CROTALARIA JUNCEA, *CANAVALIA ENSIFORMIS* AND *MUCUNA SP* AS POSSIBLE NITROGEN SOURCES FOR FERTILISATION IN SUGARCANE COMMERCIAL NURSERIES

By

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Abstract

THE OBJECTIVES of this study were to: a) Evaluate the rotation of "*Crotalaria juncea, Canavalia ensiformis* and *Mucuna* sp and their effect on the production of sugarcane during three sowing times. b) To determine the decomposition of the legume plants, and quantify the contribution of nitrogen of each one to the system. An experiment was carried out in a Mollisol soil of the Finca El Naranjo, located in the low area of the sugar region of Guatemala, evaluating the three species of legumes, on three dates of sowing in the winter, starting with the planting of the legumes on June 6th 2006 and repeating it every 15 days for subsequent dates. In all cases the sugarcane planting was made two months after the planting of the legumes. Two further treatments were included, being the commercial practice without legumes and a control without legumes and without N. Plots of cane with legumes were not fertilised with nitrogen. The experimental design used was randomised complete blocks with three replications. Sowing times were the main plot and the sub-plots were the three species of legumes. In order to quantify the decomposition of the legumes, the methodology used was the same as that used by Resende *et al* (1999) by the use of degradation bags buried under the plots being evaluated at the 7th, 14th, 21st, 35th, 60th, 75th and 120th day after the incorporation of the legumes. To estimate the decomposition rate, we used the Thomas and Asakawa Model, cited by Resende (2000). The results indicated that all the treatments where the legumes were incorporated exceeded the commercial control in terms of sugarcane seed with *Canavalia ensiformis* which produced 7.4 TCH more than those which were fertilised. The accumulation of nitrogen from the legumes was between 144 and 349 kg of N/ha during the evaluation period with *Crotalaria juncea* being the best contributor. The average half time of decomposition for the legumes was similar and varied from 17 to 20 days, while the half time of the nitrogen to be mineralised was 5 to 7 days, with *Mucuna* sp presenting the lowest average half time of decomposition of residues, and the lowest half time of the nitrogen to be mineralised was the *Crotalaria juncea*.

Introduction

The Guatemalan sugarcane industry replants annually around 20% of the cultivated area (46 000 ha of 230 000 ha), which means that it should establish 4600 ha of seedbeds for plant supply. These seedbeds are planned over a year in advance and fallowed for 6 to 8 months before being used, which means that the fields used for such activity are not cropped for about 2 to 4 months, and are covered with weeds and sugarcane volunteers from the previous harvest.

Looking for an agro ecological practice that avoids fallowing**,** there is an opportunity to rotate three species of legumes aiming to find the best season to rotate them in the fields designated for the commercial propagation of the sugarcane.

Crotalaria juncea, *Canavalia ensiformis* and the *Mucuna* sp are legumes of fast growth and could contribute up to 275 kg of N/ha (Flores, 2005). In addition, they are species that would improve the soil structure, contribute organic matter, and their cover protects the soil from water and wind erosion.

These species were evaluated to determinate their suitability under the conditions of the Finca Naranjo San Diego, and also to measure their contribution in terms of nitrogen to the soil, the mineralisation of the residues, and the increase in the amount of the sugarcane seed compared to traditional methods.

In other sugar agro industries, rotation with legumes has provided benefits in tonnage of cane and seed, and they contribute nitrogen and organic matter to the soil. Resende (2000), in Brazil, evaluated *Crotolaria juncea*, *Canavalia ensiformis* and *Mucuna deeringiana* and determined that these species may fix up to 50% of the total N from the atmosphere for use by the crop.

Methodology

Two factors were studied: a) three dates of sowing (of legumes and sugarcane) and three species of legumes. A randomised blocks design with three replications was used. Sowing times were the main plots starting with the first one on June 6th of 2006 and the other two starting 15 and 30 days after. The cane planting was established two months after the legume sowing. Legumes were the sub-plots and they have two controls: one absolute and another fertilised without legumes.

The fertilisation of the sugarcane varied in the treatments depending on presence or absence of a legume crop. In the plots where legumes were planted, the cane did not receive nitrogen. Every plot was fertilised with 60 kg of phosphorus per ha, excepting the absolute control, which did not receive fertilisation. Sixty days after the legume sowing, the experimental units were planted with sugarcane variety CP 72-2086.

To ensure the presence of N_2-fixing micro organism in the legume species to be evaluated, the seeds were inoculated with soil from the seedbeds of *Canavalia ensiformis*. The harvest of legumes was done 60 days after the sowing, where all the materials were cut leaving only the residues scattered on the soil. The residues were incorporated mechanically with skid equipment the day after harvest.

The decomposition of the studied legumes, was determined with the aid of degradation bags like the ones used by Resende *et al.* (1999), burying the samples in the soil. A sample was taken on the 7th, 14th, 21st, 35th, 60th, 75th, 120th day after the burial day. The total amount of nitrogen contained in the samples was determined by the digestion method of Kjeldahl.

To estimate the constant decomposition of the residues, we used the Thomas and Asakawa method cited by Resende (2000): $Lr/LiI = e^{-kt}$, where Lr = dried biomass of the residues incorporated in the soil n days after the sowing: Li = dried biomass of the residues before incorporation (0 days); e = base of natural logarithms; t = sample time interval expressed in days, and k= the rate of the constant of decomposition per day. The value of k, was calculated as the time necessary for the residues to disappear after their incorporation in the soil (t1/2).

The planting of the sugarcane was made with seed from a semi-commercial seed bed with hydrothermal treatment (Buenaventura, 1990) of the variety CP 72-2086. The planting was made five days after the incorporation of the legume residues. The harvest of the seed of the treatments was made manually with machetes making packages of 30 canes. The harvest was made 7 months after the planting.

The parameters evaluated were the following:

a) for the legumes: weight of green mass, dry weight (kg/ha), nitrogen accumulated in the biomass and also the time of degradation of the residues in the soil;

b) for the cane seed: population of stems (number of stems/ha), diameter of the cane stems in cm and production of cane seeds (TCH).

Data were analysed by the analysis of variance and means were compared by Tukey's Test.

Results

Weight of seed cane and components of the production

The variance analysis indicated statistically significant effects for the times of sowing and the legumes on weight of seed sugarcane. However, there was no interaction between the two variables.

The averages of the effects of the times of sowing and the legumes for the weight of seed cane, population and diameter of stems appear respectively in Tables 1 and 2.

Table 1—Average effect of legume species in rotation on the weight of seed cane, population and stem diameter.

Legume rotation – cane	Seed weight (TCH)	Population of stem (No. stems/lineal metre)	Stem diameter (cm)
Mucuna sp + sugarcane (without N)	71.2 (a)	13 (a)	2.40 (a)
Crotalaria juncea + sugarcane (without N)	69.4 (ab)	15 (a)	2.32 (a)
Canavalia ensiformis+ sugarcane (without N)	73.9 (a)	14 (a)	2.38 (a)
Commercial control (only sugarcane with N)	66.6 (ab)	14 (a)	2.27 (a)
Absolute control (only sugarcane without N)	66.0 (b)	15 (a)	2.24 (a)
CV=7.78			

Small letters indicate no significant differences between means according to Tukey test at p = 0.05

In relation to species of legumes in rotation (Table 1) the seed weights were between 66.8 and 73.1 tonnes of cane/ha.

Two of the legumes, on average, exceeded the commercial controls. Increases of 7.3 and 4.6 tonnes of cane / ha were obtained with the rotation of *Canavalia ensiformis* and *Mucuna sp* respectively, compared to the commercial control without commercial fertiliser

Table 2—Average effect of sowing times on the weight of seed cane, population and stem diameter.

Sowing time	Seed weight (TCH)	Population of stem (No. stems/ lineal metre)	Stem diameter (cm)
Time 1 (Starting on 06–06–06)	68.4 (b)	14 (a)	2.33 (a)
Time 2 (Starting on 21–06–06)	66.8 (b)	16 (a)	2.36 (a)
Time 3 (Starting on 06–07–06)	73.1 (a)	14 (a)	2.28 (a)
CV=7.78			

Small letters indicate no significant differences between means according to Tukey test at p = 0.05

In relation to the sowing time (Table 2), it is observed that the weight of sugarcane seed varied from 66.8 to 73.1 tonnes of cane/ha, depending on the sowing time. The increased production was achieved when legumes were sown in Time 3, being significantly higher than for the other two times.

Weight of biomass and nitrogen contribution of legumes

Tables 3 and 4 show the averages of fresh biomass, total N and N accumulation in biomass, respectively, for the sowing and the species of legumes in rotation.

Table 3—Fresh biomass, total N and N accumulation (dry base) in three species of legumes in rotation.

Species of legumes in rotation	Aerial biomass weight (t/ha)	Humidity (%)	Content of N (%)	N accumulated in aerial biomass (kg N/ha)
Mucuna sp	26.1 (b)	82.90	4.8 (a)	216.6 (b)
Crotalaria juncea	50.8 (a)	81.20	3.6 (b)	349.1 (a)
Canavalia ensiformis	22.5 (b)	81.67	3.5 (b)	144.1 (b)
CV=14.72				

Small letters indicate no significant differences between means according to Tukey test at p = 0.05

In relation to species of legumes (Table 3), it is observed that the species with the highest average yield of biomass and the highest N accumulation was *Crotalaria juncea.* This species reaches a yield of fresh biomass of 50.8 t/ha with 81.2% moisture and accumulates 349 kg N/ha in 60 days, contrasting with the yields obtained with the other two species.

Muchovej (1995) quotes that in Florida, United States, the peanut is capable of providing up to 235 kg of N/ha. In Brazil, it is known that *Crotalaria juncea* incorporates around 180 to 200 kg N/ha. On the other hand, Garside *et al.* (1998) reported on the time of harvest of the sugarcane in 1994–1995 with 4 species of legumes: beans cowpea, mucuna, peanuts and soybeans planted at 3 different times. The results showed that, with soybean, around 310 kg N/ha is incorporated; it was the species with the largest amount of nitrogen incorporated into the soil, while the other 3 species incorporated up to170 kg of N/ ha.

Table 4—Fresh biomass, N Content and N accumulation in dry biomass of the three legume species evaluated in the three sowing seasons.

Sowing time	Aerial biomass weight (t/ha)	Humidity (%)	Content of N (%)	N accumulated in aerial biomass (kg N/ha)
Time 1 (Starting on 06–06–06)	39.3 (a)	89.9	3.6 (a)	136.1 (b)
Time 2 (Starting on 21–06–06)	29.5 (b)	77.9	3.9 (a)	260.2 (a)
Time 3 (Starting on 06–07–06)	33.2 (ab)	77.8	4.2 (a)	313.3 (a)
CV=14.72				

Small letters indicate no significant differences between means according to Tukey test at p = 0.05

Table 4 shows that the highest concentration of total N and increased N accumulation in biomass of the legumes were obtained when sowing was during the first week in July (06–07–06) and decreased as sowing was advanced to the first week of June. During the two later times, the highest amount of N was accumulated in the aerial biomass although, in terms of fresh biomass and more water content, the yield was higher in Time 1 caused mainly by the greater weight of *Crotalaria juncea* at this time.

Degradation time of legumes residues

The analysis of variance showed statistically significant effects between sowing time and the legume species in rotation, but not for the interactions between time and legumes. The average of the constant decomposition per day and average time of degradation of the legume residues per time of planting and legume using the Thomas and Asakawa methodology cited by Resende (2000) are presented in Tables 5 and 6.

Table 5—Time and rate of decomposition of the three legumes evaluated in the study.

Species of legumes	Decomposition rate (k)	Average time of biomass decomposition ($T_{1/2}$ days)
Mucuna sp	0.040 (a)	17 (a)
Crotalaria juncea	0.046 (a)	20 (a)
Canavalia ensiformis	0.036 (a)	19 (a)
CV=35.95		

Small letters indicate no significant differences between means according to Tukey test at p = 0.05

Table 5 shows that the decomposition rates of the legume species varied a little from 0.036 to 0.046, and there were minor variations also in the average time of decomposition from 17 to 20 days (Figure 1). These comparisons are supported by the variance analysis and Tukey test.

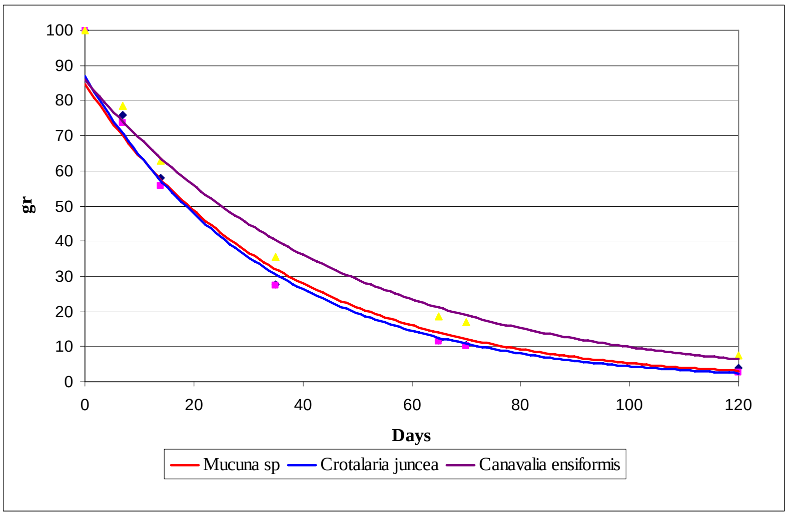

Fig. 1—Decomposition of residues of three legumes.

In practical terms, the rates of decomposition and the average time of decomposition of the three legume species evaluated were very similar and very fast due to the good conditions of temperature and humidity prevailing in the sugarcane region of Guatemala.

Resende (2000) in Brazil evaluated the decomposition rate and the average time of decomposition of four species of legume, *Crotalaria juncea*, *Crotalaria spectabilis*, *Canavalia ensiformis* and *Mucuna deeringianum*. He found that *Crotalaria juncea* was the legume that presented the slowest degradation with a half time of 46 days for decomposition. The *Crotalaria spectabilis*, *Canavalia ensiformis* and *Mucuna deeringiana* had an average of 22, 42 and 45 days respectively.

Resende (2000) reported that the rate and half time difference between *Crotalaria juncea* and the *Canavalia ensiformis* was 0.001 and 3 days respectively, which were similar to results obtained in this study, 0.001 and 1 day respectively.

In terms of sowing time, it was observed that the daily rate of decomposition varied from 0.028 to 0.053. The highest rate was in Time 1 (first week of June sowing), where residues were degraded in a lower average time (15 days) as shown in Table 2.

The highest rate of decomposition of legumes in Time 1 would be associated with a higher humidity on the soil at this time, due to increased rainfall during the initial test compared with the rainfall of Time 3.

Table 6—Average effect of the time of sowing and time of degradation of 3 legumes.

Sowing time	Decomposition rate (k)	Average time of biomass decomposition ($T_{1/2}$ days [1])
Time 1 (Starting on 06–06–06)	0.053 (a)	15 (a)
Time 2 (Starting on 21–06–06)	0.040 (a)	18 (a)
Time 3 (Starting on 06–07–06)	0.028 (a)	23 (a)
CV=35.95		

Small letters indicate no significant differences between means according to Tukey test at p = 0.05

The average mineralisation of nitrogen per day and half time per sowing time and legumes are presented in Tables 7 and 8.

Table 7—Rate of mineralisation of nitrogen and average time of decomposition of three legumes evaluated in the study.

Species of legumes	Decomposition rate of N (k)	Average time of decomposition ($T_{1/2}$ days)
Mucuna sp	0.115 (a)	6 (a)
Crotalaria juncea	0.135 (a)	5 (a)
Canavalia ensiformis	0.114 (a)	6 (a)
CV = 16.18		

Small letters indicate no significant differences between means according to Tukey test at p= 0.05

The daily decomposition rate of daily nitrogen contributed by the three legume species evaluated (Table 7) varied from 0.114 and 0.135, with variations of one day (5 to 6 days) in the average time of decomposition.

The nitrogen contributed by the legume species that were evaluated had a faster decomposition rate than the decomposition of residues; this agrees with the study conducted by Resende (2000), where residues of legumes evaluated deteriorated in a period of time of 45 days and the mineralisation of nitrogen varied from 14 to 35 days; unlike this study, the residues were left on the floor.

This apparently is because most of the nitrogen is found in the tissues and decompose more rapidly, fixing a small part of the nitrogen compared to more recalcitrant compounds such as lignin and polyphenols, which have slower decomposition (Resende, 2000).

The daily decomposition of nitrogen at various times varied from 0.107 to 0.131, and similar mineralisation was observed between Time 1 and Time 3. The rate of mineralisation was also similar. The highest rate was during Time 3 (first week of July sowing) where nitrogen is mineralised in a period of 5 days.

[1] $T_{1/2}$ = Time in which 50% of residues are away from the bag

Table 8—Average effect of the sowing date on rate and nitrogen mineralisation time.

Sowing time	Decomposition rate (k)	Average time of decomposition ($T_{1/2}$ days)
Time 1 (Starting on 06–06–06)	0.130	6
Time 2 (Starting on 21–06–06)	0.107	7
Time 3 (Starting on 06–07–06)	0.131	5
CV = 16.18		

Conclusions

The rotation of the three species of legumes produced on average more sugarcane seed cane compared to the commercial control without rotation and properly fertilised. Increases were observed of 7.3 and 4.6 t/ha, respectively, with the rotation of *Canavalia Ensiformis* and *Mucuna* sp.

It was determined that *Crotalaria juncea* accumulated an average of 349 kg N/ha to 50 t/ha of biomass in 60 days while *Mucuna* sp and *Canavalia ensiformis* accumulated on average 216 and 144 kg N / ha in the same period.

Half time degradation of the aerial biomass of the legume species took 17 to 20 days with similar daily rates of decomposition; the average time of nitrogen decomposition was 5 to 6 days with similar rates between sowing times.

The average time for degradation of nitrogen between sowing times varied from 5 to 7 days, in Time 2, which was planted on June 21st 2006, and had a lower daily rate of decomposition (k=0.107) than the other two studied.

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CROTALARIA JUNCEA, CANAVALIA ENSIFORMIS ET MUCUNA SP COMME SOURCES POSSIBLES D'AZOTE DANS LES PEPINIERES COMMERCIALES DE CANNE A SUCRE

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MOTS-CLÉS: Minéralisation d'Azote,
Engrais Vert, Rotation.

Résumé

LES OBJECTIFS de cette étude étaient : a) d'évaluer la rotation de *Crotalaria juncea, Canavalia ensiformis et Mucuna sp* et leur effet sur la production de canne à sucre après trois semis. b) de déterminer la décomposition de ces légumineuses, et de mesurer leur contribution en azote au système. Une expérimentation a été menée sur un Mollisol de la Finca El Naranjo, situé dans les zones basses de la région sucrière du Guatemala. Trois espèces des légumineuses ont été évaluées pour trois dates hivernales de semis, en commençant les semis le 6 juin 2006 et en les répétant tous les 15 jours pour les dates suivantes. Dans tous les traitements, la plantation de canne à sucre a été réalisée deux mois après le semis des légumineuses. Deux traitements supplémentaires ont été inclus, la pratique commerciale sans légumineuses et un témoin sans légumineuses et sans N. Les parcelles de canne avec légumineuses n'ont pas été fertilisées avec de l'azote. Le dispositif expérimental était constitué de blocs complets randomisés avec trois répétitions. Les parcelles principales comportaient les dates de semis et les parcelles secondaires, les trois espèces des légumineuses. La méthodologie utilisée pour mesurer la décomposition des légumineuses fut celle employée par Resende *et al*. (1999). Des sacs contenant les légumineuses furent enterrés dans les parcelles correspondantes puis évalués 7, 14, 21, 35, 60, 75 et 120 jours après la récolte et l'incorporation des légumineuses. Pour estimer le taux de décomposition nous avons utilisé le modèle de Thomas et Asakawa, cité par Resende (2000). Tous les traitements où les légumineuses ont été incorporées ont entraîné une production de canne supérieure à celle de la pratique commerciale Ainsi *Canavalia ensiformis* produisit 7.4 TCH de plus que le témoin commercial fertilisé. Pendant la période d'évaluation , l'accumulation d'azote provenant des légumineuses fut comprise entre 144 et 349 kg de N/ha, *Crotalaria juncea* étant la légumineuse ayant la production d'azote la plus élevée. La demi période de décomposition des légumineuses fut comprise entre 17 à 20 jours, alors que la demi période de minéralisation de l'azote variait de 5 à 7 jours. La demi période de décomposition la plus basse fut observée chez *Mucuna sp*, et la demi période de minéralisation de l'azote fut observée chez *Crotalaria juncea*.

CROTALARIA JUNCEA, *CANAVALIA ENSIFORMIS* Y *MUCUNA SP* COMO POSIBLES FUENTES DE NITRÓGENO EN LA FERTILIZACIÓN DE LA CAÑA DE AZÚCAR DE SEMILLEROS COMERCIALES

Por

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PALABRAS CLAVE: Mineralización del Nitrógeno, Abono verde, Rotación.

Resumen

LOS OBJETIVOS de este estudio fueron: a) Evaluar la rotación con *Crotalaria juncea, Canavalia ensiformis* y *Mucuna* sp y su efecto en la producción de caña de azúcar durante tres fechas de siembra. b) Determinar la descomposición de las plantas leguminosas, y cuantificar la contribución de nitrógeno de cada una al sistema. Se realizó un experimento en un suelo Mollisol de la Finca El Naranjo, ubicado en la zona baja de la región azucarera de Guatemala, evaluandose las tres especies de leguminosas, en tres fechas de siembra invernales, comenzando con el cultivo de las leguminosas el 6 de junio de 2006, y repitiendose cada 15 días para fechas posteriores. En todos los casos, la plantación de caña de azúcar se hizo dos meses después de la siembra de las leguminosas. Se incluyeron dos tratamientos más: la práctica comercial sin leguminosas y un testigo sin leguminosas y sin N. Las parcelas de caña con leguminosas no fueron fertilizados con nitrógeno. El diseño experimental utilizado fue de bloques completos al azar con tres repeticiones. La época de siembra constituyó las parcelas principales y las sub-parcelas fueron las tres especies de leguminosas. Con el fin de cuantificar la descomposición de las leguminosas, la metodología utilizada fue la misma que la propuesta por Resende *et al.* (1999) en la cual se utilizan bolsas de la degradación enterradas bajo las parcelas que se evaluaron a los 7, 14, 21, 35, 60, 75 y 120 días posteriores a la incorporación de las leguminosas. Para estimar la tasa de descomposición se utilizó el modelo de Thomas y Asakawa, citado por Resende (2000). Los resultados indicaron que todos los tratamientos donde las leguminosas se incorporaron superaron al control comercial en términos de producción de semillas de la caña de azúcar. *Canavalia ensiformis* produjo 7,4 TCH más que los que fueron fertilizados. La acumulación de nitrógeno de las leguminosas fue de entre 144 y 349 kg de N/ha durante el período de evaluación donde *Crotalaria juncea* fue la de mayor contribución. El tiempo promedio de la mitad de descomposición de las leguminosas fue similar y varió desde 17 hasta 20 días, mientras que el tiempo medio de mineralización de nitrógeno fue de 5 a 7 días, con *Mucuna* sp presentando el menor promedio de tiempo de media descomposición de los residuos. El tiempo más bajo de la mitad de mineralización del nitrógeno registrado fue el de la *Crotalaria juncea*.