Contribution of nitrogen derived from crop residues in nutrition of sugar cane ratoons

André Cesar Vitti[A], Caio Fortes[B], Henrique Coutinho Junqueira Franco[B], Danilo Alves Ferreira[B], Rafael Otto[B], Emídio Cantídio Almeida de Oliveira[B], Paulo Cesar Ocheuze Trivelin[B]

[A]Agência Paulista de Tecnologia dos Agronegócios (APTA), Pólo Centro-Sul. Rod. SP 127, km 30, CP 28, CEP13400-970, Piracicaba, São Paulo, Brasil. Phone: +55 19 3421 1478. E-mail: acvitti@apta.sp.gov.br
[B]Centro de Energia Nuclear na Agricultura - CENA/USP, Laboratório de Isótopos Estáveis. Av Centenário 303, CP 96, Piracicaba, São Paulo 13400-970, Brazil. Phone: +55 19 3429 4670. E-mail: pcotrivelin@cena.usp.br

Abstract
Starting from the hypothesis that nitrogen fertilization favors the mineralization of crop residues, it consequently contributes to crop nutrition. The objective of this study was to evaluate the utilization of N derived from crop residues (trash-^{15}N) by sugarcane in relation to nitrogen fertilization. The experiment was carried out at the São Martinho Ethanol Plant (Pradópolis-SP), for two consecutive years in an area of ratoon cane (variety SP81-3250), of the 1st and 2nd ratoon (2006/2007 and 2007/2008 harvests) respectively. The treatments were without addition of N and with the application of 150 kg N ha^{-1}, applied over the cane trash and next line. In the microplots, 1.5m x 2m, the original residual straw was replaced by straw labeled with the isotope ^{15}N (0.83 % in atoms of ^{15}N) equivalent to 10 t ha^{-1} of dry matter (41 kg ha^{-1} of N). For both treatments, there was a decrease in the utilization of the trash-N by the 2nd ratoon in relation to that obtained in the 1st ratoon. Crop utilization of the N contained in the straw was 7.5 and 11.3% (3.0 and 4.6 kg N ha^{-1}) in the 1st ratoon and 2.0 and 4.9 % (0.8 and 2.0 kg N ha^{-1}) in the 2nd ratoon. The application of N on the ratoon favored the recovery of trash-^{15}N by the above ground part of sugarcane in the two years of evaluation, being 9.3% (3.8 kg ha^{-1} of N) and 15.4% (6.3 kg ha^{-1} of N) for the treatments without addition of N and 150 kg ha^{-1} of N respectively.

Key Words
Saccharum spp, isotope technique, straw

Introduction
Harvest without straw burning (green cane) generates a significant quantity of plant residues (dry leaves, tops and pieces of stalk) on the soil surface, which will change the nutrient dynamic in this agricultural system, and thereby requiring study so that the relationship between the N stored in the crop residues and their utilization by the crop may be better understood. These residues, denominated cane straw or cane trash, present around 40 to 120 kg N ha^{-1} (Vitti et al., 2007), thus increasing the quantity of organic matter and nutrients in the soil (Oliveira et al., 1999). Sugarcane straw presents, on average, a content of from 390 to 450 g kg^{-1} of carbon and 4.6 to 6.5 g kg^{-1} of nitrogen (Ng Kee Kwong et al., 1987; Oliveira et al., 1999), which makes for a C:N ratio of around 100. In these conditions, one expects an intense immobilization of soil N; in other words, small net mineralization in the period of only one agricultural year (Gava et al., 2003). Thus, the addition of nitrogen via fertilizer over the residual cane trash should increase its decomposition due to reduction of the C:N ratio. In such supplementing, it is necessary to evaluate the effects of this nitrogen fertilization on the dynamic of N from the cane trash, and the utilization of this by the sugarcane. However, it is normally difficult to quantify N in studies on its dynamic in the soil-plant system. As such, the utilization of a source labeled with ^{15}N constitutes the method that allows quantification of the efficiency of the use of this nutrient from the originating source like the soil, organic and inorganic fertilizers. The objective of this study was to evaluate the utilization by sugarcane of the N derived from residual ^{15}N straw from planted cane in relation to the application of N fertilizer on ratoon cane in two consecutive agricultural cycles by means of the ^{15}N isotope tracer technique.

Material and Methods
Site description
The experiments were performed in a sugar cane producing area located in the state of São Paulo, Brazil. The third area, belonging to the São Martinho Ethanol plant(USM), 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 this area is a Rhodic Eutrustox. The sugar cane was planted from March 2-6, 2005.

Experimental design

After the first harvest (July 2006), the experiment in randomized blocks with four replications was installed. In the study with the crop residues (cane trash) two treatments were established, with the first being without application of N and the second with the addition of 150 kg N ha^{-1} in the form of ammonium sulphate, applied in a strip over the straw, around 20 cm from the row. The experimental plots presented 12 rows of 15 meters with a 1.5 m spacing. Within the plot was installed a microplot of 3 m^2 (2 m length and 1.5 m width) where the crop residues were deposited (equivalent to 10 t ha^{-1} of dry matter and 41 kg ha^{-1} of N), enriched with 0.83% in atoms of ^{15}N, derived from planted cane experiment (urea enriched with 5.04% of ^{15}N atoms).

Sampling

The harvest of the first ratoon (second cutting) was undertaken in August 2007, manually collecting the entire above ground part of the plants in 1.0 m of the row in the center of each microplot and in contiguous positions in adjacent rows, separating samples of dry leaves, green tops and stalks. In these samples, the mass of natural plant matter was determined directly in the field. All the material derived from the microplot was chopped in a mechanical forage chopper. After grinding and homogenization of each moist sample, a subsample was removed, which was weighed and dried in a laboratory oven (72 hours at 65 °C), for determination of dry matter. The dry matter was ground in a Wiley mill and analyzed in a mass spectrometer for determination of total N (%) and abundance of ^{15}N (% in atoms of ^{15}N). The other rows of the experimental plots were harvested by a mechanical harvester. After this operation, the experimental plots were maintained, with the covering of the residual straw from the first ratoon over the residual straw from the planted cane. Subsequently, nitrogen fertilization was performed in the same doses as performed in the previous harvest (150 kg ha^{-1} and without application and N). Harvesting of this crop was made in July 2008, and the procedures adopted and the analyses were the same as in the previous experiment.

Data analysis

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

(a) NPPP = [(A - C)/(B – C)].NT;
(b) R (%) = (NPPP/NDA).100

where NPPP is the nitrogen in the plant derived from trash; A is the abundance of ^{15}N atoms in the plant; B is the abundance of ^{15}N atoms in the trash; C is the natural abundance of ^{15}N atoms (0.366%); Total-N is the total nitrogen of the aboveground part in kg N ha^{-1}; R - recovery of ^{15}N-trash by sugarcane; NDA – nitrogen dose applied (kg N ha^{-1}).

Results

The utilization of ^{15}N from crop residues by the 1st ratoon was 4.6 kg ha^{-1} or 11.3% of the trash-N in relation to the treatment that did not receive N (3.0 kg ha^{-1}or 7.3% of trash-N). For the 2nd ratoon, the recovery of the trash-^{15}N remaining in the field was 2.0 kg ha^{-1} (4.9%) for the plots that received nitrogen fertilization of the ratoon, and 0.8 kg ha^{-1} (2.0%) for the plots that did not receive it (Table 1). The total recovery by the sugarcane crop after two years of the cane trash in the field was 3.8 kg N ha^{-1} (9.3% of the trash-N) for the treatment that did not receive nitrogen fertilization on the ratoon and 6.3 kg N ha^{-1} (15.4% of trash-N) for the treatment with 150 kg ha^{-1} of N, however, an increase of 6.1 % in relation to the plot without N, showing synergism between application of nitrogen and the mineralization of the crop residues (Table 1). Regardless of the nitrogen fertilization, for the 1st and 2nd ratoon, the greatest recoveries from the trash-N were observed in the stalks, followed by the green tops and dry leaves. The greater utilization by the stalk is principally owing to the greater accumulation of total N present in this pool, due to its greater mass in relation to the dry leaves and green top (Table 1).

Table 1. Recovery of N-trash in the above ground part (stalks, green tops and dry leaves) the 1st and 2nd ratoon, respectively, in 2006/2007 and 2007/2008 seasons, related with and without nitrogen fertilization (150 kg N ha^{-1}).

Crop Season	Rate of N	Stalks	Dry Leaves	Green Tops	Total
	kg ha^{-1}	------------------------	Recovery (kg/ha)	------------------------	
First ratoon	0	1,7±0,3 ^{NS}	0,5±0,1 ^{NS}	0,8±0,2 ^{NS}	3,1±0,6 ^{NS}
	150	2,6±0,0	0,7±0,2	1,3±0,2	4,6±0,1
SMD		1,2	0,7	0,6	2,0
CV (%)		24,0	50,0	26,0	23,1
Second ratoon	0	0,4±0,1 ^{NS}	0,1±0,0 A	0,3±0,0 ^{NS}	0,8±0,1 A
	150	1,1±0,1	0,5±0,0 B	0,4±0,1	2,0±0,1 B
SMD		0,7	0,2	0,4	0,6
CV (%)		41,8	35,9	51,0	18,0
1st + 2nd ratoon	0	2,2±0,3 A	0,6±0,1 ^{NS}	1,1±0,2 A	3,9±0,6 A
	150	3,7±0,1 B	1,2±0,2	1,7±0,1 B	6,6±0,1 B
SMD		1,1	0,9	0,5	2,0
CV (%)		16,1	43,9	15,4	17,0
Crop Season	**kg ha^{-1}**	---------------------------	**Recovery (%)**	---------------------------	
First ratoon	0	4,2±0,1 ^{NS}	1,2±0,2 ^{NS}	2,1±0,4 ^{NS}	7,5±1,5 ^{NS}
	150	6,3±0,1	1,8±0,4	3,3±0,3	11,3±0,1
SMD		2,8	1,7	1,6	4,9
CV (%)		24,0	50,0	26,0	23,1
Second ratoon	0	1,1±0,4 ^{NS}	0,3±0,1 A	0,7±0,1 ^{NS}	2,1±0,4 A
	150	2,7±0,2	1,2±0,2 B	0,9±0,3	4,7±0,2 B
SMD		1,8	0,55	0,9	1,4
CV (%)		41,8	34,4	51,0	18,0
1st + 2nd ratoon	0	5,2±0,8 A	1,5±2,0 ^{NS}	2,8±0,4 A	9,5±1,4 A
	150	8,9±3,0 B	2,9±0,5	4,2±0,2 B	16,0±0,2 B
SMD		2,6	2,1	1,2	4,9
CV (%)		16,1	43,4	15,38	17,0

^{NS}: not significant, SMD: significant mean deviation, CV: coefficient of variation, Distinct capital letters in the column differ among themselves by the Tukey test at the level of $p < 0,05$.

For both treatments, the results are near to those obtained by Ng Kee Kwong et al. (1987) and Gava et al. (2003), where recoveries by the above ground part of the sugar cane of 5 to 10% of the total N contained in the straw were observed.

The positive effect of the addition of inorganic N to the system is probably due to its contribution to the increase of mineral N in the soil solution, in addition to favoring the activity of microorganisms, resulting in greater N uptake by the sugar cane. In this sense, one may deduce that the nitrogen fertilization with nitric or ammoniacal sources increases the rate of decomposition of the trash by reducing its C:N ratio. In studies with a corn crop, Amado et al. (2003) observed that the total N released by crop residues of black oats during the corn cycle was positively influenced by nitrogen fertilization, being inversely proportional to the C:N ratio of the residues produced.

The greater recovery observed in the plots where the dose of 150 kg N ha^{-1} was applied may also be attributed to the greater development of the root system (RS) of the plants, which may have favored the uptake of nutrients and also of trash-^{15}N. Otto (2007) verified in the same experimental area that the mass of roots where nitrogen fertilization of the ratoon was performed was greater in relation to the treatment that did not receive N. The maturity of the RS may have affected the recovery of the trash-^{15}N by the 2nd ratoon, since throughout the cycles, the sugarcane root complex presents fewer radicels and a smaller proportion of root hairs, which results in less efficiency in water and nutrient uptake.

In the 2nd ratoon, there was a reduction for both treatments in the utilization of the trash-^{15}N when compared to the 1st ratoon. This reduction in the utilization was owing, possibly, to the lower productivity of the 2nd ratoon in relation to the 1st, resulting in less accumulation of total N by the above ground part of the crop (Vasconcelos et al., 2008). There is also the possibility of the majority of the mineralized nitrogen derived from the residues in the cycle of the 1st ratoon being easily decomposed, in connection with compounds like sugars, cellulose, free aminoacids, proteins, among others, remaining for the cycle of the 2nd ratoon compounds that are more recalcitrant to microbial attack, as, for example, lignin and polyphenols, which impedes the mineralization process. Although the sugarcane crop residues have presented a low quantity of N made available for the crops, the straw deposited in the soil in successive harvests can contribute to the greater accumulation of organic N in the soil, and this release, as demonstrated before, is closely connected to nitrogen fertilization. In areas in which the harvest without straw burning is being implanted, there is the possibility that the application of greater doses of N is perhaps necessary to assist in the dynamic of the trash-N in this system, as well as to assist in greater utilization of this N by the sugar cane crop.

Conclusion

The application of nitrogen in ratoon cane favored the recovery of trash-^{15}N by the above ground part of sugarcane in the two years of evaluation, and regardless of the nitrogen fertilization, there was a decrease in the utilization of the trash-N by the 2nd ratoon in relation to the st ratoon.

References

Amado TJC, Santi A, Acosta JAA (2003) Adubação nitrogenada na aveia preta. II – influência na decomposição de resíduos, liberação de nitrogênio e rendimento de milho sob sistema plantio direto. *Revista Brasileira de Ciência do solo* **27**,1085-1096.

Gava GJC, Trivelin PCO, Vitti AC, Oliveira MW (2003) Recuperação do nitrogênio (^{15}N) da uréia e da palhada por soqueira de cana-de-açúcar *(Saccharum spp). Revista Brasileira de Ciência do Solo* **27**, 621-630.

Harris GH, Hesterman OB (1990) Quantifying the nitrogen contribution from alfafa to soil and two succeeding crops using Nitrogen-15. *Agronomy Journal* **82**, 129-134.

Ng Kee Kwong KF, Deville J, Cavalot PC, Riviere V (1987) Value of cane trash in nitrogen nutrition of sugarcane. *Plant and Soil* **102**, 79-83.

Oliveira MW, Trivelin PCO, Penatti CP, Piccollo MC (1999) Decomposição e liberação de nutrientes da palhada de cana-de-açúcar em campo. *Pesquisa Agropecuária Brasileira* **34**, 2359-2362.

Otto R (2007) *Desenvolvimento de raízes e produtividade de cana-de-açúcar relacionados à adubação nitrogenada*. 117p. Dissertação de Mestrado – Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo.

Vasconcelos ACM, Casagrande AA (2008) Fisiologia do Sistema Radicular. In 'Cana-de-Açúcar**,** 1 Ed' (Eds LL Dinardo-Miranda, ACM Vasconcelos, MGA Landell) pp. 79-98. (Campinas: IAC, **1**,)

Vitti AC, Trivelin PCO, Gava GJC, Franco HCJ, Bologna IR, Faroni CE (2007) Produtividade da cana-de-açúcar relacionada à localização de adubos nitrogenados aplicados sobre os resíduos culturais em canavial sem queima. *Revista Brasileira de Ciência do Solo* **31**, 491-498.