Australian Journal of Crop Science AJCS

AJCS 11(06):711-715 (2017) ISSN:1835-2707
doi: 10.21475/ajcs.17.11.06.p437

AUSTRALIAN JOURNAL OF CROP SCIENCE | SUBMITTED: 07-DECEMBER 2016 | REVISED: 09-MARCH-2017 | ACCEPTED: 12-APRIL-2017

Drought tolerance of the sugar cane varieties during the initial development

Janaína de Miranda Silverio[1], Tonny José Araújo da Silva[2], Edna Maria Bonfim-Silva[2*], Antonio Marcos Iaia[2], Thiago Franco Duarte[2], Regina Célia Matos Pires[3]

[1]Federal University of Mato Grosso, Cuiabá, Mato Grosso, Brazil
[2]Department of Agricultural Engineering, Federal University of Mato Grosso, Rondonópolis, Mato Grosso, Brazil
[3]Agronomic Institute (IAC), Campinas, São Paulo, Brazil

Abstract

This study was conducted to identify the water-deficit tolerant sugarcane varieties (*Saccharum officinarum* L.) by cultivating them under mild-to-severe water deficit conditions. The experiments were performed in a greenhouse, employing the randomized block design in a 7 x 5 factorial scheme corresponding to seven sugarcane varieties (RB867515, RB92579, RB855536, RB72454, RB073036, RB073028, and RB073040) and five types of soil water stress (12, 24, 36, 48, and 60 kPa). Water stress was maintained throughout the experiment period. The experimental units included 10 dm^3 pots, with three replications, accounting for 105 pots in total. Height, diameter, and stalk dry mass were the variables analyzed and evaluations were done 90 days post transplantation. Finally, the RB073028, RB867515, and RB72454 varieties were identified as being tolerant to severe water stress. The varieties of RB073036 and RB073040 could tolerate moderate water deficit and the RB92579 and RB855536 varieties showed water deficit sensitivity.

Keywords: *Saccharum officinarum* L.; biometric; soil moisture.
Abbreviations: DAT_Days after Transplantation.

Introduction

In 2015/2016 the sugarcane production (*Saccharum officinarum* L.) in Brazil touched 655,158.9 million tons, 21.7% of which came from the Central–West region alone (CONAB, 2015). The raw material from the sugarcane is used to manufacture sugar and ethanol as an energy source.
Central–West Brazil offers the largest percentage of land favorable for extensive sugarcane cultivation, making 45% of the estimated total land area available (Marin & Nassif, 2013). The Cerrado biome is predominant in this region, with irregular rainfall, limiting plant growth in a certain period of the year. This region shows great potential for increasing the sugar and ethanol sector, but suitable methods are required, particularly with respect to drought. Sugarcane is composed of about 30% dry mass and 70% water (Inman-Bamber et al., 2005). Adapted to the conditions of high luminosity, high temperatures, and relative tolerance to drought, it still needs large amounts of water, mainly in the phenological stage of sprouting and tillering (Inman-Bamber, 2004; Inman-Bamber & Smith, 2005; Batista, 2013). The water deficit risk for sugarcane cultivation varies with each soil type in terms of its water retention capacity. In this case, sandy soils are those that present a greater susceptibility, independent of the place and planting date (Vianna & Sentelhas, 2014). Acric and Alic soils and soils with low water retention are typically observed in the Cerrado biome, which limits crop growth, resulting in increased susceptibility to drought. Therefore, water-deficit tolerant varieties, including those plants with higher dry mass production (Pincelli & Silva, 2012) are better alternatives. Also the ones with greater stalk diameter, under conditions of poor water availability (Sousa et al., 2015), are suitable to minimize the unfavorable effects of the water deficit. This study aims to identify the water deficit–tolerant sugarcane varieties best suited for cultivation in the Cerrado of Mato Grosso, by assessing their biometric characteristics in response to cultivation environments having a water deficit.

Results and Discussion

Biometric responses of sugarcane

The stalk length was significant at 12, 36, and 48 kPa of soil water tension (Figure 3). Figure 3A shows that in the treatment having 12 kPa tension, a higher number of stem length variations were observed in the RB073040, RB867515, RB72454, RB855536 and RB073028 varieties with 45.83 cm, 45.50 cm, 44.66 cm, 42.50 cm, and 40, 66 cm, respectively; this was ascribed to the greater availability of soil water at 90 DAT. However, for the 36 kPa tension, only the RB073028 clone was remarkable compared with the other varieties, with a stalk length of 45.50 cm. In contrast, the RB073036 clone presented the shortest stem length, with 33.33 cm (Figure 3B). At 48 kPa tension, the RB073028 clone revealed a stem length of 38.33 cm, a significant difference when compared with the RB855536 control variety, which showed a stem length of 29.83 cm (Figure 3C). However, for the 60 kPa tension a significant difference in stem length was noted among the varieties (Figure 3D).
According to the report of Ecco et al., (2014), the RB867515 variety showed a stem height increase of 13.7 cm under

Table 1. Chemical and granulometric characterization of the Oxisol sample collected in the 0–0.20 m layer

pH	P	K	Ca	Mg	H	Al	SB	CTC	V	M.O	Sand	Silt	Clay
$CaCl_2$	mg dm^{-3}		------------cmol$_c$ dm^{-3}---------------						%	g dm^{-3}	----------g kg^{-1}--------		
4,0	1.4	23	0.4	0,2	5,4	0.8	0,7	6,8	10,3	27,1	423	133	444

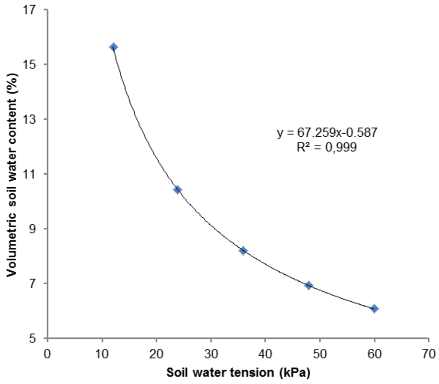

Fig 1. The ML3 sensor calibration curve of (y-axis), using the tensiometers (x-axis), in the sandy loam textured dystrophic Oxisol.

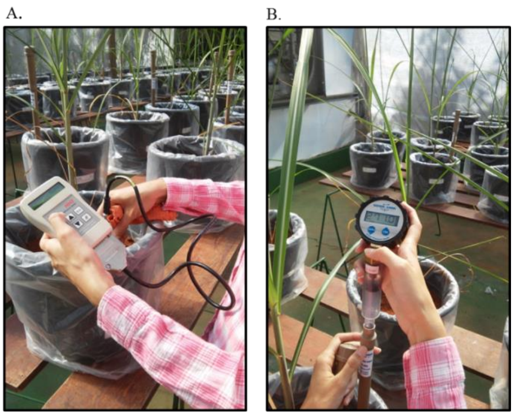

Fig 2. Demonstration of taking instrumental measurements during the experiments. A) Insertion of the ML3 sensor with four rods without soil to obtain the volumetric moisture. B) Reading without tensiometer to obtain the soil water tension without soil.

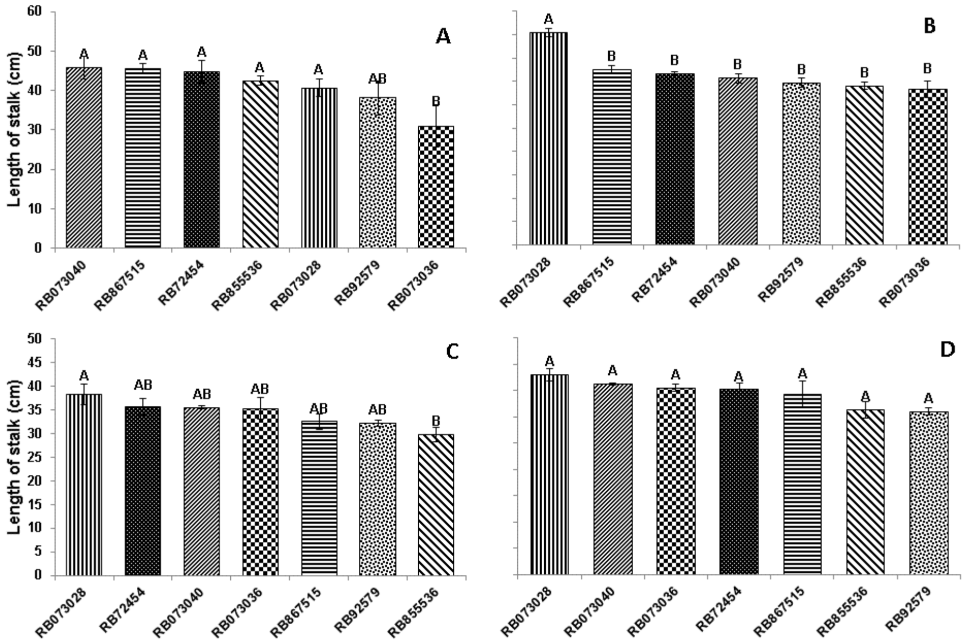

Fig 3. Length of stalks of varieties studied 90 DAT, in soil water stresses: A) 12 kPa; B) 36 kPa; C) 48 kPa, and D) 60 kPa; Columns with the same letters do not differ from each other by the Tukey test, at 5% probability. Coefficient of variation = 8.54%. Bars represent standard error of the mean.

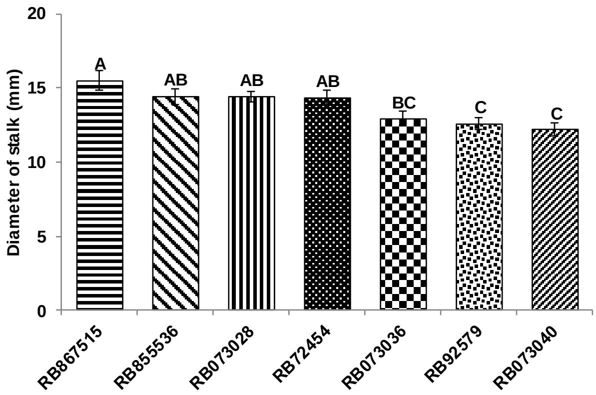

Fig 4. The stalk diameters of the varieties examined 90 DAT. Columns with equal letters do not differ by Tukey test, at 5% probability. Coefficient of variation = 11.17%. Bars represent standard error of the mean

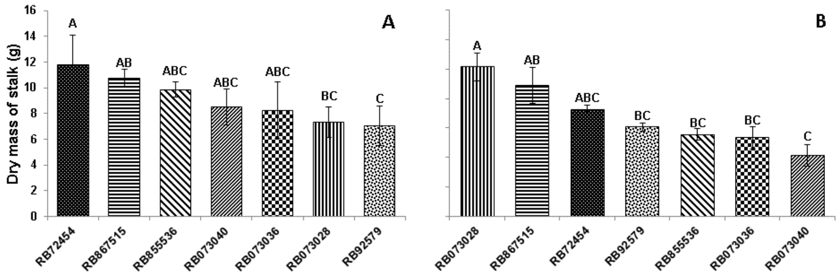

Fig 5. Dry stalk masses of all the varieties in this study 90 DAT, showing interaction with soil volumetric moisture: A) 36 kPa and B) 12 kPa. Columns with equal letters do not differ by Tukey test, at 5% probability. Coefficient of variation = 9.09%. Bars represent standard error of the mean.

conditions of water stress. This value was lower compared to the RB855536 variety, with 14.8 cm. The longer stress time, obviously made for a slower plant recovery, and thus a slower development. As the duration of water deficit increased, it affected the post-stress recovery more negatively, again concurring with the results of the current study (Quintela et al., 2015). In their assessment, Machado et al., (2009) evaluated the biometric responses to water deficit in sugarcane during the different phenological phases, and compared the clones. Based on the evidence of variations in plant height they could identify whether the varieties were tolerant of or susceptible to water stress. The RB867515 variety was confirmed to be prominent in stem diameter, with a value of 15.50 mm showing a significant difference when compared with the RB92579 and RB073040 varieties, recording 12.59 mm and 12.17 mm, respectively, the plants being maintained under conditions of water stress (Figure 4). In their study Santos et al., (2013) noted that among the various biometric variables analyzed, the stem diameter showed the least degree of variation, as it directly depended on the intrinsic genetic features, as noted in the current study. Campos et al. (2014) reported that fine stalks influenced the crop yield negatively, and thus it was likely that the water deficit condition would negatively impact sugarcane productivity.

Dry mass responses

At 12 kPa tension, the RB72454 variety revealed a value of 11.79 g in dry stalk mass, showing a significant difference when compared with the RB073028 and RB92579 varieties, with values of 7.33 g and 7.06 g, respectively (Figure 5A). The RB867515 clone accumulated 10.77 g in dry stalk mass, showing a significant difference when compared with the RB92579 variety. The RB073028 variety recorded 10.14 g of dry stalk mass for a tension of 36 kPa (Figure 5B). It also revealed a difference in the dry stalk mass accumulation when compared with the RB92579, RB855536, RB073036, and RB073040 varieties, with values of 6.05 g, 5.56 g, 5.32 g, and 4.13 g, respectively. However, RB867515 with 8.91 g of dry stalk mass showed a significant difference in comparison to the RB073040 clone, with 4.13 g.Ecco et al., (2014), recorded substantial drops in the dry weight of stalks in the RB855536 and RB867515 varieties subjected to water stress. According to the authors, this significant reduction of dry mass in the RB855536 variety implied higher energy consumption under deficit conditions, whereas, the RB867515 variety did not exhibit this effect. This could possibly imply its higher degree of water stress tolerance, as noted in the current study.If particular sugarcane varieties reveal more number of variables, for example, prominent length, diameter, and dry stalk mass, and if these are identified in highly water-stressed soils, they will be termed as, ‘severe water-stress tolerant’. However, when a variety is associated with a fewer number of variables that are striking even under conditions of high water tension, they will be regarded as being moderately water-deficit tolerant. When the varieties show no noteworthy association with any of the variables, they are termed ‘water-stress sensitive’.

Materials and Methods

Plant material

The plant species used was sugarcane (*Saccharum officinarum* L.), with six varieties: RB867515, RB92579, RB855536, RB72454, RB073036, RB073028, and RB073040.

Site description

The experiments were performed in the greenhouse of the Graduate Program in Tropical Agriculture, at the Federal University of Mato Grosso, Cuiabá-MT, having the geographical coordinates of 15º36' South latitude and 56º3' West Longitude. The mean temperature in the greenhouse was 29ºC and relative air humidity 65.6%, during the experiment, from June to September 2015.

Soil type

Soil having a sandy loam texture and termed 'Oxisol' was collected from 0.0–0.20 m depth, in a region supporting the Cerrado vegetation (EMBRAPA, 2013). The soil was sieved in a 2 mm mesh for chemical and granulometric analysis based on the method proposed by EMBRAPA (1997) (Table 1). For pot fillings, the soil was sieved in a 4 mm mesh.

Based on the soil characteristics, liming was performed using dolomitic limestone (Total Neutralization Power = 80.3%), increasing the base saturation to 60%. The soil was incubated with limestone for a period of 30 days. The soil was fertilized with nitrogen (30 kg ha^{-1}), phosphorus (200 kg ha^{-1} of P_2O_5), and potassium (180 kg ha^{-1} of K_2O), using urea, potassium chloride, and simple superphosphate, respectively, employing the methods mentioned in the Technical Bulletin 100 (Raij et al., 1996).

The stems of each variety chosen were chopped into lengths of approximately 3-cm size, packed in plastic boxes, and covered with substrate in a 3:1:1 ratio of filter cake, soil, and a commercial substrate, Plantmax, respectively. Soil moisture was kept steady at field capacity to support the pre-sprouting process. Twenty days later the plants were individuated in tubes to form sugarcane seedlings (Landell et al., 2012).

After 10 days of being cultivated in tubes, the seedlings were transplanted into the experimental polypropylene pots of 10 dm^3 capacity. The pots which contained the accurately correct and fertilized soil were maintained in the field capacity up to 26 DAT, to ensure the early development of plants.

Experimental design and sugarcane varieties

A randomized block design in a 7 x 5 factorial scheme was selected for the experiments with three replications, corresponding to seven sugarcane varieties (RB867515, RB92579, RB855536, RB72454, RB073036, RB073028, and RB073040) and exposed to five different soil water stresses (12, 24, 36, 48, and 60 kPa), to account for a total of 105 experimental units. These tensions were maintained throughout the experiment. Each experimental unit contained only one plant. The RB073036, RB073028, and RB073040, varieties were chosen for their favorable agronomic and technological features, and are in the multiplication phase of the sugarcane genetic improvement program of RIDESA (Inter-University Network of Development of the Sugar and Ethanol Sector), in the Mato Grosso state.

The RB867515 and RB92579 varieties were selected for their drought tolerance, whereas, RB72454 and RB855536 were selected for their drought sensitivity, and both were considered as control varieties against which the RB073036, RB073028, and RB073040 varieties, in the genetic improvement phase of RIDESA, could be compared.

Soil moisture treatments

The characteristic soil water retention curve was determined in the laboratory utilizing a Richard extractor (Soil Moisture Equipment, Santa Barbara, California) and the data were adjusted to the model proposed by Van Genuchten (1980) with the SWCR software (Dourado Neto et al., 2000). Using the soil water retention curve, the field capacity was calculated equivalent to 10 kPa, and thus, the water stresses of the various treatments were assessed. The induced soil water tension was: 12 kPa (without water stress); 24 and 36 kPa (moderate water stress); and 48 and 60 kPa (severe water stress).

The volumetric soil moisture equivalent to the treatments was established using a capacitive sensor model ML3 (Delta-T Devices Ltd., Cambridge, United Kingdom). This was done by first determining the correlation (calibration) curve between the ML3 sensor and a standard sensor (tensiometer). For this, the tensiometers were installed in the pot with three repetitions. Fifteen percent, 10%, 8%, 7%, and 6% of the volumetric soil moisture readings in the ML3 were equal to tensions in the tensiometers of 12, 24, 36, 48, and 60 kPa, respectively (Figure 1).

Twenty-six DAT the water stress treatments commenced. The irrigations were monitored using the volumetric soil moisture readings. To periodically read the capacitance sensor during the experimental process, tensiometers were placed in the pot with the treatments at 12, 36, and 60 kPa. The soil moisture was monitored by taking the measurements regularly (Figure 2).

To determine the water replacement volume in the soil the following equation was used:

$VR = (\theta_{vi}-\theta_{vf}) \times 10000$

in which:

VR - Volume of soil water replacement (ml);

θ_{vi} - Volumetric water content equivalent to the tension of the treatment (%);

θ_{vf} - Volumetric water content at the moment of soil moisture reading (%).

Dry mass and Biometric evaluations

The dry stalk mass, diameter, and length were the biometric variables analyzed 90 DAT or 64 days after the stress treatments were established. Stem height was measured using a tape measure, taking the measurements from the plant ground base to the visible atrium (or first visible collar) at the point of leaf insertion + 1. The stem diameter was measured at the place median of the first node formed, using a pachymeter. The plants were cut 90 DAT, in the tillering phase of the crop, around 120 days from the initial sprouting. The dry stalk mass was determined by conditioning the plants in paper bags before placing them in a forced ventilation oven at 65ºC until constant weight. The sample masses were then taken out of the oven and left at room temperature. Weight was recorded using a 0.01 g precision scale.

Statistical analysis

The data of each of the variables were submitted to the analysis of variance by the F test, at 5% probability, and when found to be significant they were analyzed by the Tukey test ($p <= 0.05$) using the SISVAR statistical program (Ferreira, 2008).

Conclusion

The RB073028, RB867515, and RB72454 varieties show greater stalk length and diameter linked with a higher dry stalk mass, under conditions of higher water tension, revealing tolerance to the severe water deficit. The varieties RB073036 and RB073040 reveal longer stem lengths, linked with greater diameter and higher water stress, and they show tolerance to the moderate water deficit. The RB92579 variety with its longer length and higher water tension as also the RB855536 variety, have a larger diameter. Both show no association with the other variables and reveal a susceptibility to water deficit.

Acknowledgments

The authors express gratitude to FAPEMAT/CAPES for providing the scholarship, and RIDESA for funding the research to CNPQ.

References

Batista LMT Avaliação morfofisiológica da cana-de-açúcar sob diferentes regimes hídricos.Master Thesis. Universidade de Brasília.

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

CONAB - Companhia Nacional de Abastecimento (2015) Acompanhamento da safra brasileira de cana-de-açúcar, v. 2 – Safra 2015/16, n. 2 - Segundo Levantamento, Brasília, agosto/2015.

Dourado Neto D, Nielsen DR, Hopmans JW, Reichardt K, Bacchi OOS (2000) Software to model soil water retention curves (SWRC, version 2.0). Sci Agri. 57:191-192.

Ecco M, Santiago EF, Lima PR (2014) Respostas biométricas em plantas jovens de cana-de-açúcar submetidas ao estresse hídrico e ao alumínio. Com Sci. 5:59-67.

EMBRAPA (2013) Empresa Brasileira de Pesquisa Agropecuária. Sistema brasileiro de classificação de solos. 3 ed. Brasília. 353p.

Ferreira DF (2008) SISVAR: um programa para análises e ensino de estatística. Rev Symp. 6:36-41.

Guimarães ER, Mutton MA, Mutton MJR, Ferro MIT, Ravaneli GC, Silva JA (2008) Free proline accumulation in sugarcane under water restriction and spittlebug infestation. Sci Agri.65:628-633.

Inman-Bamber NG (2004) Sugarcane water stress criteria for irrigation and drying off. F Crop Res. 89:107-122.

Inman-Bamber NG, Smith DM (2005) Water relations in sugarcane and response to water deficits. Fie Crop Res.92:185-202.

Landell MGA, Campana MP, Figueiredo P (2012) Sistema de multiplicação de cana-de-açúcar com uso de mudas pré-brotadas (MPB), oriundas de gemas individualizadas. Campinas: IAC. (Documentos IAC, N. 109 online).

Machado RS, Ribeiro RV, Marchiori PER, Machado DFSP, Machado EC, Landell MGA (2009) Respostas biométricas e fisiológicas ao deficit hídrico em cana-de-açúcar em diferentes fases fenológicas. Pesq Agro Bras.44:1575-1582.

Marin F, Nassif DSP (2013) Mudanças climáticas e a cana-de-açúcar no Brasil: Fisiologia, conjuntura e cenário futuro Rev Br Eng Agri Amb.17:232–239.

Pincelli RP, Silva MA (2012) Alterações morfológicas foliares em variedades de cana-de- açúcar em resposta à deficiência hídrica. Bios Jour.28:546-556.

Quintela MP, Pedrosa EMR, Willadino L, Rolim MM, Silva ÊFF, David MFL (2015) Intensity and duration of water deficit on the pathosystem sugarcane x Meloidogyne incognita. Rev Br Eng Agri Amb.19:581–586.

Raij B, Cantarela H, Quaggio JÁ, Furlani AMC (1996) Recomendações de adubação e calagem para o estado de São Paulo.2.ed. Campinas: IAC (Boletim técnico, 100). 285p.

Santos HRB, Pedrosa EMR, Nogueira RJMC, Rolim MM, Maranhão SRVL, Medeiros DB (2013) Crescimento de três variedades de cana-de-açúcar submetidas a estresse hídrico associado à Meloidogyne incógnita. Rev Bras Cie Agr.4:547-554.

Sousa CCM, Pedrosa MR, Rolim MM, Cavalcante MT, Monte Júnior P, Filho JVP (2015) Initial development and chemical components of sugarcane under water stress associated with arbuscular mycorrhizal fungi. Rev Br Eng Agri Amb.19: 548–552.

Van Genuchten MT (1980) A closed form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci Soc Am Jour.44:892-898

Vianna MS, Sentelhas PC (2014) Simulação do risco de deficit hídrico em regiões de expansão do cultivo de cana-de-açúcar no Brasil. Pesq Agro Bras. 49:237-246