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BIOTECHNOLOGY

Production components of agroindustrial interest of sugarcane varieties under subsurface drip irrigation in semiarid conditions

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ABSTRACT. The identification of promising commercial varieties for irrigated crops in semiarid conditions based on characters of interest to sugarcane agro-industries is important, considering the search for high sugarcane yields to obtain sustainable crops. Thus, the objective of this work was to evaluate production components of agroindustrial interest of different sugarcane varieties grown under subsurface drip irrigation in the Semiarid region of Brazil, during two crop cycles. A randomized block experimental design was used, in an 8×2 factorial arrangement (varieties and cycles) with three replications. The sugarcane juice quality, sugar yield, and culm yield were evaluated in each cycle. Gross sugar percentage, sugarcane culm yield, juice apparent sucrose content, and juice purity were affected by the crop cycles. Soluble solids content presented strong significant correlation with most variables of agroindustrial interest. The path coefficient analysis showed that juice apparent sucrose content was the explanatory character with higher direct effect on soluble solids and that this variable presented high indirect effects on most explanatory variables. The sugarcane varieties RB72454 and Q124 are recommended for production managements with drip irrigation under semiarid conditions. Soluble solids content can be used as an alternative for direct selection of varieties with higher sugar yields in different cycles.

Keywords: *Saccharum* sp.; technological quality parameters; Pearson's correlation; path coefficient analysis.

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Introduction

Brazil is the largest sugarcane (*Saccharum* sp.) producing country and one of the main suppliers of sugar and ethanol to the world (Chea, Saengprachatanarug, Posom, Wongphati, & Taira, 2020). The large planted areas and favorable edaphoclimatic conditions to sugarcane make Brazil highly competitive in international markets. The Northeast region of Brazil presents promising areas for the expansion of sugarcane crops due to the favorable conditions of logistics, soil, and climate for the crop (Oliveira, Braga, Santos, & Walker, 2016). According to Silva et al. (2021), the cultivation of sugarcane, combined with the use of its by-products, can generate social and economic benefits in the producing region.

The performance of sugarcane crops in Juazeiro, Lower Middle São Francisco Valley, state of Bahia, Brazil, stands out among other producing regions of the country, mainly due to favorable edaphoclimatic conditions (Simões, Calgaro, Coelho, Souza, & Lima, 2015), in addition to high mean yields (Oliveira & Braga, 2019). The increasing use of fertigation managements and efficient irrigation are among the factors responsible for yield gains in the latest crops seasons in this region. (Simões, Calgaro, Guimarães, Oliveria, & Pinheiro, 2018).

However, sugarcane crops in the Northeast region of Brazil are undergoing many challenges regarding adaptation of varieties to different production environments, focused on selecting desirable characteristics according to the environmental conditions (Oliveira et al., 2016). Intrinsic characteristics of the plants, such as contents of juice apparent sucrose and soluble solids, purity, and percentages of fiber, moisture, and polarizable sugar (Pol), known as technological parameters, can define the sugarcane quality for sugar and ethanol productions (Fernandes, 2011).

Thus, information obtained through genotypical and phenotypic correlations are important to indicate the correlation level between variables of interest for sugarcane crops (Tena, Mekbib, & Ayana, 2016; Ukoskit et al., 2019; Chea et al., 2020). However, the correlation coefficient between two characteristics is dependent on the effect of a third variable or a group of variables on them (Cruz, 2013).

Thus, path coefficient analysis is indispensable to better understanding phenomena associated with correlations between variables of agronomic interest for sugarcane crops. Some studies have emphasized the importance of estimating correlations using path coefficient analysis for sugarcane (Tahir, Khalil, & Rahman, 2014; Barbosa et al., 2017).

Therefore, the hypothesis raised was that the semiarid climate conditions combined with full irrigation favor technological parameters of sugarcane varieties over the cycles. Moreover, information on parameters of easy measurement that can be used for sugarcane production makes easy the screening process. Thus, considering the need for improving the identification process of promising sugarcane varieties for semiarid conditions, the objective of this work was to evaluate agroindustrial components of different sugarcane varieties grown under subsurface drip irrigation in the Semiarid region of Brazil, during two crop cycles.

Material and methods

The experiment was conducted in a commercial parcel of a sugarcane agro-industry in the municipality of Juazeiro, state of Bahia, Brazil (9°25'S, 39°39'W, and altitude of 370 m). The climate of the region is BSwh, tropical semiarid, according to the Köppen classification. The region presents mean annual rainfall depths of approximately 500 mm, irregularly distributed, and concentrated from November to April; mean annual relative air humidity of 66%; and mean annual air temperature of 26.5°C, with the highest peaks from October to December, and milder temperatures in July (Lopes, Guimarães, Melo, & Ramos, 2017). Monthly climate data of temperature, precipitation, and reference evapotranspiration during the experiment in two crop cycles (plant and ratoon) were collected by a meteorological station installed near the experimental area (Figure 1).

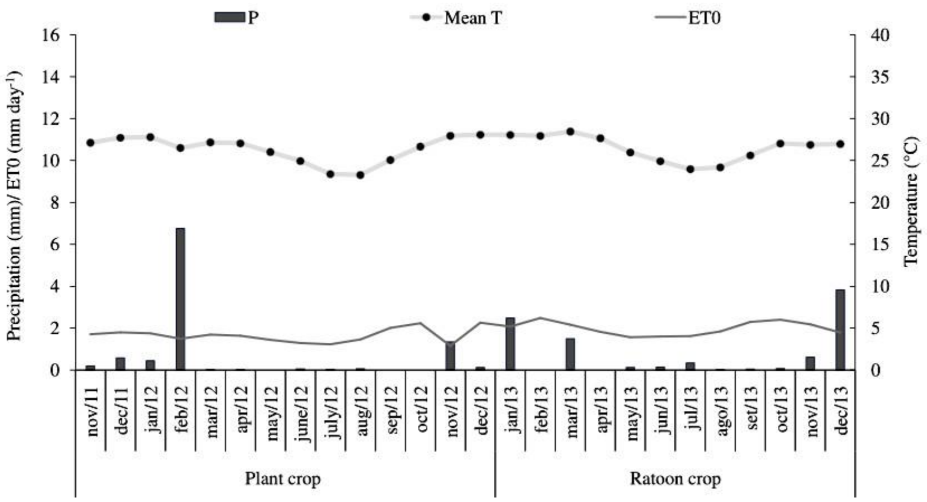

Figure 1. Monthly climate data of mean temperature (mean T), precipitation (P) and reference evapotranspiration (ET0) during the experiment. Juazeiro, Bahia State, Brazil.

A randomized block experimental design was used, in an 8 × 2 factorial arrangement with three replications; the first factor consisted of eight sugarcane varieties: RB92579, RB835089, RB72454, SP716949, VAT90212, SP943206, Q124, and RB957508, and the second factor consisted of two crop cycles (plant crop and ratoon crop), resulting in 16 treatments and 48 plots.

The planting was carried out in double rows with spacing of 0.70 × 1.30 m. The experimental plots consisted of 5 double rows with 10 m width and 12 m length. The evaluation areas consisted of the 3 central double rows, using the central 6 m width and 8 m length of each plot, totaling 48 m^2.

A subsurface drip irrigation system was used, with flow of 1.6 L h^{-1} and drips spaced 0.50 m apart, buried to a depth of 0.2 m. A daily watering shift was used, according to the calendar of irrigations of the agro-industry. The irrigation water depth of the system was calculated using the reference evapotranspiration, Kc, and the crop phenological stage, as described by Allen, Pereira, Raes, and Smith (2006).

Cultural practices and agrochemical applications were carried out according to the crop needs, using integrated pest and disease management. Soil fertilizer application at planting was based on the soil fertility analyses of the area, and topdressing applications were carried out through fertigation three times a week, according to the sugarcane crop nutrient absorption curve.

Harvest operations were carried out in December; the duration of the cycle was 14 months for the plant crop and 12 months for the ratoon crop. Ten culms were randomly collected in the evaluation area of each plot during the harvests, which were weighed and subjected to technological analyses; the remaining plants were harvested and weighed to obtain the sugarcane culm yield (Mg ha^{-1}) (SCY).

The samples were taken to the Laboratory of Technological Analysis of the agro-industry for analysis of technological parameters of the juice sugarcane: soluble solids content (°Brix), juice apparent sucrose content (POL), gross sugar percentage (GSP), sugarcane juice purity (SJP), sugarcane moisture (SM), and industrial fiber (IF), according to the manual of the company, which is based on the normative ABNT NBR 16271.

The effects of genotypes and cycles were considered as random. The residual homogeneity of variances of the two crop cycles was assessed through the ratio between the highest and lowest mean squared residuals, considering seven as the limit value for validation of the analysis of variance for the factorial arrangement, as described by Cruz (2013).

The data were analyzed using analysis of variance by the F test at 5% probability level. The characteristics whose results showed significance for the interaction between varieties and crop cycles were analyzed through statistical breakdown of varieties within crop cycles and crop cycles within varieties.

Estimates of correlation coefficients between sugarcane technological and production parameters were calculated using the Pearson's method. Considering the correlation matrices found with this method, path coefficient analysis was carried out, considering the soluble solids content (°Brix) as the base variable and SCY, POL, SJP, GSP, SM, and IF as explanatory variables.

The means were grouped by the Scott & Knott test at 5% probability level ($p < 0.05$). All analyses were carried out using the program Genes (Cruz, 2013).

Results and discussion

The analysis of variance (Table 1) confirmed the occurrence of interaction between varieties and crop cycles ($p < 0.05$) only for gross sugar percentage; this interaction denotes variation in the performance of the sugarcane varieties due to the variation in environments (cycles) for this character. The results also show significant differences ($p < 0.01$) between cycles for sugarcane culm yield, juice apparent sucrose content, juice purity, and gross sugar percentage. Soluble solids content, sugarcane moisture, and industrial fiber were not significantly affected, showing similarity between these characteristics for the varieties evaluated in the two crop cycles under semiarid conditions.

Table 1. Analysis of variance and overall means for sugarcane culm yield (Mg ha^{-1}) (SCY), soluble solids content (°Brix), juice apparent sucrose content (POL), sugarcane juice purity (SJP), gross sugar percentage (GSP), sugarcane moisture (SM), and industrial fiber (IF), evaluated in eight sugarcane varieties in two crop cycles. Juazeiro, Bahia State, Brazil, 2012/2013 crop season.

Source of variation	Mean square							
	DF	SCY	Brix	POL	SJP	GSP	SM	IF
Block	2	826.58	2.02	0.35	8.69	0.23	0.39	0.37
Variety (V)	7	360.88^{ns}	2.18^{ns}	2.28^{ns}	18.49^{ns}	1.28^{ns}	0.41^{ns}	0.39^{ns}
Crop cycle (CC)	1	11381.37^{**}	1.66^{ns}	444.32^{**}	572.01^{**}	75.93^{**}	0.81^{ns}	0.77^{ns}
V × CC	7	186.74^{ns}	1.73^{ns}	3.25^{ns}	33.73^{ns}	2.35^{*}	0.91^{ns}	0.87^{ns}
V/CC1	7	-	-	-	-	1.87^{ns}	-	-
V/CC2	7	-	-	-	-	1.76^{ns}	-	-
CC/V1	1	-	-	-	-	9.05^{**}	-	-
CC/V2	1	-	-	-	-	14.48^{**}	-	-
CC/V3	1	-	-	-	-	1.67^{ns}	-	-
CC/V4	1	-	-	-	-	9.08^{**}	-	-
CC/V5	1	-	-	-	-	26.31^{**}	-	-
CC/V6	1	-	-	-	-	22.36^{**}	-	-
CC/V7	1	-	-	-	-	0.44^{ns}	-	-
CCV8	1	-	-	-	-	8.99^{**}	-	-
Residual	30	185.53	1.01	1.65	43.33	0.97	0.74	0.7
Mean		162.77	16.53	16.14	81.67	11.65	67.76	15.81
CV (%)		8.36	6.10	7.97	8.05	8.46	1.27	5.31
Highest MSR/lowest MSR					1.03			

DF = degrees of freedom; MSR = mean squared residual; ns = not significant, ** and * = significant at 1% and 5% probability level by the F test, respectively.

Gross sugar percentage represents the percentage of sucrose contained in a sugar solution (Fernandes, 2011), the statistical breakdown of varieties within crop cycles showed that the gross sugar percentage found for sugarcane varieties responded differently to the crop cycles. According to the results, the varieties RB72454 and Q124 stood out with the highest gross sugar percentage in both cycles, whereas the other varieties presented higher gross sugar percentage in the ratoon crop cycle (Table 2).

Table 2. Gross sugar percentage (GSP) in the first (plant crop) and second crop cycles (ratoon crop) for eight sugarcane varieties grown under drip irrigation. Juazeiro, Bahia State, Brazil, 2012/2013 crop season.

Variety	Plant crop		Ratoon crop		Mean (variety)
RB92579	10.67	Ba	13.13	Aa	11.9
RB835089	9.72	Ba	12.83	Aa	11.28
RB72454	11.66	Aa	12.71	Aa	12.18
SP716949	10.85	Ba	13.31	Aa	12.08
VAT90212	9.30	Ba	13.48	Aa	11.39
SP943206	10.16	Ba	14.02	Aa	12.09
Q124	11.02	Aa	11.56	Aa	11.29
RB957508	9.77	Ba	12.21	Aa	10.99
Mean (cycle)	10.39		12.91		

Means followed by same uppercase letter in the rows, or lowercase letters in the columns, constitute a statistically homogeneous group by the Scott Knott test at 5% probability level.

The differentiation between sugarcane varieties is carried out based on genetic factors (Bezerra et al., 2018). According to Ukoskit et al. (2019), genes involved in sugar metabolism are associated with several kinase proteins and transcription factors that probably regulate the accumulation of sucrose in sugarcane. This shows that not only environmental factors, but genetic differences can be connected to variations in characteristics of economic interest, such as gross sugar percentage.

According to Parazzi, Ortigosa, Medeiros, and Verruma-Bernardi (2018), sucrose contents are directly connected to the sugarcane maturation; mature culms present different sugar proportions. Thus, most varieties probably did not express their full potential to accumulate sucrose in the first crop cycle (plant crop).

The other variables evaluated showed significant differences between cycles, with increases over the years for sugarcane juice apparent sucrose content and juice purity, and a trend of decrease in sugarcane culm yield, whereas industrial fiber, soluble solids content, and sugarcane moisture showed no variations over the cycles (Table 3).

Table 3. Mean sugarcane culm yield (Mg ha^{-1}) (SCY), industrial fiber (IF), juice apparent sucrose content (POL), juice purity (SJP), soluble solids content (°Brix), and sugarcane moisture (SM) in two crop cycles. Juazeiro, Bahia State, Brazil, 2012/2013 crop season.

Cycles	SCY	IF	POL	SJP	°Brix	SM
Plant crop	180.63 a	15.94 a	12.10 b	78,23 b	16.78 a	67.90 a
Ratoon crop	147.38 b	15.69 a	19.18 a	85.13 a	16.35 a	67.63 a

Means followed by the same letter in the columns are not significantly different from each other by the F test (ANOVA) at 5% probability level.

Mean sugarcane culm yield presented differences between crop cycles; plant crop resulted in a yield of 180.63 Mg ha^{-1}, higher than that found for ratoon crop (147.8 Mg ha^{-1}). Silva, Arantes, Rhein, Gava, and Kolln, (2014) reported that an economically productive sugarcane crop should be grown until the mean yield reaches approximately 65 Mg ha^{-1}.

According to Araujo, Alves Junior, Casaroli, and Evangelista (2016), the stem elongation rate starts to decrease under air temperatures below 25°C in the sugarcane development stage, which extends from initial tillering to full growth before the maturation stage. Mean temperatures of 27.16°C (April 2012) and 24.92°C (June 2013) were recorded during the crop development stage for plant crop and ratoon crop, respectively (Figure 1). Thus, a low temperature may have been sufficient to initiate a decrease in sugarcane growth, consequently resulting in a decrease in stem yield.

The mean sugarcane culm yield of the ratoon crop (Table 3) was well above the minimum required for the renewal of the area, denoting that these varieties, under this management, could be indicated as the most profitable. The advantages of sugarcane crops in the Semiarid region of Brazil are probably connected to the use of irrigated systems, which allows for higher yields because of no water restrictions in the main crop development stages (Oliveira et al., 2016).

The percentages of industrial fiber presented no difference between cycles, with mean values of 15.94% and 15.69% in the plant crop and ratoon crop, respectively. According to Fernandes (2011), the higher the sugarcane fiber contents, the lower the sugarcane juice extraction efficiency; thus, medium fiber contents, between 11 and 13%, are recommended.

However, high fiber contents are important for cogeneration of energy when the sugarcane bagasse is used for burning in the agro-industry or when sold as a by-product. In addition, high proportions of fiber improve resistance to lodging and penetration of pests into the plants (Santos, Oliveira, & Barbosa, 2018).

In this context, the varieties RB92579, RB835089, RB72454, SP716949, VAT90212, SP943206, Q124, and RB957508 are favorable for bioenergy and biomass production due to their high yield and fiber contents in both crop cycles (Table 3).

Juice apparent sucrose content represents the percentage of sucrose in a sugar solution; it also showed differences between production cycles, with 12.10% for the first cycle and higher (19.18%) for the second cycle. The mean juice apparent sucrose content in the second cycle was within the standards recommended by Fernandes (2011): between 14 and 24% for mature plants.

Simões et al. (2015) found that variables related to sucrose contents in sugarcane ratoon crops yielded higher results compared to plant crops, confirming the results found in the present work (Table 3). They reported that these differences between cycles may be correlated with variations in environmental conditions, mainly a decrease in rainfall over the years which may have contributed to an increase in stalk quality provided by a higher accumulation of sucrose.

The sugarcane juice purity reflects the correlation between amounts of sucrose and other soluble solids. The means found for sugarcane juice purity were 78.23 and 85.13% for the first and second cycles, respectively. The result of the second cycle was statistically higher than that of the first cycle (Table 3). According to Fernandes (2011), when the purity is lower than 75%, the agro-industry is unable to reject the load. Thus, the juice purity of the sugarcane varieties in the two crop cycles was within the recommended standards and, thus, they were considered adequate for processing.

The results of the Pearson's correlation are expressed by coefficients that encompass magnitudes from 0 to 1, which can be positive or negative. The results showed significant positive correlation between soluble solids content × juice apparent sucrose content (0.78), soluble solids content × gross sugar percentage (0.87), juice apparent sucrose content × gross sugar percentage (0.98), and sugarcane juice purity × industrial fiber (0.88); and significant negative correlation between mean sugarcane culm yield × sugarcane juice purity (-0.88), sugarcane juice purity × sugarcane moisture (-0.88), and sugarcane moisture × industrial fiber (-1.0) (Table 4).

Table 4. Pearson's coefficients of phenotypic correlation for sugarcane culm yield (Mg ha^{-1}) (SCY), soluble solids content (°Brix), juice apparent sucrose content (POL), sugarcane juice purity (SJP), gross sugar percentage (GSP), industrial fiber (IF), and sugarcane moisture (SM) evaluated in eight sugarcane varieties in two crop cycles. Juazeiro, Bahia State, Brazil, 2012/2013 crop season.

	SCY	°Brix	POL	SJP	GSP	SM
°Brix	0.11^{ns}					
POL	-0.44^{ns}	0.78^{*}				
SJP	-0.88^{**}	0.19^{ns}	0.75^{ns}			
GSP	-0.34^{ns}	0.87^{*}	0.98^{**}	0.64^{ns}		
SM	0.70^{ns}	-0.13^{ns}	-0.69^{ns}	-0.88^{**}	-0.53^{ns}	
IF	-0.70^{ns}	0.13^{ns}	0.69^{ns}	0.88^{**}	0.53^{ns}	-1.00^{*}

ns = not significant; ** and * = significant at 1% and 5% probability level.

The strong and significant positive correlation found for soluble solids content denotes that a selection using soluble solids content can be a viable alternative, as this variable presents positive correlation with juice apparent sucrose content and gross sugar percentage, which are also considered important production components. According to Fernandes (2011), soluble solids content is one of the most important quality parameters for the sugarcane industry because it is one of the components that defines the sugar yield.

Tena et al. (2016) evaluated the correlation between agroindustrial components of sugarcane production and found a positive correlation between soluble solids content and gross sugar percentage, confirming the findings of the present work. The strong and significant positive correlation between juice apparent sucrose content and gross sugar percentage denotes that sugarcane sucrose affects juice sucrose. Therefore, the soluble solids content is directly correlated with apparent sucrose content in sugarcane juice (Parazzi et al., 2018).

The strong positive correlation found between industrial fiber contents and sugarcane juice purity contrasts with the findings of Ukoskit et al. (2019), who found highly significant negative phenotypic correlation between industrial fiber and sugarcane juice purity, reporting that the purity is inversely connected to fiber contents.

The Pearson's correlation showed a statistically strong and negative correlation between sugarcane culm yield and sugarcane juice purity, sugarcane juice purity and sugarcane moisture, and sugarcane moisture and industrial fiber content (Table 4). The $r^2 = -1$ found for fiber and moisture was expected due to their direct correlation in the calculations; the fiber characteristic refers to the percentage of plant shoot dry weight, and the correlation of 100% is explained by the equation: dry matter % + moisture % = 1.

These negative correlations were probably due to the sugarcane composition (sugars, fibers, and water); increases in the percentage of one of these components decreases one or the other two components (Fernandes, 2011). These results denote that one of the correlated characters decreases as any of them increases.

Despite the usefulness of these correlations to determine the magnitude and direction of the effect of the components on the identification of a main characteristic, simple correlations may not express the actual cause-and-effect relationship (Baye, Berihun, Bantayehu, & Derebe, 2020). Thus, the use of path coefficient analysis is suggested to better understand phenomena of correlation between variables.

According to Fernandes (2011), high sugarcane yield and commercially extractable sucrose contents are the two main commercial characteristics for sugarcane. Therefore, path coefficient analysis was carried out adopting soluble solids content as a base variable because it is a characteristic of easy measurement and is considered the main character used for indirect selection of correlated characters. Thus, sugarcane culm yield, juice apparent sucrose content, sugarcane juice purity, gross sugar percentage, sugarcane moisture, and industrial fiber were considered explanatory variables (Table 5).

According to the results shown in Table 4, the coefficient of determination was higher and the effect of the residual variable was lower; thus, the path coefficient analysis with seven characteristics showed to be reliable to explain the effects of characters on the base variable. The characters with the highest direct effect favorable for selection should be identified among those highly correlated with the main character, thus ensuring that the correlation can accurately explain the true existing relationship (Cruz, 2013).

Juice apparent sucrose content presented higher direct effect estimate than soluble solids content, followed by sugarcane moisture, industrial fiber, and gross sugar percentage, which presented lower values, denoting a good combination between path coefficient analysis and phenotypic correlation and a significant contribution of this variable for the increase in soluble solids content.

Considering these variables, gross sugar percentage showed a low direct effect, denoting that it did not provide satisfactory gains for the base variable. Therefore, the best strategy is a simultaneous selection of characters, with emphasis on those with high and significant indirect effects (Cruz, 2013). The analysis of indirect effects showed high indirect effects for gross sugar percentage through juice apparent sucrose content, denoting that juice apparent sucrose content had higher indirect effect on the base variable (soluble solids content).

However, sugarcane culm yield presented direct and low negative effect on soluble solids content and sugarcane culm yield, and sugarcane juice purity presented high and negative correlation with solid soluble content. However, according to the results, these variables exhibited positive correlation coefficient (Table 3), denoting that direct selection using sugarcane culm yield and sugarcane juice purity may not provide satisfactory gains for soluble solids content.

According to Cruz (2013), an explanatory variable presenting direct effect in a unfavorable direction indicates absence of a cause-and-effect relationship, i.e., the independent variable is not the main determinant of changes in the main variable, and other factors may have a higher impact in terms of selection gains.

The indirect effects were high for sugarcane juice purity through juice apparent sucrose content and for sugarcane culm yield through sugarcane juice purity, showing that juice apparent sucrose content and sugarcane juice purity had higher indirect effect on the base variable soluble solids content. This result indicates viability for indirect selection to obtain gains for the character of higher primary importance.

The results found with the path coefficient analysis are consistent with the literature, considering that soluble solids content is strongly correlated with sugarcane sucrose concentration (Parazzi et al., 2018). High purity is associated with high sucrose contents in the sugarcane juice, resulting in high industry yields and in improved sugarcane juice quality due to decreases in contents of amino acids, organic acids, starch, reducing sugars, and other precursors and color-forming agents (Silva et al., 2014).

In addition, the industrial quality of the sugarcane crop's raw material and the crop yield are the main components for estimating the value of the sugar produced from sugarcane and its economic potential (Correia et al., 2014). Thus, it is possible to obtain significant gains through indirect selection for soluble solids content through juice apparent sucrose content, which makes it a reliable parameter to estimate sugar yield of sugarcane varieties grown in semiarid conditions.

The results found allow for the inference that the explanatory variables should not be totally discarded due to their low direct effects on the main variable. In addition, juice apparent sucrose content is the variable that presents the highest indirect effect on the other explanatory variables.

Information on the correlation between different agroindustrial components enables a more deliberate selection of sugarcane varieties for early or late development of sugar and fiber yields. This denotes the positive effect of correlations between technological quality parameters on sugarcane varieties grown under subsurface drip irrigation and semiarid conditions.

Table 5. Phenotypic path coefficient analysis for sugarcane culm yield (Mg ha^{-1}) (SCY), soluble solids content (°Brix), juice apparent sucrose content (POL), sugarcane juice purity (SJP), gross sugar percentage (GSP), and industrial fiber (IF) evaluated in eight sugarcane varieties in two crop cycles. Juazeiro, Bahia State, Brazil, 2012/2013 crop season.

Variables	Correlation path	Estimate
SCY	Direct effect on °Brix	-0.20
	Indirect effect on POL	-0.59
	Indirect effect on SJP	0.80
	Indirect effect on GSP	-0.07
	Indirect effect on SM	0.55
	Indirect effect on IF	-0.38
	Total	0.11
POL	Direct effect on °Brix	1.34
	Indirect effect on SCY	0.09
	Indirect effect on SJP	-0.68
	Indirect effect on GSP	0.20
	Indirect effect on SM	-0.54
	Indirect effect on IF	0.37
	Total	0.78
SJP	Direct effect on °Brix	-0.91
	Indirect effect on SCY	0.18
	Indirect effect on POL	1.00
	Indirect effect on GSP	0.13
	Indirect effect on SM	-0.69
	Indirect effect on IF	0.47
	Total	0.19
GSP	Direct effect on °Brix	0.21
	Indirect effect on SCY	0.07
	Indirect effect on POL	1.31
	Indirect effect on SJP	-0.58
	Indirect effect on SM	-0.41
	Indirect effect on IF	0.28
	Total	0.87
SM	Direct effect on °Brix	0.78
	Indirect effect on SCY	-0.14
	Indirect effect on POL	-0.93
	Indirect effect on SJP	0.80
	Indirect effect on GSP	-0.11
	Indirect effect on IF	-0.54
	Total	-0.13
IF	Direct effect on °Brix	0.54
	Indirect effect on SCY	0.14
	Indirect effect on POL	0.93
	Indirect effect on SJP	-0.80
	Indirect effect on GSP	0.11
	Indirect effect on SM	-0.78
	Total	-0.13
Coefficient of determination (R^2)		1.00
Effect of the residual Variable		0.02

Conclusion

The sugarcane varieties RB72454 and Q124 presented better agroindustrial production potential and, thus, they can be recommended for production managements with drip irrigation under semiarid conditions. Soluble solids content can be used as an alternative for direct selection of varieties with higher sugar yield in different cycles.

References

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (2006). *Evapotranspiración del cultivo. Guías para la determinación de los requerimientos de água de los cultivos*. Roma, IT: FAO.

Araújo, R., Alves Junior, J., Casaroli, D., & Evangelista, A. W. P. (2016). Variação na qualidade da matéria-prima da cana-de-açúcar em decorrência da suspensão da irrigação antes da colheita e da ocorrência de baixas temperaturas. *Bragantia*, *75*(1), 118-127.

Barbosa, R. P., Alcântara Neto, F., Gravina, L. M., Gravina, G. A., Portela, M. G. T., & Bezerra, A. A. C. (2017). Early selection of sugarcane using path analysis. *Genetics and Molecular Research*, *16*(1), 1-8. DOI: https://doi.org/10.4238/gmr16019038

Baye, A., Berihun, B., Bantayehu, M., & Derebe, B. (2020). Genotypic and phenotypic correlation and path coefficient analysis for yield and yield-related traits in advanced bread wheat (*Triticum aestivum* L.) lines. *Cogent Food & Agriculture*, *6*(1), 1-17. DOI: https://doi.org/10.1080/23311932.2020.1752603

Bezerra, J. D. C., Ferreira, G. D. G., Oliveira, M. W., Campos, J. M. S., Andrade, A. P., & Nascimento Júnior, J. R. S. (2018). Cana-de-açúcar: Melhoramento genético e suas finalidades forrageiras. *Nucleus Animalium*, *10*(2), 131-147. DOI: https://doi.org/10.3738/21751463.3518

Chea, C., Saengprachatanarug, K., Posom, J., Wongphati, M., & Taira, E. (2020). Sugar yield parameters and fiber prediction in sugarcane fields using a multispectral camera mounted on a small unmanned aerial system (UAS). *Sugar Tech*, *22*(4), 605-621. DOI: https://doi.org/10.1007/s12355-020-00802-5

Correia, C. B. G., Azevedo, H. M., Neto, J. D., Carvalho, C. M., Silva, L. L., & Feitosa, S. O. (2014). Cana-de-açúcar: parâmetros tecnológicos em função de diferentes lâminas de irrigação e adubação de cobertura. *Revista Brasileira de Agricultura Irrigada*, *8*(1), 26-37. DOI: https://doi.org/10.7127/rbai.v8n100204

Cruz, C D. (2013). Genes - a software package for analysis in experimental statistics and quantitative genetics. *Acta Scientiarum. Agronomy*, *35*(1), 271-276. DOI: https://doi.org/10.4025/actasciagron.v35i3.21251

Fernandes, A. C. (2011). *Cálculos na agroindústria da cana-de-açúcar* (3. ed.). Piracicaba, SP: Stab.

Lopes, I., Guimarães, M. J. M., Melo, J, M, M, & Ramos, C. M. C. (2017). Balanço hídrico em função de regimes pluviométricos na região de Petrolina-PE. *Irriga*, *22*(3), 443-457. DOI: http://doi.org/10.15809/irriga.2017v22n3p443-457

Oliveira, A. R., Braga, M. B., Santos, B. L. S., & Walker, A. M. (2016). Biometria de cultivares de cana-de-açúcar sob diferentes reposições hídricas no vale do Submédio São Francisco. *Revista Energia na Agricultura*, *31*(1), 48-58. DOI: http://doi.org/10.17224/EnergAgric.2016v31n1p48-58

Oliveira, A. R., & Braga, M. B. (2019). Variedades de cana-de-açúcar submetidas a diferentes lâminas de reposição hídrica por gotejamento subsuperficial. *Energia na Agricultura*, *34*(3), 350-363. DOI: http://doi.org/10.17224/EnergAgric.2019v34n3p350-363

Parazzi, C., Ortigosa, L. M., Medeiros, S. D. S., & Verruma-Bernardi, M. R. (2018). Estudo da qualidade físico-química, tecnológica e sensorial de caldos de cana-de-açúcar para consumo. *Revista Ciência, Tecnologia & Ambiente*, *8*(1), 3-10. DOI: http://doi.org/10.4322/2359-6643.08101

Santos, C. S., Oliveira, S., & Barbosa, B. H. (2018). Análise da eficiência energética do bagaço da cana na geração de vapor em uma usina sucroalcooleira. *Revista Metropolitana de Sustentabilidade*, *8*(3), 106-121.

Silva, D.L.G., Batisti, D. L. S., Ferreira, M. J. G., Merlini, F. B., Camargo, R. B. & Barros, B. C. B. (2021). Cana-de-açúcar: Aspectos biológicos, sociais, ambientais, subprodutos e sustentabilidade. *Research, Society and Development*, *10*(7), 1-17. DOI: http://dx.doi.org/10.33448/rsd-v10i7.14163

Silva, M. D. A., Arantes, M. T., Rhein, A. F. D. L., Gava, G. J., & Kolln, O. T. (2014). Potencial produtivo da cana-de-açúcar sob irrigação por gotejamento em função de variedades e ciclos. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *18*(3), 241-249. DOI: https://doi.org/10.1590/S1415-43662014000300001

Simões, W. L., Calgaro, M., Coelho, D. S., Souza, M. A. D., & Lima, J. A. (2015). Respostas de variáveis fisiológicas e tecnológicas da cana-de-açúcar a diferentes sistemas de irrigação. *Revista Ciência Agronômica*, *469*(1), 11-20. DOI: https://doi.org/10.1590/S1806-66902015000100002

Simões, W. L., Calgaro, M., Guimarães, M. J. M., Oliveira, A. R., & Pinheiro, M. P. M. A. (2018). Sugarcane crops with controlled water deficit in the Sub-Middle São Francisco Valley, Brazil. *Revista Caatinga*, *31*(4), 963-971. DOI: http://dx.doi.org/10.1590/1983-21252018v31n419rc

Tahir, M., Khalil, I. H., & Rahman, H. (2014). Evaluation of important characters for improving cane yield in sugarcane (*Saccharum* sp.). *Sarhad Journal of Agriculture*, *30*(3), 319-323.

Tena, E., Mekbib, F., & Ayana, A. (2016). Heritability and correlation among sugarcane (Saccharum spp.) yield and some agronomic and sugar quality traits in Ethiopia. *American Journal of Plant Sciences*, *7*(10), 1453-1477. DOI: https://doi.org/10.4236/ajps.2016.710139

Ukoskit, K., Posudsavang, G., Pongsiripat, N., Chatwachirawong, P., Klomsa-Ard, P., Poomipant, P., & Tragoonrung, S. (2019). Detection and validation of EST-SSR markers associated with sugar-related traits in sugarcane using linkage and association mapping. *Genomics*, *111*(1), 1-9. DOI: https://doi.org/10.1016/j.ygeno.2018.03.019