UTILISATION OF NITROGEN FROM TRASH BY SUGARCANE RATOONS

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Abstract

A LARGE AMOUNT of crop residue (dry leaves, stem pieces and tips) remains on the soil surface after mechanical harvesting of unburnt sugarcane. These residues are often referred to as straw or trash and are a source of nutrients for following crops. In order to evaluate the ability of sugarcane to recover the nitrogen (N) from this trash, three experiments were carried out in Santa Adélia (SA), São Martinho (SM) and São Luiz (SL) Sugarcane Mills located in São Paulo State, Brazil, in two consecutive crop seasons (2006 and 2007). Microplots (1.5 x 2.0 m), replicated four times in a randomised block design, were installed at the start of a 1st ratoon crop of the variety SP 81-3250. No fertiliser N was applied to the microplots. The field crop residues in the microplots were replaced with 10 t/ha DM of ^{15}N labelled trash. The rate of trash-N and ^{15}N abundances were 41, 41 and 51 kg/ha and 1.01, 0.83, and 1.00 atom % for SA, SM and SL experiments, respectively. The highest ^{15}trash-N uptake was observed in the 1st ratoon crop in the SL experiment (4.3 kg/ha Trash-N), followed by SM and SA experiments (3.8 and 3.1 kg/ha of Trash-N). For the 2nd ratoon crop (2008), Trash-N recoveries could only be determined for the SA and SM experiments due to an accidental firing in the SL experiment. The SA experiment had the highest Trash-N uptake in the 2nd ratoon crop and was more than double the Trash-N recovery measured in the 1st ratoon crop. Nitrogen recovery from the trash on SM was 0.8 kg/ha of N, substantially lower than that observed in the 1st ratoon crop. After two crops (1st and 2nd ratoon crops), the total Trash-N recovered was 3.9 kg/ha (9.8%) and 9.6 kg/ha (23%), for SM and SA experiments, respectively.

Introduction

When sugarcane is mechanically harvested without previous burning, a considerable amount of dry leaves, pieces of stem and tip remains on the surface, forming a vegetable residue covering called trash or straw. This trash promotes changes in the nitrogen (N) cycle, mainly due to the immobilisation and mineralisation reactions mediated by microorganisms. In addition, these residues will serve as a source of nutrients for the soil macro and microflora as well as for the sugarcane crop (Wood, 1991).

The amount of sugarcane trash after an un-burnt harvest, can vary from 10 to 30 t/ha of dry matter and containing about 40 to 80 kg/ha of N (Oliveira *et al*., 2002; Vitti *et al*., 2007) which can lead to an increase in the amount of organic matter and nutrients in the soil (Wood, 1991; Vallis *et al*., 1996).

The mineralisation of crop residues (trash) added to soil is mainly dependent on the quality (chemical composition) of crop residues as well as environmental factors such as temperature, humidity, and soil aeration. The quality of the trash is typically defined by the C:N ratio, contents of lignin, cellulose, hemicellulose, and polyphenols (Ng Kee Kwong *et al*., 1987, Oliveira *et al*., 2002). The organic complexes from the trash mineralisation, such as humic acid, accumulate in the soil because of their high degree of recalcitrance and resistance to microbial attack. Therefore, the components that control the kinetics of the transformation of the organic N to inorganic N in the organic matter are various and complex (Janssen, 1996).

The sugarcane trash, on average, contains 390 to 450 g/kg of carbon and 4.6 to 6.5 g/kg of N (Ng Kee Kwong *et al*., 1987; Oliveira *et al*., 2002), which indicates an average C:N ratio of 100. Under these conditions, a strong immobilisation of N from soil and a small net mineralisation in just one agricultural year is expected (Gava *et al*., 2005). Residues that present nitrogen content lower than 18 g/kg and C:N ratio above 20 usually enable immobilisation (Janssen, 1996; Jingguo and Bakken, 1997). Thus, the contribution of N from the trash to the crop mineral nutrition may be small, since the decomposition of these residues with high C: N ratio promotes a competition between roots and soil microorganisms for the N available in the system (Jingguo and Bakken, 1997).

In a study performed by Vitti *et al*. (2005) to assess the trash-^{15}N recovery in sugarcane second ratoon (3rd harvest), it was observed, after one year, that 73% of the total N present in the trash, remained in the trash,22% in soil and only 4% was recovered by the plant. Despite the small contribution of N from trash to the crop nutrition in the first year of residence in the field, most of the N accumulated by sugarcane occurred in the last months before the harvest. Therefore, the largest contribution of N from trash may occur in the following crop seasons, since more than 20% of the nutrient remained in the soil, besides decreasing the C: N residue ratio over time.

In this way, the work presented here aimed to assess the utilisation of mineralised N from residual trash (trash-N) by the sugarcane crop, during the period after the harvest of the plant crop till the harvest of the 2nd ratoon (2007, 2008) using the ^{15}N isotope tracer technique.

Material and methods

The experiment was conducted in three areas cultivated with sugarcane which were mechanically harvested without burning, located in São Paulo State, Brazil. The areas belonged to, respectively, the Santa Adélia (SA) (Latitude 21°15'S, Longitude 48°18'W), the São Martinho (SM) (Latitude 21°15'S, Longitude 48°18'W) and São Luiz Sugarcane Mills (SL) (Latitude 21°59'S, Longitude 48°02'W). The soil is an Arenic Kandiustults (Latossolo Vermelho distrófico) in SA, a Rhodic Eutrustox (Latossolo Vermelho eutrófico) in SM and a Typic Eutrustox (Latossolo Vermelho Amarelo eutrófico) in SL, according to Soil Survey Staff (2003) and Embrapa (2006), respectively. The soil analysis was conducted in the three locations at 0-25 and 25–50 cm depth, after harvesting the plant-cane (Table 1).

The planting was performed in February for SL, March for SM and in April 2005 for SA, in which 17 to 20 buds/m of SP81-3250 sugarcane cultivar were distributed. In the bottom of the furrows we applied 120 kg/ha of K_2O as potassium chloride, 120 kg/ha P_2O_5 as simple superphosphate and 80 kg/ha as urea.

After harvesting the plant-cane, the experiment was installed in randomised blocks with 4 replicates. Each experimental plot consisted of 12 rows, 15 metres long and 1.5 m row spacing. In October 2006, microplots (2 m length and 1.5 m width) were installed. Within the microplots, residual trash from the mechanical harvesting was replaced by trash labelled with the ^{15}N isotope equivalent to 10 t/ha DM. The trash was coming from an experiment with nitrogen fertilisation employing ^{15}N-fertiliser (urea enriched with 5.04% in ^{15}N atoms) and presented ^{15}N enrichment of

1.01% (SA), 0.83% (SM) and 1.00% (SL) in ^{15}N atoms. The total amount of N present in the residues was equivalent to 41, 41 and 51 kg/ha for the 1st ratoon for SA, SM and SL respectively. Results from the 2nd ratoon (2008) for SL were not collected due to an accidental fire in the experimental area.

Table 1—Soil analysis at 0–25 and 25–50 cm depth, of the three experimental areas of São Luiz (SL), Santa Adélia (SA) and São Martinho (SM) Sugarcane Mills, performed after the first sugarcane harvest.

Sugarcane mill	Depth	S.O.M.	pH	P	S	K	Ca	Mg	H+Al	BS	CEC	V
	cm	g/dm^3	$CaCl_2$	Mg/dm^3		mmol/dm^3						%
SL	0–25	21	5.9	5	2	1.9	35	9	15	45.4	60.4	75
	25–50	16	5.2	2	12	1.4	14	4	19	19.1	38.6	49
SA	0–25	21	5.4	15	2	3.2	21	12	22	35.8	57.7	62
	25–50	16	4.5	6	22	2.2	9	4	31	15.1	46.2	32
SM	0–25	35	5.2	48	7	4.3	39	11	41	54.5	95.5	57
	25–50	28	5.4	34	18	2.4	36	10	32	47.4	79.5	57

The 1st ratoon harvest was performed in July 2007 (SA and SL) and in August 2007 (SM). The above-ground parts of the plants located in 1m of furrow in the centre of each microplot and beside each one of the microplots were harvested manually. The samples were separated into dry leaves, tips and stems. The mass of trash was determined directly in the field. All the material from the microplots was ground in a mechanical forage chopper.

After grinding and homogenising each wet sample, a subsample was taken, which was weighed and dried in an oven (72 hours at 65°C), and the dry mass and the moisture content of the material were determined. The dry material was ground in a Wiley mill and analysed by mass spectrometry for total N (%) and ^{15}N abundance (% in ^{15}N atoms).

The remaining rows of the plots were harvested by mechanical harvester. After the harvest of the 1st ratoon, the experimental plots and microplots were maintained. In the microplots, the unlabelled trash of the 1st ratoon overlapped the labelled trash-^{15}N of the plant-cane.

Nitrogen fertiliser was not used in the ratoon, so that the effect of the trash-^{15}N recovery could be isolated. The second ratoon crop was harvested in July 2008, and the procedure adopted was the same as the previous season. The nitrogen in the plant derived from trash (NPDS) and the N utilisation (NR) from the aerial part were calculated using the equations:

$$NPDS = [(A – C) / (B – C)].\ NT \quad (1)$$

$$NR (\%) = (NPDS / NAF)\ .100 \quad (2)$$

where: NPDS = N in the plant from the trash-^{15}N (kg/ha); NR = utilisation of trash-^{15}N by the aerial part of the plant (%); A = ^{15}N abundance (atoms %) of the plant; B = ^{15}N abundance (1.01%-SA, 0.83%-SM and 1.00%-SL atoms %) of the labelled trash; C = ^{15}N natural abundance (0.366% of atoms); NT = N content of the plant (kg/ha); NAF = amount of N in the trash (kg/ha).

The results were submitted to analysis of variance and, when F was significant, the means were compared by Tukey test at 1% probability.

During the experimental period, the amount of rainfall and the average maximum and minimum temperature were measured in automatic stations installed near to the experimental areas (Figure 1).

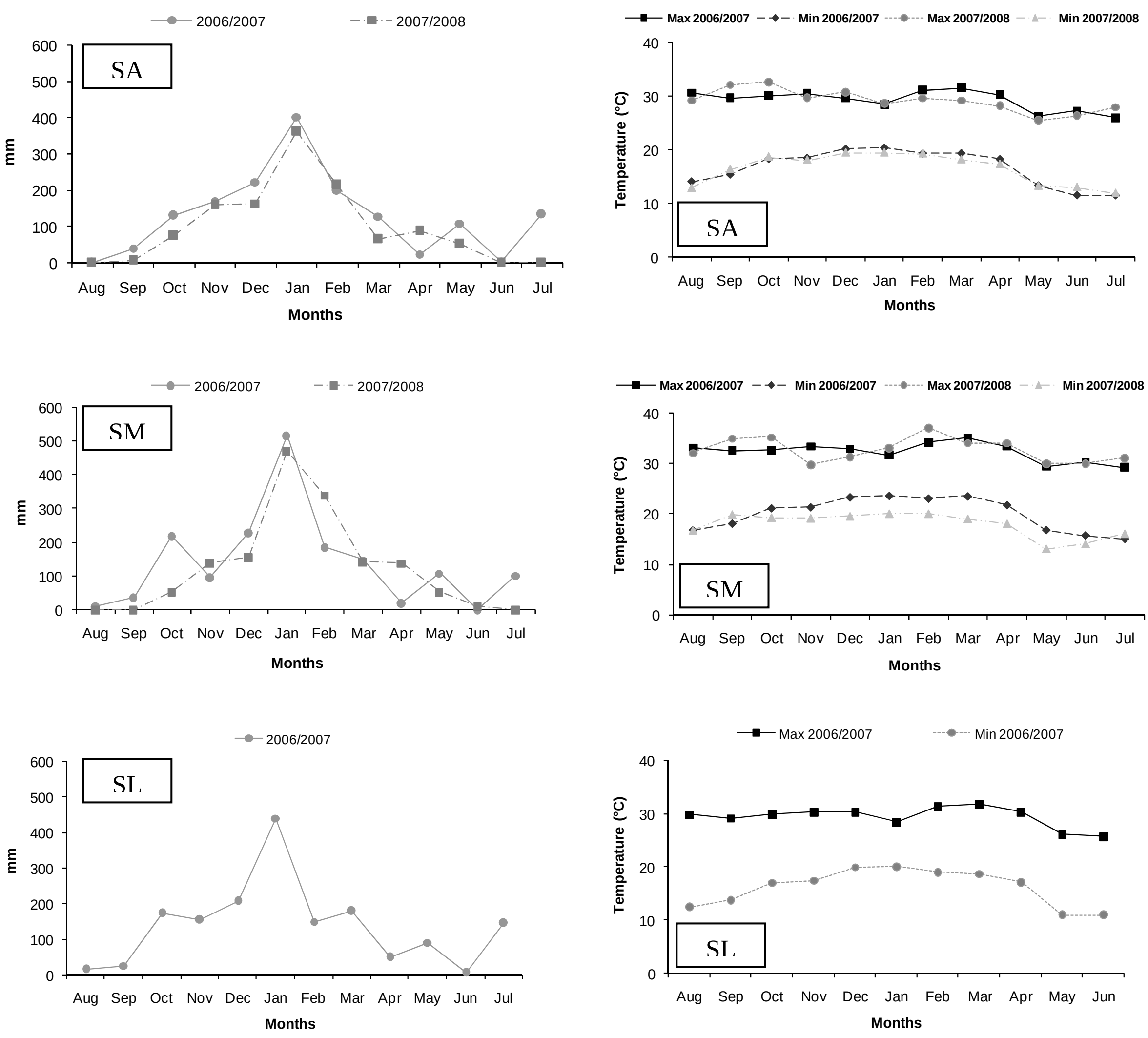

Fig. 1—Rainfall (mm) and monthly average maximum and minimum temperatures (°C) in the Santa Adélia (SA), São Martinho (SM) and São Luis (SL) Sugarcane Mills during the 2006/2007 crop seasons (2nd harvest or 1st regrowth) and 2007/2008 (3rd harvest or 2nd regrowth), respectively.

Results and discussion

At the end of the 1st ratoon cycle, the above-ground plant components accumulated approximately 3.8, 3.0 and 4.3 kg/ha of N, which corresponds to a recovery of 9.5, 7.3 and 8.4% of nitrogen (^{15}N) in the initial crop residues for SA, SM and SL, respectively (Table 2). For the three areas, the results are similar to those presented by Ng Kee Kwong *et al*. (1987) and Gava *et al*. (2005), who observed from 5 to 14% of the N-total presented in the trash was recovered by above-ground parts of sugarcane. For the 2nd ratoon, the recovery of trash-^{15}N in the field was 6.6 kg/ha (17.7%) for SA and 0.8 kg/ha (2.1%) for SM (Table 2).

The total recovery of trash-N by the sugarcane after two years was 3.9 kg/ha (9.6%) for SM and 9.6 kg/ha (23%) for SA, showing a small contribution to the nitrogen nutrition of sugarcane. Meier *et al*. (2006) showed that trash supplies N slowly and in small amounts to the succeeding crop, and N mineralisation from a single trash blanket is not important for sugarcane production in the wet tropics. Among the plant components, the largest recoveries of trash-N were observed in the stems, regardless of nitrogen fertilisation, followed by the tip and dry leaf components. The greater allocation of N in the stem is due to the greater mass of this compartment in relation to the dry leaf and tip (Table 3).

Although the recovery for the 1st ratoon at SL site was not the largest one (8.4%), it presented the best results (4.3 kg/ha), probably due to the greater accumulation of total N present in the trash (51 kg/ha) in relation to the SA and SM areas (41 kg/ha).

For SA site, the trash-N recovery for the 2nd ratoon was double that observed in the 1st ratoon. This result was higher than those found by Ng Kee Kwong *et al*. (1987) and Gava *et al.* (2005). The greater utilisation by sugarcane of trash-N in the 2nd ratoon is mainly due to the decrease in the C: N ratio with the trash decomposition, favouring mineralisation instead of immobilisation. The mineralisation of residues depends, therefore, on the material C:N ratio, besides the quality of the residue (Oliveira *et al*., 2002) and the degree of partition and transfer ('turnover') in the soil of the mineralised nitrogen of vegetal residue (Myers *et al*., 1994). Those authors reported that during the decomposition of crop residues, there is a partitioning of N into the mineral N (soil and fertiliser) pool, N-humic pool and N-immobilised by the microbial biomass of the soil, as well as a continuous transfer ('turnover') of this N between the compartments. Jadhav (1996) observed, over time, that through the trash decarboxylation, CO_2 was released, keeping the N in the system, resulting in a decrease in C:N ratio from 120:1 to 20:1. This close relationship to the microorganisms C:N ratio (about 12:1) intensifies the mineralisation, increasing the N pool in soil from the trash decomposition, resulting in a greater N availability for the plants.

Table 2—Recovery from trash-N by the above-ground plant components (stem, tip and dry leaf), respectively, of the 1st and 2nd ratoon crops (2006/07 and 2007/08 seasons) for the Santa Adélia (SA), São Martinho (SM) and São Luiz (SL) sugarcane mill areas.

Sugarcane mill	Parts of plant	Trash-N recovery	
		$NPDS_{total}$[1] (kg/ha)	R(%)
First ratoon (2006/07)			
SA	Stem	2.6 ± 0.2	5.7 ± 0.6
	Dry leaf	0.6 ± 0.0	1.4 ± 0.1
	Tip	0.9 ± 0.1	2.4 ± 0.3
	Aerial part	3.8 ± 0.2	9.5 ± 0.6
SM	Stem	1.7 ± 0.3	4.2 ± 0.1
	Dry leaf	0.5 ± 0.1	1.2 ± 0.2
	Tip	0.9 ± 0.1	2.1 ± 0.4
	Aerial part	3.1 ± 0.6	7.5 ± 0.3
SL	Stem	2.0 ± 0.6	3.9 ± 1.1
	Dry leaf	1.2 ± 0.2	2.3 ± 0.4
	Tip	1.1 ± 0.4	2.2 ± 0.8
	Aerial part	4.3 ± 0.7	8.4 ± 1.4
Second ratoon (2007/08)			
SA	Stem	2.6 ± 1.5	6.9 ± 4.0
	Dry leaf	0.4 ± 0.2	1.0 ± 0.6
	Tip	3.5 ± 2.5	9.4 ± 6.9
	Aerial part	6.5 ± 4.2	17.3 ± 11.5
SM	Stem	0.4 ± 0.1	1.1 ± 0.4
	Dry leaf	0.1 ± 0.0	0.3 ± 0.1
	Tip	0.3 ± 0.0	0.7 ± 0.1
	Aerial part	0.8 ± 0.1	2.1 ± 0.4

[1] $NPDS_{total} = NP_{1*}DS_{1*} + 2\ NP_{1*\pm1}DS_{1*}$ (Trivelin *et al*., 1994). Mean and standard deviation ($m \pm s_m$) of 4 replicates.

At the SM experiment site, there was a decrease in the utilisation of N in the 2nd ratoon in relation to the 1st ratoon. This is probably due to the reduced productivity of 2nd ratoon in relation to the 1st ratoon, resulting in a lower accumulation of total N in the above-ground plant material. On the other hand, most of the nitrogen mineralised in the 1st ratoon cycle is located in the part of the trash which easily decomposes, linked to compounds such as sugars, cellulose, free amino acids, proteins, nucleic acids and nucleotides (Killham, 1994). Therefore, the N remaining in the trash for utilisation by the 2nd ratoon crop is found in compounds more recalcitrant to microbial attack, such as lignin and polyphenols (Paul and Clark. 1996), impeding the mineralisation process. The trash-^{15}N recovery by the 2nd ratoon may also be affected by the root system ageing since, during the course of the crop, the sugarcane roots consist of less fibrous roots and a lower proportion of the root hairs, which results in lower efficiency of nutrients and water absorption (Vasconcelos and Casagrande, 2008).

Table 3—Production of dry matter and nitrogen accumulated in the above-ground plant components (stem, tip and dry leaf) for the 1st and 2nd ratoon crops for Santa Adélia (SA), São Martinho (SM) and São Luiz (SL) Sugar Mill.

Sugarcane mill	Parts of plant	Dry matter (t/ha)	Nitrogen accumulation (kg/ha)
First ratoon (2006/07)			
SA	Stem	26 ± 1.3	50 ± 5
	Dry leaf	10 ± 0.3	33 ± 2
	Tip	4 ± 0.2	43 ± 5
SM	Stem	24 ± 0.3	56 ± 11
	Dry leaf	8 ± 0.1	23 ± 7
	Tip	7 ± 0.1	53 ± 14
SL	Stem	17 ± 0.9	31 ± 4
	Dry leaf	8 ± 0.3	31 ± 2
	Tip	4 ± 0.2	40 ± 5
Second ratoon (2007/08)			
SA	Stem	22 ± 1.7	43 ± 4
	Dry leaf	3 ± 0.4	9 ± 3
	Tip	6 ± 02	50 ± 10
SM	Stem	12 ± 0.7	33 ± 4
	Dry leaf	4 ± 0.3	13 ± 2
	Tip	2 ± 0.2	16 ± 4

[1] Mean and standard deviation ($m \pm s_m$) of 4 replicates.

The precipitation rates and the mean temperatures were also lower in the 2007/2008 period compared to 2006/2007 period, which may have affected the trash decomposition, since it is favoured by high temperatures and high humidity. It was noted by Stanford *et al*. (1973) and Katterer *et al*. (1998) that, in the range 5 to 35°C, the mineralisation rate doubles every 10°C of temperature increase.

In work done by Quemada and Cabrera (1997), in which the organic matter of *Trifolium incarnatum* L. was placed on the soil surface, a decrease in mineralisation of about 20% was found, when the soil incubation temperature decreased from 28 to 20°C. In line with this reasoning, the higher recovery of the 2nd ratoon in the SA can be explained, considering that it presented the most favourable conditions of temperature and humidity in relation to the 1st ratoon (Figure 1).

When quantifying the trash-N recovery, it may be necessary to also take into account the translocation of N from the above-ground plant components to the root system mainly during the sugarcane maturation, as suggested by Vitti *et al*. (2007).

Therefore, the recovery may be greater than that presented here if the N in roots and rhizomes was accounted for. Vitti *et al*. (2007) observed that the root system of sugarcane can be on average 1/3 of total N accumulated by shoots.

Although the sugarcane crop residues have presented low amounts of N available for uptake by the crop, the trash deposited in the soil in successive harvests can contribute to a greater accumulation of organic N in the soil, up to 79% of N can be retained in the soil, as observed by Robertson and Thorburn (2007). Studies conducted in Australia by Vallis *et al.* (1996) indicate that the sugarcane trash left on the soil surface for a period of 20 years may result in the reduction of up to 40 kg/ha in N fertilisation. Thus, the crop residues generated by mechanical harvesting without the use of fire to burn trash represent an important stock of nitrogen in the soil-plant system, and certainly they will contribute to a reduction in N rates used in ratoons cultivated in Brazil.

Conclusion

The trash-N recovery was significant in the two year period of this experiment, ranging from 7.5% to 9.5% and 2.2% to 17.7% in 1st and 2nd ratoons, respectively.

The lower utilisation of trash-N in the experimental site located in the São Martinho Sugarcane Mill area could be attributed to the less favourable weather conditions in relation to other areas, resulting in a lower mineralisation rate of the residues. The participation of trash-N in the sugarcane ratoons nutrition represented a small part of the total N. However, over many years, this N source may help in reducing N rates employed in the agricultural system as suggested in similar studies in other regions.

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UTILISATION DE L'AZOTE DES PAILLES PAR LES REPOUSSES DE CANNE A SUCRE

Par

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MOTS-CLES: Canne à Sucre, Azote, Résidus, Paille, Matière Organique, Fertilité Des Sols, Nutrition, ^{15}N.

Résumé

UNE GRANDE quantité des résidus de récolte (feuilles sèches, morceaux de tiges, et bouts blancs) restent à la surface du sol après la récolte mécanique de canne sans brûlage. Ces résidus, souvent appelés paille sont une source d'éléments nutritifs pour les récoltes suivantes. Afin d'évaluer la capacité de la canne à récupérer l'azote de ces pailles, trois expérimentations ont été conduites à Santa Adélia (SA), São Martinho (SM) and São Luiz (SL), sucreries situées dans l'état de São Paulo, Brésil, pendant deux campagnes consécutives (2006 et 2007). Des micro-parcelles (1.5 × 2.0 m) répétées 4 fois selon un dispositif en bloc randomisé, ont été installées en début de 1ère repousse de la variété SP 81-3250. Aucune fertilisation azotée n'a été appliquée dans les micro-parcelles et les résidus de récolte dans les micro-parcelles ont été remplacés par 10 t/ha de matière sèche de paille marquée avec de l'azote ^{15}N. Les doses de N du paillis et d'abondance en ^{15}N furent respectivement de 41, 41 et 51 kg/ha et fr 1.01, 0.83 et 1.00 de % d'atome pour les essays SA,SM et SL. La plus forte assimilation de ^{15}N provenant des pailles a été observée dans la première repousse de l'expérimentation de SL (4.3 kg/ha de N-paille), suivie par les expérimentations de SM et SA (3.8 et 3.1 kg/ha de N-paille). En 2ème repousse, la récupération de l'azote provenant des pailles n'a pu être déterminée que pour les expérimentations de SA et SM, suite au feu accidentel survenu dans celle de SL. L'expérimentation de SA a eu le plus fort taux de prélèvement d'azote en provenance de la paille en 2ème repousse, soit plus du double de ce qui avait été mesuré en 1ère repousse. L'azote en provenance de la paille à SM a été de 0.8 kg/ha, soit bien plus bas que ce qui avait été observé en 1ère repousse. Après deux années de culture (1ère et 2ème repousse), la quantité totale de N en provenance des pailles a été respectivement de 3.9 kg/ha (9.8%) et 9.6 kg/ha (23%) pour SM et SA.

UTILIZACIÓN DEL NITRÓGENO A PARTIR DEL TRASH POR LAS CAÑAS SOCAS

Por

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Resumen

DESPUÉS DE LA cosecha mecánica de la caña en verde (sin quema), queda sobre la superficie del suelo una gran cantidad de residuos del cultivo (hojas secas, trozos de tallo y despunte). A estos residuos se los conoce frecuentemente como paja o trash y son una fuente de nutrientes para los cultivos subsiguientes. Con el objetivo de evaluar la capacidad de la caña de azúcar para recuperar nitrógeno (N) a partir de este residuo, se realizaron tres experiencias en los ingenios azucareros Santa Adélia (SA), São Martinho (SM) y São Luiz (SL), ubicados en el estado de San Pablo, Brasil, durante dos ciclos sucesivos de cultivo (2006 y 2007). Se trabajó con la variedad SP 81-3250, en la edad de primera soca, utilizando microparcelas (1.5 × 2.0 m) en un diseño experimental de bloques al azar con cuatro repeticiones. En las microparcelas no se realizó fertilización nitrogenada. El residuo de la cosecha en las microparcelas fue remplazado por el equivalente a 10 t/ha (materia seca) de trash marcado con ^{15}N. La tasa de trash-N y ^{15}N fue 41, 41 y 51 kg/ha y 1.01, 0.83, y 1.00 átomo % para las experiencias en SA, SM y SL, respectivamente. La mayor absorción de ^{15}trash-N se observó en la soca 1 de la experiencia en SL (4.3 kg/ha de N del trash), seguida por las experiencias en SM y SA (3.8 y 3.1 kg/ha de N del trash). Para la edad de soca 2 (2008), la recuperación de N del trash solo pudo ser determinada para las experiencias en SA y SM, debido a un incendio accidental en la experiencia de SL. En la soca 2 la experiencia de SA presentó la más alta absorción de N del trash y fue más del doble de la recuperación de N del trash medida en la soca 1. La recuperación de N a partir del trash en SM fue de 0.8 kg de N/ha, sustancialmente menor que la observada en la primera soca. Después de dos ciclos de cultivo (1º y 2º soca) el total de N recuperado del trash fue 3.9 kg/ha (9.8%) y 9.6 kg/ha (23%), para las experiencias de SM y SA, respectivamente.