academicJournals

Vol. 12(4), pp. 260-269, 26 January, 2017
DOI: 10.5897/AJAR2016.11789
Article Number: 86A7ECD62517
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Stalk productivity and quality of three sugarcane varieties at the beginning, in the middle, and at the end of the harvest

Daniele Costa de Oliveira[1]*, Mauro Wagner de Oliveira[2], Manoel Gomes Pereira[3], Tâmara Cláudia de Araújo Gomes[4], Vinicius Santos Gomes da Silva[5] and Terezinha Bezerra Albino Oliveira[2]

[1]Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Av. Pádua Dias, 11, 13418-900, Piracicaba, São Paulo, Brazil.
[2]Centro de Ciências Agrárias, Universidade Federal de Alagoas, BR 104, Km 85, s/n, 57100-000. Rio Largo, Alagoas, Brazil.
[3]Departamento de Pesquisa, Usina Triunfo, Vila Triunfo, s/n, 57680-000, Boca da Mata, Alagoas, Brazil.
[4]Empresa Brasileira de Pesquisa Agropecuária, Centro de Pesquisa Agropecuária dos Tabuleiros Costeiros, Unidade de Execução de Pesquisa de Rio Largo. BR 104, Km 85, s/n, Rio 57100-000. Rio Largo, Alagoas, Brazil.
[5]Departamento de Agronomia, Universidade Federal Rural de Pernambuco, Av. Dom Manoel de Medeiros, s/n, 52171-900, Recife, Pernambuco, Brazil.

Received 4 October, 2016; Accepted 13 January, 2017

This paper evaluated the stalk productivity and quality of the RB961552 and RB98710 sugarcane varieties, compared with RB92579, during the cane-plant and regrowth cycles. The study was conducted in a random block experimental design with five repetitions. The plots composed of 7 furrows measuring 8 m in length with 1.0 m spacing. Juice quality from the lower, middle, and upper thirds of the industrialized stalks was evaluated at the beginning, in the middle, and at the end of the harvest. At the end of the harvest, industrialized stalk and sugar productivity was also quantified. In all the evaluation periods, RB961552 had a lower apparent sucrose level than the other two varieties. RB92579 and RB98710 only differed in the collections at the beginning of the harvest and in the first regrowth cycle, at which time RB98710 presented a higher sucrose level. RB92579 sugar production in the cane-plant and first regrowth cycles was 14.37 and 18.44%, respectively, and greater than the average for the RB961552 and RB98710 varieties.

Key words: Phosphorus in sugarcane juice, sucrose, production systalk, industrial quality.

INTRODUCTION

The sugar-alcohol sector in Brazil is one of the most technology intensive in the world. This is the result of research, with technological improvement programs developed in the country over decades making new varieties available with high productive potential. There have been great advances in knowledge of soils and plant nutrition, in cultivation practices, production management, and cane payment for juice quality

(Oliveira et al., 2014a; Simões et al., 2015; Rhein et al., 2016). The adoption of improved varieties has also contributed to an increase in cane productivity and crop profitability (Souza et al., 2012; Silva, 2013). Among these new varieties, RB92579, RB98710, and RB961552 stand out. RB92579 is characterized by its high productivity, hydric efficiency, optimal sucrose content, and short flowering period. RB98710 has a high productivity and sucrose content, low fiber content, early maturity, and is recommended for restricted environments, with it rarely flourishing or toppling. RB961552 is highly productive and responds excellently to irrigation (RIDESA, 2010).

Soil and climate conditions have a great impact on sugarcane juice production and quality. For this reason, it is important to carry out studies to determine the productivity and industrial quality of juice, in various production environments, in order to establish cultivation practices that make it possible to exploit sugarcane productive potential to the maximum (Calheiros et al., 2012; Silva et al., 2014).

In evaluations of the productive potential of particular sugarcane varieties, industrialized stalk productivity per hectare (TSH) and juice quality should be evaluated, especially apparent sucrose (AS) and inorganic phosphorus (Pi) levels (Tasso Júnior et al., 2014; Rhein et al., 2016). Sucrose is the raw material in sugar and alcohol production and the Pi concentration in juice is important both for yeast metabolism in alcoholic fermentation and in sugar production (Oliveira et al., 2011; Tasso Júnior et al., 2014; Mohammed et al., 2016). Pi is important in the sugarcane juice clarification process during sugar production. On reacting with the slaked lime ($Ca[OH]_2$), tricalcium phosphate is formed, which through flocculation and sedimentation draws the impurities to the bottom of the decanter (Calheiros et al., 2012; Oliveira et al., 2014b; Mohammed et al., 2016). Pi levels greater than 50 mg L^{-1} have been prescribed for good alcoholic fermentation to occur and Pi levels greater than 100 mg L^{-1} for efficient juice clarification (Martins, 2004; Tasso Júnior et al., 2014).

Juice quality varies according to stalk position and sugarcane maturity, with it therefore being important to evaluate juice quality in different parts of the stalk and different harvesting periods in order to identify the best period for each variety. In light of this, the aim of this paper was to evaluate the productive potential of the recently launched RB961552 and RB98710 sugarcane genotype varieties, compared to RB92579, in the cane-plant and first regrowth cycles, in cultivations in the Zona da Mata (scrub region) in Alagoas State, as well as juice quality in three harvesting periods in different parts of the stalk.

MATERIALS AND METHODS

The study was conducted at the Jequiá Plantation, located in the municipality of Anadia, AL, at 09°41'04"S latitude and 36°18'15"W longitude, and belonging to the Triunfo Mill, over the period from August 2011 to January 2014. The evaluations were carried out in two cycles: cane-plant and first regrowth. The region's climate is rainy tropical with dry summers, according to the Koppen classification. The average annual precipitation is 1200 mm, with an average annual temperature of 29°C. In 2012, accumulated rainfall in the months of November and December was only 1.4 mm. In 2013, the volume of rain in the months from January to March was lower than in 2012 (Figure 1).

The study was set up in Yellow Dystrophic Latosol (Embrapa, 2013) with an average texture. Prior to setting up the study, a chemical analysis of the soil was carried out at depths of 0 to 20 and 20 to 40 cm. With the results, dolomitic limestone and plaster were applied in a proportion of 3:1, and in sufficient quantity to raise base saturation to 60% in the topsoil layer and reduce aluminum saturation on the subsurface, as proposed by Oliveira et al. (2007) and Raij (2011). After 60 days, the soil was plowed, harrowed, and subsequently furrowed.

Planting was carried out in August 2011. 500 Mg ha^{-1} of 09-14-22 chemical fertilizer was applied at the bottom of the planting furrows. Table 1 shows the results of the soil analysis after soil fertilization. Three sugarcane varieties were planted: RB92579, RB961552, and RB98710, with treatments placed in random blocks with five repetitions. RB92579 was chosen as a reference due to it currently being the most widely-planted cane variety in Alagoas (Ridesa, 2012). RB961552 and RB98710 are promising varieties, but there is little information available in the literature.

The study was carried out in an random block experimental design with five repititions. The plots consisted of 7 furrows, measuring 8 m in length, with 1.0 m spacing and a total area of 56 m^2. The useful area was 30 m^2, composed of 5 central rows, excluding one meter borders. Plant density fluctuated between 15 and 18 seedlings per meter of furrow, which were collected from a nursery at the Triunfo Mill. The seedlings were manually covered with soil, with an approximately 5 cm layer of earth placed over them and Tebutiuron herbicide applied straight afterwards in doses of 1.0 kg of active ingredient per hectare. Fipronil was also used to control leafcutter ants. Leafhopper (*Mahanarva* species) and sugarcane borer *(Diatraea* species) controls were carried out via biological control, with the use of *Metarhizium anisopliae* and *Cotesia falvipes*, respectively (Benedini, 2006). Fertilization of the cane from first regrowth was carried out after cane-plant harvesting. 500 kg ha^{-1} of 20-05-25 fertilizer was applied by manually spreading the fertilizer. The weed and pest controls adopted in first cane regrowth were the same as those for the cane-plant stage.

The quality of the lower, middle, and upper thirds of the industrialized stalks were evaluated at 14, 15, and 17 months of sugarcane age, and at 9, 10, and 12 months in first regrowth, corresponding to the beginning, middle, and end of the harvest, respectively. In the Northeast of Brazil, the beginning of the harvest corresponds to the months of September and October, the middle of the harvest to November and December, and the end of the harvest to January and February (Souza et al., 2012).

In each of the evaluations, five stalks from the second row from

*Corresponding author. E-mail: danielecoliveira@usp.br. Tel: 55-19-34172130 or 55-19-981698831.

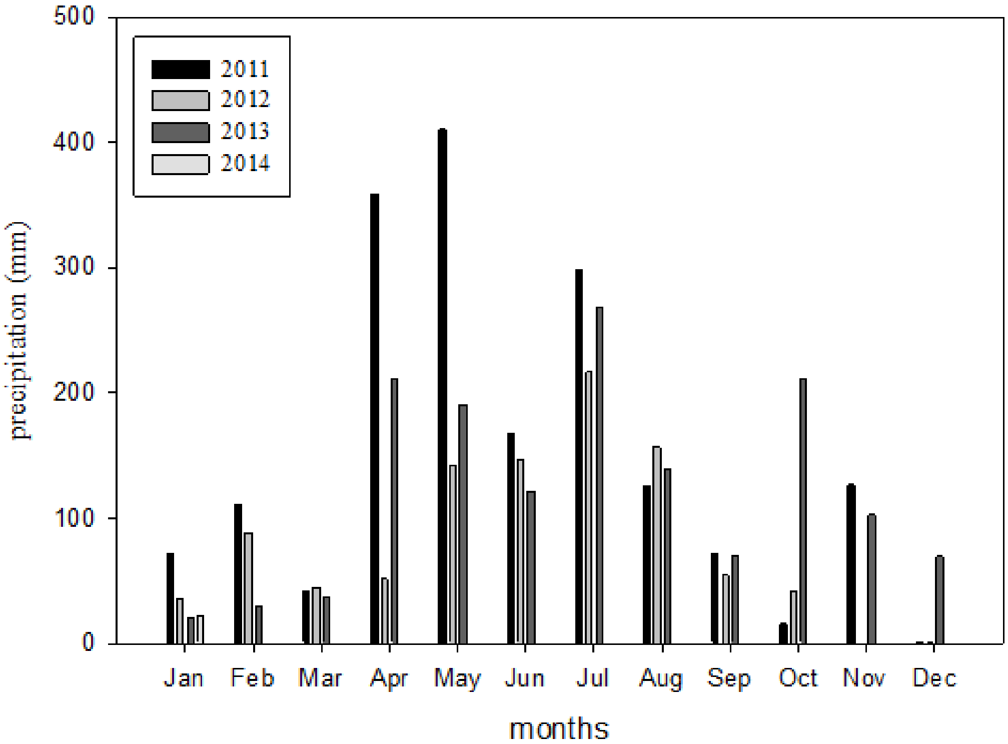

Figure 1. Monthly precipitation during the period studied.

Table 1. Chemical analysis of the soil from the experimental area after fertilization.

Determinations	Depth	
	0-20 cm	20-40 cm
pH (H_2O)	5.9	5.7
Na (mg dm^{-3})	21	21
P (mg dm^{-3})	6	4
K (mg dm^{-3})	48	28
Ca ($cmol_c$ dm^{-3})	2.8	1.3
Mg ($cmol_c$ dm^{-3})	0.9	1.2
Al ($cmol_c$ dm^{-3})	0.05	0.11
H + Al ($cmol_c$ dm^{-3})	3.0	2.2

left to right were collected, separated, clipped, divided into lower (LT), middle (MT), and upper (UT) thirds, and then weighed. The samples for each third were passed through a forage cutter and homogenized. A subsample of 500 ± 1.0 g of chopped stalks was pressed at 250 kgf cm^{-2} for 60 s to separate the juice from the pulp (CONSECANA, 2006). The juice obtained was analyzed for apparent sucrose levels in the juice (AS), juice purity (PUR), total recoverable sugars in the juice (TRS), and inorganic phosphorus (Pi). From the wet pulp, the stalk fiber level (fiber) was determined. The Pi calculation was carried out at the Center for Agricultural Sciences Agricultural Chemistry Laboratory (ASAC) of Alagoas Federal University (UFAL), in accordance with the methods described by Delgado et al. (1984). The other analyses were carried out at the Triunfo Mill Juice Quality Analyses Laboratory, following the methods described by Fernandes (2000) and Lavanholi (2008).

In the last evaluation, at 17 months after planting and at 12 months after cane-plant collection, industrialized stalk and sugar productivity were determined for each variety. The evaluation was carried out in plot rows 3, 4, and 5, from left to right. The plants were cut close to the soil, separated, clipped, and weighed, to determine industrialized stalk productivity in tons of sugarcane per hectare (TSH). In a subsample of these stalks, the juice was extracted and the TRS was determined (Fernandes, 2000). Gross income per hectare of sugar (GIS) was obtained by multiplying stalk productivity per hectare by TRS.

The data were submitted for variance analysis using the F test and the averages compared using the Scott-Knott test with a 5% probability. These analyses were carried out with the help of the Sisvar software (Ferreira, 2011).

RESULTS AND DISCUSSION

In the cane-plant cycle, the AS and TRS levels were significantly influenced by the varieties, by the harvesting period, and by the stalk third (Tabel 2). There was a significant difference in fiber between the stalk thirds and the harvesting periods, while PUR was only affected by the stalk third (Table 2). Pi was influenced by the variety and by the stalk third. In the first regrowth cycle, all of the variables were influenced by the varieties, by the harvesting period, and by the stalk third (Table 2). There was interaction between the harvesting period and the stalk third for all the juice quality variables analyzed in the first regrowth cycle (Table 2) and for AS, PUR, and TRS in the cane-plant cycle. The interaction between the varieties and harvesting period was significant for Pi in the cane-plant cycle and for AS, PUR, and TRS in the first regrowth cycle.

RB961552 presented AS and TRS levels that were 10 and 9% lower than the averages for the RB92579 and RB98710 varieties, in the cane-plant cycle, and 10 and 8% lower in the first regrowth cycle, respectively (Table 3). The R92579 and RB98710 varieties presented statistically similar averages in the two cycles, for AS and TRS, except for AS in the first regrowth cycle, when RB98710 presented a 2.4% higher average. TRS and AS behaviors are similar, since the TRS variable depends on the sucrose level present in the cane juice (Oliveira et al., 2014b).

In a study conducted by Calheiros et al. (2012), regarding RB867515 and RB92579 cultivated in Rio Largo, in the Zona da Mata in Alagoas, in the cane-plant cycle, AS values were obtained for RB92579 that are similar to those observed in this study. Moreover, Oliveira et al. (2011), in a study conducted in Boca da Mata, AL, observed AS levels fluctuating around 18.0% for RB98710, RB867515, and RB92579, collected at the end of the Alagoan harvest.

AS and TRS levels were always lower at the beginning of the harvest (Table 3). The increase in sucrose in the stalk is associated with the reduction in available soil water and the action of invertase enzymes and sucrose phosphate, as cited by Vieira (1988) and Casagrande and Vasconcelo (2008). In these studies, it was verified that acid invertase activity is high in internodes in elongation, but absent in mature internodes. In the mature stalk internodes, there is an increase in alkaline invertase and sucrose phosphate synthesis. In the cane-plant cycle, there was no statistical difference for AS and TRS levels in the middle and at the end of the harvest. However, in the second year of cultivation, the sugarcane collected at the end of the harvest presented a higher AS level. This occurs due to the reduciton in available soil water and consequent hydric restriction in the plant, which influences sugarcane maturation (Toppa et al., 2010). In Brazil, the low temperatures associated with hydric deficit are the main climatic factors responsible for sugarcane maturation. In Alagoas, it is the main climatic factor related to sugarcane maturation (Calheiros et al., 2012).

In the MT and LT, AS and TRS levels did not differ between any crop cycle (Table 3), with an average of 18.93% and 149.70 kg Mg^{-1} in the cane-plant cycle and 19.47% and 156.75 kg Mg^{-1} in first regrowth, respectively. The difference between the UT and MT and LT averages was 25.94 and 17.15%, respectively. This difference was lower than that observed by Martins (2004), who while working with the SP823530, SP835073, and RB835486 varieties observed an average difference of 71.43%. This greater difference in sucrose levels between stalks is due to a shorter sugarcane maturation phase, as excess rainfall in the study delayed cane dehydration.

In the interaction between the harvest period and stalk thirds (Tables 4 and 5), it was observed that the UT always presented lower AS and TRS levels. For cane-plant, there was no statistical difference for AS and TRS levels in the MT and LT in any harvest period. On the other hand, for first regrowth, the AS and TRS levels increased in the UT, MT, and LT at the beginning of the harvest. As the harvest advanced, the difference in sucrose concentrations between the thirds decreased, showing advanced maturity (Leite et al., 2010; Toppa et al., 2010).

From the analysis of the interaction between variety and harvest period, in the first regrowth cycle (Table 6), it is observed that AS and TRS levels increase progressively as the harvest advances. The RB92579 and RB98710 varieties did not differ between each other in the three harvest periods, and were always greater than RB961552. The percentage difference between the AS level in RB961552 and the average for the other two varieties was 10.07, 15.29, and 14.23%, at the beginning, in the middle, and at the end of the harvest, respectively. On the other hand, RB961552 presented a lower TRS at the beginning and in the middle of the harvest, however was similar to RB92579 and RB98710 at the end of the harvest.

In the cane-plant cycle, there was no statistical difference between the varieties studied, with the average PUR value being 87.15% (Tables 2 and 3). In the first regrowth cycle, RB92579 was the variety that presented the greatest PUR, with 88.75%, this being 1.6% greater than the average for the other varieties. The harvest period only influenced PUR in the first regrowth cycle, when the juice collected at the end of the harvest presented greater purity. In both cycles, the UT presented lower purity than the MT and LT. This lower purity in the UT is the result of the sugarcane maturation process, which occurs from the base to the apex (Segato et al., 2006; Leite et al., 2010; Toppa et al., 2010).

On analyzing the interaction between the stalk thirds and harvest period, it was observed that, in the two cultivation cycles (Tables 4 and 5), the UT had less juice purity, however, at the end of the harvest, there was no

Table 2. Values and significance of average squares from variance analyses and variation coefficients of soluble solid percentages (SS), apparent sucrose in juice (AS), purity (PUR), total recoverable sugars (TRS), and inorganic phosphorus (Pi), for three sugarcane varieties, in three harvesting periods (P), in three parts of the stalk (third), in the cane-plant and first regrowth cycles.

Source of variation	G.L	Average squares				
		AS (%)	PUR (%)	Fiber (%)	TRS (Mg ha^{-1})	Pi (mg L^{-1})
Cane plant						
Variety (V)	2	43.55**	11.36^{ns}	1.31^{ns}	2,419.14**	1,331.58**
Third (T)	2	361.79**	822.42**	10.88**	20,792.27**	1,290.13**
Period (P)	2	64.62**	14.59^{ns}	30.86**	2,142.24**	119.08^{ns}
Block	4	1.35	11.99	0.39	59.99	313.35
V × T	4	2.42^{ns}	6.33^{ns}	0.43^{ns}	61.60^{ns}	50.556^{ns}
V × P	4	2.43^{ns}	10.67^{ns}	0.99^{ns}	61.01^{ns}	417.58**
T × P	4	30.76**	223.26**	0.44^{ns}	1,664.56**	19.21^{ns}
V × T × P	8	1.13^{ns}	12.90^{ns}	0.63^{ns}	17.95^{ns}	121.38^{ns}
Residual	104	2.56	6.52	0.66	96.45	93.14
General average		17.29	87.15	14.34	137.32	49.03
C.V (%)		9.27	2.93	5.66	7.15	19.68
First regrowth						
Variety (V)	2	46.82**	30.35**	1.51*	2,243.32**	1,343.41**
Third (T)	2	199.56**	201.16**	110.27**	16,524.14**	333.12*
Period (P)	2	114.90**	35.44**	28.48**	4,108.60**	2,084.41**
Block	4	0.94	4.71	0.29	93.14	348.37
V × T	4	2.62^{ns}	10.03^{ns}	2.59^{ns}	108.96^{ns}	40.69^{ns}
V × P	4	3.51*	16.03*	0.38^{ns}	191.40*	114.01^{ns}
T × P	4	10.91**	29.73**	5.55**	358.45**	556.57**
V × T × P	8	1.30^{ns}	4.96^{ns}	0.52^{ns}	45.54^{ns}	353.21**
Residual	104	1.15	6.16	0.35	74.26	96.53
General average		18.56	87.81	14.90	145.73	105.67
C.V (%)		5.78	2.83	3.99	5.91	9.30

^{ns},*,** represent, respectively, not significant and significant to 5.0% and 1.0% probability using the F test.

Table 3. Average levels of Apparent Sucrose in Juice (AS) in %, Total Recoverable Sugars (TRS) in kg Mg^{-1}, Purity (PUR) in %, Fiber (F) in %, and inorganic Phosphorus (Pi) in mg L^{-1}, for the RB92579, RB961552, and RB98710 sugarcane varieties, cultivated in Anadia, in the Alagoan *agreste* region, and collected at the beginning, in the middle, and at the end of harvest, in the upper, middle, and lower thirds.

Parameter	AS	PUR	F	TRS	Pi	AS	PUR	F	TRS	Pi
		%		kg Mg^{-1}	mg L^{-1}		%		kg Mg^{-1}	mg L^{-1}
Variety			Cane-plant					First regrowth		
RB92579	17.99^a	87.7^a	14.30^a	141.64^a	45.80^b	18.90^b	88.7^a	14.74^a	147.98^a	99.4^b
RB98710	17.72^a	86.7^a	14.20^a	141.48^a	55.31^a	19.97^a	87.4^b	15.10^a	151.39^a	108.7^a
RB961552	16.17b	87.0^a	14.53^a	128.86^b	45.98^b	17.41^c	87.3^b	14.87^b	137.81^b	108.9^a
Harvesting periods										
Beginning	15.91^b	86.5^a	13.42^c	129.64^b	47.71^a	17.08^c	87.1^b	14.10^c	137.01^b	101.8^b
Middle	18.06^a	87.5^a	14.59^b	142.98^a	48.54^a	18.34^b	87.5^b	14.93^b	144.23^a	113.5^a
End	17.92^a	87.5^a	15.02^a	139.36^a	50.85^a	20.25^a	88.8^a	15.69^a	155.94^a	101.6^b
Stalk thirds										
Upper	14.02^b	82.2^b	14.89^a	112.57^b	43.65^c	16.13^b	85.4^b	16.71^a	123.67^b	108.8^a
Middle	18.87^a	89.4^a	14.21^b	148.16^a	49.08^b	19.61^a	88.8^a	14.07^b	155.24^a	103.8^b
Lower	29.99^a	89.6^a	13.94^b	151.25^a	54.36^a	19.33^a	89.3^a	13.93^b	158.27^a	104.4^b

[1]Averages followed by the same letter in the column do not differ statistically between each other using the Scott-Knott test with a 5% probability.

Table 4. Average values of Apparent Sucrose in Juice (AS) in %, Total Recoverable Sugars (TRS) in kg Mg^{-1}, Purity (PUR) in %, in the upper, middle, and lower thirds, collected at the beginning, in the middle, and at the end of harvest, in the cane-plant cycles.

Stalk thirds	Collection periods		
	Beginning of harvest	Middle of harvest	End of harvest
AS (%)			
Upper	10.79^B	15.47^B	15.79^B
Middle	18.06^A	19.23^A	18.86^A
Lower	18.88^A	19.45^A	19.09^A
TRS (kg Mg^{-1})			
Upper	91.36^B	122.61^B	123.73^B
Middle	145.55^A	153.77^A	145.15^A
Lower	152.01^A	152.56^A	149.18^A
PUR (%)			
Upper	76.78^B	83.35^B	86.53^A
Middle	90.73^A	89.44^A	88.05^A
Lower	91.98^A	89.63^A	87.88^A

Averages followed by the same letter in the column do not differ statistically between each other using the Scott-Knott test with a 5% probability.

Table 5. Average values of Apparent Sucrose in Juice (AS) in %, Total Recoverable Sugars (TRS) in kg Mg^{-1}, Purity (PUR) in %, Fiber (F) in %, and inorganic Phosphorus (Pi) in mg L^{-1}, in the upper, middle, and lower thirds, collected at the beginning, in the middle, and at the end of harvest, in the first regrowth cycles

Stalk thirds	Collection periods		
	Beginning of harvest	Middle of harvest	End of harvest
AS (%)			
Upper	13.81^c	15.86^b	18.73^b
Middle	18.10^b	19.75^a	20.97^a
Lower	19.32^a	19.43^a	21.05^a
TRS (kg Mg^{-1})			
Upper	110.48^b	121.86^b	138.67^b
Middle	145.77^b	156.41^a	163.55^a
Lower	154.79^a	154.41^a	165.62^a
PUR (%)			
Upper	83.55^b	80.16^b	87.88^a
Middle	88.15^a	88.97^a	88.56^a
Lower	89.57^a	90.35^a	89.95^a
Fiber (%)			
Upper	15.18^a	13.86^a	18.16^a
Middle	13.54^b	13.17^b	14.49^b
Lower	13.56b	13.23^b	14.40^b
Pi (mg L^{-1})			
Upper	109.98^a	115.90^a	85.06^b
Middle	87.77^b	108.23^a	92.22^b
Lower	86.15^b	101.00^a	107.92^a

Averages followed by the same letter in the column do not differ statistically between each other using the Scott-Knott test with a 5% probability.

Table 6. Average values of Apparent Sucrose in Juice (AS) in %, Total Recoverable Sugars (TRS) in kg Mg^{-1}, and Purity (PUR) in %, in the RB92579, RB961552, and RB98710 varieties, collected at the beginning, in the middle, and at the end of harvest, in the first regrowth cycle.

Variety	Collection periods		
	Beginning of harvest	Middle of harvest	End of harvest
AS (%)			
RB92579	17.35[a]	18.92[a]	20.44[a]
RB961552	15.89[b]	16.67[b]	19.67[b]
RB98710	17.99[a]	19.44[a]	20.65[a]
TRS (kg Mg^{-1})			
RB92579	138.60[a]	148.54[a]	156.81[a]
RB961552	128.50[b]	132.65[b]	152.30[a]
RB98710	143.93[a]	151.49[a]	158.73[a]
PUR (%)			
RB92579	87.48[a]	88.03[a]	89.179[a]
RB961552	86.32[a]	86.01[b]	89.203[a]
RB98710	87.46[a]	85.45[b]	88.020[a]

Averages followed by the same letter in the column do not differ statistically between each other using the Scott-Knott test with a 5% probability.

statistical difference between the thirds. Uniformity of purity in the stalk is expected when sugarcane reaches maximum maturity, presenting a maturity index between 0.85 and 1.0 (Toppa et al., 2010). The maturation index is the proportion of apparent sucrose content, determined using polarimetry, from the base to the industrially useable stalk. It is an index used to evaluate sugarcane maturation (Liz et al., 2016).

Analyzing the interaction between the varieties and the harvest period (Table 6), in the first regrowth cycle, it is found that in the middle of the harvest, RB92579 presented greater purity, however it did not differ from the other varieties at the beginning and end of the harvest.

In all of the harvesting periods, all of the varieties presented over 80% purity, which is considered adequate for sugarcane industrialization (Rhein et al., 2016; Rodolfo Junior et al., 2016). In this paper, average purity in the cane-plant and first regrowth cycles was greater than that reported by Oliveira et al. (2011) and Silva (2013). High PUR in sugarcane juice is desired at the time of harvesting, since it implies a higher concentration of sucrose and reduced amino acids, organic acids, starch, reducing sugars, and other color precursor compounds (Rhein et al., 2016; Rodolfo Junior et al., 2016).

The average fiber level in the three varieties for cane-plant was 14.34% (Table 3), approximately 11.08% higher than that observed by Oliveira et al. (2011) and Silva (2013). In the first regrowth cycle, RB98710 presented a higher level of fiber, with 15.10%, while the RB92579 and RB961552 varieties did not differ between each other and present an average of 14.80%. In both cycles, the level of fiber increased as the harvest advanced and the UT presented a higher level of fiber than the MT and LT, which did not differ between each other. The difference between the UT and the average for the MT and LT was 5.51 and 16.21% in the cane-plant cycle and first regrowth, respectively. The higher level of fiber in the UT is probably due to the lower accumulation of sucrose compared to the other thirds.

Fiber is important when it comes to industries' energy balance, as pulp is used for obtaining electrical energy; however, a high level of fiber causes resistance to juice extraction (Simões et al., 2015; Rodolfo Junior et al., 2016). To maintain energy balance, a percentage of fiber between 10 and 12.5% has been recommended. However, the Northeast region of Brazil presents greater evapotranspiration than the Center-South region, for which reason sugarcane cultivated in the Northeast has a higher level of fiber at the time of harvesting (Oliveira et al., 2011, 2014b).

RB92579 presented a lower level of Pi in the two cultivation cycles, although it did not differ from RB961552 in the cane-plant cycle (Table 3). On the other hand, RB98710 was the variety that presented the highest level of Pi in the juice. In the cane-plant cycle, the level of Pi in RB92579 juice was lower at the beginning of the harvest, but the concentration rose during the harvest, reaching the same values as RB98710 at the end of the harvest (Table 7). The Pi concentration in the sugarcane cycle was lower than in the first regrowth cycle, probably due to the greater production of biomass in the cane-plant cycle, resulting in dilution of the absorbed phosphorus (Oliveira et al., 2007). The average

Table 7. Average values for inorganic phosphorus (Pi) in mg L^{-1} in the RB92579, RB961552, and RB98710 varieties, collected at the beginning, in the middle, and at the end of harvest, in the cane plant cycle.

Variety	Collection periods		
	Beginning of harvest	Middle of harvest	End of harvest
Pi (mg L^{-1})			
RB92579	38.99^c	44.38^b	54.04^a
RB961552	47.11^b	46.93^b	46.90^b
RB98710	57.03^a	54.30^a	54.61^a

Averages followed by the same letter in the column do not differ statistically between each other using the Scott-Knott test with a 5% probability.

Pi levels in RB92579, RB961552, and RB98710 juice for the two cycles were 73, 77, and 82 mg L^{-1} of P, respectively. High Pi levels in sugarcane juice during industrialization are desirable for reducing the cost of clarifying the juice, since the addition of exogenous Pi is necessary when juice levels are not adequate for good clarification (below 100 mg L^{-1}) (Mohammed et al., 2016). Pi levels in juice of around 180 mg L^{-1} were obtained by Oliveira et al. (2011) in studies conducted in the Alagoan Agreste region involving the RB867515 variety. Tasso Júnior et al. (2014) evaluated Pi levels in the CTC9, CT15, and CTC16 cane varieties and did not find any difference between the varieties with regards to Pi in the juice, finding an average juice value of 147 mg L^{-1}. In the study conducted by Martins (2004), the Pi level was influenced by the variety, with Pi values of 151, 236, and 388 mg L^{-1} for the SP823530, SP835073, and RB835486 varieties, respectively.

The Pi levels only differed between the harvesting periods in the first regrowth cycle, when the sample corresponding to the middle of the harvest presented a higher Pi level than in the other samples (Table 3). Pi level behavior in the thirds differs between the cycles studied. In the cane-plant cycle, the highest Pi content was observed in LT, however in first regrowth, the UT presented the highest Pi level. By analyzing the interaction between the thirds and the harvesting periods in the first regrowth cycle (Table 5), it is observed that at the beginning of the harvest, the UT presented the lowest Pi level, in the middle of the harvest there was no difference between the thirds, and at the end of the harvest the LT has the highest Pi level. When sugarcane is not yet completely mature, the UT is the most biochemically active part, demanding greater quantities of Pi (Oliveira et al., 2014b; Tasso Júnior et al., 2014). With sugarcane maturity, Pi comes to be required in greater quantities in the LT and MT, where it acts as an energy source in the sucrose accumulation process in the cell vacuoles (Casagrande and Vasconcelos, 2008). Thus, when sugarcane starts the maturation process, Pi migrates from the UT to the MT and LT.

Table 8 presents the average square results from the variance analysis for TSH, TRS, and GIS, for the RB92579, RB98710, and RB961552 varieties, in the cane-plant and first regrowth cycles. It is observed that there was a varietal effect for all the variables only in the cane-plant cycle. The averages for TSH, TRS, and TRS_{ha} in the cane-plant cycle are shown in Table 9.

RB92579 was the variety that presented the highest TSH, at around 15% more than the other varieties, and consequently the highest GIS. RB98710, despite having similar TRS to RB92579, produced fewer stalks and therefore its GIS was lower. RB961552 was less productive for all the varieties analyzed. The RB92579 variety presented a higher GIS than those observed by Aquino et al. (2016). Ferreira Junior et al. (2014) indicated that RB98710 has a high sugar level and high productivity. When cultivated using drip irrigation, they observed that RB98710 sugar productivity was 17.8 Mg ha^{-1} (Ferreira Junior et al., 2014), similar to the RB92579 productivity observed in this study. The stalk productivity obtained in this study (118.52 Mg ha^{-1}) is considered as average to high for the state. In Alagoas, the maximum sugarcane growth phase occurs on short days, and therefore under low luminosity, unlike in the Center-South of Brazil, where increased luminosity coincides with greater hydric availability. The non-coincidence of maximum hydric availability with luminosity negatively influences photosynthetic rates, resulting in lower cane productivity in Alagoas compared to the Center-South (Oliveira et al., 2011; Calheiros et al., 2012).

Studies carried out in Brazil (Calheiros et al., 2012; Oliveira et al., 2014b) indicate RB92579 as one of the most productive varieties, and this is one of the reasons for which, together with RB867515, it is in expansion. However, the juice from this variety presents high phenolic and flavonoid levels (Oliveira et al., 2011), characteristics that are not contemplated in sugarcane payment for recoverable sugar (TRS), but which negatively contribute to juice color and makes industrialization difficult. Phenolic compounds are substances that negatively influence juice color and consequently that of the sugar, reducing the quality and acceptability of the product (Qudsieh et al., 2002). They

Table 8. Average values from variance analysis for Industrialized Stalk Production (ISP) in Mg ha^{-1}, Total Recoverable Sugars in Juice (TRS) in kg Mg^{-1} and Gross Income of Sugar (GIS) in Mg ha^{-1}, for the RB92579, RB961552, and RB98710 varieties, in the cane plant and first regrowth cycles, collected at the end of harvest.

Source of variation	GL	Average squares					
		Cane-plant			First regrowth		
		ISP (Mg ha^{-1})	TRS (kg Mg^{-1})	GIS (Mg ha^{-1})	ISP (Mg ha^{-1})	TRS (kg Mg^{-1})	GIS (Mg ha^{-1})
Variety	2	800.62**	162.60*	19.17**	226.301^{ns}	89.10^{ns}	4.51^{ns}
Blocks	4	242.08	28.47	4.65	170.61	29.19	3.40
Residual	8	42.19	35.45	0.57	45.67	19.98	1.06
General average		118.52	132.70	15.73	66.98	156.61	10.47
C.V. (%)		5.48	4.49	4.83	10.09	2.85	9.86

**Significant to 1% probability using the F test; ^{ns}Not significant to 1% probability.

Table 9. Average values of Industrialized Stalk Productivity (ISP) in Mg ha^{-1}, Total Recoverable Sugars (TRS) in kg Mg-^{1}, and Gross Income of Sugar (GIS) in Mg ha^{-1}, for the RB92579, RB961552, and RB98710 varieties, in the cane plant cycle, collected at the end of harvest.

Variety	ISP (Mg ha^{-1})	TRS (kg Mg-^{1})	GIS (Mg ha^{-1})
RB92579	133.10^{A}	135.15^{A}	17.92^{A}
RB961552	112.00^{B}	126.18^{B}	14.14^{B}
RB98710	110.46^{B}	136.77^{A}	15.13^{B}
General Average	118.52	132.70	15.73

Averages followed by the same letter in the column do not differ statistically between each other using the Scott-Knott test with a 5% probability.

also have a negative effect on fermentation, especially by reducing the action of invertase excreted by the yeast.

The productive superiority of RB92579 was not proven in the first regrowth cycle, as there was no significant difference for any of the variables in this cycle. The averages for TSH, TRS, and GIS in the first regrowth cycle were 66.98 Mg ha^{-1}, 156.61 kg Mg^{-1}, and 10.47 Mg ha^{-1}, respectively (Table 8). The TRS was similar to that found by Silva (2013), however the TSH and GIS were lower. The decrease in productivity in the first regrowth cycle was high and probably influenced due by the hydric stress in the growth phase in the second cycle of the study.

Hydric deficit in the growth phase is one of the main causes of reduced sugarcane productivity (Rhein et al., 2016; Rodolfo Junior et al., 2016), since it causes morphophysiological defense alterations such as reductions in leaf area and gas exchange. Bueno et al. (2012) studied 10 sugarcane genotypes in the first regrowth cycle collected in different periods in the state of Paraná, where it was observed that hydric deficit in the cane growth phase reduced agricultural production and the accumulation of sugar collected in April, the beginning of the harvest in the region.

Conclusions

RB961552 has lower levels of apparent sucrose, total recoverable sugars, and purity, than RB92579 and RB98710. However, all the varieties have ideal apparent sucrose and purity levels for the samples in the three harvest periods, with these values increasing as the harvest advanced.

RB98710 has higher Pi levels in the juice than RB92579 and RB921552. In the cane-plant cycle, all the varieties have lower than ideal Pi levels for juice clarification, while in the first regrowth cycle, RB98710 and RB961552 have Pi levels within the ideal range.

In the cane-plant cycle, the RB92579 variety has higher stalk and sugar productivity than the other varieties.

Conflict of Interests

The authors have not declared any conflict of interests.

AKNOWLEDGEMENTS

The authors acknowledge the Triunfo Mill for the logistical support in conducting the study and CAPES for granting the funding to develop the paper.

REFERENCES

Aquino GS, Medina CC, Menezes Junior AO, Pasini A, Brito OR, Cunha

ACB, Santos Júnior JH, Kussaba DAO, Almeida LF (2016). Impact of harvesting w ith burning and management of straw on the industrial quality and productivity of sugarcane. Afr. J. Agric. Res. 11(28):2462-2468.

Benedini MS (2006). Controle biológico de pragas na cana-de-açúcar. In: Marques et al.Tópicos em tecnologia sucroalcooleira. São Paulo, SP:101-119.

Bueno PMC, Daros E, Oliveira RA, Zambon JLC, Bespalhok Filho JC, Weber H (2012). Harvest dates and the productivity in sugarcane genotypes, in first ratoon. Semin: Cien. Agrar. 33:2715-2726.

Calheiros AS, Oliveira MW, Ferreira VM, Barbosa GVS, Santiago AD, Aristides EVS. (2012). Production of biomass, from sugar and protein in function of sugarcane varieties and phosphorous fertilization. Semin: Cien. Agrar. 33:809-818.

Casagrande AA, Vasconcelos ACM (2008). Fisiologia da parte aérea. In: Dinardino-Miranda LL, Vasconcelos ACM, Landell MGA. Cana-de-Açúcar, Instituto Agronômico, Campinas. pp. 57-78.

CONSECANA (2006). Conselho dos produtores de cana-de-açúcar, açúcar, álcool do estado de São Paulo. Manual de instruções. 5 ed. Piracicaba, 112p.

Delgado AA, Cesar, MAA, Ferreira LJ, Michelon JAA (1984). Determination of phosphates in sugarcane juice in the sugar and alcohol industries. STAB. 3:31-34.

Embrapa – Empresa Brasileira de Pesquisa Agropecuária. (2013). Sistalka brasileiro de classificação de solos. Centro Nacional de Pesquisa de Solos: Rio de Janeiro 353p.

Fernandes AC (2000). Cálculos na agroindústria da cana-de-açúcar . STAB – Soc. Técn. Açúcar. Alcool. Bras. 193p.

Ferreira DF (2011). Sisvar: a computer statistical analysis systalk. Ciênc. Agrotec. 35:1039-1042.

Ferreira Junior RA, Souza JL, Escobedo JF, Teodoro I, Lura GB, Araújo Neto RA (2014). Sugarcane w ith drPi irrigation in tw o row spacing. Rev. Bras. Eng. Agríc. Ambient. 18:798-804.

Lavanholi MGDP (2008). Qualidade da cana-de-açúcar como matéria prima para a produção de açúcar e álcool. In: Dinardo-Miranda LL, Vasconcelos ACM, Landell MGA (Org.). Cana-de-Açúcar. Campinas: Instituto Agron. Camp. 1:697-722.

Leite GHP, Crusciol CAC, Siqueira GF, Silva MA (2010). Technological quality at different portions of the stalk and productivity of sugarcane under effect of rPieners. Bragantia 69(4):861-870.

Liz CN, Rodrigues RA, Silva SW, Santos AC, Melo TF (2016). Production of artisanal cachaça and its context: a case study w ith alambiques of south of Minas Gerais. Rev. UIIPS. 4(4):20.

Martins NGS (2004). Phosphates in sugarcane. Dissertação (Mestrado) - Escola Superior de Agricultura "Luiz de Queiroz.", Piracicaba. 99 p.

Mohammed H, Solomon WK, Bultosa G (2016). Optimization of phosphate and anionic polyacrylamide flocculant (apf) level for sugar cane juice clarification using central c)omposite design. J. Food Process. Preserv. 40:67-75.

Oliveira FM, Aguilar PB, Teixeira MFF, Aspiazú I, Monção FP, Antunes APS (2014a). Agrotecnólogical characteristics of cane sugar at different times of suppression of irrigation and fertilizer levels. Semin: Cien. Agrar. 35:1587-1606.

Oliveira MW, Freire FM, Macêdo GAR, Ferreira JJ (2007). Mineral nutrition and fertilization of sugarcane. Inf. Agropecu. 28:30-43.

Oliveira MW, Magrini JL, Lyra FEV, Valduga GR, Pereira MG, Tenorio CJM, Aristides EVS (2011). Production of RB867515 influenced by application of humic substances, amino acids and seaw eed extract. STAB. 30:30-33.

Oliveira MW, Silva VSG, Reis LS, Oliveira DC, Silva JCT (2014b). Yield and quality of the juice from three sugarcane varieties cropped on northeast Minas Gerais. Ciênc. Agric. 12:9-16.

Qudsieh HY, Yusof S, Osman A, Rahman RA (2002). Effect of Maturity on Chlorophyll, Tannin, Color, and Polyphenol Oxidase (PPO) Activity of Sugarcane Juice (Saccharum officinarum Var. Yellow Cane). J. Agric. Food Chem. 50(6):1615-1618.

Raij B (2011). Fertilidade do solo e manejo de nutrientes. International Plant Nutrition Institute: Piracicaba 420 p.

Rhein A FL, Pincelli RP, Arantes MT, Dellabiglia WJ, Kölln OT, Silva MA (2016). Technological quality and yield of sugarcane grown under nitrogen doses via subsurface drPi fertigation. R. Bras. Eng. Agríc. Ambiental. 20(3):209-214.

RIDESA - Rede Interuniversitária para o Desenvolvimento do Setor Sucroalcooleira (2012). Censo varietal Brasil. Available at:<http://ridesa.agro.ufg.br/pages/44741>. Access in: 5 SET 2016.

RIDESA - Rede Interuniversitária para o Desenvolvimento do Setor Sucroalcooleira (2010). Catálogo nacional de variedades "RB" de cana-de-açúcar. Curitiba 136 p.

Rodolfo Junior F, Ribeiro Junior WQ, Ramos MLG, Rocha OC, Batista LMT, Silva FAM, (2016). Productivity and quality of third ratoon sugarcane varieties under variable hydrological regime. Nativa. Sinop. 4(1):36-43.

Segato SV, Mattiuz CF, Mozambani AE (2006). Aspectos fenológicos da cana-de-açúcar. In: Segato SV, Pinto AS, Jendiroba E, Nóbrega JCM (Ed.). Atualização em produção de cana-de-açúcar. Piracicaba: 2:19-36.

Silva TGF, Moura MSB, Zolnier S, Souza LSB (2014). Accumulated dry biomass, partitioning and industrial yield of irrigated sugarcane in the Brazilian Semi-Arid. Rev. Cer. 61:686-696.

Silva VSG (2013). Status nutritional, quality industrial and productivity of varieties of sugarcane in cycles of cane-plante, first ratoon and second ratoon. Dissertação (Mestrado em Agronomia) – Universidade Federal de Alagoas, Rio Largo. 64p.

Simões WL, Calgaro M, Coelho DS, Souza MA, Lima JA (2015). Physiological and technological responses of sugarcane to different irrigation systalks. Rev. Cienc. Agronom. 46:11-20.

Souza PHN, Bastos GQ, Anunciação Filho CJ, Dutra Filho JA, Machado PR (2012). Evaluation of sugarcane genotypes for initial season in the central microregion of Pernambuco. Ceres 59(5):677-683.

Tasso Júnior LC, Silva Neto HF, Homem BFM, Marques MO (2014). inorganic phosphates in juices from different parts of sugarcane stalks (cultivars CTC 9, CTC 15 and CTC 16). Interciência 39:274-276.

Toppa EVB, Jadoski CJ, Julianette A, Hulshof T, Ono EO, Rodrigues JD (2010). Aspectos da fisiologia de produção da cana-de-açúcar (*Saccharum officinarum* L.). Pesqui. Apl. Agrotecnol. Guarap. 3(3):217-223.

Vieira IMS (1988). Relationship betw een sugar levels and invertase activities in tissues of four cultivars of sugarcane (Saccharum ssp.) cultivated in the field. Tese (Doutorado) – Escola Superior de Agricultura "Luiz de Queiroz", Piracicaba 129 p.