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AGROMETEOROLOGY - Article

Variation in the sugar yield in response to drying-off of sugarcane before harvest and the occurrence of low air temperatures

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ABSTRACT: The need to irrigate sugarcane in the Brazilian Savanna is due to the lack of rain from April to September. For efficient sugar accumulation, the crop needs water stress or heat stress at the maturation stage. However, when the water deficit is intense at this stage, it occurs the reduction in crop production. The objective of this study was: (i) to assess the quality of the raw material of sugarcane in different drying-off seasons before harvest; (ii) to evaluate the influence of heat stress on the culture. The experiment was conducted in Santo Antônio de Goiás (GO), Brazil, in Oxisol, with CTC4 variety in cane-plant cycle. A randomized block design in a split-plot array in time was used. The treatments of the plots were five drying-off times (90, 60, 30, 15 and 0 days before harvest) and, in the subplots, five seasons of the yield evaluation. Irrigation was carried out by surface drip method, which provided 50% of crop water requirement. The best results for sugar yield occurred 30 days before harvest, period in which the crop irrigation could be interrupted. The water deficit of 37.76 mm appears to be the critical limit of water shortage in the soil, from which the sugarcane yield starts to be reduced. The sugar concentration in the stalk was more influenced by low air temperatures than sugarcane yield.

Key words: water stress, irrigation management, Brazilian savanna, thermal stress.

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INTRODUCTION

According to Carr and Knox (2011), in the production of irrigated sugarcane, water supply is interrupted before harvest to make the soil less moist and to increase the concentration of saccharose in the stalk. Water content in the soil above the soil friability can cause its excessive compaction, as the harvest is already fully mechanized in many regions.

Water stress during maturation enhances the production of saccharose (Inman-Bamber and Smith 2005), by limiting its vegetative growth. However, in addition to water stress, low air temperatures (thermal stress) and reduced nitrogen levels also limit the growth of sugarcane (Ludlow et al. 1992). Under these conditions, there is the accumulation of sugar in the stalk caused by the lower consumption by the plant (Cardozo and Sentelhas 2013). According to Robertson and Donaldson (1998), water restriction can be applied by increasing the interval between irrigations or by complete interruption some time before harvest.

The intensity of water stress at the maturity stage must be correctly monitored. When the water content available in the soil reduces to below 50%, the growth and productivity of stalks are reduced (Inman-Bamber and Smith 2005). Under severe drought stress, sugar synthesis decreases as well as the biomass of stalks (due to dehydration). According to Robertson and Donaldson (1998), saccharose yield in plants under water stress occurs to dehydration levels of up to 10%. In accordance with Scarpari and Beauclair (2009) and Cardozo and Sentelhas (2013), it is not known yet the optimal level of water available in the soil at the maturity stage. This value would be the one that preserves the biomass already produced, favors the concentration of sugar in the plant and ensures continuity in saccharose synthesis.

Low air temperatures favor the concentration of saccharose by reducing the metabolism of plants and consequently their growth (Wilson 1975). Thus, there is a positive return between fixed and consumed carbon, resulting in a greater storage. For Yates (1972), the low air temperatures influence more the interruption of sugarcane growth than water stress. Nevertheless, according to Cardozo and Sentelhas (2013), there is no consensus on the thermal parameters of the crop and, in tropical areas, the low air temperatures may not be sufficient to affect the maturation.

Knowing the influence of different levels of soil water availability and the effects of low air temperatures can guide management techniques. This knowledge will also be useful in agroclimatological zoning studies and in reducing the use of ripening agents. This study aimed: (i) to assess the quality of the raw material of sugarcane in different drying-off periods before harvest; and (ii) to evaluate the influence of thermal stress on the crop.

MATERIAL AND METHODS

The experiment was developed in the municipality of Santo Antônio de Goiás, state of Goiás, Brazil (16°28’50”S; 49°21’07”W; altittude of 760 m), in Oxisol of medium texture (27% clay, 13% silt and 60% sand). According to the Köppen climate classification, the climate of the region is Aw, with average annual temperature, relative humidity (RH%) and rainfall of 22.5 °C, 71% and 1,460 mm, respectively (Kliemann et al. 2006).

Soil preparation consisted of plowing and harrowing. Fertility amendment was performed by application of 2.0 $t{\cdot}ha^{-1}$ of gypsum and 4.0 $t{\cdot}ha^{-1}$ of lime to raise base saturation to 70%. At planting, 120 $kg{\cdot}ha^{-1}$ of P_2O_5 were applied. One-hundred days after planting (DAP), 380 $kg{\cdot}ha^{-1}$ of the fertilizer mix 18-00-27 were applied as top-dressing. Weed control was made after planting by applying 2.0 $kg{\cdot}ha^{-1}$ hexazinone and diuron and 0.09 $kg{\cdot}ha^{-1}$ isoxaflutole. At 100 DAP, 1.6 $L{\cdot}ha^{-1}$ tebuthiuron and 0.09 $kg{\cdot}ha^{-1}$ isoxaflutole were applied at the time of breaking soil. Planting was carried out in April 2013 and the harvest, in September 2014. The variety planted was CTC4 of medium-late cycle. The study was conducted during the cane-plant cycle.

Irrigation was applied by surface drip, with one dripline per planting row. Climatic data were provided by a weather station installed at 400 m from the experimental area. The reference evapotranspiration (ET_0) was estimated by the method of Hargreaves and Samani, according to Allen et al. (1998). This method was chosen because the station collected only the data of temperature, RH% and rainfall. The crop coefficient (Kc) used was 0.75 for the maturity stage (Doorenbos and Kassan 1979). We used the evapotranspiration reduction coefficient of 0.574, calculated as the wetted area percentage of 33% according to Keller e Bliesner (1990). We used the deficit irrigation

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management, supplying 50% of crop evapotranspiration. The whole experimental area began to be irrigated 30 days before the start of data collection, before the end of the rainy season.

This was a split-plot randomized block experimental design with five replications. The treatments consisted of five drying-off periods (90, 60, 30, 15 and 0 days of drying-off before harvest — DDBH) and five evaluation periods (90, 60, 30, 15 and 0 days before harvest — DBH: 6/13/2014, 7/13/2014, 8/12/2014, 8/27/2014 and 9/11/2014, respectively). Drying-off periods before harvest (DDBH) were assigned to the plots and the evaluation times before harvest (DBH), to subplots.

Each plot consisted of ten planting rows, 8.0 m long, spaced at 1.5 m. Each subplot consisted of a 2.5 m row. Soil moisture was determined by gravimetric method, at 90, 60, 30, 15 and 0 DBH, with soil sampling at layers with a thickness of 0.15 m, to a depth of 0.9 m.

Data of soil moisture of each drying-off treatment were used to calculate their respective values of water availability. For the present study, soil moisture at field capacity was 0.22 $g \cdot g^{-1}$, and permanent wilting point was 0.11 $g \cdot g^{-1}$ (Arruda et al. 1987). The effective depth of the root system was 0.75 m, in which 80% of the total root mass were found (sampling was performed to a depth of 2.0 m, in which roots were found). The critical water content in the soil was obtained on the basis of the daily reference evapotranspiration (Doorenbos and Kassan 1979). Stalk productivity was estimated by the harvest of ten stalks per subplot for complete technological analysis. This analysis determined: (i) total soluble solids (°Brix); (ii) saccharose content (POL, %); (iii) apparent purity of sugarcane (%); (iv) fiber (%); (v) stalk moisture (%); and (vi) total recoverable sugars (TRS).

In agreement with Scarpari and Beauclair (2004), the method of negative degree days (NDD) is used to relate the air temperature to sugarcane maturity. NDD comprise the accumulation of temperature that is below the basal temperature of the crop and were calculated by means of Equation 1. The sum of daily results provided the accumulated NDD (ANDD).

$$\text{For } Tb < Tm \rightarrow NDD = \frac{(Tb - Tm)^2}{2(TM - Tm)}$$

$$\text{For } Tb < Tm \rightarrow NDD = 0$$

where:

TM is the daily maximum air temperature (°C); Tm is the daily minimum air temperature (°C); Tb means the basal temperature of the crop, in which its development is interrupted (°C).

Based on the value of Tb = 18 °C, recommended by Teruel et al. (1997) for the conditions of São Paulo, we used, in this study, the value of 20 °C for the conditions of the Brazilian Savannah.

The agricultural contribution margin (ACM) was calculated according to Fernandes (2000). Data were subjected to analysis of variance followed by comparison of means by Tukey test at 5% probability. Also, correlations were made between water availability of each drying-off treatment (DDBH) and the accumulated negative thermal sum with the parameters of crop quality.

RESULTS AND DISCUSSION

During the experiment, the total rainfall was 19.6 mm (Figure 1a). The average air temperature remained close to the basal temperature of the crop (Figure 1b), and the maximum air temperature was around 30 °C (Figure 1c). During the three experimental months, 198.0 NDD were accumulated (Figure 1d).

There was no significant difference for stalk yield per hectare (SYH) between the drying-off treatments or between the evaluation periods (Table 1). Between the evaluation periods, there was a downward trend for yield, while, between the dying-off treatments, the trend was upward for yield with maintenance of irrigation. According to Inman-Bamber and Smith (2005), the development stage of the crop is the most sensitive to water deficit in the soil. For these authors, the development phase extends from initial tillering through full growth before the maturity stage. Our results demonstrate that the continuity of irrigation during the ripening period may not be advantageous due to the low response obtained. Nevertheless, Vieira et al. (2013) achieved a reduction of 21.5% in stalk yield in the treatment with 51 drying-off days (in soil with 83% sand).

For the treatment of 90 drying-off days before harvest, the reduction in water availability decreased SYH ($R^2 = 0.910^{**}$) (Tables 2, 3). For the treatment 0 DDBH, the lowest reduction in water availability caused an increase in

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SYH ($R^2 = -0.714^{**}$). According to Inman-Bamber (2004), the accumulation of biomass in sugarcane is only significantly reduced when the annual water deficit is greater than 120 mm. The maximum water deficit in this study was 41.88 mm, not enough to significantly differentiate the treatments. However, for the treatment 30 DDBH, reduction in water availability did not reduce SYH; therefore, 37.76 mm deficit seems to be the critical limit. From that limit, sugarcane stalk yield will be gradually reduced until 120 mm deficit, from which losses will be significant.

According to Ludlow et al. (1992), with air temperature below 25 °C, the stalk elongation rate begins to be reduced, since the optimum temperature for the growth of the culture is between 28 and 30 °C (Carr and Knox 2011). Throughout the experiment, the average temperature was 20.02 °C (Figures 1b,c), sufficient to reduce the growth of sugarcane. Thus, the ANDD may have minimized metabolism of the plants of all the drying-off treatments.

In the treatments 90 and 60 DDBH, low air temperatures intensified the effects of drought by inhibiting the increase in SYH. In turn, when there was enough water (treatments 30, 15 and 0 DDBH), the increase in ANDD did not lead to increases in SYH, but helped to preserve the biomass already produced. This is because, under low air temperatures, respiratory rates are lower, which reduces the metabolism of plants (Cardozo and Sentelhas 2013) with a consequent loss of water.

The TRS were significantly different between the evaluation periods (Table 1). At 90 DBH, TRS presented the lowest value. The highest sugar yields per ton were found for evaluations at 30, 15 and 0 DBH, which were not statistically different from each other. From the first to the last evaluation period, there was a 19.74% increase in the amount of sugar (30.35 $kg \cdot t^{-1}$). This value was higher than that found by Robertson and Donaldson (1998), who reported a maximum increase of 15%. Possibly, the amount of sugar in the new varieties of sugarcane explains this difference, since the varieties investigated by Robertson and Donaldson (1998) are no longer grown in Brazil.

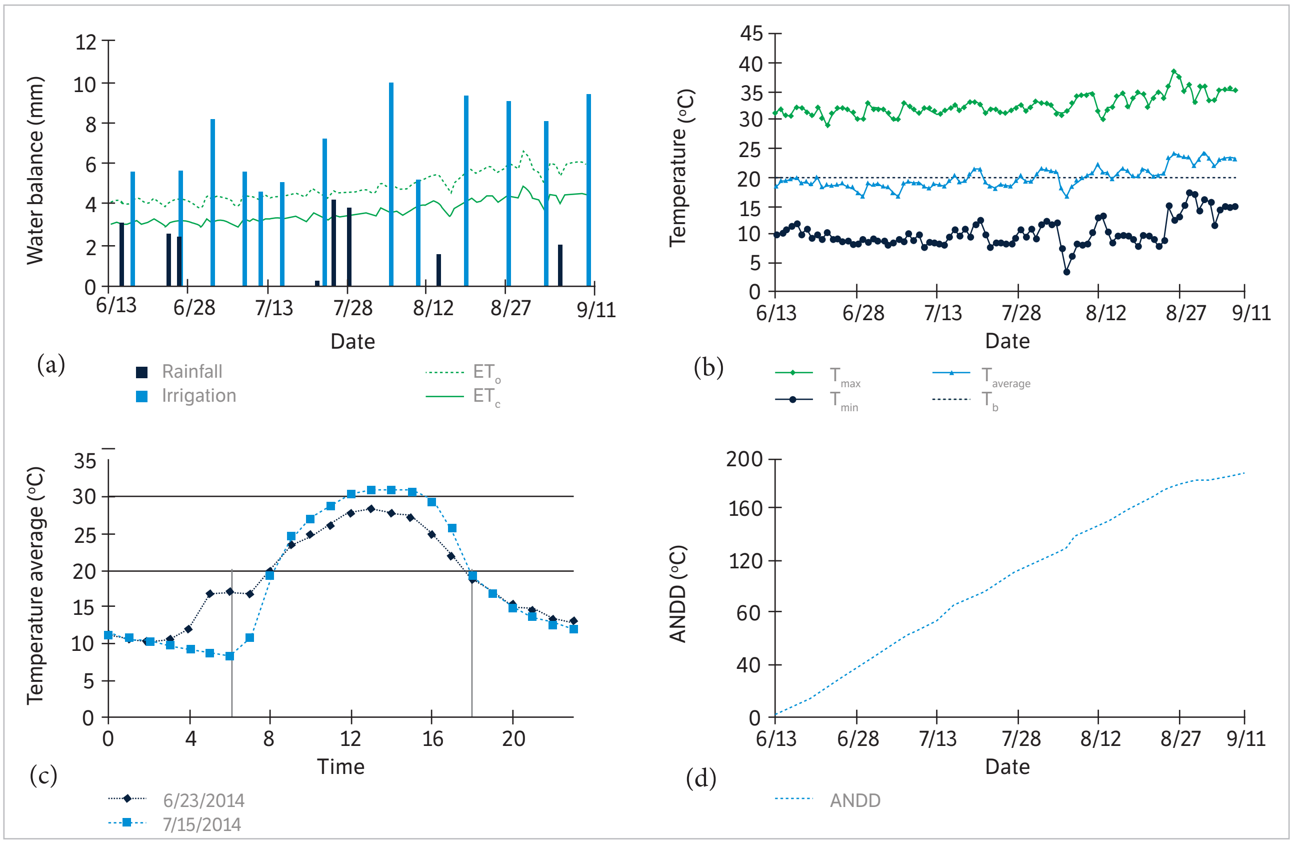

Figure 1. (a) Rainfall, reference evapotranspiration (ET0), crop evapotranspiration (ETc) and irrigation, for the period between June and September 2014; (b) Maximum, minimum and average temperature and basal temperature (Tb) of the sugarcane crop; (c) Daily average temperature for the days 6/23/2014 and 7/15/2014, indicating temperatures of 20 and 30 °C and times of 6 and 18h; (d) Accumulated negative degree days (ANDD) during the 90 experimental days, in Santo Antônio de Goiás (GO), Brazil.

The TRS were negatively correlated with water availability of each drying-off treatment and positively with the accumulated negative thermal sum (Table 2), confirming the findings of Ludlow et al. (1992). Even under drought stress, the plant continues synthesizing sugar. Photosynthesis is affected only under annual water deficits above 145 mm (Inman-Bamber 2004).

For the State of São Paulo, Delgado-Rojas and Barbieri (1999) observed that irrigation during the maturity stage resulted in no increase in stalk and sugar yield in cane. These authors attributed their results to the lower sensitivity of sugarcane to water shortage during the maturity stage. Even dealing with different regions, these authors' result also corroborates ours.

Vieira et al. (2013) detected no significant difference for TRS between the treatments of suspended irrigation before harvest. Water deficit, with maximum interruption of 51 days, was opposite to the increase in TRS. In the treatment with no suspension of irrigation, the authors observed the highest value of TRS, showing that another factor may have influenced the sugar accumulation. However, the authors did not analyze the influence of temperature on the results.

In addition, there was no significant difference in stalk moisture between the drying-off treatments; however, there were differences between the evaluation periods (Table 1, Figure 2d). Moisture varied over the 90 days before harvest — from 70.97% at 90 DBH to 68.38% at 60 DBH — and remained, on average, 67.5% from 30 DBH.

Water deficit was recorded in all treatments from 30 DBH (Table 3, Figure 3). With water deficit and its intensification, the moisture of the stalk remained constant (Figure 2d). Under favorable conditions of water availability, transpiration

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Table 1. Analysis of variance and Tukey's test (5% probability) for stalk yield per hectare, total recoverable sugars, stalk moisture and agricultural contribution margin of different drying-off treatments before harvest and in five evaluation periods for the sugarcane variety CTC4 in Santo Antônio de Goiás (GO), Brazil.

SYH (t·ha^{-1})				TRS (kg·t^{-1})			
Evaluation period — days before harvest(1)		**Days of irrigation suspension(2)**		**Evaluation period — days before harvest(1)**		**Days of irrigation suspension(2)**	
90	170.68 a	90	168.44 a	90	153.70 c	90	173.75 a
60	171.23 a	60	170.15 a	60	164.59 b	60	174.57 a
30	173.19 a	30	170.30 a	30	184.08 a	30	173.55 a
15	169.98 a	15	172.00 a	15	182.71 a	15	173.59 a
0	167.74 a	0	171.92 a	0	184.05 a	0	173.67 a
CV% (1)	4.87	DMS (1)	17.99	CV% (1)	2.39	LSD (1)	3.61
CV% (2)	6.27	DMS (2)	18.81	CV% (2)	2.65	LSD (2)	3.63
1	NS	2	NS	1	**	2	NS
1 × 2		NS		1 × 2		NS	
Stalk moisture (%)				**ACM (R$·ha^{-1})**			
Evaluation period — days before harvest(1)		**Days of irrigation suspension(2)**		**Evaluation period — days before harvest(1)**		**Days of irrigation suspension(2)**	
90	70.95 a	90	68.39 a	90	7.131.96 c	90	8.442.78 a
60	68.38 b	60	68.31 a	60	7.945.75 b	60	8.603.72 a
30	67.82 c	30	68.55 a	30	9.488.67 a	30	8.543.87 a
15	67.64 c	15	68.47 a	15	9.184.03 a	15	8.640.60 a
0	67.37 c	0	68.43 a	0	9.130.83 a	0	8.650.27 a
CV% (1)	0.88	DMS (1)	0.52	CV% (1)	6.95	LSD (1)	517.06
CV% (2)	1.01	DMS (2)	0.54	CV% (2)	8.42	LSD (2)	570.48
1	**	2	NS	1	**	2	NS
1 × 2		NS		1 × 2		NS	

Means followed by different lowercase letters in the same column are significantly different by Tukey's test at 5% probability. **F-test with 1% significance. (1)The treatments consisted of five evaluation periods (90, 60, 30, 15 and 0 days before harvest, DBH — 6/13/2014,7/13/2014,8/12/2014, 8/27/2014, and 9/11/2014, respectively); (2)ive drying-off periods (90, 60, 30, 15 and 0 days of irrigation suspension before harvest, DDBH) DDBH were assigned to the plots and DBH, to the subplots. SYH = Stalk yield per hectare; TRS = Total recoverable sugars; ACM = Agricultural contribution margin; CV = Coefficient of variation; LSD = Least significant difference; NS = Non-significant F-test.

of sugarcane occurs normally. However, as the water supply provided only 50% of the total evapotranspirometric demand, the evolution of water deficit has resulted in reduction of transpiration, keeping moisture stalk with values close to the onset of the deficit (30 DBH). In sugarcane, water loss to the atmosphere and excessive dehydration are controlled by stomatal closure. This is the first defense mechanism used by the plant to adapt to the availability of water in the soil (Machado et al. 2009).

A positive correlation was verified between stalk moisture and water availability (Table 2). Meanwhile, low water loss in the stalk (3.58% over 90 days) can be explained by the ANDD, which were negatively correlated with moisture in the stalk. Under low temperatures, the crop reduced its metabolism, which reduced its transpiration and resulted in lower water loss (Figure 2d, 1d).

There was no significant difference in the ACM between the drying-off treatments; nevertheless, there were differences between the evaluation periods (Table 1, Figure 2e). Between the evaluation periods, there was variation in ACM from 7,131.96 $\text{R\$}\cdot\text{h}^{-1}$ at 90 DBH to 7,945.75 $\text{R\$}\cdot\text{ha}^{-1}$ at 60 DBH, which remained on the average at 9,200.00 $\text{R\$}\cdot\text{ha}^{-1}$ from 30 DBH. As from 30 DBH there was no significant difference, it is suggested that irrigation could be suspended at this time, avoiding spending on irrigation pumping and related costs. On the other hand, Vieira et al. (2013) observed that, under the conditions of Jaíba

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Table 2. Simple correlation coefficients between stalk yield per hectare, total recoverable sugars, stalk moisture, agricultural contribution margin and water availability for the respective treatments (drying-off days before harvest) and the accumulated negative degree days for the sugarcane variety of CTC4 in Santo Antônio de Goiás (GO), Brazil.

SYH ($t\cdot ha^{-1}$)					
Simple correlations	**R^2**	**S**	**Simple correlations**	**R^2**	**S**
WA90 × SYH90	0.910	**	ANDD × SYH90	−0.933	**
WA60 × SYH60	0.651	**	ANDD × SYH60	−0.547	**
WA30 × SYH30	−0.065	NS	ANDD × SYH30	0.153	NS
WA15 × SYH15	−0.462	**	ANDD × SYH15	0.457	**
WA0 × SYH0	−0.714	**	ANDD × SYH0	0.656	**
TRS ($kg\cdot t^{-1}$)					
Simple correlations	**R^2**	**S**	**Simple correlations**	**R^2**	**S**
WA90 × TRS90	−0.988	**	ANDD × TRS90	0.987	**
WA60 × TRS60	−0.979	**	ANDD × TRS60	0.986	**
WA30 × TRS30	−0.972	**	ANDD × TRS30	0.982	**
WA15 × TRS15	−0.961	**	ANDD × TRS15	0.991	**
WA0 × TRS0	−0.995	**	ANDD × TRS0	0.994	**
Stalk moisture (%)					
Simple correlations	**R^2**	**S**	**Simple correlations**	**R^2**	**S**
WA90 × Moisture% Stalk90	0.987	**	ANDD × Moisture% Stalk90	−0.975	**
WA60 × Moisture% Stalk60	0.910	**	ANDD × Moisture% Stalk60	−0.951	**
WA30 × Moisture% Stalk30	0.902	**	ANDD × Moisture% Stalk30	−0.963	**
WA15 × Moisture% Stalk15	0.918	**	ANDD × Moisture% Stalk15	−0.968	**
WA0 × Moisture% Stalk0	0.921	**	ANDD × Moisture% Stalk0	−0.925	**
ACM ($\text{R\$}\cdot ha^{-1}$)					
Simple correlations	**R^2**	**S**	**Simple correlations**	**R^2**	**S**
WA90 × ACM90	−0.981	**	ANDD × ACM90	0.977	**
WA60 × ACM60	−0.949	**	ANDD × ACM60	0.963	**
WA30 × ACM30	−0.940	**	ANDD × ACM30	0.961	**
WA15 × ACM15	−0.950	**	ANDD × ACM15	0.980	**
WA0 × ACM0	−0.994	**	ANDD × ACM0	0.985	**

**Significant at 1% probability. SYH = Stalk yield per hectare; TRS = Total recoverable sugars; ACM = Agricultural contribution margin; ANDD = Accumulated negative degree days; WA = Water availability; R^2: Correlation coefficient; S: Correlation significance; NS = Non-significant.

(Minas Gerais State, Brazil), on soil with 82% sand, suspension of irrigation before harvest is not recommended. These authors obtained higher profitability with treatment without drying-off — 26 t·ha^{-1} more stalks (21.5%) compared to the treatment with 51 days without irrigation, but there was no significant difference for sugar yield between periods.

ACM was negatively correlated with water availability and positively with the ANDD (Table 2). The results for the SYH and TRS explain this correlation. The water deficit between periods was not enough to significantly distinguish stalk yield. However, the ANDD influenced the increase in sugar concentration in the stalk (TRS).

Table 3. Water availability in soil per 0.15 m layer and per effective depth of the root system (0.75 m) of different drying-off treatments before harvest (90, 60, 30, 15 and 0 days) for the sugarcane variety CTC4 in Santo Antônio de Goiás (GO), Brazil.

Days of irrigation suspension before harvest	**Soil depth**	**Days before harvest**				
		90	**60**	**30**	**15**	**0**
		(6/13)	**(7/13)**	**(8/12)**	**(8/27)**	**(9/11)**
	(m)	**WA (mm)**				
90	0 – 0.15	17.14	6.03	−8.54	−9.92	−11.29
	0.15 – 0.30	18.72	5.48	−4.77	−6.86	−8.95
	0.30 – 0.45	20.40	3.21	−3.06	−5.35	−7.64
	0.45 – 0.60	16.86	8.71	−2.26	−4.73	−7.19
	0.60 – 0.75	18.26	10.89	−0.37	−3.59	−6.81
	WA$_{total}$	**91.37**	**34.32**	**−19.00**	**−30.44**	**−41.88**
60	0 – 0.15	15.43	10.59	−4.94	−9.57	−11.00
	0.15 – 0.30	19.95	13.26	−4.54	−4.47	−8.66
	0.30 – 0.45	17.24	9.28	−2.86	−5.39	−7.56
	0.45 – 0.60	17.33	9.50	0.33	−4.59	−6.99
	0.60 – 0.75	18.47	9.91	−2.16	−4.42	−4.83
	WA$_{total}$	**88.42**	**52.54**	**−14.17**	**−28.43**	**−39.04**
30	0 – 0.15	17.83	19.24	−0.45	−5.99	−9.40
	0.15 – 0.30	16.83	14.07	−1.60	−6.46	−9.31
	0.30 – 0.45	18.05	11.96	3.83	−3.09	−7.89
	0.45 – 0.60	18.74	11.64	0.22	−4.38	−4.78
	0.60 – 0.75	18.01	12.10	0.34	−3.98	−6.38
	WA$_{total}$	**89.46**	**69.01**	**2.33**	**−23.89**	**−37.76**
15	0 – 0.15	14.74	17.10	−1.05	−2.66	−5.36
	0.15 – 0.30	17.56	11.70	−0.43	−2.96	−6.65
	0.30 – 0.45	19.05	13.75	−0.91	−2.32	−6.52
	0.45 – 0.60	17.79	13.04	2.41	0.56	−3.99
	0.60 – 0.75	19.43	12.63	1.76	−1.64	−4.13
	WA$_{total}$	**88.57**	**68.22**	**1.78**	**−9.02**	**−26.65**
0	0 – 0.15	17.35	15.97	3.10	−1.09	1.55
	0.15 – 0.30	18.98	12.50	−2.51	0.48	3.49
	0.30 – 0.45	18.84	13.54	−0.70	−0.31	1.60
	0.45 – 0.60	18.98	15.98	2.48	0.55	−0.76
	0.60 – 0.75	19.06	12.59	1.17	3.45	1.42
	WA$_{total}$	**93.21**	**70.58**	**3.53**	**3.07**	**7.31**

WA = Water availability at the layer 0 – 0.75 m (effective depth of the root system for the sugarcane variety CTC4 in this experiment). WA = ((C – Crit) × bd × Z)/10, where C = Current soil moisture; Crit = Critical soil moisture; bd = Soil bulk density; Z = Effective depth of the root system. It was considered: Moisture at field capacity (FC) = 0.22 g·g^{-1}; Moisture at permanent wilting (PW) = 0.11 g·g^{-1}; Average bd = 1.42 g·cm^{-3}; Available water capacity (AWC) = 158.45 mm; Factor of water availability in the soil (f) = 0.7 for the region of Santo Antônio (GO); Crit = 0.15 g·g^{-1} until 7/13/2014 and 0.16 g·g^{-1} from 7/13/2014.

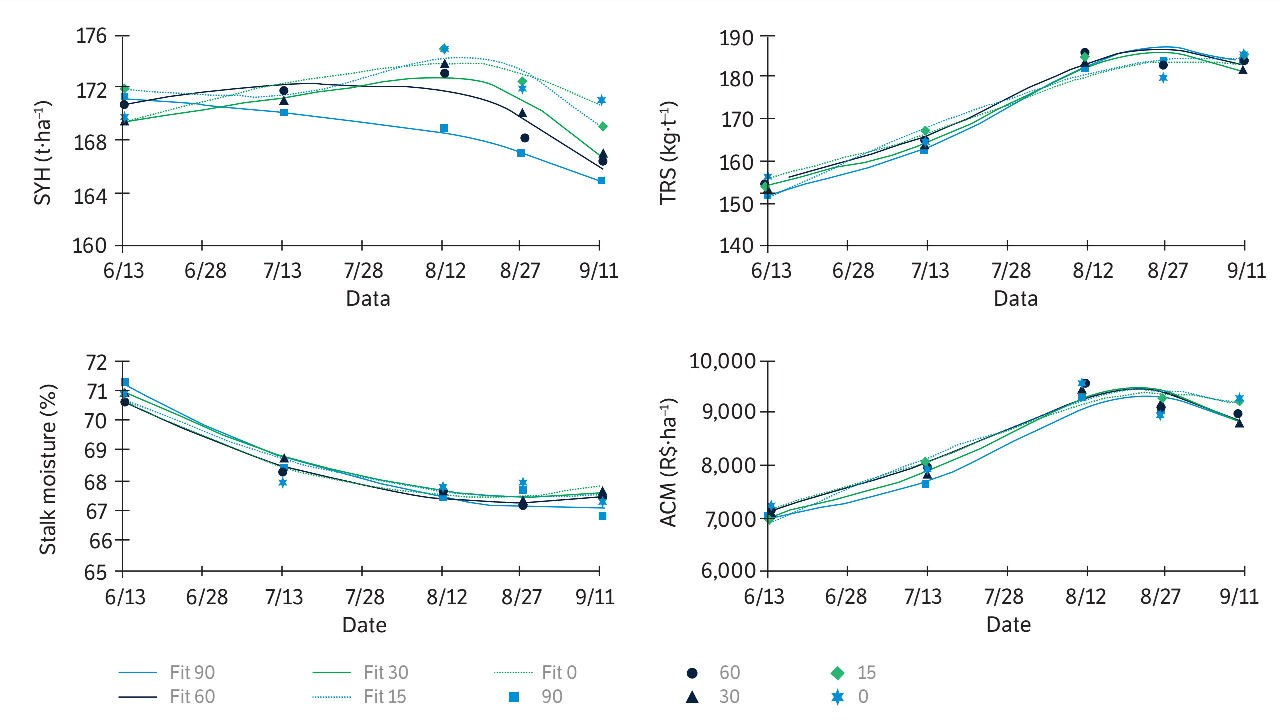

Figure 2. (a) Stalk yield per hectare (SYH); (b) Total recoverable sugars (TRS); (c) Stalk moisture; (d) Agricultural contribution margin (ACM) for different drying-off treatments before harvest (90, 60, 30, 15 and 0 days) and respective fit curves (Table 4) for the sugarcane variety CTC4 in Santo Antônio de Goiás (GO), Brazil.

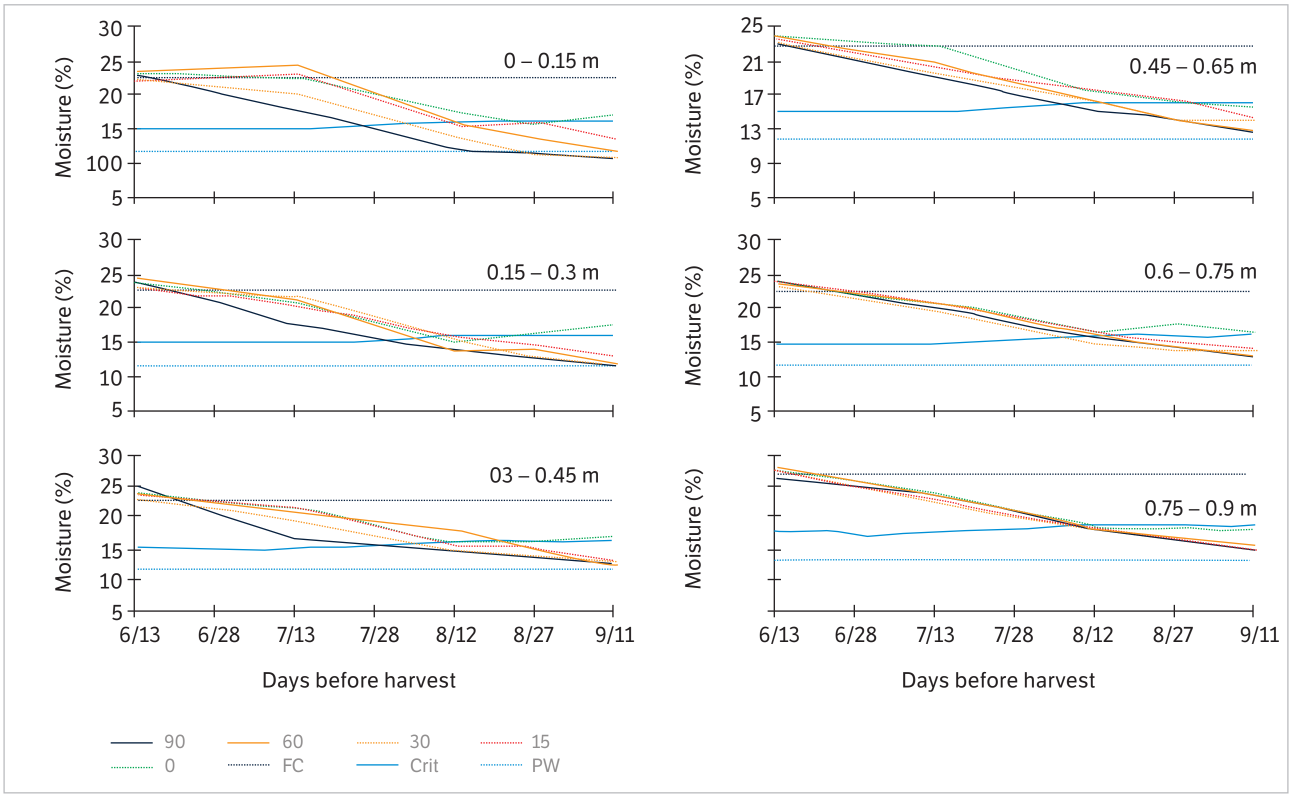

Figure 3. Soil moisture at the depth of 0 – 0.9 m in 0.15 m thickness layers for different drying-off treatments before harvest (90, 60, 30, 15 and 0 days). FC = Moisture at field capacity (22.69%); PW = Moisture at permanent wilting (11.83%); Crit = Critical moisture (15.09% until 7/13/2014 and 16.17% from 7/13/2014, in g·g⁻¹).

Table 4. Fit equation models for the different dates of evaluation of the drying-off treatments before harvest and their respective fit coefficients for the sugarcane variety CTC4 in Santo Antônio de Goiás (GO), Brazil.

Fit equations	R^2	Significance
$SYH90 = 1.650e{+}02 + 1.719e{-}01 \times DBH - 2.012e{-}03 \times DBH^2 + 9.587e{-}06 \times DBH^3$	−0.108	NS
$SYH60 = 1.659e{+}02 + 3.245e{-}01 \times DBH - 4.938e{-}03 \times DBH^2 + 2.160e{-}05 \times DBH^3$	−0.080	NS
$SYH30 = 1.666e{+}02 + 4.246e{-}01 \times DBH - 8.583e{-}03 \times DBH^2 + 4.699e{-}05 \times DBH^3$	−0.093	NS
$SYH15 = 1.689e{+}02 + 4.419e{-}01 \times DBH - 1.092e{-}02 \times DBH^2 + 7.089e{-}05 \times DBH^3$	−0.035	NS
$SYH0 = 1.707e{+}02 + 2.217e{-}01 \times DBH - 4.507e{-}03 \times DBH^2 + 2.105e{-}05 \times DBH^3$	−0.112	NS
$TRS90 = 183.9 + 0.5598 \times DBH - 0.0252 \times DBH^2 + 0.0001675 \times DBH^3$	0.905	**
$TRS60 = 183.1 + 0.512 \times DBH - 0.02128 \times DBH^2 + 0.0001338 \times DBH^3$	0.878	**
$TRS30 = 181.5 + 0.623 \times DBH - 0.02505 \times DBH^2 + 0.0001641 \times DBH^3$	0.879	**
$TRS15 = 184.7 + 0.05435 \times DBH - 0.00739 \times DBH^2 + 0.00002933 \times DBH^3$	0.912	**
$TRS0 = 182.9 + 0.2292 \times DBH - 0.01351 \times DBH^2 + 0.00008443 \times DBH^3$	0.752	**
$Moisture\%\ Stalk90 = 67.2024072 - 0.0065371 \times DBH + 0.0005627 \times DBH^2$	0.721	**
$Moisture\%\ Stalk60 = 67.5213070 - 0.0191772 \times DBH + 0.0006005 \times DBH^2$	0.853	**
$Moisture\%\ Stalk30 = 67.6421876 - 0.0134583 \times DBH + 0.0005592 \times DBH^2$	0.873	**
$Moisture\%\ Stalk15 = 67.5703923 - 0.0100764 \times DBH + 0.0005039 \times DBH^2$	0.686	**
$Moisture\%\ Stalk0 = 67.8465096 - 0.0280628 \times DBH + 0.0006562 \times DBH^2$	0.652	**
$ACM90 = 8.943.5516 + 54.9149 \times DBH - 2.0490 \times DBH^2 + 0.0134 \times DBH^3$	0.491	**
$ACM60 = 8.950.08967 + 58.60751 \times DBH - 1.89015 \times DBH^2 + 0.01136 \times DBH^3$	0.597	**
$ACM30 = 8.873.00659 + 71.86950 \times DBH - 2.33616 \times DBH^2 + 0.01466 \times DBH^3$	0.581	**
$ACM15 = 9.258 + 31.39 \times DBH - 1.208 \times DBH^2 + 0.006438 \times DBH^3$	0.781	**
$ACM0 = 9.233 + 31.86 \times DBH - 1.311 \times DBH^2 + 0.007883 \times DBH^3$	0.525	**

Significance of the fit: **Significant at 1% probability. DBH = Days before harvest; SYH = Stalk yield per hectare ($t \cdot ha^{-1}$); TRS = Total recoverable sugars ($kg \cdot t^{-1}$); Moisture% Stalk = Sugarcane stalk moisture (%); ACM = Agricultural contribution margin ($R\$ \cdot ha^{-1}$); R^2 = Correlation coefficient; NS = non-significant.

CONCLUSION

Suspension of irrigation for 90 DBH did not significantly reduce the yield of stalks and sugar. Water deficit of 37.76 mm seems to be the critical limit of water deficit in the soil, from which the sugarcane stalk yield starts to be reduced.

The NDD positively influenced the increase in sugar yield. The influence on the sugarcane stalk yield was associated with soil water availability. The best results of raw material quality in sugarcane were observed 30 DBH, when irrigation of the crop may be suspended.

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