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WATER DEPTHS AND NITROGEN RATES ON SUGARCANE GROWTH AND DRY BIOMASS ACCUMULATION

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Abstract

Irrigation and soil fertilization management are essential agricultural practices that improve the growth and development of sugarcane plants and, consequently, increase their production capacity, which is important for sugar and alcohol productions. In this context, the objective of this work was to evaluate the effect of water depths and nitrogen rates on the growth and dry biomass accumulation of sugarcane plants. The treatments consisted in four water depths (1,498; 1,614; 1,739; and 1,854 mm), five nitrogen rates (0; 20; 40; 80; and 120 kg ha^{-1}) and five evaluation times. The experiment was conducted in a randomized block design with a split-split-plot arrangement and four replications, including the factors water depths, nitrogen rates, and days after planting. The dry biomasses of the plant pointer, leaves and culms, culm diameter, plant height, and number of plants were analyzed. The application of nitrogen increased the sugarcane biomass, mainly the pointer (with leaves) and dry culm biomass, and the number of plants. The highest dry culm biomass accumulation and dry leaf biomass were found at the end of the crop cycle for the treatment with the application of nitrogen rates of 80 and 120 kg ha^{-1}. The increases in water depths applied increased the number of plants per linear meter, but the culm and dry leaf biomass did not happen.

Keywords: Crop cycle. Irrigation. Nitrogen fertilizer application. *Saccharum* spp.

1. Introduction

Sugarcane (*Saccharum* spp.) crop has a significant importance in the world's current situation. The crop is important not only for sugar production but also for biofuel and electrical energy production. The adaptation of the crop to the edaphoclimatic conditions of Brazil and the large planted area made the country responsible for 61.80% of the world's sugar exports (MAPA 2016).

Brazil is currently the largest sugarcane-producing country in the world, with an estimated planted area of approximately 8,407,000 ha in the 2020/2021 crop season (CONAB 2020). Despite the Northeast region having a smaller planted area with sugarcane than other regions of Brazil, such as the Southeast region, it had an estimated planted area of approximately 861,000 ha in the crop season of 2020/2021, representing 10.24% of the national area with sugarcane crop.

Sugarcane is the crop with the largest irrigated area in Brazil, approximately 30% (ANA 2017). Considering the large planted area with sugarcane in the Southwest and Central-West regions of Brazil and the importance of correct irrigation management and soil fertilizer application to increase the crop yield, studies related to irrigation management and soil fertilizer application for this crop have been more frequent in these regions (Pereira et al. 2015; Román et al. 2015; Lopes Sobrinho et al. 2019). Moreover, studies in the Northeast region are incipient and many times restricted to small areas, which denotes the need for studies on these issues for the region, focusing on increasing the crop yield and expanding the crop area in the region, especially in the Zona da Mata region, in the state of Pernambuco.

Silva et al. (2015) found that the sugarcane plants grown in the Coastal Tablelands region of the state of Alagoas, Brazil, presented a water demand of 1,279 mm; and Resende et al. (2016) found a water demand of approximately 1,500 mm.

In addition to irrigation, soil fertilization management is also important since the development of sugarcane plants is compromised without a balanced source of nutrients, resulting in crop yields below those expected. Nitrogen is the most studied macronutrient since it participates in the composition of amino acids, proteins, chlorophyll, and many enzymes that are essential to stimulate the growth and development of the shoot and root system of these plants (Marschner 2012) and is one of the most absorbed nutrients by sugarcane crop.

Esperancini et al. (2015) reported that nitrogen is one of the nutrients that most limit the sugarcane yield; they found that a rate of 170 kg ha^{-1} of nitrogen, using urea, is required to obtain a yield of 140 Mg ha^{-1}. Moreover, Román et al. (2015) reported that 100 kg ha^{-1} of nitrogen increases the yield by 27.50% when using irrigation to supply 100% of the crop water demand. In addition, Pires et al. (2018) found that the application of 100 kg ha^{-1} of urea over the sugarcane cycle contributes to increasing the gross yield of sugar and alcohol by 12.74 and 14.10%, respectively.

In this context, this work's objective was to evaluate sugarcane crops' growth subjected to different water depths and nitrogen rates in the Zona da Mata region in the Pernambuco State, Brazil.

2. Material and Methods

A field experiment was conducted at the agricultural area of the Experimental Station for Sugarcane of Carpina (EECAC), a research unit of the Federal Rural University of Pernambuco (UFRPE), in Carpina, Pernambuco State, Brazil (7º51'13''S, 35º14'10''W, and 180 m of altitude).

The soil of the experimental area was classified as a Typic Hapludult (Argissolo Amarelo distrofico abruptico) according to EMBRAPA (2013) and analyzed for physical and chemical characteristics using samples collected from the 0.0-0.2 and 0.2-0.4 m layers (Table 1). The soil pH was corrected by applying limestone at the rate of 465 kg ha^{-1}. The soil preparation consisted of one harrowing (plow and leveler) for crushing the soil, cutting crop residues, incorporating the limestone, systematization of the area, and subsequent opening of furrows for planting.

Table 1. Soil chemical and physical characterization of the experimental area before the implementation of the experiment.

Layer	Chemical characteristics									
	pH	P	H+Al	Al^{3+}	Ca^{2+}	Mg^{2+}	K^{+}	CEC	BS	AS
m	H_2O	mg dm^{-3}	--------------------cmol$_c$ dm^{-3}--------------------						-----%-----	
0-0.20	5.18	17.5	3.45	0.25	1.67	1.63	0.15	6.90	50.00	6.76
0.20-0.40	5.06	17.0	4.00	0.30	1.67	1.13	0.15	6.95	42.44	9.23

Layer	Physical characteristics						
	SD	Sand	Silt	Clay	Θ_{FC}	Θ_{PWP}	Textural Class
m	mg m^{-3}	------------g kg^{-1}---------			---m^3 m^{-3}---		
0-0.20	1.72	848.7	13.9	137.4	0.15	0.10	Sandy loam
0.20-0.40	1.86	826.2	16.4	157.4	0.18	0.12	Sandy loam

CEC = cation exchange capacity; BS = base saturation; AS = aluminum saturation; SD = soil density; Θ_{FC} = soil moisture at field capacity; Θ_{PWP} = soil moisture at permanent wilting point.

Mineral soil fertilizer was applied at planting, using 30 kg ha^{-1} of P_2O_5, 60 kg ha^{-1} of K_2O, and nitrogen (according to each treatment), using simple superphosphate, potassium chloride, and urea, respectively, as sources. The soil pH was corrected by liming, and the mineral fertilizer applications were carried out as recommended by Cavalcanti et al. (2008).

The experiment was conducted in a randomized block design, arranged in a split-split-plot design, with four replications. The treatments consisted of four irrigation water depths, five nitrogen rates, and five different periods of time. The irrigation water depths used were: 1,498 mm (WD0), 1,614 mm (WD1), 1,739 mm (WD2), and 1,854 mm (WD3), which were calculated based on the crop evapotranspiration, including the accumulated rainfall and initial water depths applied (1,360 + 138 mm). The nitrogen rates used were: 0, 20, 40, 80, and 120 kg ha^{-1}. The parameters were analyzed at 165, 225, 263, 306, and 349 days after planting (DAP).

The data were subjected to a normality test (Shapiro-Wilk) and analysis of variance (ANOVA) by the F test. When the effects were significant, the data were subjected to regression analysis at a 5% probability.

The nitrogen rates applied were defined considering the standard rate used for sugarcane crops (first cycle) in the state of Pernambuco, which is 40 kg ha^{-1} based on recommendations of Cavalcanti et al. (2008). The doses of nitrogen used in the study were calculated based on percentages of the standard rate.

The planting was carried out manually, using sugarcane seedlings of the variety RB92579. The experimental plots consisted of 10.0 m sugarcane plant rows spaced 1.1 m apart, totaling an area of 66.0 m^2, with an evaluation area of 39.6 m^2, totaling 80 experimental plots.

The irrigation system used was a line-source sprinkler system (sprinkler in rows), according to the methodology developed by Hanks et al. (1976). The system consisted of a central row with seven sprinklers spaced 15 m apart on a pipe in the center of the experimental area. The sprinklers type KS1500 (PLONA, Curitiba, Brazil) were used, had openings with a diameter of 16.0 × 5.0 mm, service pressure of 245 kPa, a nominal flow rate of 13.61 m^3 h^{-1}, and a wet diameter of 60 m.

The ratio between the reference water depth (100%) and the others used, and water depths applied in each treatment, was obtained by evaluations of the irrigation system. The tests to measure the irrigation water depths consisted of distribution collectors along the sprinkler row, using five collectors per plot, spaced 1 m apart, distributed in each experimental block between the planting rows. The water depths were defined by the mean volume of water collected in the five collectors (Table 2).

Irrigation was used when the difference between the daily crop evapotranspiration (ETc) and rainfall depth in the period reached 40% of the soil's total available water. The daily ETc (mm) was calculated using Equation 1:

$$ET_c = ECA \times Kp \times Kc \qquad (1)$$

Where: ECA = evaporation of Class A pan, mm; Kp = coefficient of the Class A pan; and Kc = crop coefficient.

Table 2. Results of the evaluation of the irrigation system and volume of water applied.

Water depth	WF (mm h^{-1})	WDi (%)	WDa (mm)	WD (mm)	RD (mm)	WDt (mm)
WD3	27.8	150	356	138	1360	1,854
WD2	18.5	100	241	138	1360	1,739
WD1	9.6	48	116	138	1360	1,614
WD0	0.0	0	0	138	1360	1,498

WF = water flow rate of the irrigation system; WDi = irrigation water depth based on the crop evapotranspiration; WDa = irrigation water depth applied during the crop cycle (mm); RD = rainfall depth during the experiment; WDt = total water depth applied (mm).

The total soil available water was determined considering the soil moisture results at field capacity and permanent wilting point and the root system depth. The water balance during the sugarcane crop cycle is shown in Figure 1.

The coefficients of the Class A pan (Kp) were obtained according to Doorenbos and Pruitt (1976) using data on wind speed, relative air humidity, and evaporation in the Class A pan installed next to the experimental area with ground vegetation and a border of 10 m. The Kc was determined using the values recommended by Doorenbos and Kassam (1994) for the developmental stages of the crop.

In the first three months of the crop cycle, the areas of all treatments were homogeneously irrigated, using a water depth of 138 mm, since the planting was done in the summer, within the dry season, to ensure the uniformity of sprouting and establishment of plants. This irrigation was done using a mobile cannon sprinkler with an opening diameter of 101.6 mm, a flow rate of 54 $m^3 h^{-1}$, and a pressure of 392 kPa. The application of the different water depths was then started using the line-source sprinkler system. The irrigation was stopped at 270 days after planting (DAP) to reduce the vegetative sugarcane growth and stimulate physiological maturation.

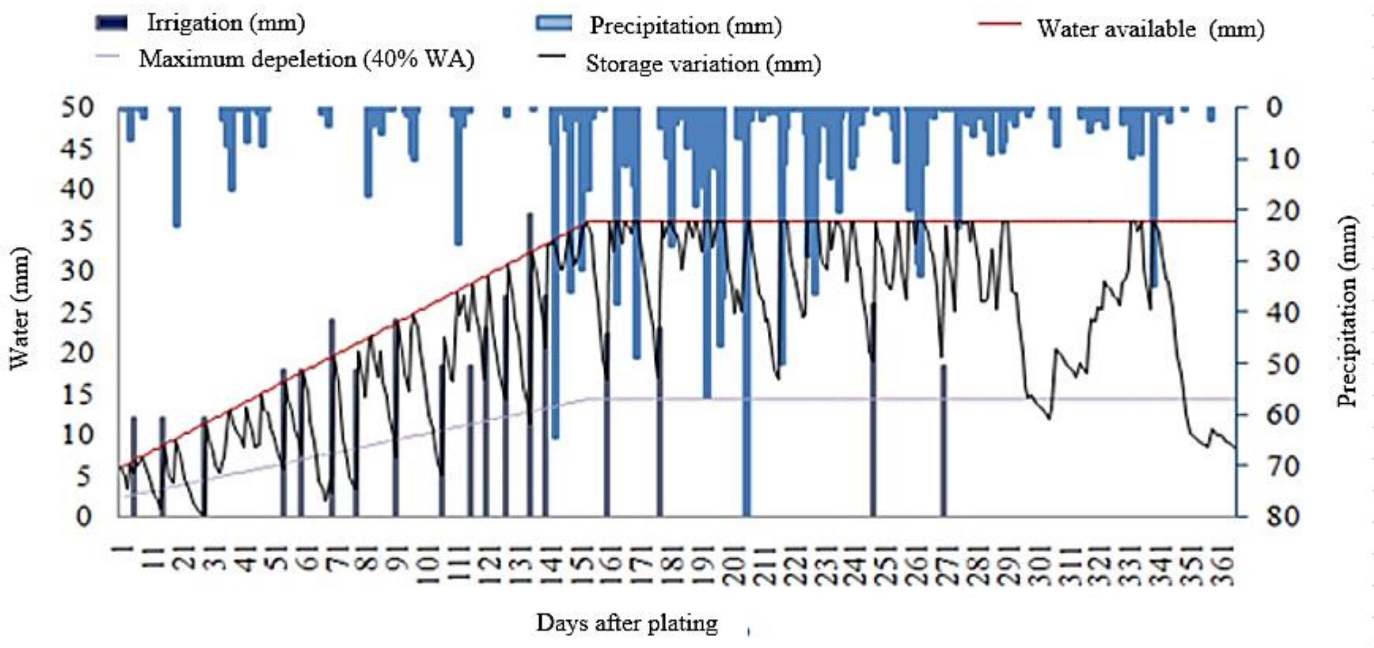


Figure 1. Water balance during the sugarcane crop cycle (plant crop).

The plant height and culm diameter were determined at 116, 179, 238, 301, and 363 DAP. For evaluation, 10 plants were considered in the six central rows. The number of plants in these rows was counted. Plant height from the ground to the base of the +1 leaf was measured using a tape ruler. The culm diameter was measured at 20 cm height from the base of the plants using a digital caliper. The number of plants was quantified by counting the plants per linear meter.

Five evaluations of plant shoots (10 randomly selected plants per evaluation) were carried out for each treatment to evaluate the shoot dry biomass. The plants were collected at 165, 225, 263, 306, and 349 DAP in each experimental plot's external rows (rows 1, 2, 9, and 10). After the collections, the shoots of the plants were separated into pointer, leaves, and culms.

The pointer, leaves, and culms were then weighed to determine their total fresh biomass and then crushed in a forage cutter; subsamples were collected to determine the fresh biomass moisture. These plant materials were placed in a forced air circulation oven at approximately 65 °C until constant weight to obtain the dry biomass. The total dry biomass production was quantified considering the fresh biomass of the plants and the moisture in the different plant parts.

3. Results

The isolated effect of the nitrogen rates and days after planting (DAP) was significant for the sugarcane pointer and leaf dry biomass accumulations at a 1% probability level. The effect of the interactions between nitrogen rates and water depths and nitrogen rates and DAP was significant for dry culm biomass accumulation at 5% and 1% probability levels, respectively (Table 3).

The plant height was affected at a 1% probability level by the effect of the interactions between water depths and nitrogen rates, water depths and DAP, and nitrogen rates and DAP. The culm diameter was affected at a 1% probability level by the interaction between water depths and nitrogen rates. The number of plants per linear meter was significantly affected by the isolated effect of nitrogen rates, and by the effect of the interaction between water depths and DAP, at 5% and 1% probability levels, respectively (Table 3).

Table 3. ANOVA for dry biomass accumulation (DBA) (top, leaf, and culm), plant height, culm diameter, and number of plants of sugarcane subjected to different water depths (WD) and nitrogen rates (NR), evaluated over the crop cycle (DAP).

Source of variation	DF	DBA Top	DBA Leaf	DBA Culm	Plant height	Culm diameter	Number of plants
		------------Mg ha^{-1}-----------			--------------cm----------		Plants m^{-1}
Block	3	0.80^{ns}	3.63^{ns}	0.80^{ns}	3.94*	6.72*	7.62**
WD	3	1.98^{ns}	1.87^{ns}	2.29^{ns}	3.08*	3.02^{ns}	6.65*
Error (WD)	9	---	---	---	---	---	---
NR	4	10.24**	28.48**	39.02**	15.88**	19.16**	4.68*
Error (NR)	12	---	---	---	---	---	---
DAP	4	13.55**	15.98**	270.37**	2509.20**	4.31*	192.03**
Error (DAP)	12	---	---	---	---	---	---
WD × NR	12	1.30^{ns}	1.21^{ns}	2.57*	2.53**	2.40**	1.851^{ns}
WD × DAP	12	1.70^{ns}	0.71^{ns}	1.19^{ns}	3.35**	1.29^{ns}	3.76**
NR × DAP	16	1.28^{ns}	1.66^{ns}	3.63**	2.86**	6.24^{ns}	1.05^{ns}
WD × NR × DAP	48	0.75^{ns}	1.07^{ns}	1.27^{ns}	0.54^{ns}	0.46^{ns}	0.46^{ns}
Error ($_{WD \times NR \times DAP}$)	264	---	---	---	---	---	---
Mean		3.25	7.68	65.46	228.71	2.55	14.62
CV $_{WD}$ (%)		15.25	15.58	27.45	13.64	9.90	19.55
CV $_{NR}$ (%)		17.55	15.40	16.45	12.14	7.48	25.62
CV $_{DAP}$ (%)		13.89	16.84	10.13	9.10	10.87	18.15
CV $_{WD \times NR \times DAP}$ (%)		30.98	13.55	11.97	4.64	5.06	13.58

DF = degrees of freedom; ns = not significant, * = significant at 5%, and ** = significant at 1% of probability by the F test. Values of F calculated.

The maximum dry biomass accumulation in the sugarcane plant pointer (4.89 Mg ha^{-1}) was found for the application of the nitrogen rate of 120 kg ha^{-1}, and the lowest (3.92 Mg ha^{-1}) was found for the treatment without nitrogen fertilizer application. It represented an increase in biomass accumulation of 0.008 Mg ha^{-1} per kilogram of nitrogen applied (Figure 2). The dry biomass accumulations found for the nitrogen rates of 20, 40, and 80 kg ha^{-1} were 3.77, 4.16, and 4.71 Mg ha^{-1}, respectively (Figure 2). The pointer dry biomass had the highest accumulation (5.23 Mg ha^{-1}) at 349 DAP and the lowest (3.88 Mg ha^{-1}) at 165 DAP.

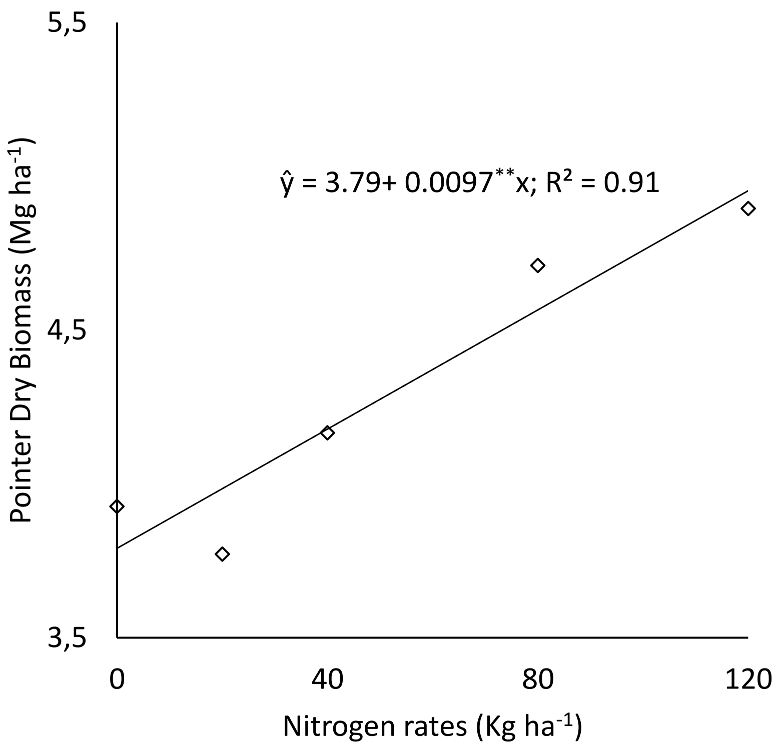


Figure 2. Top dry biomass accumulation of sugarcane plants (plant crop) of the variety RB92579 as a function of nitrogen rates.

Considering the effect of the nitrogen rates on the leaf dry biomass accumulation, the lowest accumulation was 8.60 Mg ha^{-1}, which was found for the treatment without nitrogen application. The highest was 12.64 Mg ha^{-1}, which was found for the nitrogen rate of 120 kg ha^{-1}, representing an increase of 0.033 Mg ha^{-1} per kilogram of nitrogen applied (Figure 3A).

The effect of DAP on leaf dry biomass accumulation showed a decreasing quadratic response, with decreases from 165 to 220 DAP and subsequent increases up to 349 DAP. The mean leaf dry biomass accumulation at 165, 225, and 349 DAP were 7.02, 7.80, and 9.80 Mg ha^{-1}, respectively (Figure 3B).

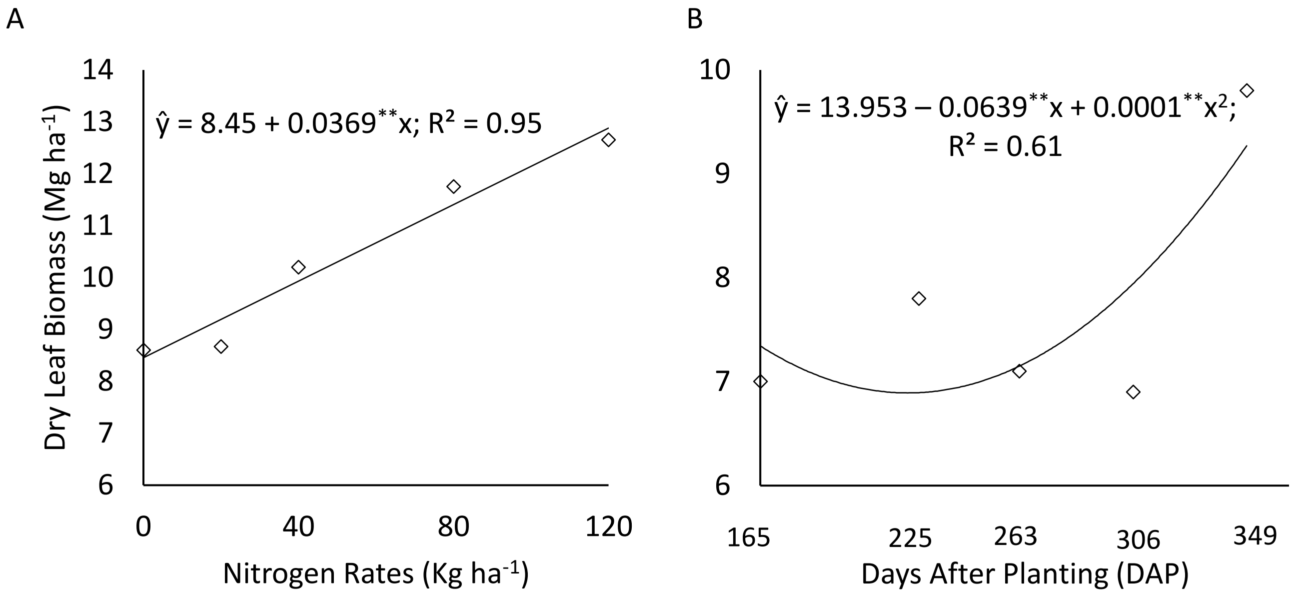


Figure 3. Dry Leaf biomass accumulation of sugarcane plants (plant crop) of the variety RB92579 A - as a function of nitrogen rates and B - days after planting.

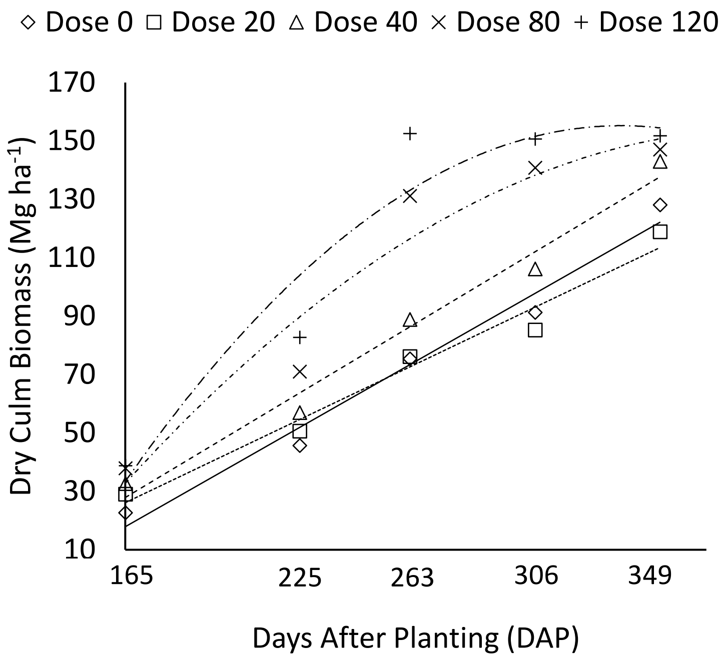
The effects of the DAP on the dry culm biomass accumulation showed variations over the crop cycle within each nitrogen rate applied, fitting linear equations for the nitrogen rates of 0, 20, and 40 kg ha^{-1} and quadratic equations for the rates of 80 and 120 kg ha^{-1} (Figure 4).

The highest dry culm biomass accumulations (128.08, 118.88, 142.98, 147.06, and 151.73 Mg ha^{-1}) were found at 349 DAP, and the lowest (22.66, 28.98, 32.60, 37.90, and 98.81 Mg ha^{-1}) at 165 DAP. At 349 DAP occurred, an increase of 11.63% from the rate of 0 to the rate of 20 kg ha^{-1}.

The effect of the nitrogen rates on plant height in each water depth applied showed linear increases in plant height in the four water depths (Figure 5). The highest heights were found for the nitrogen rate of 120 kg ha^{-1}, with means of 3.70, 3.8, 3.9, and 3.7 m for the water depths of 1,498, 1,614, 1,739, and 1,854 mm, respectively. The lowest plant height found were 3.4, 3.3, 3.4, and 3.3 m, respectively, which was found for treatments without nitrogen application with water depths of 1,498, 1,614, 1,739, and 1,854 mm, representing increases of 8.8, 15.1, 14.7, and 12.1%, respectively, when compared to the treatments without nitrogen application for the nitrogen rate of 120 kg ha^{-1}, within the respective water depths.

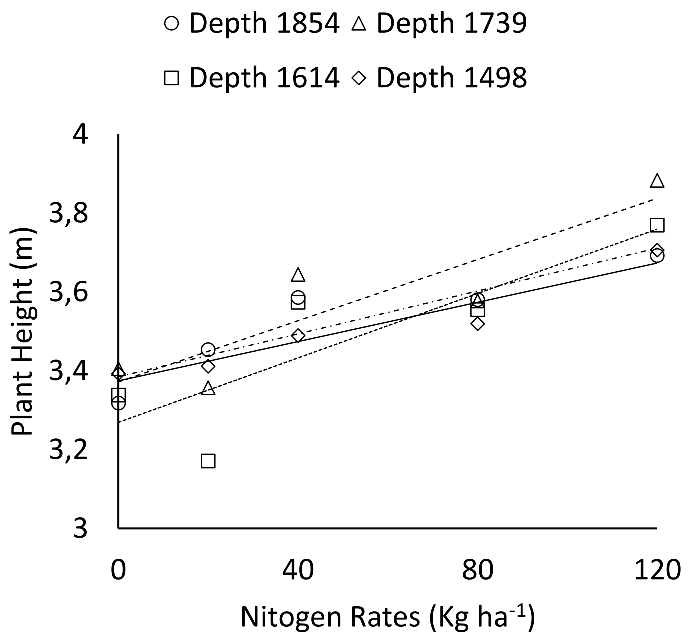
The plant height was significantly affected by the DAP within each water depth applied, fitting to increasing linear models (Figure 6A). The highest plant height was found at the end of the crop cycle (363 DAP), with 3.50, 3.48, 3.57, and 3.53 m, and the lowest at 116 DAP, with 0.84, 0.93, 1.03, and 1.09 m for the water depths of 1,498; 1,614; 1,739, and 1,854 mm, respectively (Figure 6A).

The plant height was affected by the interaction between nitrogen rates and DAP, fitting to linear models over the crop cycle (Figure 6B). The highest plant height was found at 363 DAP and the lowest at the beginning of the crop cycle (116 DAP). The plant heights were 3.36, 3.35, 3.56, 3.26, and 3.76 m at 363 DAP, and 0.89, 0.89, 0.98, 1.04, and 1.04 m at 116 DAP for the nitrogen rates of 0, 20, 40, 80, and 120 kg ha^{-1}, respectively. It represented an increase of 16.8% when compared to the treatment without nitrogen application for the nitrogen rate of 120 kg ha^{-1}, and highlighted the importance of this nutrient for increases in plant growth rate.



◇	$\hat{y} = -75.608 + 0.57^{**}x$	$R^2 = 0.98$
□	$\hat{y} = -52.206 + 0.47^{**}x$	$R^2 = 0.97$
△	$\hat{y} = -70.568 + 0.59^{**}x$	$R^2 = 0.98$
×	$\hat{y} = -216.03 + 1.92^{*}x - 0.0025^{*}x^2$	$R^2 = 0.93$
+	$\hat{y} = -316.39 + 2.81^{**}x - 0.0042^{**}x^2$	$R^2 = 0.92$

Figure 4. Dry culm biomass accumulation of sugarcane plants (plant crop) of the variety RB92579 as a function of days after planting in each nitrogen rate.



◇	$\hat{y} = 3.37 + 0.0025^{**}x$	$R^2 = 0.92$
□	$\hat{y} = 3.27 + 0.041^{*}x$	$R^2 = 0.72$
△	$\hat{y} = 3.37 + 0.0039^{**}x$	$R^2 = 0.79$
○	$\hat{y} = 3.38 + 0.0027^{**}x$	$R^2 = 0.83$

Figure 5. Heights of sugarcane plants (plant crop) of the variety RB92579 as a function of nitrogen rates in each water depth applied.

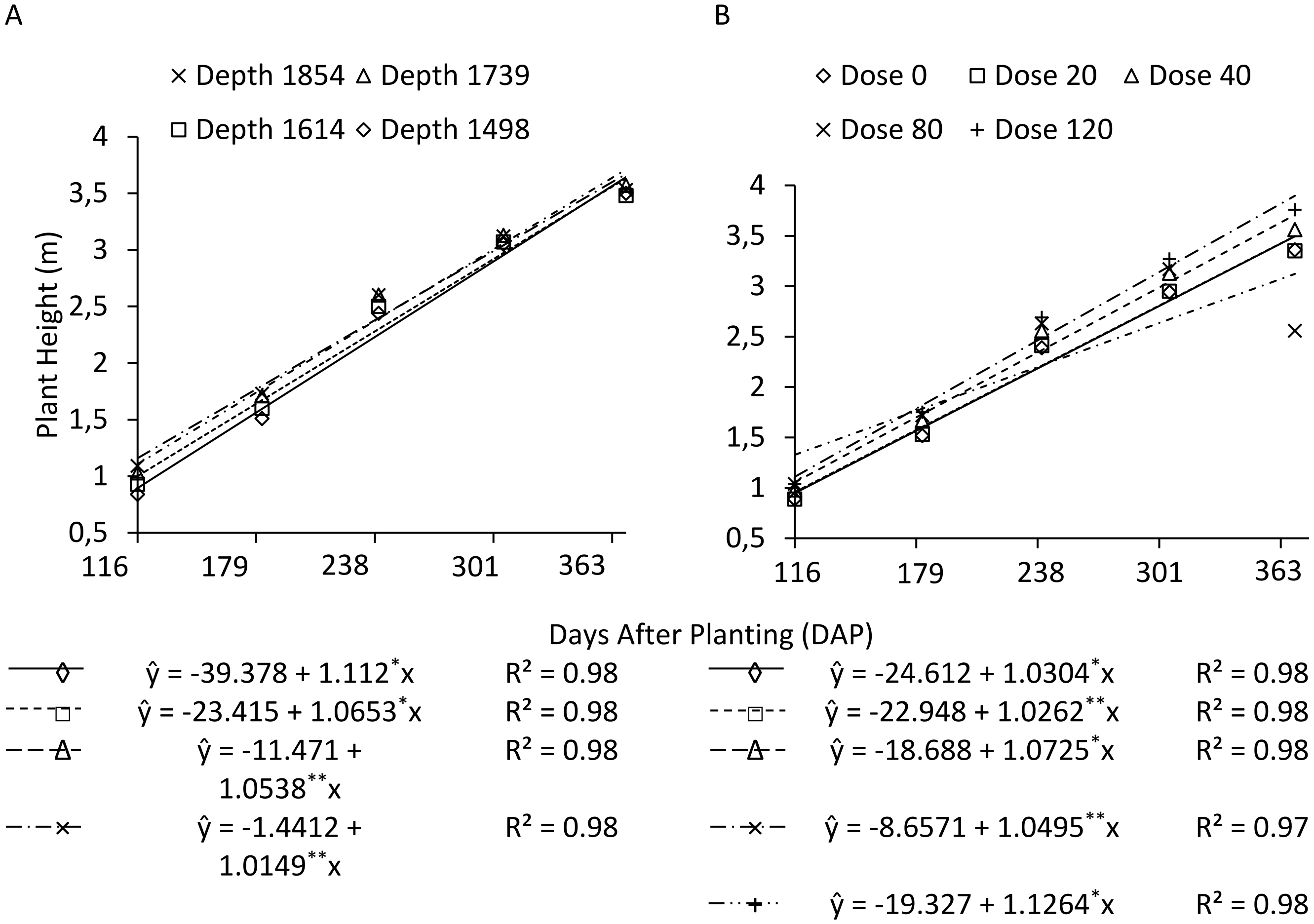


Figure 6. Heights of sugarcane plants (plant crop) of the variety RB92579 A - as a function of days after planting in each water depth and B - nitrogen rate applied.

The effect of the nitrogen rates on culm diameter in each water depth (Figure 7) was significant for the water depths of 1,614; 1,739; and 1,854 mm, with the data fitting to linear increasing models within the respective water depths. The highest diameters (2.56, 2.72, and 2.78 cm) were found for the nitrogen rate of 120 kg ha^{-1}, and the lowest (2.47, 2.64, and 2.59 cm) for the treatment without nitrogen application, for the water depths of 1,614; 1,739; and 1,854 mm, respectively. This represented increases of 3.64, 3.03%, and 7.33% in culm diameter for the water depths of 1,614; 1,739; and 1,854 mm, respectively.

The increase in nitrogen rates resulted in a linear increase in the number of plants per linear meter (Figure 8A). The highest number of plants (15.74) was found for the nitrogen rate of 120 kg ha^{-1} and the lowest (13.70) for the treatment without nitrogen application. This represented an increase in the number of plants of 14.9% from the treatment without nitrogen application to the nitrogen rate of 120 kg ha^{-1}.

The interaction between water depths and DAP (Figure 8B) affected the number of plants per linear meter in the four water depths studied. The numbers of plants found at 116 DAP were 19.39, 20.95, 21.59, and 23.45 plants m^{-1} for the water depths of 1,498; 1,614; 1,739; and 1,854 mm, respectively. The number of plants decreased at the end of the cycle, showing means of 12.33, 12.08, 15.19, and 11.70 plants m^{-1} for the water depths of 1,498; 1,614; 1,739; and 1,854 mm, respectively.

4. Discussion

The decrease in pointer dry biomass over the DAP may be related to the vegetative development of other plant parts. Marafon et al. (2015) evaluated the growth and yield of sugarcane plants in four crop seasons in the Coastal Tablelands region of the Alagoas State, Brazil, and found decreases in pointer biomass production for the second half of the sugarcane cycle.

Gírio et al. (2015) evaluated the effects of nitrogen application on the initial growth of sugarcane plants grown from pre-sprouted seedlings and found that the use of a nitrogen rate of 50 kg ha^{-1} increased four-fold the straw production when compared with the treatment without nitrogen application, agreeing with the fact that the nitrogen contributes to increasing the biomass production. Silva et al. (2019) applying until 180 kg ha^{-1} could also verify the contribution of nitrogen to biomass accumulation and industrial yield of irrigated sugarcane crops and also found linear increases for shoot dry biomass accumulation as the nitrogen rates were increased. Pereira et al. (2020) also found increases in shoot dry biomass production for sugarcane plants due to nitrogen applications.

The plant's initial growth depends on the sett's reserves to produce the organs. After the development of the root system and leaf expansion, plants acquire water and nutrients from the soil and start processes dependent on photosynthesis and those nutrients and water, entering a growth stage with the highest increases in dry biomass accumulation, according to the resources available (Taiz and Zeiger 2013).

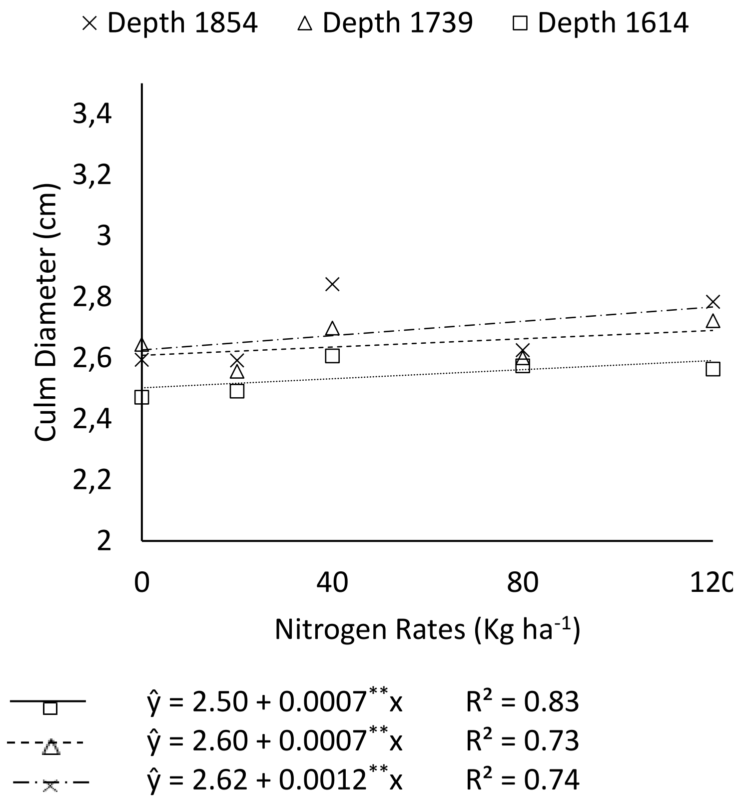


Figure 7. Culm diameter of sugarcane plants (plant crop) of the variety RB92579 as a function of nitrogen rates for each water depth used.

Bastos et al. (2015) evaluated the effect of irrigation water depths and nitrogen rates on the sugarcane yield and dry biomass accumulation and found that the use of 100 kg ha^{-1} of urea increased the sugarcane culm production in 20.85 Mg ha^{-1}, which is due to increases in dry biomass production. Dinh et al. (2018) reported that the dry culm biomass of sugarcane plants grown under increasing nitrogen rates up to 180 kg ha^{-1} tends to increase, as much as the nitrogen available, and emphasized that water stress affects the use of the nutrient by the plant and, consequently, the crop yield, with higher yields for plants grown under no water deficit.

Dry culm biomass directly affects the sugarcane yield. Nutrients are mainly absorbed in the maturation stage and used for culm development, making it the main nutrient drain of the plant. Kölln et al. (2016) evaluated the shoot dry matter production of sugarcane plants as a function of the application of nitrogen rates and found that this nutrient resulted in an increase of 98 Mg ha^{-1} in the culm yield in two agricultural years. Cunha et al. (2016) found that the use of 100 kg ha^{-1} of urea resulted in a plant growth rate of 1.42 cm day^{-1}, contrasting with the 1.33 cm day^{-1} found for the treatment without nitrogen application.

Water is essential for the elongation of internodes, which results in plants with higher heights under favorable conditions for plant growth. Silva et al. (2016) evaluated the effect of different water availability on the growth, development, and yield of sugarcane plants and found that the application of 93.50% of the required irrigation results in increases in maximum plant height of 3.22 m. Moreover, Oliveira et al. (2016a) evaluated the application of different water depths in sugarcane plants of different cultivars and found that plants of the RB92579 cultivar reached a mean height of 3.76 m at 270 days after planting when applying a water depth of 82% of the evapotranspiration. In addition, Nogueira et al. (2016) reported that irrigation positively affects the vegetative growth of sugarcane plants and recommended a water depth of 78% of the evapotranspiration for stable and balanced development of the crop.

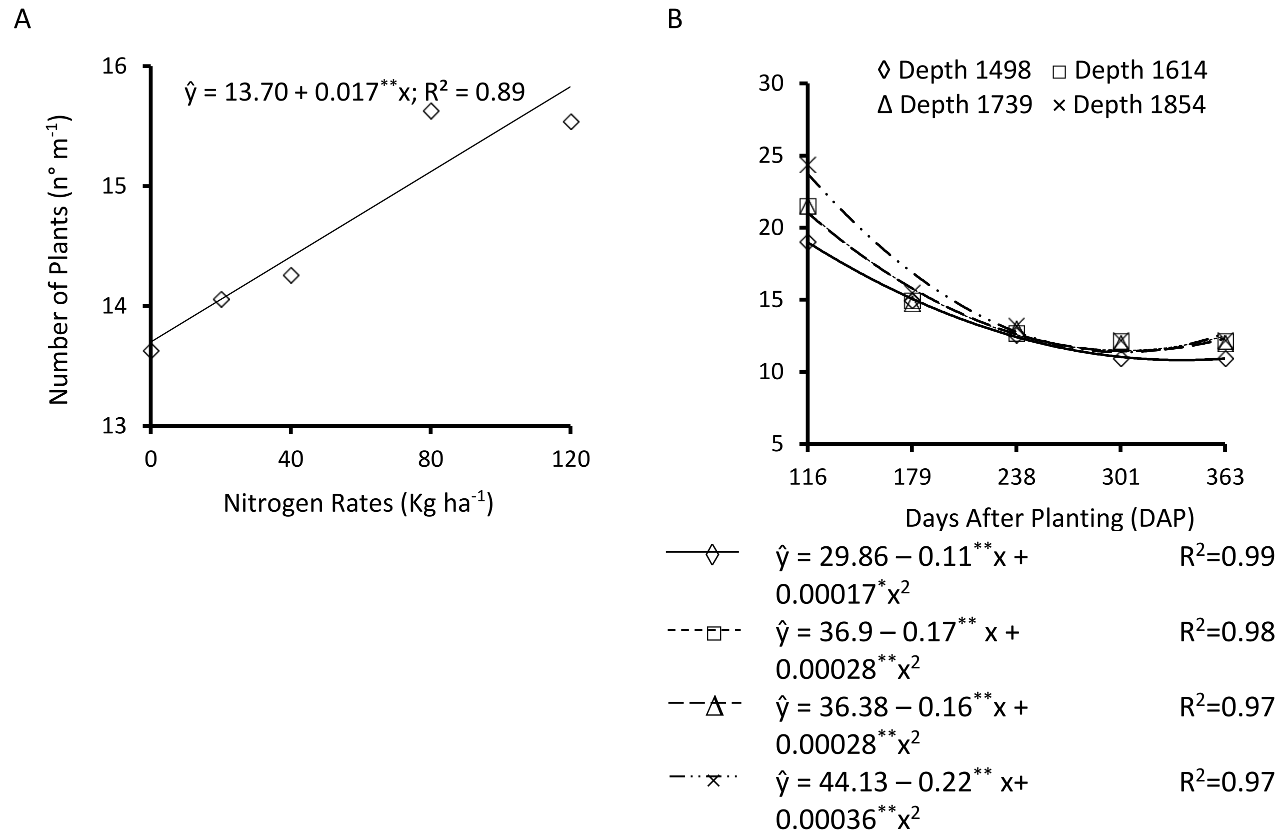


Figure 8. Number of sugarcane plants (plant crop) of the variety RB92579 A - as a function of nitrogen rates and B - days after planting for each water depth used.

Oliveira and Simões (2016b) evaluated nitrogen application for an intercrop with diazotrophic bacteria and found that plants that received the fertilizer presented lower culm diameter, including those of the cultivar RB92579.

The more pronounced decrease in the number of plants was found for the water depth of 1,854, which showed a decrease of 50.1% from the beginning to the end of the crop cycle. These mean numbers of plants per linear meter are consistent with those found by Pellin et al. (2015); this denotes that the application of 1,854 mm of water may have leached the nutrients out of the root zone, harming the sugarcane development, in comparison to the lower water depths.

Increasing soil water availability is essential for plants to absorb water and nutrients and, thus, complete their cycle with the maximum yield. Improving water availability up to a proper quantity increases the sprouting of sugarcane plants, resulting in increases in the number of plants. A higher number of plants at the beginning of the cycle helps establish a good stand of plants and, consequently, affects sugarcane yield. The number of plants found for the irrigation water depths used is consistent with those found by Oliveira et al. (2016a), who found a mean of 20.97 at 90 days after planting for plants of the cultivar RB92579 irrigated with a water depth of 60% of the crop evapotranspiration.

Gonçalves et al. (2020) found that nitrogen affects the emission of tillers and, consequently, the formation of a stand of plants favorable to a good crop yield in the field; and that the use of nitrogen as topdressing to plants inoculated with *Azospirillum brasilense* increases the formation of plants, with increases in the number of plants as the nitrogen rates is increased. Similarly, Bastos et al. (2017) found that the use of a nitrogen rate of 120 kg ha^{-1} applied on the second ratoon is enough to increase the number of sugarcane plants by 19% when compared to treatment with no nitrogen application.

5. Conclusions

The nitrogen rates applied resulted in increased plant height, number of plants per linear meter, and pointer, leaf, and dry culm biomass accumulations of the sugarcane crop.

To the environmental edaphoclimatic from the northeast, the highest dry culm biomass accumulations, the number of plants per linear meter, and dry leaf biomass were found at the end of the crop cycle for the application of nitrogen rates of 80 and 120 kg ha^{-1}.

The increases in water depths applied resulted in increases in the number of plants per linear meter, helping to form and stand plants viable to develop through the cycle. The dry culm biomass and the dry leaf biomass had a better result in the 1,614 mm and 1,739 mm water depths.

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