Utilization by plant cane, and first and second ratoon crops of nitrogen fertiliser applied at planting

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Abstract
Sugarcane, as a semi-perennial crop, depends on the nutrient stocks in the root system in order to support the initial growth of sprouts, and there is evidence of a direct relationship of these nutrient stocks with the management of nitrogen fertilization. However, there is little knowledge about the amount of N fertilizer applied in a crop season that can still be used by sugarcane in a subsequent crop season. In order to evaluate urea-N utilization by sugarcane in the plant cane crop season and its residual effect in subsequent ratoon crops, three experiments were carried out in the São Paulo State, Brazil, from February of 2005 to July of 2008. The experimental design was randomized complete blocks, with four treatments, being three rates of urea-N: 40, 80 and 120 kg N/ha applied in furrow at planting, and a control without N fertilizer. In the center of the plots with urea-N fertilization were installed microplots that received urea labeled with ^{15}N. On average, the recovery by plant cane was about 80% of total N recovered in the three harvests. In the first and second ratoon crops the utilization was lower being around 15% and 5% of total N recovered respectively. These results showed that the nitrogen fertilization in a crop season also can be used by the crop in subsequent ratoons, and the amount recovered will depend on the crop management adopted, since the efficiency of nitrogen fertilization in this work, considering the three crop seasons, was low, about 35% of total N applied at planting.

Key Words
Saccharum spp, urea-^{15}N, isotopic technique.

Introduction
In the literature, for the majority of studies regarding the response of sugar cane to nitrogen fertilization, both in plant cane and in ratoon cane, fertilizations were evaluated by the yield of the cycle (year/harvest) of the crop for which fertilization was made. In this sense, sugar cane has been considered as an annual crop, and rare are studies like those of Penatti *et al.* (1997) and Orlando Filho *et al.* (1999) which maintained the experimental plots for consecutive harvests in the field so as to evaluate the cumulative effect of fertilizations with N doses on the yield of plant cane and ratoon cane. Studies of this nature have shown this effect and have confirmed that the response of plant cane to nitrogen was reflected in greater vigor of the ratoon cane, increasing the yield in subsequent ratoon crops when comparing sugar cane with and without nitrogen fertilization. Vitti *et al.* (2007) observed a notable residual effect of nitrogen fertilization of the third ratoon for stalk yield of the subsequent ratoon (4^{th} ratoon).

In this scenario, is it not the case to question regarding the possibility of nitrogen fertilization, both at planting and in ratoon cane, as being related to root growth and to the formation of a nutrient stock in the underground part of the crop with an effect on the yield accumulated in subsequent cuttings? In fact, Franco *et al.* (2007) noted that nitrogen fertilization at planting significantly increased the quantity of macronutrients in the plant cane reserve organs (roots and rhizomes).

On the other hand, there is still the question: is it possible that the nitrogen coming from fertilizer applied in the previous year is still being utilized by the sugar cane plants in the next agricultural cycle? To respond to this question, the use of nitrogen fertilizers labeled with ^{15}N is necessary.

In these studies, the destination of a considerable part of the ^{15}N-fertilizer (20% to 40%) applied to the sugar cane crop is the soil, where the nutrient is incorporated in the stock of N of the organic matter (Cantarella *et al.* 2007). Nevertheless, under Brazilian conditions, the results obtained under field conditions regarding recovery of residual ^{15}N-fertilizer (applied in the previous agricultural cycle) by sugar cane in the subsequent cycle are practically non-existent.

Thus, the objective of this study was to evaluate the utilization of ^{15}N-fertilizer applied at the planting of plant cane by the subsequent ratoons (residual effect), seeking better understanding of the causes of the responses of the sugar cane crop to nitrogen fertilization.

Material and Methods

Site description

The experiments were performed in three 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 Eutrustox (Embrapa 2006). 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 a Arenic Kandiustults (Embrapa 2006). The sugar cane was planted from April 4-8, 2005. The third area, belonging to the São Martinho Ethanol plant (SM), is in Pradópolis county (Latitude 21º 15' S, Longitude 48º 18' W). The predominant altitude in the region is 580 m, and the climate is Aw (Tropical savanna, in the Köppen classification). The soil in this area is a Rhodic Eutrustox (Embrapa 2006). The sugar cane was planted from March 2-6, 2005.

Experimental design

Fertilizer treatments of the planted cane consisted of one of three doses of N (40, 80 and 120 kg/ha of N as urea) applied at the bottom of the planting furrow, plus one control without nitrogen fertilizer. These doses were chosen based on the recommendations of the Technical Bulletin 100 (Espironello *et al.* 1996), which recommends the application of up to 90 kg/ha of N at planting. The treatments were distributed in a randomized block design with four replications. The experimental plots were composed of 48 rows of 15 meters in length with a space between rows of 1.5 m. In the inside of each plot, a microplot was installed, with dimensions of 2 m in length and 1.5 m width (totaling 3 m^2), which received urea labeled with ^{15}N (excess of 4.67 % atoms of ^{15}N). In the SM area only the treatment of 80 kg/ha was treated with the ^{15}N labeled urea. The variety of sugar cane planted was SP81 3250, as it is highly adaptable and very productive and one of the varieties planted most in the Center-South region of Brazil. In all of the plots, at the bottom of the furrow, 120 kg/ha of K_2O and 120 kg/ha of P_2O_5 were applied as potassium chloride and triple superphosphate, respectively.

The plant cane was harvested around 16 months after planting (June, July and August of 2006, at SL, SA and SM respectively), with the experimental plots being maintained, applying only 150 and 60 kg/ha of K_2O and P_2O_5 respectively to all the plots. Harvest of the first ratoon was made 12 months after harvest of the plant cane. After the harvest of the first ratoon, the same doses of P and K were applied over the residual straw to all the plots, with the harvest of this crop undertaken at 24 months after the harvest of the plant cane.

Sampling

For evaluation of the utilization of the ^{15}N-urea in the plant cane and first and second ratoon cycles, the plant shoots of the microplots were manually harvested in all the experiments (SL, SA and SM), and the roots only in the SL and SA areas. Harvest of the plants from the microplots with ^{15}N-urea and also in the control, without nitrogen fertilization, was undertaken in 1m of the row, in the center and in contiguous positions in the rows adjacent to the microplot, separating samples of dry leaves, tips and stalks. In these samples, natural plant material mass was determined. All the material was chopped in a mechanical forage chopper. After grinding and homogenization of each moist sample, a subsample was removed, which was dried in a laboratory oven (65 ºC), and the moisture content of this material was determined. The dry matter was ground in a Wiley mill and used in the determinations of total N and of ^{15}N abundance (% of atoms of ^{15}N) in a mass spectrometer ANCA/SL, model 20/20 from Europa Scientific, Krewe, U.K. The roots were evaluated only at the harvest of the plant cane, being collected by means of a 55 mm internal diameter probe in the center of the microplots. Sampling was made at a depth of 0-60 cm. The roots and rhizomes separated from the soil were washed in running water and also dried in a ventilated laboratory oven at 65 ^oC. The root dry matter was processed and analyzed in regard to total N content and abundance of ^{15}N (% of atoms of ^{15}N) in the same way as undertaken for the shoot samples.

Data analysis

The utilization of urea-^{15}N by sugar cane was calculated according to equations:

(a) $NDFF = [(A - C)/(B - C)].NT$;

(b) $R (\%) = (NDFF/NAF).100$

where NDFF is the nitrogen in the plant derived from fertilizer; A is the abundance of ^{15}N atoms in the plant;

B is the abundance of ^{15}N atoms in the fertilizer; C is the natural abundance of ^{15}N atoms (0.366%); NT is the total nitrogen of the aboveground part in kg N/ha; R - recovery of ^{15}N-fertilizer by sugar cane; NAF – nitrogen dose applied (kg/ha). (Hope these changes are correct!!)

Results

Utilization of the N-fertilizer (Tables 1 to 3) applied at the planting of the sugar cane field by the sugar cane crop was greater in the plant cane cycle, representing, in the mean of the areas, 80% of the total of N-urea recovered in the three crop cuttings. In spite of that, 15% of the total N-urea recovered throughout the three cycles was taken up by the plants of the first ratoon. This confirmed, in spite of the small quantities (around 3.0 kg/ha of N), that nitrogen fertilization presented a quantitative residual effect, and may therefore have an effect on crop yield in subsequent cuttings. In spite of not having worked with fertilizers enriched with ^{15}N, Penatti *et al.* (1997), Orlando Filho *et al.* (1999) and Vitti *et al.* (2007) observed this residual effect in field tests with nitrogen fertilization in plant cane and ratoon cane.

The results of N-fertilizer use by the second ratoon were only measured in the areas of SA and SM, keeping in mind that at SL there was an accidental fire which resulted in the results of this harvest being lost. At any rate, the results of the remaining areas (SA and SM) showed that the utilization by the second ratoon of the N-fertilizer applied at planting was very low, 42 months after its application.

Table 1. Utilization by sugar cane of urea-^{15}N applied at planting. São Luiz Ethanol plant field

N Rates (kg/ha)	Stalks	Dry Leaves	Tips	Above ground Part	Roots	Entire Plant
	Planted Cane					
	kg/ha					
40	6,1 ± 0,7	3,2 ± 0,3	2,2 ± 0,2	11,5 ± 0,5	1,4 ± 0,4	12,3 ± 0,6
80	9,7 ± 1,8	5,9 ± 0,2	3,1 ± 0,8	18,7 ± 2,4	2,2 ± 0,5	20,0 ± 2,1
120	13,5 ± 1,3	6,7 ± 1,0	3,2 ± 1,1	23,4 ± 2,4	2,5 ± 0,8	24,9 ± 2,4
	1st Ratoon					
40	0,5 ± 0,02	0,5 ± 0,08	0,4 ± 0,02	1,4 ± 0,10	———	———
80	0,8 ± 0,05	1,3 ± 0,73	1,6 ± 0,55	3,7 ± 0,70	———	———
120	1,9 ± 0,56	1,6 ± 0,38	1,4 ± 0,25	5,0 ± 1,10	———	———
	Sum of crops					
40	6,5 ± 0,7	2,5 ± 0,3	3,1 ± 0,2	12,1 ± 0,5	1,4 ± 0,4	13,5 ± 0,5
80	15,4 ± 1,8	5,1 ± 0,6	9,0 ± 1,1	29,5 ± 2,1	2,2 ± 0,5	31,7 ± 2,0
120	13,9 ± 1,6	7,0 ± 1,3	6,9 ± 1,3	27,8 ± 3,3	2,5 ± 0,8	30,3 ± 3,2

Table 2. Utilization by sugar cane of urea-^{15}N applied at planting. São Martinho Ethanol plant field

Season	Stalks	Dry Leaves	Tips	Above ground Part
	kg/ha			
Planted Cane	18,9 ± 2,1	3,1 ± 0,3	2,7 ± 0,7	24,7 ± 3,1
1st Ratoon	1,3 ± 0,4	0,7 ± 0,2	2,0 ± 0,7	3,9 ± 1,2
2st Ratoon	0,9 ± 0,3	0,6 ± 0,1	1,4 ± 0,6	2,9 ± 0,4
Sum of Crops	21,0 ± 0,2	4,4 ± 0,3	6,1 ± 1,3	31,5 ± 1,4

Table 3. Utilization by sugar cane to urea-^{15}N applied at planting. Santa Adélia Ethanol plant field

N Rates (kg/ha)	Stalks	Dry Leaves	Tips	Above ground Part	Roots	Entire Plant
	Planted Cane					
	kg/ha					
40	6,1 ± 0,8	3,2 ± 0,2	2,2 ± 0,2	11,5 ± 1,0	0,8 ± 0,1	12,3 ± 1,0
80	9,7 ± 1,7	5,9 ± 0,8	3,1 ± 0,6	18,7 ± 2,8	1,3 ± 0,3	20,0 ± 3,0
120	13,5 ± 1,3	6,7 ± 2,1	3,2 ± 0,5	23,4 ± 3,0	1,5 ± 0,3	24,9 ± 3,0
	1st Ratoon					
40	1,0 ± 0,16	0,4 ± 0,05	0,6 ± 0,12	2,0 ± 0,31	———	———
80	1,8 ± 0,27	1,1 ± 0,17	1,5 ± 0,41	4,4 ± 0,79	———	———
120	1,8 ± 0,28	1,2 ± 0,57	0,5 ± 0,33	3,5 ± 0,72	———	———
	2st Ratoon					
40	0,5 ± 0,10	0,2 ± 0,01	0,2 ± 0,02	0,8 ± 0,09	———	———
80	0,7 ± 0,25	0,3 ± 0,15	0,3 ± 0,17	1,3 ± 0,53	———	———
120	0,7 ± 0,08	0,4 ± 0,03	0,5 ± 0,09	1,6 ± 0,17	———	———
	Sum of Crops					
40	7,5 ± 0,21	3,8 ± 0,05	2,9 ± 0,13	14,3 ± 0,37	0,8 ± 0,1	15,1 ± 0,4
80	12,2 ± 0,12	7,3 ± 0,23	4,9 ± 0,37	24,4 ± 0,58	1,3 ± 0,3	25,7 ± 0,6
120	16,0 ± 0,33	8,3 ± 0,58	4,2 ± 0,38	28,5 ± 0,84	1,5 ± 0,3	30,0 ± 0,8

Conclusion

These results showed that the nitrogen fertilization in a crop season also can be used by the crop in subsequent ratoons, and the amount recovered will depend on the crop management adopted, since the efficiency of nitrogen fertilization in this work, considering the three crop seasons, was low, about 35% of total N applied at planting.

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