Growth indices of eleven sugarcane varieties grown under full irrigation environments in Brazil

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Abstract
Growth analysis is considered a standard method for measuring the biological productivity of plant species in determined environmental conditions. The objective of this study was to evaluate growth and dry matter production in the planted cane cycle of eleven varieties of sugarcane (SP79-1011, RB813804, RB863129, RB872552, RB943365, RB72454, RB763710, SP78-4764, SP81-3250, RB867515, RB92579), cultivated under full irrigation. The experiment was installed in field conditions in Carpina county, PE, Brazil. A randomized block statistical design was used, with four replications. Growth analysis of the varieties consisted of height and diameter measurement of the stalks, evaluated monthly, in eleven periods of the cultivation that extended from 60 to 360 days after planting (DAP). Dry matter production in the above ground part was quantified from 120 until 360 DAP, with sampling intervals of every two months. At 360 DAP the varieties RB72454, RB92579 and RB867515 obtained the highest stalk height, while the varieties RB863129, RB72454 and RB867515 presented the greatest diameter values. However the greatest dry matter in above ground productions at 360 DAP was observed in the varieties RB92579, SP81-3250 and RB872552.

Key Words
Saccharum spp, height, diameter, dry matter.

Introduction
Sugarcane growth occurs through the interaction of the crop with environmental factors. The best comprehension of such interactions may be obtained by means of quantitative analysis of growth and by biometric measurements of the plants during their development, thus permitting the use of physiological indices in the attempt to verify the differences among varieties and model growth on different management and production environments. (Keating *et al.* 1999; Machado *et al.* 1982). The present study had the objective of evaluating growth and dry matter production in the above ground part during the planted cane cycle in eleven varieties of sugarcane cultivated under full irrigation

Material and methods
Site description
The study was at the Sugarcane Experimental Station of Carpina (EECAC/UFRPE), located in the State of Pernambuco, Brazil. The experimental area is situated in Carpina county, latitude 7º51’133’’S and longitude 35º14’102’’W in a soil classified as Arenic Ultisoil. Research was performed in the planted cane cycle during the 2006/2007 agricultural season, with registration of annual rainfall in this period of 1.732 mm and average temperatures greater than 25oC.

Experimental design
The experiment was conducted in a randomized block experimental design with four replications. Eleven varieties of sugarcane were evaluated, with five being of early maturity (SP79-1011, RB813804, RB863129, RB872552 and RB943365) and six of medium to late maturity (RB72454, RB763710, SP78-4764, SP81-3250, RB867515 and RB92579).

Water balance
The study was conducted under full irrigation until 300 days after planting (DAP), the replacement water was calculated based in the crop evapotranspiration (ETc) up to 0.6 m of depth. For this purpose, the results of water field capacity (WFC) and water permanent wilting point (WPWP) of the soil to a respective depth were taken into consideration, as well as the precipitation and the efficiency of the irrigation system used.

The water replaced took into consideration the crop water consumption estimated by the Equation: $Etc = ECA \times Kc \times Kp$, in which: ETc = crop evapotranspiration (mm); ECA = Class A pan evaporation (mm); Kc = crop coefficient; Kp = Class A pan coefficient (Inman-Bamber and McGlinchey, 2003).

Sampling
For growth evaluation, ten cane plants in the three central rows of each experimental plot were identified and stalk height and diameter data was collected monthly. Stalk height was measured from the soil level up to the dewlap (+1) and the stalk diameter was measured on the middle third of the plant. The leaf (+1) was considered as that which presented the first clearly visible dewlap. The dry matter production in the above ground was evaluated at 120, 180, 240, 300 and 360 DAP, collecting eight samples from the sugarcane in each experimental plot. The samples were divided up into tops, leaves and stalk, later being weighed, chopped in a forage chopper and subsampled. The subsamples were dried in a forced air circulation laboratory oven at 65ºC until reaching a constant weight and moisture was determined. With the moisture values and tillering (sugarcane per meter), dry matter accumulation in kg/ha was calculated.

Statistical analysis
The growth and dry matter data were submitted to analysis of variance in randomized block design, using the F test at $p<0,05$. For the significant variables, regressions were adjusted in relation to the period of growth and accumulation of dry matter for each variety evaluated. As criteria for the choice of regression models, models were selected that presented the greatest coefficient of determination and significance of the regression parameters up to 5% probability by the t test.

Results and discussion
Sugarcane growth in reference to stalk height obtained logistical adjustment (Table 1), characterizing three phases of development (Figure 1 A and B). The first phase of growth was similar for all the varieties studied, with a small increase in stature being observed up until 60 DAP, with mean values of 18 cm. In the second phase of growth, which occurred between 60 and 240 DAP, differences among the varieties and the greatest growth rates were seen, with mean values of 1.5 cm/dia. At the end of the second phase of growth, the early maturity varieties RB872552 and RB863129 obtained the greatest heights with values of 305 and 282 cm respectively (Figure 1 A). For the medium to late maturity varieties, RB867515, RB763710 and RB92579 presented the greatest growth in stalk length, with values of 306, 298 and 287 cm respectively (Figure 1B). In the third phase of growth, the varieties obtained mean gains of 49 cm, which represented 15 % of the total stalk height. In this phase, the greatest final growth was observed in the varieties RB72454, RB92579, RB867515, with values greater than 350 cm, while the variety SP79-1011 presented the lowest values of growth, with an estimated mean of 268 cm (Figure 1 A and B).

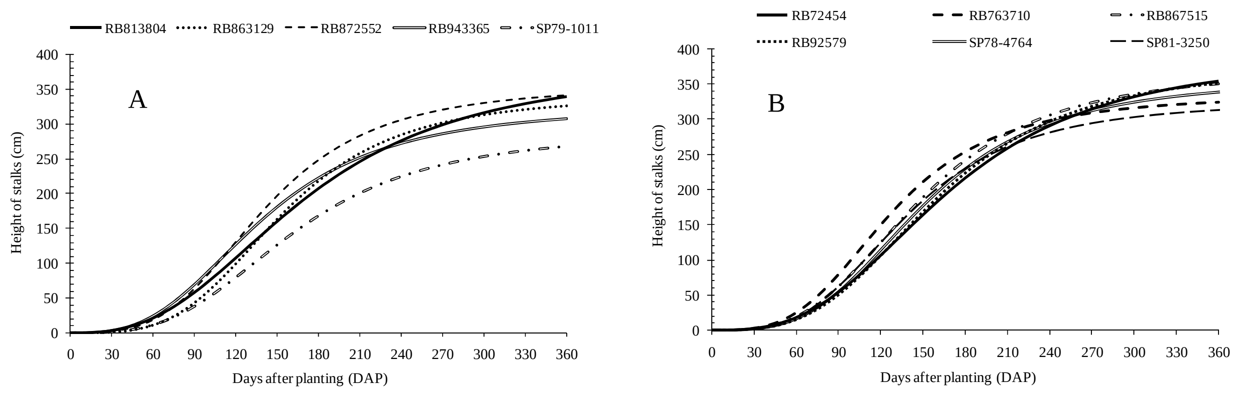

Figure 1. Stalk height in relation to time in sugarcane varieties of early maturity (A) and of medium to late maturity (B).

The first and second phase of growth were responsible for 85% of the total sugar cane stalk height among the varieties studied; in other words, the first two growth phases occurred from the months of October to June, a period characterized by low precipitation, greater light intensity and more elevated temperatures, which, when associated with water availability promoted by full irrigation, resulted in mean gains of 280 cm in stalk height. In the central south region of Brazil, Oliveira *et al.* (2004) in non-irrigated varieties observed the greatest gains in stalk height from the months of December to March, with mean growth rates of 1.7 cm/dia, making for final stalk statures of 326 cm, similar values to those observed in this study.

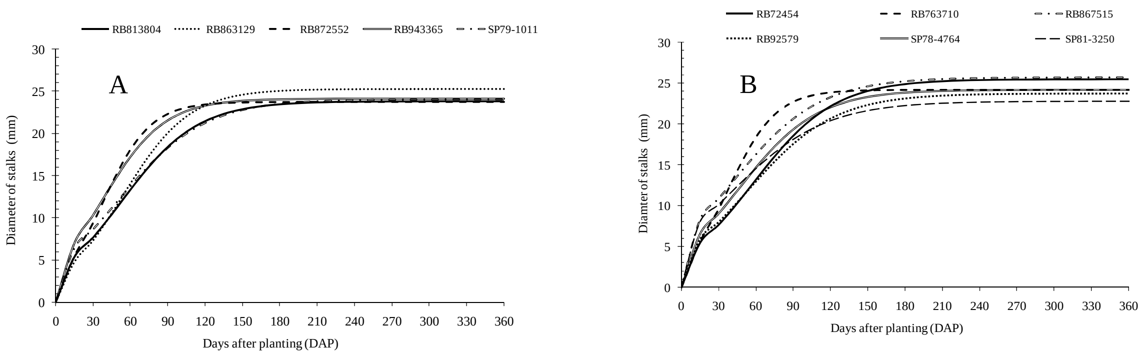

Figure 2. Stalk diameter in relation to time in sugar cane varieties with early maturity (A) and with medium to late maturity (B).

In relation to stalk diameter, the data was adjusted to the sigmoid model (Table 1), characterizing two phases of development (Figure 2 A and B). In the first phase, the increase in stalk diameter was rapid and constant, presenting a mean of 18 cm at the end of the period. The initial growth in stalk diameter differed among the varieties, In the varieties RB763710, RB867515, RB863129, RB872552 and RB913365, it was observed that the first phase continued up to 60 DAP and in RB72454, RB92579, SP78-4764, SP81-3250, RB813804 and SP79-1011, up to 90 DAP (Figures 2A and B). In the second phase, the sugarcane stalk diameter presented a small increase, obtaining mean values of 24 mm. Among the varieties, RB863129 of early maturity, and RB72454 and RB867515 of medium to late maturity presented the greatest diameters at 360 DAP, with a mean value of 26 mm respectively (Figures 2A and B).

The results for dry matter production in the above ground also differed among the varieties evaluated and, as observed for stalk height, the data obtained logistical adjustment (Table 1), which characterized three phases of accumulation of dry matter (Figure 3 A and B). The first phase occurred up to 90 DAP for all the varieties, except in RB943365 and RB813804, which presented the end of this phase at 60 and 120 DAP respectively. In this phase, mean accumulations in the above ground part of 8 Mg/ha were observed, with the medium to late maturity variety RB763710 and the early maturity variety RB943365 standing out, which accumulated 16 and 10 Mg/ha respectively in the first periods of development. In the second phase of growth, accumulation of dry matter was more intense and presented different periods among the varieties, making for the formation of three distinct groups. The first group, formed by the varieties RB763710 and RB867515, obtained accumulations of 52 Mg/ha from the end of the first phase up to 210 DAP. The varieties RB72454, SP78-4764, RB943365 and SP79-1011 presented the lowest accumulations in the second phase, with mean gains of 41 Mg/ha up to 240 DAP being observed. The third group, formed by the varieties RB92579, SP81-3250, RB813804, RB863129 and RB872552 presented the second period of development in the interval from 90 to 300 DAP, with mean accumulations of 56 Mg/ha. It was observed that this phase represented, for the three groups of varieties formed, 73, 65 and 74% respectively of the total accumulated shoot dry matter.

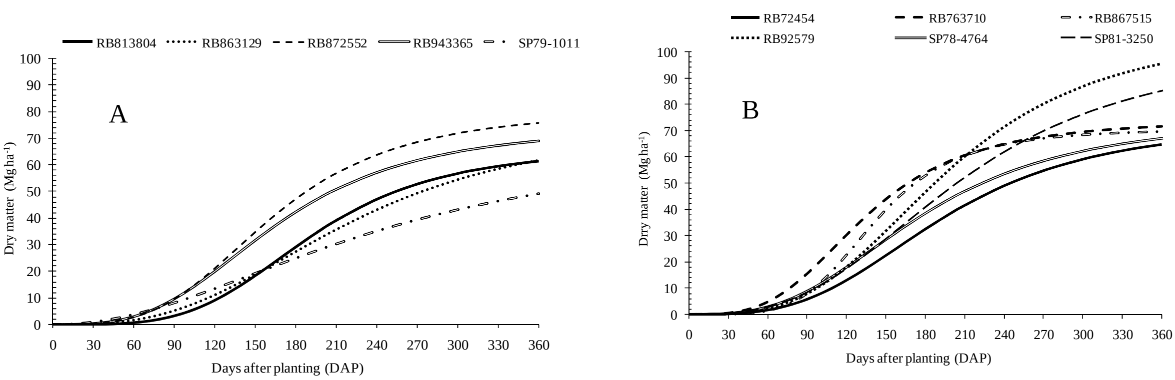

Figure 3. Accumulated shoot dry matter in relation to time in sugar cane varieties with early maturity (A) and with medium to late maturity (B).

In the third phase, the early maturity variety RB872552 stood out from the rest, with final accumulations of 76 Mg/ha of dry matter (Figure 3A). In the medium to late maturity varieties, the greatest accumulations were obtained by RB92579 and SP81-3250, with production of 96 and 85 Mg/ha of dry matter in the above ground respectively. These results give evidence of the high response of these varieties to full irrigation management in the edafoclimatic conditions of the Brazilian northeast. The results of dry matter production obtained corroborate with those found by Almeida *et al.* (2008), who also observed in the variety RB92579 the greatest accumulations of dry matter, but with a yield of 30 t/ha less than that observed in this study. The smallest responses to full irrigation were seen among the varieties RB72454, SP78-4764, RB813804, RB863129 and SP79-1011 with shoot accumulations of 65, 67, 61, 61 and 49 Mg/ha respectively (Figure 3 A and B).

Table 1. Equations adjusted for stalk height, stalk diameter and shoot dry matter in relation to time in sugar cane varieties with early maturity and with medium to late maturity (* significant to p < 0,01).

Varieties of early maturity			
	Hight	Diameter	Dry matter
RB813804	$Y= 382,3/[1+(DAP/169,2)^{-2,7293}]$; $R^2 = 0,97^*$	$Y= 23,84/[1+ \exp^{\{-(DAP-52,69)/30,46\}}]$; $R^2 = 0,90^*$	$Y= 66,38/[1+(DAP/191,8)^{-3,9276}]$; $R^2 = 0,94^*$
RB863129	$Y= 341,0/[1+(DAP/153,6)^{-3,6176}]$; $R^2 = 0,97^*$	$Y= 25,24/[1+ \exp^{\{-(DAP-53,98)/26,70\}}]$; $R^2 = 0,85^*$	$Y= 75,82/[1+(DAP/219,0)^{-2,9341}]$; $R^2 = 0,95^*$
RB872552	$Y= 354,1/[1+(DAP/140,7)^{-3,4223}]$; $R^2 = 0,97^*$	$Y= 23,74/[1+ \exp^{\{-(DAP-38,03)/18,90\}}]$; $R^2 = 0,85^*$	$Y= 80,68/[1+(DAP/163,2)^{-3,3995}]$; $R^2 = 0,95^*$
RB943365	$Y= 325,2/[1+(DAP/139,2)^{-2,9968}]$; $R^2 = 0,96^*$	$Y= 24,11/[1+ \exp^{\{-(DAP-37,27)/24,79\}}]$; $R^2 = 0,80^*$	$Y= 75,00/[1+(DAP/165,9)^{-3,1381}]$; $R^2 = 0,96^*$
SP79-1011	$Y= 288,6/[1+(DAP/162,3)^{-3,1994}]$; $R^2 = 0,96^*$	$Y= 24,07/[1+ \exp^{\{-(DAP-49,99)/34,53\}}]$; $R^2 = 0,82^*$	$Y= 70,81/[1+(DAP/242,0)^{-2,0634}]$; $R^2 = 0,98^*$
Varieties of medium to late maturity			
RB72454	$Y= 391,4/[1+(DAP/167,5)^{-2,9509}]$; $R^2 = 0,97^*$	$Y= 25,46/[1+ \exp^{\{-(DAP-57,70)/32,75\}}]$; $R^2 = 0,84^*$	$Y= 73,72/[1+(DAP/193,6)^{-3,2163}]$; $R^2 = 0,93^*$
RB763710	$Y= 334,8/[1+(DAP/127,7)^{-3,3379}]$; $R^2 = 0,97^*$	$Y= 24,17/[1+ \exp^{\{-(DAP-37,97)/19,05\}}]$; $R^2 = 0,83^*$	$Y= 74,33/[1+(DAP/134,3)^{-3,3258}]$; $R^2 = 0,86^*$
RB867515	$Y= 370,5/[1+(DAP/148,1)^{-2,2120}]$; $R^2 = 0,97^*$	$Y= 25,74/[1+ \exp^{\{-(DAP-40,83)/34,99\}}]$; $R^2 = 0,82^*$	$Y= 70,81/[1+(DAP/141,6)^{-4,5326}]$; $R^2 = 0,92^*$
RB92579	$Y= 377,5/[1+(DAP/160,5)^{-323,21}]$; $R^2 = 0,96^*$	$Y= 23,70/[1+ \exp^{\{-(DAP-53,61)/34,83\}}]$; $R^2 = 0,84^*$	$Y= 109,05/[1+(DAP/196,8)^{-3,2584}]$; $R^2 = 0,95^*$
SP78-4764	$Y= 357,5/[1+(DAP/151,0)^{-3,3094}]$; $R^2 = 0,98^*$	$Y= 24,19/[1+ \exp^{\{-(DAP-46,47)/31,59\}}]$; $R^2 = 0,87^*$	$Y= 75,23/[1+(DAP/177,1)^{-2,9753}]$; $R^2 = 0,98^*$
SP81-3250	$Y= 326,5/[1+(DAP/138,5)^{-3,3460}]$; $R^2 = 0,96^*$	$Y= 22,76/[1+ \exp^{\{-(DAP-38,46)/38,03\}}]$; $R^2 = 0,81^*$	$Y= 102,25/[1+(DAP/207,2)^{-2,9149}]$; $R^2 = 0,88^*$

Conclusion

Stalk growth and dry matter accumulation differed among the varieties analyzed. The varieties more responsive to management with full irrigation, when associated with climate and soil conditions as observed in this study, intensified plant development in relation to traditional cultivation without irrigation. Thus, varieties like RB872552, RB92579 and SP81-3250 which are responsive to irrigation, become an important tool in varietal management and in the profitability of the sugarcane fields located in regions that have an elevated water shortage for most of the crop season.

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