.08 and 11.88%, superior fiber to values found by Maschio (2011), respectively. This fact can be explained by the more pronounced water déficit in the study conducted with déficit irrigation of 50% of ETc. These fiber levels are still low for support of sugarcane of high yields, which should have on an average of 12.5%, as it appears in the field plants due to the large amount of green mass can fall down, causing losses during the process of mechanical harvesting (Marques et al., 2008).

For the POL variable, the values ranged from 16.08 and 18.07%, among the 16 varieties evaluated, in which significant differences were found between the SP86-0042 that had the largest numerical value, and variety IAC87-3396, which had the lowest value. All other varieties showed intermediate values. The variety CTC18 showed the worst result for the variable purity (Table 1).

The larger (27.57 t ha^{-1}) and lower (18,88 t ha^{-1}) means for TPH were observed in varieties SP86-0042 and CTC18, respectively (Table 2). High levels of TPH (greater than 20 t ha^{-1}) show a major economic viability in industrial processing (Landell & Bressiani, 2008). Although some varieties present high values of TPH, these were limited to the harvest season, and could have reached higher values because these are varieties with medium or medium-late maturity.

Conclusions

With deficit irrigation (50% ETc) for production of second year (2^{nd} harvest) in the 'Cerrado' (Brazilian Savanna, Vale do São Patrício in Goiás State), varieties of sugarcane with higher number of tillers per meter of crop row were IACSP94-2094, CTC11 and SP86-0042, and varieties with more productive in stalk weight were CTC2, CTC4, CTC11, CTC15, IAC91-1099, IACSP94-2094, RB867515, RB92579 and SP86-0042, while for the sugar production all showed similar results, especially the variety SP86-0042.

The mean content of fiber was considered low to support the sugarcane of high yields. It was observed in the field, that large amount of green mass caused lodging of plants difficulting mechanical harvesting.

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