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Research Article

Hydric characteristics and agro-industrial quality of sugarcane under application of correctives and fertilizers in Alagoas, Brazil

Características hídricas e qualidade agroindustrial da cana-de-açúcar sob aplicação de corretivos e fertilizantes em Alagoas, Brasil

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ABSTRACT

The objective of this research was to evaluate meteorological variables, water balance and agro-industrial quality of sugarcane under isolated and combined application of pH correctives and organic and mineral fertilization in planting furrows, under rainfed conditions. The statistical design used was in randomized blocks, with five replications and 8 treatments: T_1 = limestone, T_2 = agricultural gypsum; T_3 = poultry litter; $T_4 = T_1 + T_2$; $T_5 = T_1 + T_3$; $T_6 = T_2 + T_3$; $T_7 = T_1 + T_2 + T_3$ and T_8 = conventional mineral fertilizer. The cultivar used was RB92579 and the agro-industrial quality variables studied were: brix of broth, sugarcane broth apparent sucrose, broth purity, reducing sugars, total recoverable sugars and fiber. The air temperature was not a limiting factor for the growth of sugarcane. The crop evapotranspiration, in 16 months of cultivation, was 2,054 mm. In general, the application of agricultural gypsum in the planting furrow generates higher agro-industrial quality of the sugarcane in comparison with the application of poultry litter. The agro-industrial quality of sugarcane fields cultivated with agricultural limestone and conventional fertilization does not differ significantly from the areas where agricultural gypsum is applied or the areas where poultry litter is used.

KEYWORDS: *Saccharum* spp. Agricultural limestone and gypsum. Poultry litter. Evapotranspiration. Total recoverable sugar.

RESUMO

O objetivo desta pesquisa foi avaliar variáveis meteorológicas, balanço hídrico e qualidade agroindustrial da cana-de-açúcar sob aplicação isolada e combinada de corretivos de pH e adubação orgânica e mineral em sulcos de plantio, em condições de sequeiro. O delineamento estatístico utilizado foi em blocos casualizados, com cinco repetições e 8 tratamentos: T_1 = calcário, T_2 = gesso agrícola; T_3 = cama de frango; $T_4 = T_1 + T_2$; $T_5 = T_1 + T_3$; $T_6 = T_2 + T_3$; $T_7 = T_1 + T_2 + T_3$ e T_8 = fertilizante mineral convencional. A cultivar utilizada foi a RB92579 e as variáveis de qualidade agroindustriais estudadas foram: brix do caldo, sacarose aparente do caldo de cana, pureza do caldo, açúcares redutores, açúcares totais recuperáveis e fibra. A temperatura do ar não foi um fator limitante para o crescimento da cana-de-açúcar. A evapotranspiração da cultura, em 16 meses de cultivo, foi de 2.054 mm. Em geral, a aplicação de gesso agrícola no sulco de plantio gera maior qualidade agroindustrial da cana-de-açúcar em comparação com a aplicação de cama

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de frango. A qualidade agroindustrial dos canaviais cultivados com calcário agrícola e adubação convencional não difere significativamente das áreas onde é aplicado gesso agrícola ou das áreas onde é utilizada cama de frango.

PALAVRAS-CHAVE: *Saccharum* spp. Calcário e gesso agrícola. Cama de frango. Evapotranspiração. Açúcar total recuperável.

INTRODUCTION

Sugarcane is one of the main agricultural crops cultivated in a wide range of the planet, due to its ability to tolerate unfavorable edaphoclimatic conditions, such as prolonged dry periods, acidic and poor soils. Its cultivation generally receives inadequate management, mainly in areas of small and medium producers (SHUKLA *et al.* 2019). In the 2021/22 harvest, Brazil produced 715 million tons of sugarcane, with an average yield of 71.7 Mg ha^{-1}. The Southeast region was the largest national producer with 415 million tons. In this harvest, the state of Alagoas produced 17.4 million tons of sugarcane, with an average productivity of 59.9 Mg ha^{-1}, accounting for 32.9% of the sugarcane produced in the Northeast and consolidating itself as the seventh largest producer nationally among the Brazilian states. And that highlights this Brazilian state in the national sugar-energy scenario (IBGE 2022).

Located in the Northeast of Brazil, the state of Alagoas has a climate characterized by little variation in solar radiation, with a photoperiod of around 12 hours and an average air temperature of 25 °C (KRIEGER *et al.* 2024). Despite this small variation, LOPES JÚNIOR *et al.* (2023) state that these meteorological variables have different behaviors in the growth phases of sugarcane, mainly because it is a long-cycle agricultural crop. The average accumulated annual rainfall in the east of the state, the region where sugarcane crops are concentrated, is 1,500 mm, while in the west it varies from 400 to 600 mm per year (BARROS *et al.* 2012). However, rainfall distribution occurs seasonally, with a dry season for part of the year. In view of the above, research that aims to verify the productive responses of sugarcane in relation to the climatic conditions of this region and increase the efficiency of crop management becomes important, since extreme events due to climate change have become increasingly frequent, which makes decision-making in sugarcane cultivation difficult.

In addition, the east of Alagoas, Coastal Plateaus of the Northeast, has soils with a high degree of weathering that make them mostly acidic and associated with low values of base saturation in surface horizons, generally below 39% (LIMA NETO *et al.* 2009). The ideal value for sugarcane cultivation is base saturation above 50% (GUIMARÃES *et al.* 1999), and the soils must be well drained, which influences water availability for the plant (AMORIN *et al.* 2019). Therefore, it is observed that the acid pH in the soils of the Coastal Plateaus of the Brazilian Northeast affects the availability of essential nutrients for the plants. Furthermore, it reduces the efficiency of the fertilization carried out in the crops in this region and this favors low agricultural productivity. This highlights the importance of studies such as this one, that increase efficiency and reduce fertilizer waste in sugarcane cultivation, since this is one of the main inputs that burdens the production process.

In view of the above, and noting that most farmers and researchers focus on isolated nutrients to relate to agricultural productivity, the isolated or combined application of soil acidity correctives, such as limestone and agricultural gypsum, in the sugarcane planting furrow, combined with mineral and/or organic fertilization, can increase soil pH, improve the physicochemical properties of the variables, increase the availability of nutrients and ensure normal growth of this agricultural crop, mainly by reducing abiotic stresses and ultimately improving the agro-industrial quality of sugarcane and increasing profits for sugar and alcohol producers and mills. It should be noted that the quality of the raw material, climate conditions and management practices directly impact the agro-industrial yield of sugarcane. Therefore, producers who invest in cultivation technologies can increase yield, optimizing production and, consequently, profits (TEODORO *et al.* 2015).

Despite the existence of studies on sugarcane cultivation and responses to corrective soil acidity and fertilization (VIECELI *et al.* 2020, AZEVEDO *et al.* 2021), there is little information on the agro-industrial quality of this crop in relation to isolated and combined application of these inputs, in the planting furrow, in the Coastal Plateaus of the Brazilian Northeast.

For the above reasons, the objective of this research was to evaluate the meteorological variables, the water balance and the agro-industrial quality of sugarcane under isolated and combined application of different soil pH correctives and organic and mineral fertilization, in rainfed cultivation in the Coastal Plateaus of Alagoas, Brazil.

MATERIAL AND METHODS

The research was carried out in the municipality of Teotônio Vilela (9º58'11.93" S; 36º28'02" W; 160 m), state of Alagoas, Coastal Plateaus of Northeast Brazil, from July 2021 to December 2022. According to the Köppen climate classification, the local climate is type AS, tropical, with seasonal rainfall distribution, with water deficit between spring and summer and excess between autumn and winter. Average annual rainfall and temperature are 1,200 mm and 25 °C, respectively (BARROS *et al.* 2012).

Sugarcane has been cultivated uninterruptedly for more than 30 years in the experiment area and no soil acidity correction or organic fertilizer has ever been applied, only mineral topdressing fertilization. The soil in the experiment area is classified as an Oxisol (SANTOS *et al.* 2018) and the physical-hydric and chemical properties of the 0 – 20 and 20 – 40 cm layers, obtained by laboratory analyzes, are shown in Table 1.

Soil preparation was carried out with harrowing and furrow opening, 40 cm deep, two days before planting. The spacing was 1.0 m between planting lines, with stalks divided into wheels containing three buds, a total of 12 buds per linear meter. RB92579 was cultivated in rainfed conditions. This cultivar, the most planted in the region, is characterized by high sprouting and tillering, in addition to high agricultural productivity, amount of total recoverable sugar (TRS), and rapid recovery after water stress (OLIVEIRA *et al.* 2021).

Table 1. Chemical and physical-hydric properties of the soil of the research area.

Chemical Properties	**Unit**	**Soil Layers (cm)**	
		0 – 20	**20 – 40**
pH	-	5.2	4.7
P	ppm	25	13
K	ppm	15	10
Ca	meq 100 mL^{-1}	0.7	0.5
Mg	meq 100 mL^{-1}	0.8	0.7
Al	meq 100 mL^{-1}	0.2	0.5
Na	ppm	14	12
Sum of bases	-	1.6	1.3
Effective C.T.C.	-	1.9	1.8
Base saturation (V)	%	35	33
M.O.	%	1.6	0.6
Physical Properties	**Unit**	**Soil Layers (cm)**	
		0 – 20	**20 – 40**
Coarse sand	g kg^{-1}	729	658
Thin sand	g kg^{-1}	210	246
Total sand	g kg^{-1}	939	904
Silt	g kg^{-1}	8	14
Clay	g kg^{-1}	62	82
Hydric properties	**Unit**	**Soil Layers (cm)**	
		0 – 40	
Field capacity	m^{3} m^{-3}	0.067	
Permanent wilting point	m^{3} m^{-3}	0.043	
Available water capacity	mm	9.60	
Soil density	g m^{-3}	1.50	

In the planting furrow, after sowing, an insecticide based on Fipronil was applied (250 g i.a. ha^{-1}, 300 L of mixture ha^{-1}), and after closing the furrows, the pre-emergent herbicide was applied based on S-Metolachlor (2.0 L p.c. ha^{-1}, 200 L of mixture ha^{-1}).

The statistical design adopted was randomized blocks, with five replications and eight treatments. The 40 experimental plots consisted of five rows of 5.0 m in length (5.0 x 5.0 m = 25 m²) and the total area of the experiment was 1,000 m². The useful area of each plot was formed by the three central lines, disregarding the 1.5 m borders of each line. Therefore, the net useful area was 6.0 m².

The eight treatments were: T_1 = limestone, T_2 = agricultural gypsum; T_3 = poultry litter; T_4 = limestone + agricultural gypsum; T_5 = limestone + poultry litter; T_6 = agricultural gypsum + poultry litter; T_7 = limestone + agricultural gypsum + poultry litter and T_8 = conventional mineral fertilizer. The correctives used were limestone and agricultural gypsum. The amount of limestone applied was 1.50 Mg ha^{-1}, to raise the base saturation (V%) of the soil to a minimum of 50%, the source used had guarantees of 24% calcium (Ca), 14% magnesium (Mg) and relative total neutralizing power (RTNP) of 57%. The amount of agricultural gypsum applied was 0.5 Mg ha^{-1}, and was determined according to the clay content of the soil, the source used had guarantees of 16% Ca and 13% sulfur (S). Both corrective doses applied were determined according to GUIMARÃES *et al.* (1999). Regarding organic fertilization, 8.0 Mg ha^{-1} of poultry litter was applied.

Conventional fertilization was performed in all treatments. In the base fertilization, 120 kg ha^{-1} of P_2O_5 was applied, with the simple superphosphate fertilizer (18% of P_2O_5) used as a source of phosphorus (P), and 60 kg ha^{-1} of K_2O, whose source of potassium (K) was potassium chloride fertilizer (58% K_2O). Topdressing fertilization was carried out 180 days after planting (DAP), with 60 kg ha^{-1} of nitrogen (N), using urea (45% of N) as source, and 60 kg ha^{-1} of K_2O, with the same source of the base.

Daily rainfall data were obtained from an automatic pluviometer from the National Center for Monitoring and Natural Disaster Alerts (CEMADEN). The daily air temperature was obtained with a thermo-hygrometer (HTC-2, Supermedy) installed in the cultivation area. With the daily values of meteorological variables, means and standard deviations (±) were obtained. Reference evapotranspiration (ET_0) was estimated by HARGREAVES & SAMANI (1985), according to Equation 1.

$$ET_0 = a \cdot \frac{R_a}{2{,}45} \cdot (T_{MAX} - T_{MIN})^b \times (T_{AVE} + c) \qquad \text{Eq. (1)}$$

where: ET_0 is reference evapotranspiration (mm day^{-1}); R_a extraterrestrial solar irradiance (MJ m^{-2}); T_{MAX} is the maximum air temperature (°C); T_{MIN} is the minimum air temperature (°C) and T_{AVE} is the average air temperature (°C). The values of *a*, *b* and *c* are equation adjustment coefficients, where *a* = 0.0023, *b* = 0.5 and *c* = 17.8.

Extraterrestrial solar irradiance was estimated by Equation 2.

$$R_a = 37{,}6\left(\frac{d}{D}\right)^2\left[\left(\frac{\pi}{180}{}^{\circ}\right) hnsen\Phi sen\delta + cos\Phi cos\delta senhn\right] \qquad \text{Eq. (2)}$$

$$\left(\frac{d}{D}\right)^2 = 1 + 0{,}033cos\left(NDA\frac{360}{365}\right) \qquad \text{Eq. (3)}$$

where: R_a is extraterrestrial solar irradiance (MJ m^{-2}); Φ is local latitude (degrees); δ is solar declination (degrees); *hn* is the hour angle at sunrise (degrees); d/D is the relative earth-sun distance and NDA is the day number of the year or Julian day.

The water balance of the crop, on a ten-day scale, was determined by the Thornthwaite-Mather method (1955), according to PEREIRA *et al.* (2002).

The sugarcane harvest and analysis of the agro-industrial quality of the raw material were carried out 16 months after planting (MAP). The culms of the useful area of the plots were harvested to obtain the culm productivity (TCH - Mg ha^{-1}), for this purpose, the stalks were weighed on a 0.01 kg precision scale (Milla, China). For the agro-industrial quality analysis, eight culms from the useful area of each plot were sent to the laboratory at the Coruripe plant, in the municipality of Coruripe - AL, to determine the variables: brix of the broth ($BRIX_{BROTH}$ – %); apparent sucrose of the broth - (POL_{BROTH} – %); sugarcane apparent sucrose (POL_{CANE} – %); broth purity (PZA – %); broth reducing sugar content (SR – %); total recoverable sugars (TRS – kg Mg^{-1}) and water-insoluble solids content (FIBER – %), according to SINDAÇÚCAR – AL (2018).

The determination of $BRIX_{BROTH}$ was done with a digital refractometer, with automatic reading, automatic temperature correction and the final value expressed at 20ºC. The POL_{BROTH} was determined in an automatic digital saccharimeter, with a resolution of 0.01, measured at 20º C.

The FIBER content was obtained by Equation 4.

$$FIBER = 0{,}0779 \times PBU + 2{,}3136 \qquad \text{Eq. (4)}$$

where: PBU is wet bagasse weight (g).

POL_{CANE} was determined by Equation 5.

$$POL_{CANE} = POL_{BROTH} \times (1 - 0{,}01FIBER) \times C \qquad \text{Eq. (5)}$$

where POL_{BROTH} is the apparent sucrose content of the broth (%); FIBER is the content of insoluble solids in water (%) and C is the coefficient of transformation of POL_{BROTH} extracted into absolute POL_{BROTH}, calculated by Equation 6.

$$C = 1{,}0313 - 0{,}00575 \times FIBER \qquad \text{Eq. (6)}$$

The PZA was obtained by Equation 7.

$$PZA = POL_{CANE} \div BRIX \times 100 \quad \text{Eq. (7)}$$

where: POL_{CANE} is sugarcane apparent sucrose content (%) and BRIX is broth brix (%).

SR was defined by Equation 8.

$$SR = 3{,}3459 - 0{,}02871 \times PZA \quad \text{Eq. (8)}$$

where: PZA is broth purity (%).

The TRS was determined by Equation 9.

$$TRS = 10 \times POL_{CANE} \times 1{,}0526 \times \left(1 - \frac{PI}{100}\right) + 10 \times SRS \times \left(1 - \frac{PI}{100}\right) \quad \text{Eq. (9)}$$

where: POL_{CANE} is sugarcane apparent sucrose (%); 1.0526 is the stoichiometric conversion factor of sucrose into reducing sugars; PI is the loss in the industrial process estimated at 11% and SRS is sugarcane reducing sugars (%), calculated by Equation 10.

$$SRS = RS\,\%\,broth \times (1 - 0{,}01 \times FIBER) \times C \quad \text{Eq. (10)}$$

where: RS is the reducing sugars of the broth (%); FIBER is the content of solids insoluble in water (%) and C is the coefficient of transformation of POL_{BROTH} extracted into POL_{BROTH} absolute.

The collected data were subjected to analysis of variance, according to FERREIRA (2018), and, when significant by the "F" test at 5% ($p < 0.05$) of probability, their means were compared by the Tukey test ($p < 0.05$) in relation to the agro-industrial quality variables of sugarcane.

RESULTS AND DISCUSSIONS

Meteorological variables and water balance

The mean air temperature, during the cultivation period, was 24.1 (±1.9) °C and the mean minimum air temperature was 20.8 (±1.3) °C, while the mean maximum air temperature was 29.5 (±2.9) °C (Figure 1). Regions with air temperatures ranging from 18 to 38 °C are suitable for growing sugarcane (VERMA *et al.* 2019). TEODORO *et al.* (2015) studied responses of sugarcane in the Coastal Plateaus of Alagoas in relation to meteorological variables, the researchers found, during cultivation, a temperature range of 16.6 to 35.9 °C, and ratified that in this temperature range the normal growth and development of tropical plants such as sugarcane occur. Therefore, it is observed that the cultivation area has adequate thermal availability for the growth and development of the sugarcane plants.

The accumulated rainfall, during the experimental period, from July 30, 2021 to December 5, 2022 (16 months) was 3,182 mm. November 2021 was the least rainy month, with a total of 4.0 mm, and May 2022 was the wettest month, with 809 mm. The high amount of accumulated rainfall in May 2022 was due to the strong interference of the 2022 La Niña atmospheric-oceanic phenomenon. This phenomenon is characterized by abnormal cooling in the surface waters of the tropical Pacific Ocean and, generally, causes above average rainfall in the Northeast of Brazil (OLIVEIRA 1999).

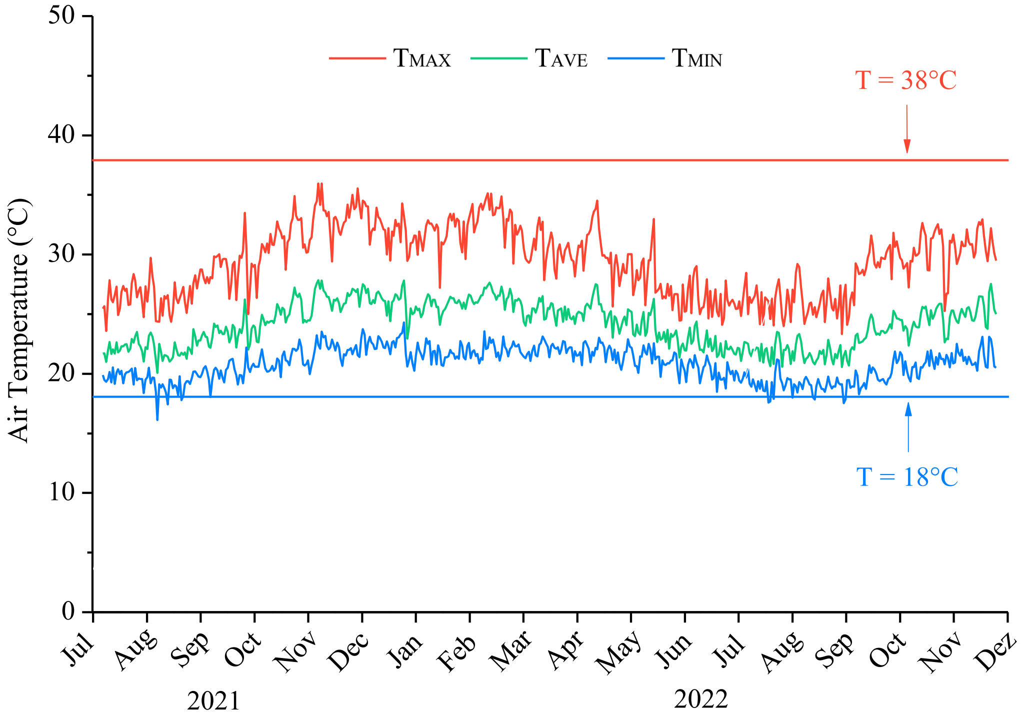


Figure 1. Minimum (T_{MIN}), average (T_{AVE}) and maximum (T_{MAX}) air temperature (°C) during the cultivation period in the region of Teotônio Vilela, AL, from July 2021 to December 2022, and thermal interval ideal for the growth and development of sugarcane.

In sugarcane-producing regions around the world, annual rainfall between 1,100 and 1,500 mm predominates, and this volume of water is considered sufficient to obtain high productivity of stalks and agro-industrial quality (CHOHAN 2019). TEODORO *et al.* (2015) obtained an average agro-industrial yield of 12.90 tons of sugar in plant cane, with the cultivar RB92579, in the Coastal Plateaus of Alagoas, under an annual rainfall of 1,806 mm. In view of the above, it is observed that in the region of Teotônio Vilela, in 2022, there was enough annual rainfall to supply the water demand of the sugarcane crop and generate high agro-industrial quality, despite the seasonality of the rain. The mean daily ET_0 was 4.0 (±0.9) mm.day^{-1}. Between the months of September 2021 and February 2022, the dry period in the region, the greater values of ET_0 were observed, with a daily mean of 4.9 (±0.6) mm.day^{-1}. And from the last ten-day period of April to the first ten-day period of July 2022, the region's rainy season, the lowest ET_0 values were observed, with a daily mean of 3.0 (±0.5) mm.day^{-1} (Figure 2).

Of the total rainfall (3,182 mm), 1,876 mm was lost as excess water (runoff or percolation). So, the effective rainfall was 1,306 mm, the amount of water that was available to the plants. Therefore, there was a water deficit of 748 mm, because the crop evapotranspiration (ET_C) was 2,054 mm, in 16 months of cultivation. The water deficit was concentrated in two periods, from the second ten-day period in August 2021 to the first ten-day period in March 2022, and the second ten-day period from September to the third ten-day period in October 2022. Based on the above, it is confirmed that the real evapotranspiration (ETr) of accumulated sugarcane, during the production cycle, was 1,306 mm, equivalent to effective rainfall. Figure 3 shows the water balance of the sugarcane cultivation period.

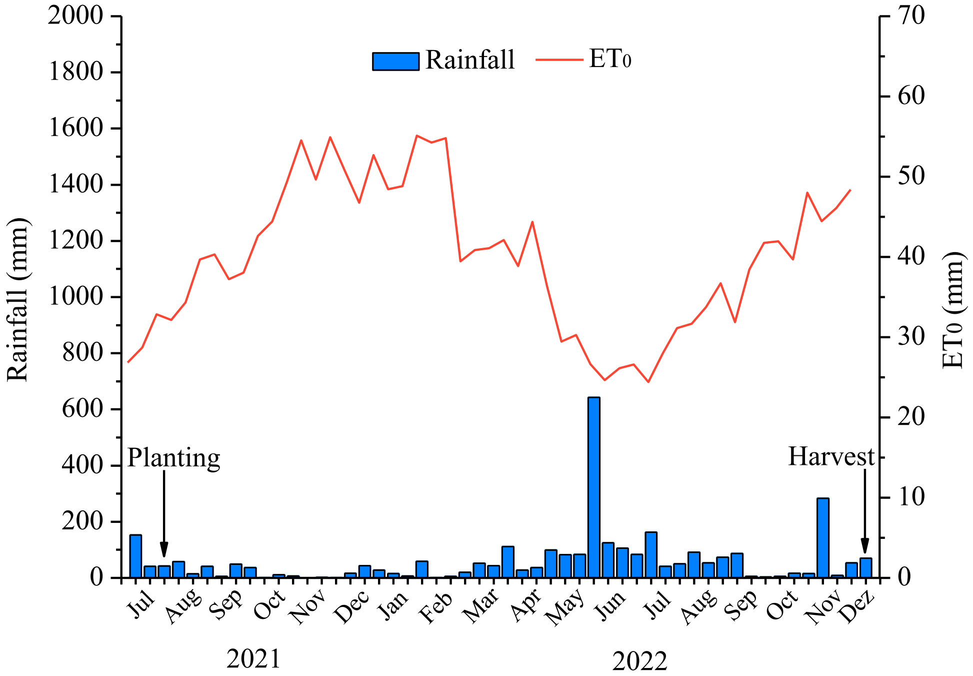


Figure 2. Ten-day rainfall (mm) and reference evapotranspiration (ET_0) during sugarcane cultivation, in the region of Teotônio Vilela, AL, Brazil, from July 2021 to December 2022.

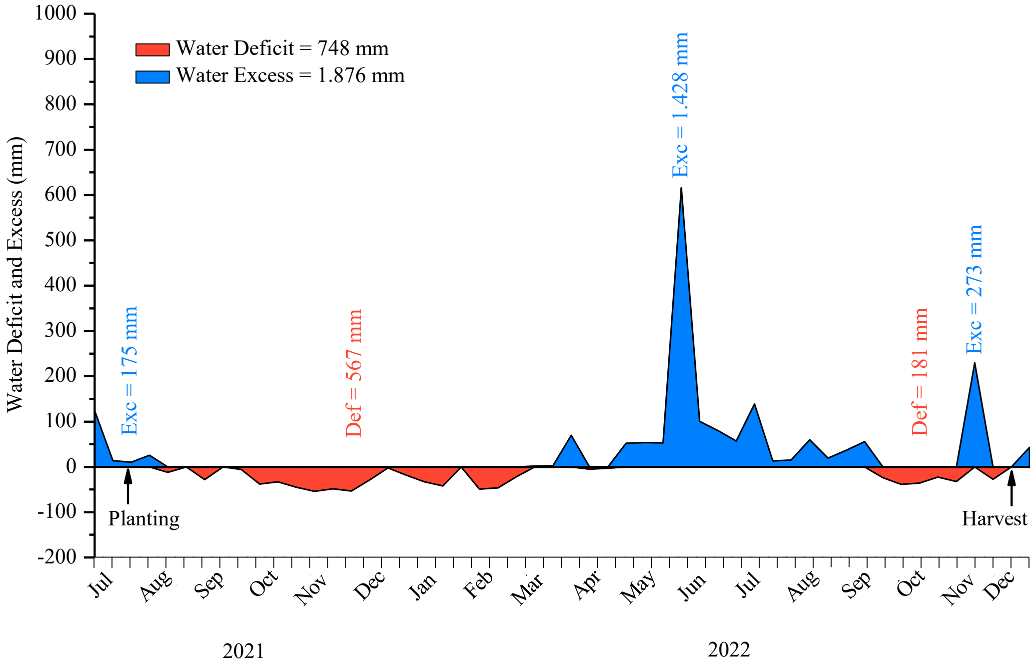


Figure 3. Ten-day water balance in the sugarcane cultivation area, with emphasis on excess and water deficit (mm), in the region of Teotônio Vilela, AL, from July 2021 to December 2022.

Agro-industrial quality of sugarcane

The studied treatments generated a significant effect ($p < 0.05$) in relation to the variables: total recoverable sugars (TRS), total soluble solids in the broth ($BRIX_{BROTH}$), and apparent sucrose from sugarcane (POL_{CANE}) and broth (POL_{BROTH}). The other studied variables were not significant. Table 2 shows the analysis of variance and the general means of the studied variables.

Table 2. Analysis of variance of agro-industrial quality variables of the sugarcane under corrective and fertilizer application in Alagoas, from July 2021 to December 2022.

Cause of variation	**D.F.**	**Square root**			
		ATR	**$\text{BRIX}_{\text{BROTH}}$**	**POL_{CANE}**	**$\text{POL}_{\text{BROTH}}$**
Treatments	7	46,331*	0.484*	0.589*	0.914*
Block	4	$77,036^{NS}$	0.525^{NS}	$1,009^{NS}$	$1,461^{NS}$
Residue	28	11,373	0.090	0.152	0.259
C.V. (%)		2,49	1.60	2.82	3.05
Overall Mean		135.44 kg Mg^{-1}	18.75%	13.84%	16.72%
		SR	**FIBRE**	**PZA**	**TCH**
Treatments	7	0.002^{NS}	0.073^{NS}	$4,136^{NS}$	428.317^{NS}
Block	4	0.005^{NS}	0.021^{NS}	$8,945^{NS}$	256.609^{NS}
Residue	28	0.001	0.113	1.863	364.562
C.V. (%)		5.35	2.53	1.53	16.54
Overall Mean		0.65%	13.31%	89.09%	115.41 Mg ha^{-1}

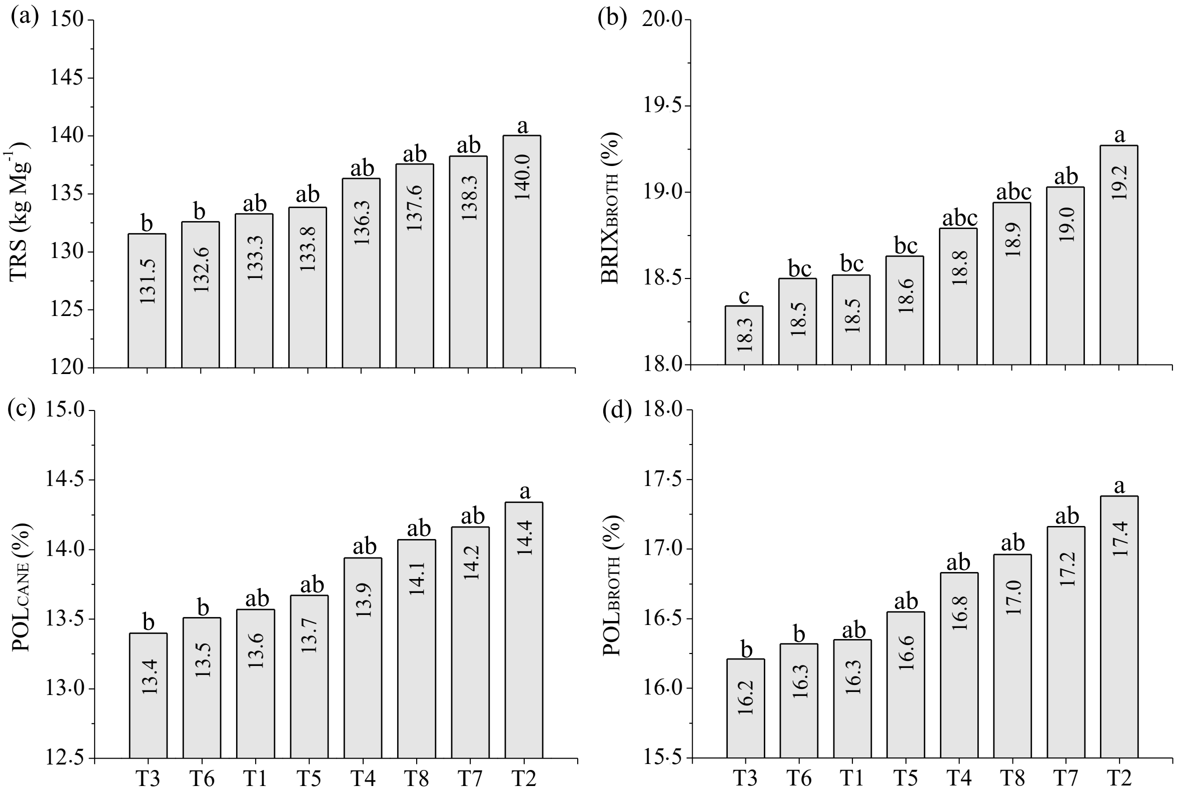
C.V. is coefficient of variation; * is significant at 5% and ^{NS} is not significant by the "F" test ($p < 0.05$).

The lowest TRS (131.5 kg Mg^{-1}), POL_{CANE} (13.4%) and $\text{POL}_{\text{BROTH}}$ (16.2%) values of sugarcane were observed in areas with poultry litter application (T_3 = Poultry litter, and T_6 = Agricultural gypsum + Poultry litter) when compared with areas where agricultural plaster was applied (T_2 = Agricultural gypsum). In the areas cultivated under T_2, values of TRS, POL_{CANE} and $\text{POL}_{\text{BROTH}}$ of 140 kg Mg^{-1}, 14.4 and 17.4%, respectively, were observed and this represents an increment of 6.4% of TRS and 7.4 % of POL in relation to the lowest values obtained.

The other treatments were equal to T_2, in which general mean values of 136.5 kg Mg^{-1} of TRS, 14.0% of POL_{CANE} and 16.9% of $\text{POL}_{\text{BROTH}}$ were observed. It should be noted that, except for T_2, all other treatments were equal in relation to the variables TRS and POL_{CANE} and $\text{POL}_{\text{BROTH}}$ (Figure 4a, c and d).

In the plots where agricultural gypsum was applied (T_2) a greater percentage of $\text{BRIX}_{\text{BROTH}}$ (19.2%) was observed, compared to the area where limestone (T_1), poultry litter (T_3), limestone plus poultry litter (T_5) and agricultural gypsum plus poultry litter (T_6) were applied, where an overall mean value of 18.5% of $\text{BRIX}_{\text{BROTH}}$ was observed, a reduction of 3.6% in the soluble solids content of the sugarcane in relation to the greater value obtained. The other treatments were equal to T_2 and generated an overall mean BRIX of 19% (Figure 4b).

The observed data indicate that, in general, the isolated or combined application of poultry litter reduces the agro-industrial quality of sugarcane. PIRES *et al.* (2024) studied the application of poultry litter doses in relation to the productivity and agro-industrial quality of sugarcane, including the dose of 8.0 Mg ha^{-1}, the same as in this research, and the researchers did not find significance in the poultry litter doses in relation to the variables of total recoverable sugar, Brix, fiber and purity.



Means followed by the same letter in the columns do not differ by Tukey test ($p<0.05$).

Figure 4. (a) Total recoverable sugars (TRS – kg Mg^{-1}); (b) broth brix ($\text{BRIX}_{\text{BROTH}}$ – %); (c) POL of sugarcane (POL_{CANE} – %) and (d) POL of broth ($\text{POL}_{\text{BROTH}}$ – %) of sugarcane under corrective and fertilization application in Alagoas, from July 2021 to December 2022.

MANOGARAN *et al.* (2022) state that poultry litter is a nutrient-rich organic waste that contains substantial amounts of nitrogen and is commonly used as an organic fertilizer in crops. Nitrogen (N) is a constituent of many plant compounds; therefore, N deficiency leads to marked chlorosis and senescence of older leaves, which inhibits plant growth. Meanwhile, the availability of N favors vegetative growth and slows down the reproductive cycle and maturation of plants (TAIZ *et al.* 2017). The researchers SALVIANO *et al.* (2017) and COSTA *et al.* (2019) confirm that nitrogen is the second most required nutrient in quantity by sugarcane and the application of high doses of nitrogen fertilizers reduces the agro-industrial quality of the crop, such as, for example, lower production of total recoverable sugars (TRS), since that delay plant maturation. Thus, it can be stated that the application of poultry litter, an organic fertilizer rich in nitrogen, favored vegetative development and reduced the agro-industrial quality of sugarcane.

Regarding the performance of the agro-industrial quality of sugarcane in areas where agricultural gypsum is applied compared to areas where poultry litter was applied, the researchers ZOCA & PENN (2017) and ARAÚJO *et al.* (2018) state that the application of agricultural gypsum is capable of: recovering sodic and acidic soils, providing Ca and S, increasing water infiltration into the soil and favoring the establishment of the sugarcane root system. ARAÚJO *et al.* (2016) confirmed this in research carried out in the Brazilian Cerrado. The researchers observed that the application of gypsum increased sugarcane productivity in four cuts, and resulted in higher levels of Ca^{2+}, Mg^{2+} and SO_4^{2-} and lower aluminum saturation in the 0–100 cm layer. In addition, the application of agricultural gypsum provided an increase in the cation exchange capacity in the 40–100 cm layer.

CRUSCIOL *et al.* (2017) studied the application of agricultural gypsum associated with limestone and silicates. In general, the researchers found that the application of limestone and silicate in association with gypsum changes soil acidity throughout the soil profile and leads to an increase in agro-industrial yield, with increased sugar gain.

These beneficial effects of plaster application in cultivation generate greater efficiency in the use of water and soil nutrients, and under high availability of solar radiation, which is common in the region where the experiment was carried out, increase the photosynthetic rates of sugarcane and, consequently, there is a greater production of photoassimilates (carbohydrates) and phytomass. Therefore, it is observed that the application of agricultural gypsum combined with adequate conventional mineral fertilization results in the greater agro-industrial quality of sugarcane compared to areas that receive the application of poultry litter, an organic fertilizer rich in nitrogen, which favors excessive nitrogen availability and generates difficulties to maturation of the sugarcane crop and, consequently, lower agro-industrial quality.

Although in areas where agricultural gypsum was applied there was a better agro-industrial quality than in areas that received poultry litter application, this second treatment was equal to the others in terms of TRS, POL_{CANE} and POL_{BROTH}. CARVALHO *et al.* (2013) did not observe significance for the application of agricultural gypsum in sugarcane cultivation in relation to agro-industrial quality. And these same researchers checked that areas where only mineral fertilization was applied have the same performance as areas where gypsum was applied. The same result was observed in this research, since the effects of conventional mineral fertilization (T_8) were not statistically different from the effects in areas with gypsum application (T_2).

This makes it clear the need for further research to verify the appropriate amount and form of application of agricultural gypsum (in furrow or total area) so that its effects are effective and generate gains in dystrophic soils such as the one in the location where this research was carried out. Therefore, the beneficial effects of agricultural gypsum are known, however, the dose to be applied may still vary depending on the soil conditions of each locality and/or region.

CONCLUSION

In regions close to the Equator, the center of the tropical region, air temperature is not a limiting factor for the growth and development of sugarcane. And, the evapotranspiration of this agricultural crop (ET_C), in a 16-month cycle, is approximately 2,054 mm. In the Coastal Plateaus region of Alagoas, there is a mean water deficit of approximately 748 mm in sugarcane crops, in 16-month cycle, because, despite the rainfall being greater than the crop's evapotranspiration, there is water scarcity at certain times of the year due to seasonality of rainfall. Despite this, the average agricultural productivity obtained was 115 Mg ha^{-1}, a value higher than the Brazilian average.

The agro-industrial quality of sugarcane cultivated in areas with the application of agricultural gypsum in the planting furrow is significantly better than that of areas cultivated with poultry litter. And the agro-industrial quality of sugarcane fields cultivated with agricultural limestone and conventional fertilization does not differ significantly from the areas where agricultural gypsum is applied or the areas where poultry litter is used. These data reinforce the productive potential of sugarcane in the region, even in the face of seasonal water challenges and variations in treatment methods for different soils

NOTES

AUTHOR CONTRIBUTIONS

Conceptualization, methodology, and formal analysis, Silva, R.B. and Santos Neto, A.L.; investigation, Silva, R.B., Santos Neto, A.L., Barros, A.C., Rosendo, V.S., Santos, W.M., Costa, B.R.S., Souza, J.W.G. and Santos, J.K.; resources and data curation, Silva, R.B., Martins, G.M. and Souza, A.A.; writing-original draft preparation, Silva, R.B., Santos Neto, A.L. and Barros, A.C.; writing-review and editing, Teodoro, I. and Martins, G.M.; supervision, Silva, R.B. and Santos Neto, A.L.; project administration, Silva, R.B. and Santos Neto, A.L. All authors have read and agreed to the published version of the manuscript.

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DATA AVAILABILITY STATEMENT

The data can be made available under request.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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