Dry matter and nitrogen accumulation of sugarcane related to nitrogen fertilization in Brazil

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Abstract
The nitrogen (N) requirement for sugarcane is based on response to fertilization and the extraction of N obtained in the harvest, but few studies evaluated the dry matter and nitrogen accumulation through the growth cycle. The objective of this study was to evaluate plant dry matter (phytomass) and N accumulation in the above ground part in response to nitrogen fertilization (0, 40, 80 and 120 kg N/ha) during the planted cane cycle of the variety SP81-3250. Therefore, in the 2005/2006 season, two experiments of a randomized block statistical design were developed, located at the São Luiz ethanol plant (SL) and the Santa Adélia ethanol plant (SA) in the State of São Paulo, Brazil. The phytomass accumulation was obtained by sampling of the above ground part during the planted cane cycle. The N total accumulated was obtained by the product of the total phytomass and the N concentration of the subsample collected. The phytomass and nitrogen accumulation of planted cane were adjusted to the sigmoid growth model, regardless of the N rates and the soil type of the experiment locations. The total amounts of N accumulated by planted cane was higher than the N applied as fertilizer, showed that other sources of N contributed to the planted cane nutrition.

Key Words
Saccharum spp, planted cane, sugarcane growth.

Introduction

The accumulation of plant matter and nutrients by sugarcane occurs through interaction of the crop with environmental factors, with the plant being an integrator of environmental stimuli. Better understanding of such interactions may be obtained by means of quantitative analysis of growth and by biometric measurements of the plants during their growth, allowing the use of physiological indexes in the attempt to explain varietal differences in relation to economic production (Machado *et al.* 1982). Considering that growth analysis is taken as the standard method for measuring the biological productivity of a crop, its use in evaluation of nitrogen fertilization at planting is an important tool for aiding understanding of this practice. According to Korndörfer *et al.* (2002) nitrogen fertilization at planting stands out as one of the cropping practices of greatest demand for research for sugar cane, because studies with nitrogen present highly variable results, many times even contradictory results. In most studies of nitrogen fertilization in planted cane, productivity evaluations were performed at final harvest, with little research that evaluated phytomass production and nitrogen accumulation during the planted cane growth cycle. In these cases, response to the addition of N on the part of planted cane may be limited by environmental factors, such as water deficiency in the period of greatest crop growth. The objective of this study was to evaluate the accumulation of phytomass production and nitrogen uptake by the above ground part of planted cane by the variety SP81-3250 in response to nitrogen fertilization at planting.

Material and methods

Site description

The experiments were performed in two sugar cane producing areas located in the state of São Paulo, Brazil. The first belongs to the São Luiz Ethanol plant (SL), in Pirassununga county (Latitude 21º 55' 54''S, Longitude 47º 10' 54''W). The altitude is 650 m and the climate is Aw (Tropical Savanna, in the Köppen classification). The area has a slightly rolling slope (< 5%), and the soil is a Typic Haplustox. The sugar cane was planted from February 21-24, 2005. The second area, belonging to the Santa Adélia Ethanol plant (SA), is in Jaboticabal county (Latitude 21º 19.98' S, Longitude 48º 19.03' W). The predominant altitude in the region is 600 m, and the climate is Aw (Tropical savanna, in the Köppen classification). The area presents a slightly rolling slope (<5%), and the soil is an Arenic Kandiustults. The sugar cane was planted from April 4-8, 2005.

Experiential design
The treatments consisted of three N rates (40, 80 and 120 kg/ha of N as urea) applied at the bottom of the planting furrow, plus one control treatment without application of nitrogen fertilizer. Treatments were distributed in a randomized block design with four replications. The experimental plots were composed of 48 rows of 15 meters length, with a space between them of 1.5 m.

Sampling
For evaluation of total phytomass accumulation, six and five samples of plant matter from the above ground part were collected in the SL and SA respectively. At SL, evaluations were undertaken in 134, 244, 293, 358 413 and 468 days after planting (DAP). In the experiment at SA, samples were taken in 186, 246, 307, 363 and 459 DAP. Sampling was characterized by collection of the entire above ground part of the sugarcane from 2 meters of the row at previously randomly drawn locations. The total mass of plant matter (dry leaves, green tops, and stalks) of each treatment was obtained directly in the field by means of weighting on an electronic scale. After weighting, each plant sample was chopped in a forage chopper, collecting a moist subsample from each sample. The subsamples were weighted in the laboratory on an analytic scale before and after drying in a ventilated laboratory dryer at 65°C (72 hours) for moisture determination of the material. Knowing the moisture of the samples, dry matter accumulation (kg/ha) was calculated. After obtaining the dry matter of the above ground part, the subsamples were passed through a Wiley type laboratory mill for later determination of the total-N content (g/kg), in accordance with Malavolta *et al.* (1997). The N accumulation (kg/ha) was determined by the product of the N concentration in the subsample and the accumulated phytomass of each sample made.

Data analysis
Data obtained from phytomass and N accumulated in planted cane were submitted to ANOVA in a randomized block design, using the F test at $p < 0,05$. To estimate the phytomass and N accumulation in the above ground part of sugar cane in the treatments with nitrogen fertilization at planting (0, 40, 80 and 120 kg/ha of N), the following logistic function was used: $Y = Y_{max} / [1+(DAP/A)^B]$. Meaning: Y: dry phytomass or N accumulation in the above ground part of planted cane, in kg/ha, DAP: days after planting, Y_{max}: dry phytomass or maximum N accumulation in the period between planting and harvest, A and B: constants of the function estimated in accordance with Zullo and Arruda (1987).

Results and discussion

Dry matter production
The accumulation of phytomass in the above ground part presented a sigmoid form (Figure 1), regardless of the treatments, characteristic of plant growth presenting the three phases of sugar cane development (Silveira 1985).

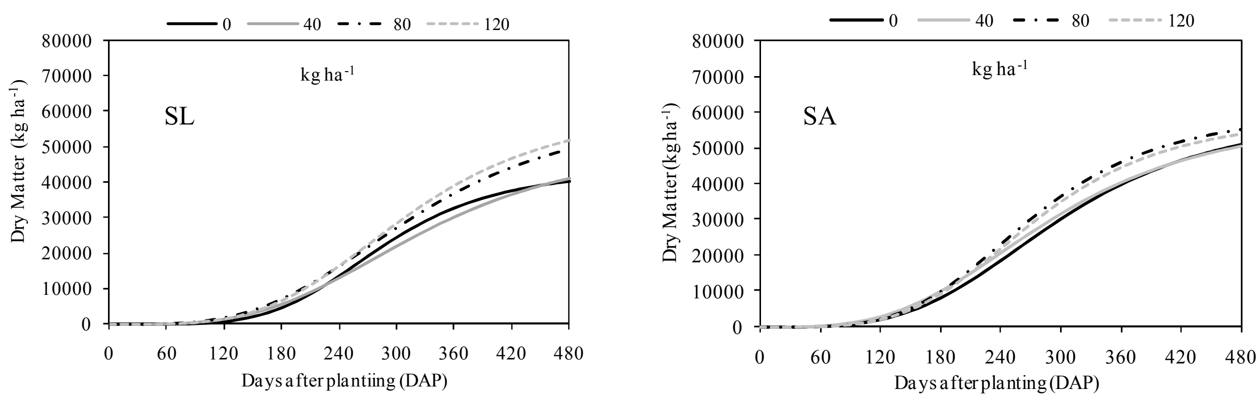

Figure 1. Dry matter accumulation of the above ground part of sugar cane during the planted cane agricultural cycle related to nitrogen fertilization. São Luiz Ethanol plant (SL) and Santa Adélia Ethanol plant (SA) experiments.

The first phase of development presented a small accumulation of phytomass and occurred up to 180 and 150 DAP at SL and SA respectively, totaling in the mean of the treatments around 14% and 10% of the obtained at final crop harvest (Figure 1). The difference between the experiments was due to the time of planting, since the sugar cane at SL was planted around 40 days before that of SA.

The second phase of growth occurred from 180 to 420 DAP at SL and from 150 to 390 DAP at SA (Figure 1). In this stage, planted cane presented rapid gain in mass due to the beginning of stem production, which at the end of the planted cane cycle represented 82% of the total accumulated dry matter in the above ground part of the sugar cane. Sampaio *et al.* (1984), in a study of planted cane in tableland soil, in the Northeast of Brazil, observed that with the emergence of stalks (around six months after planting) the crop significantly increased phytomass accumulation. The greatest production of phytomass occurred in this 2^{nd} phase (Figure 2), representing, in the mean of the treatments, 78% (35,000 kg/ha) and 80% (41,000 kg/ha) of the total accumulated in the above ground part of the plants at SL and SA respectively. It is to be highlighted that during this period there were differences between the treatments in both experimental locations, with the largest doses of N (80 and 120 kg/ha) having the best results.

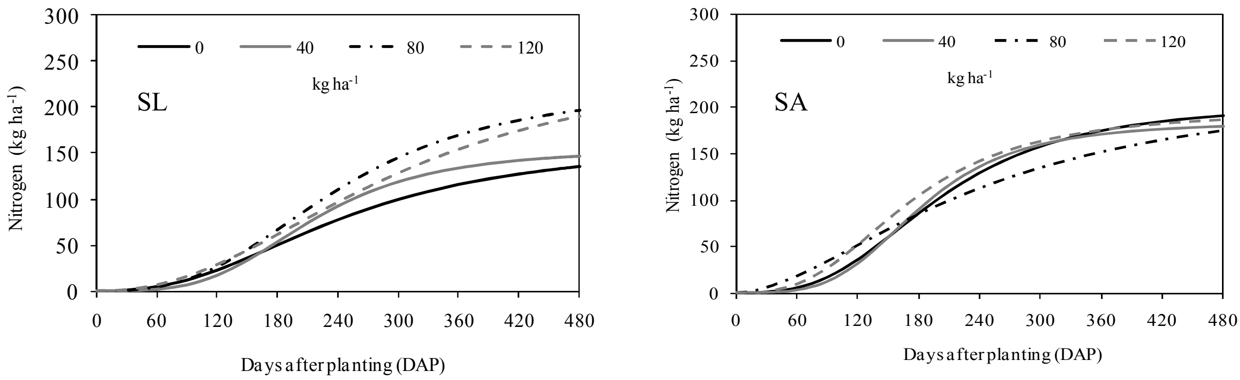

Figure 2. Nitrogen absorption by the above ground part of sugar cane during the planted cane agricultural cycle related to nitrogen fertilization. São Luiz Ethanol plant (SL) and Santa Adélia Ethanol plant (SA) experiments.

The third phase of growth, characterized as the maturation phase, occurred from 420 to 468 DAP at SL and from 390 to 459 DAP at SA. In this period, the phytomass accumulation was in the order of 4,000 and 5,000 kg/ha of dry matter, equivalent to 8% and 10% of the total accumulated by the above ground part of the crop in the planted cane cycle at SL and SA respectively (Figure 1).

Nitrogen accumulation in planted cane

For N accumulation, was observed in both experiments that the treatments influenced the N uptake in the planted cane cycle and the results of accumulation of the nutrient during crop development provided sigmoid adjustments (Table 1) in a way similar to that found for the phytomass accumulation, characterizing three phases of N demand (Figure 2). Nevertheless, the periods in which N accumulations were observed between the phases differed from those obtained for phytomass (Figure 1).

Table 1. Equations adjusted for dry matter and nitrogen accumulation during the planted cane agricultural cycle related to nitrogen fertilization (* significant to $p < 0{,}01$).

N rates kg/ha	São Luiz Ethanol plant - SL		Santa Adélia Ethanol plant - SA	
	Dry matter	N accumulation	Dry matter	N accumulation
0	$Y= 43{,}871/[1+(DAP/284{,}74)^{-4{,}6139}]$; $R^2 = 0{,}92^*$	$Y= 162/[1+(DAP/247{,}92)^{-2{,}5074}]$; $R^2 = 0{,}96^*$	$Y= 60{,}068/[1+(DAP/299{,}62)^{-3{,}6587}]$; $R^2 = 0{,}99^*$	$Y= 204/[1+(DAP/200{,}98)^{-3{,}0225}]$; $R^2 = 0{,}81^*$
40	$Y= 51{,}588/[1+(DAP/326{,}53)^{-3{,}5033}]$; $R^2 = 0{,}98^*$	$Y= 154/[1+(DAP/215{,}69)^{-3{,}5901}]$; $R^2 = 0{,}91^*$	$Y= 59{,}778/[1+(DAP/290{,}05)^{-3{,}3836}]$; $R^2 = 0{,}98^*$	$Y= 184/[1+(DAP/182{,}34)^{-3{,}7764}]$; $R^2 = 0{,}90^*$
80	$Y= 61{,}147/[1+(DAP/318{,}85)^{-3{,}5177}]$; $R^2 = 0{,}99^*$	$Y= 224/[1+(DAP/243{,}11)^{-2{,}8769}]$; $R^2 = 0{,}90^*$	$Y= 60{,}846/[1+(DAP/271{,}48)^{-4{,}019}]$; $R^2 = 0{,}99^*$	$Y= 227/[1+(DAP/242{,}83)^{-1{,}7559}]$; $R^2 = 0{,}88^*$
120	$Y= 61{,}932/[1+(DAP/312{,}24)^{-3{,}8253}]$; $R^2 = 0{,}94^*$	$Y= 254/[1+(DAP/294{,}54)^{-2{,}2773}]$; $R^2 = 0{,}98^*$	$Y= 59{,}738/[1+(DAP/275{,}55)^{-4{,}0089}]$; $R^2 = 0{,}98^*$	$Y= 196/[1+(DAP/191{,}75)^{-2{,}8734}]$; $R2 = 0{,}94^*$

The initial N accumulations obtained in the experiments at SL and SA was seen to be low in the first phase, representing a mean of 8.5 and 10% of the total accumulated by planted cane respectively.

In the second phase, greater N accumulations were seen, with mean values of 108 and 135 kg/ha at SL and SA respectively. It was observed at SL that the period of greatest N accumulation occurred between 90 and 300 DAP in the treatment that did not receive nitrogen fertilization, and from 120 to 300 DAP in the 40 kg N/ha, being equivalent, in the mean of the treatments, to 67 % of the total N accumulated in the above ground part. The rates of 80 and 120 kg N/ha showed continuous N accumulations up to harvest, which led to low differentiation from the second to the third phase in planted cane (Figure 2). This same behavior was observed for the 80 kg N/ha at SA, being different from the other treatments that also showed the phase of greatest N accumulation between 90 and 300 DAP, representing, on average, 74 % of the total accumulated

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N in the experimental period. These results were similar to those obtained by Coale *et al.* (1993). The authors observed in planted cane cultivated in the Florida, that the greatest N accumulations occurred between 150 and 270 DAP, close to the observed in SA, representing, on average, 54 % of the total N taken up by the sugar cane. The third phase, it was seen in the experiments at SL and SA that the final uptake corresponded, on average, to 17 and 13% of the total N accumulated in the planted cane cycle respectively.

Conclusions

The planted cane presented three distinct growth phases: the first with a duration of 5 to 6 months, the second with 8 months and the third with 2 months, accumulating 12, 79 and 9% of the final dry matter respectively. In the second phase showed the difference between the rates and greatest DMPR that occurred at the same time as the period with least water deficiency and greatest real crop evapotranspiration. The N accumulation also presented three phases during planted cane growth, however with periods differentiated from those found for phytomass accumulation, was observed that a period of maximum phytomass accumulation in planted cane occurred after the maximum N uptake.

Acknowledgments

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