INTRODUCTION

The utilization of nitrogen by sugar cane (*Saccharum officinarum* L.) fertilized with sunn hemp (*Crotalaria juncea* L.) as green manure and ammonia sulfate and its residual effect during two cuts were evaluated using ^{15}N tracer technique, and the impact of these sources on sugar cane yield, nitrogen contents in the plant, and soil chemical characteristics were also evaluated.

MATERIAL AND METHODS

The experiment was carried out in Piracicaba, SP, Brazil (22^{o}42'S, 47^{o}38'W, and 560 m altitude). The soil, classified as an Arenic Hapludult, was chemically characterized at different depths after cutting the green manure crop, before planting the sugarcane (Table 1).

Table 1- Soil chemical characteristics before sugarcane planting, in plots with and without green manure (sunn hemp), at depths of 0-0.2 and 0.2-0.4 m

		O.M.	pH	P	K	Ca	Mg	H+Al	BS	CEC	V
without		g dm^{-3}	$CaCl_2$	mg dm^{-3}	----------------		mmolc dm^{-3}		----------------		%
sunn hemp	1*	26	4.1	3	0.7	7	6	50	13.7	63.7	22
	2	22	4.0	14	0.5	6	5	68	11.5	79.5	14
with	1	24	4.5	6	0.3	12	11	36	23.3	59.3	39
sunn hemp	2	22	4.7	6	0.3	11	10	31	21.3	52.3	41

*Sampling layer 1= 0-0.2 m; 2= 0.2-0.4 m

In the first stage of the experiment, the sunn hemp (SH) was sown and labeled with ^{15}N. The labeled plant material with 2.412 atoms % excess ^{15}N was obtained in December, 2000. Total dry mass was equivalent to 9.150 Mg ha^{-1} with 21.4 g kg^{-1} N, correspondent to 195.8 kg ha^{-1} N added to the soil, as described by Ambrosano et al. (2003).

The sunn hemp plants after grown for 90 days were cut and the fresh material was laid down on the soil surface. Sugarcane IAC- 87-3396 was planted on March 1 2001. Ammonium sulfate (AS) was sidedressed 90 days after planting. The ammonium sulfate was labeled with 3.02 ± 0.01 atoms % ^{15}N; a rate equivalent to 70 kg N per hectare was applied in the respective treatments. The treatments were: Control; AS-^{15}N; SH-^{15}N + AS; SH-^{15}N; AS-^{15}N + SH.

The experimental plots consisted of 10 sugarcane rows 10 m in length and spaced 1.40 m. The ^{15}N-labeled sources were applied in microplots consisting of 3 contiguous sugarcane row segments 2 m in length in treatments involving SH-^{15}N, and 2 segments 1m in length in treatments involving AS-^{15}N.

Three complete +3 leaves (3rd visible auricle, according to Kuijper system) were collected from plants located in the central meter of micro plots involving ^{15}N sources, following the methodology described in Trivelin et al. (1994). The samples were collected on different seasons, 10/29/2001 (1), 02/20/2002 (2), 05/28/2002 (3), 08/24/2002(4) and 10/08/2003(5), cleaned, dried at 60°C, and ground in a Willey mill. ^{15}N abundance (atoms %) and N content (g kg^{-1}) determinations were made in a Europa Sc. ANCA-SL mass spectrometer coupled to an N analyzer.

Whole plants were also harvested in all samplings from 3 rows of 2 meters of each treatment in an area adjacent to the micro plots, to determine the fresh weight of the above-ground part of the plants for yield evolution. A sub sample was taken from these samples, immediately after grinding in a forage mill. Them the sub samples were dried in a ventilated oven at 60°C, and the dry weight were determined. The nitrogen content (g kg^{-1}) and ^{15}N abundance (atoms %) in the plant samples taken from micro plots were also determined by mass spectrometry. The mean mass yield of fresh and dry matter (Mg ha^{-1}) and total accumulated nitrogen (kg ha^{-1}) were estimated for different sampling seasons, as well as N derived from the labeled source in % (Ndff %) and amount (QNdff kg ha^{-1}) in the above-ground part of sugarcane.

The statistical analysis was performed using the concept of measurements repeated in time and the MIXED procedure in the SAS (Statistical Analysis System) version 8.2 for Windows software (Littel et al., 1996). The AKAIKE information criterion was used to select the variance and covariance matrix, by choosing the matrix with the smallest value for that parameter (Akaike, 1974 and SAS, 2004). The adjusted means for the fixed effects were obtained with the "LSMEANS" option, and mean comparisons were made by the Tukey-Kramer test at the 5% significance level.

RESULTS AND DISCUSSION

There was an increase in fresh and dry plant matter weight in the treatment with green manure and mineral nitrogen applied together compared to the control treatment (sampling season 4, first cut, Table 2). However, no difference was observed in relation to sampling 4 and 5 (first and second cut) for the treatment with green manure used alone, (Table 2). It can support the idea that this treatment may probably support better the sugar cane yield.

The SH + AS-^{15}N treatment was proeminent in relation to the control, and yielded greater fresh matter (sampling season 4, first sugarcane cut). Differences among the treatments were observed in the 28 May 2002(seasons 2 sampling), and the treatment containing SH was superior to control. The fresh and dry matter yields, as well as cumulative N, were higher in the fourth sampling. However, nitrogen contents were smaller, demonstrating the occurrence of a dilution effect of N in the plant matter produced. The cumulative N results were similar to those found by Oliveira (1999), with high nitrogen and plant material accumulation during the last three months, as also observed by Trivelin et al. (1996).

With regard to nitrogen in the sugarcane leaves derived from labeled sources (Table 3), a higher percentage derived from sunn hemp was observed in the first sampling, which demonstrates the importance of the presence of an organic source for initial nitrogen nutrition in sugarcane, which corresponds to dried season in Brazil. Considering the amounts of nitrogen in sugarcane leaves(3 and 4 sampling seasons), no differences were observed between nitrogen supplied by sunn hemp either supplemented or not with mineral N, indicating that both sources were able to supply the crop's nitrogen requirements. Smaller nitrogen recovery from sunn hemp was also verified in the second, third and four seasons, compared with nitrogen, which did not vary with time.

The higher percentage of nitrogen in sugarcane derived from sunn hemp in the first sampling may indicate that, under the soil low water availability condition the crop was facing, nitrogen was ensured by the organic source, since this value was around three times higher than from the mineral source (Table 3).

Table 2 - Fresh and dry matter of sugar cane plant, nitrogen content, and nitrogen accumulated in the plant, samples collided at 29 October 2001 (1), 20 February 2002 (2), 28 May 2002 (3), 24 August 2002, first cut (4) and 8 October 2003, second cut (5).

Sampling season	Treatments					
	Control	AS-^{15}N[2]	SH + AS -^{15}N	SH-^{15}N	Mean	SEM[1]
			Fresh matter Mg ha^{-1}			
1	7.27 Eb	9.85 Dab	13.07 Da	12.20 Cab	10.60	3.22
2	24.92 Db	31.20 Cab	36.37 Ca	36.40 Ba	32.22	3.22
3	35.82 Ca	36.62 Ca	37.70 Ca	44.25 Ba	38.60	3.22
4	85.97 Ab	106.17 Aab	128.72 Aa	92.42 Ab	103.32	3.22
5	61.07 Ba	64.75 Ba	84.47 Ba	83.72 Aa	73.51	3.22
Mean	43.01	49.72	60.07	53.80		
SEM[1]	2.88	2.88	2.88	2.88		
			Dry matter Mg ha^{-1}			
1	1.97 Eb	2.72 Eab	3.60 Da	2.92 Da	2.73	0.99
2	6.07 Db	7.42 Dab	8.65 Ca	8.80 Ca	7.74	0.99
3	11.45 Ca	10.92 Ca	11.22 Ca	13.90B a	11.87	0.99
4	25.52 Ab	31.65 Aab	37.97 Aa	27.62 Ab	30.70	0.99
5	18.15 Ba	19.40 Ba	25.15 Ba	24.75 Aa	21.85	0.99
Mean	12.60	14.36	17.31	15.60		
SEM	0.89	0.89	0.89	0.89		
			N content (%)			
1	1.52 Aa	1.57 Aa	1.62 A a	1.52 Aa	1.56	0.03
2	1.37 ABa	1.45 ABa	1.42 ABa	1.27 Ba	1.38	0.03
3	1.17 BCab	1.27 Ba	1.22 Ba	1.02 CDb	1.17	0.03
4	0.67 Da	0.75 Da	0.67 Da	0.82 Da	0.73	0.03
5	1.00 Ca	1.00 Ca	0.92 Ca	1.07 BCa	1.00	0.03
Mean	1.15	1.21	1.17	1.14		
SEM	0.02	0.02	0.02	0.02		
			Cumulative N kg ha^{-1}			
1	30.02	38.80	53.07	44.90	41.70 D	7.20
2	84.25	108.50	123.92	112.15	107.21 C	7.20
3	132.60	137.60	135.30	139.35	136.21 B	7.20
4	177.38	235.58	256.98	220.38	222.58 A	7.20
5	18.10	19.07	22.80	27.07	21.76 E	7.20
Mean	88.47 b	107.91 ab	118.42 a	108.77 a		
SEM	6.44	6.44	6.44	6.44		

Means followed by the same lower case letter, in the rows, and upper case letter, in the columns, are not different by the Tukey-Kramer test (P> 0.05)

[1]Standard error of the mean

[2]AS-^{15}N (^{15}N-labeled ammonium sulfate)

SH + AS -^{15}N (Sunn hemp + ^{15}N-labeled ammonium sulfate)

SH-^{15}N (^{15}N-labeled Sunn hemp)

Table 3 - Nitrogen in leaves derived from the labeled source (Ndff and QNdff) and nitrogen recovery (R) in samplings done on 29 October de 2001 (1), 20 February 2002 (2), 28 May 2002 (3), 24 August 2002, first cut (4) and 8 October 2003, second cut (5).

Sampling seasons	Treatments					
	AS-^{15}N[2]	SH -^{15}N + AS	SH-^{15}N	AS -^{15}N+ SH	Mean	SEM[1]
			Ndff(%)			
1	4.98 BCb	18.36 Aa	15.31 Aa	7.24 Aab	11.47	1.20
2	13.07 Aa	13.51 ABa	10.70 AB a	15.12 Aa	13.10	1.20
3	12.03 ABa	8.09 ABa	7.58 ABa	13.20 Aa	10.22	1.20
4	12.31 ABa	11.08 ABa	10.91 ABa	6.94 Aa	10.31	1.20
5	1.65 Cb	5.52 Ba	4.07 Bab	1.72 Bb	3.24	1.20
Mean	8.81	11.31	10.31	1.72		
SEM[1]	1.07	1.07	1.07	1.07		
			QNdff(kg ha^{-1})			
1	1.85 Bb	11.20AB a	6.92 Aa	3.57 Bab	5.89	1.07
2	14.63 Aa	16.33 Aa	12.24 Aa	24.53A a	16.93	2.21
3	16.11 Aa	11.08 ABa	10.73 Aa	21.65 Aa	14.89	2.08
4	5.65 ABa	6.03 Ba	5.19 Aa	4.51 Ba	5.35	0.81
5	1.79 Bb	6.78 ABa	4.57 Aab	2.85 Bab	4.00	0.34
Mean	8.01	10.29	7.93	11.42		
SEM	1.63	1.63	1.73	1.63		
			R (%)			
1	2.65B a	5.72A a	3.53A a	5.10B a	4.25	1.80
2	20.90 Aab	8.34 Abc	6.25 Ac	35.05A a	17.63	1.80
3	23.01 Aa	5.66 Ab	5.48 Ab	30.93 Aa	16.27	1.80
4	8.08 Ba	3.08 Aab	2.65 Ab	6.44 Bab	5.06	1.80
5	2.56 Ba	3.46 Aa	2.34 Aa	4.08 Ba	3.11	1.80
Mean	11.44	5.25	4.05	16.32		
SEM	1.61	1.61	1.61	1.61		

Means followed by the same lower case letter, in the rows, and upper case letter, in the columns, are not different by the Tukey-Kramer test (P> 0.05)

[1]Standard error of the mean

[2]AS-^{15}N (^{15}N-labeled ammonium sulfate)

SH-^{15}N + AS (^{15}N-labeled Sunn hemp + ammonium sulfate)

SH-^{15}N (^{15}N-labeled Sunn hemp)

AS -^{15}N+ SH (^{15}N-labeled ammonium sulfate + Sunn hemp)

This fact did reflect on nitrogen recovery, since no difference on the percentage of N recovered by sugarcane was observed due to nitrogen source in the first cut (sampling 4, Table 3). In later samplings, recovery was higher in mineral N treatments. An the second cut (sampling 5, table 3) was observed higher Ndff(%) and QNdff(kg ha^{-1}) for treatments with sunn hemp, indicating the residual effect of green manure.

Table 4 - Nitrogen in the stalk derived from the labeled source (Ndff and QNdff) and nitrogen recovery (R) in samplings on 28 May 2002 (3) and 24 August 2002, first cut (4) and 8 October 2003, second cut (5).

Sampling seasons	Treatments					
	AS-^{15}N[2]	SH -^{15}N + AS	SH-^{15}N	AS -^{15}N+ SH	Mean	SEM[1]
			------------------------------Ndff (%) -------------------------			
3	14.85 Aa	4.02 Ab	3.24 Bb	10.82Aa	8.23 A	0.49
4	10.46 A a	6.99 Aa	8.17 Aa	10.32 Aa	8.98 A	1.12
5	1.43 Bb	3.82 Aa	3.65 Bab	1.65 Bab	2.64 B	0.49
Mean	8.91	4.94	5.02	7.59		
SEM[1]	0.86	0.86	0.86	0.86		
			----------------------------QNdff (kg ha^{-1}) -----------------------			
3	4.15 Ba	0.95 Bb	0.79 Bb	3.87 Ba	2.44	0.30
4	24.06 Aa	19.29 Aa	17.27 Aa	21.06 Aa	20.42	2.78
5	2.73 Bb	8.64 Aa	10.32 Aa	3.90 Bab	6.40	0.77
Média	10.32	9.63	9.46	9.61		
SEM[1]	1.78	1.78	1.78	1.78		
			----------------------------------R (%) -------------------------------			
3	5.94 Ba	0.48 Aa	0.40 Aa	5.53 B a	3.09	1.89
4	34.37 A a	9.85 Ab	8.82 A b	30.08 Aa	20.78	1.89
5	3.90 Ba	4.41 Aa	5.27 Aa	5.57 Ba	4.79	1.89
Mean	14.74	4.92	4.83	13.73		
SEM[1]	2.02	2.02	2.02	2.02		

Means followed by the same lower case letter, in the rows, and upper case letter, in the columns, are not different by the Tukey-Kramer test (P> 0.05)

[1]Standard error of the mean

[2]AS-^{15}N (^{15}N-labeled ammonium sulfate)

SH-^{15}N + AS (^{15}N-labeled Sunn hemp + ammonium sulfate)

SH-^{15}N (^{15}N-labeled Sunn hemp)

AS -^{15}N+ SH (^{15}N-labeled ammonium sulfate + Sunn hemp)

Three months before harvest (sampling season 3, Table 4), the percentages of nitrogen in the stalk derived from an organic source were low in sunn hemp treatments, increasing to approximately 8% in the harvest season (first cut), and becoming equal to other treatments with mineral N. A greater proportion of nitrogen derived from mineral N was observed in stalk samplings obtained on 28 May 2002. However, in terms of amount of nitrogen from labeled sources in the stalk, no differences between treatments were observed on average, which indicates an adequate supply of nitrogen for sugarcane from both sources. At harvest, total recovery from stalks (AS-^{15}N +SH+ SH -^{15}N +AS) was 40.0 % (Table 4). In the second cut (8 October 2003) the percentages of nitrogen in the stalk derived from an organic source were high from sunn hemp treatments, indicated the residual effect of the green manure.

With regard to nitrogen recovered by sugarcane stalks, the relatively low values of around 30% for mineral N and 9% for organic N agree with results in the literature. Trivelin et al. (1995) found values between 19 and 43% using the mineral fertilizers Aquammonia and Urea in ratoon cane at the beginning and end of the cropping season. Similar results were obtained by Muraoka et al. (2002) using an organic source applied or not together with a mineral source. The authors concluded that the green manures provided better mineral N utilization resulting in an efficiency of use of the N source of up to 79%.

The presence of green manure and mineral N applied together affected some soil alterations which could be detected in samples collected in the sugarcane planting and harvesting seasons, promoting increases in Ca and Mg contents, Sum of Bases, pH, and Base Saturation, with a decline in potential acidity (Table 5). Similar results were obtained by Sakai et al. (2003), who worked with four velvet bean cultivars. The presence of green manure caused a significant sum of bases increase, due to increases in calcium and magnesium; consequently, treatments involving velvet bean showed higher CEC values. The presence of organic acids in the plant mass could be the reason for this change (Myasawa, 2000).

Table 5 - Chemical characterization of the soil (0-0.2 m depth) in the sugarcane planting and harvesting seasons

			Soil sampling at planting			
Treatment	pH ($CaCl_2$)	Ca	Mg	H+Al	SB	V
	0.01mol l^{-1}	------------------mmolc dm^{-3}-------------------				----- % -----
Control	5.1 ab	20.5 ab	14.5 ab	37.8 a	35.4 ab	48.2 a
AS-^{15}N[2]	4.7 b	15.8 b	9.8 b	47.0 a	25.9 b	36.0 a
SH + AS -^{15}N	5.3 a	24.8 a	17.8 a	32.0 a	42.8 a	55.8 a
SH-^{15}N	5.0 ab	18.0 ab	13.0 ab	39.0 a	31.4 ab	44.5 a
Mean	5.0	19.8	13.8	39.0	33.9	46.1
C.V.%	5.12	7.55	10.76	20.77	6.81	22.52
			Soil sampling at harvest			
Control	5.0 ab	17.8 a	14.0 ab	39.8 ab	32.2 a	44.5 ab
AS-^{15}N	4.7 b	15.3 a	9.8 b	46.5 a	25.4 a	35.8 b
SH + AS -^{15}N	5.6 a	24.7 a	26.8 a	25.5 b	44.4 a	67.5 a
SH-^{15}N	5.0 ab	19.0 a	15.3 ab	36.3 ab	34.5 a	48.5 ab
Mean	5.0	18.0	16.4	37.0	33.5	49.1
C.V.%	8.00	30.88	15.18	25.87	32.45	29.57

Means followed by different letters vertically in each sampling season are different by Tukey test ($P < 0.05$)

[2]AS-^{15}N (^{15}N-labeled ammonium sulfate)

SH + AS -^{15}N (Sunn hemp + ^{15}N-labeled ammonium sulfate)

SH-^{15}N (^{15}N-labeled Sunn hemp)

CONCLUSIONS

- In the first cut sugar cane took up the same amount of nitrogen regardless of source used;
- In the second cut sugar cane absorbed more nitrogen from green manure;
- A treatment involving the application of a green manure changed soil attributes;
- The highest sugarcane yield was obtained when the two nitrogen sources were applied together.