Intercropping of sugarcane with common bean in no-tillage and different nitrogen rates

Denizart Bolonhezi[A], Roberto Botelho Ferraz Branco[A], Marcos José Perdoná[A], Sérgio Augusto de Moraes Carbonell[B], Alisson Fernando Chiorato[B]

[A]Instituto Agronomico, APTA, Ribeirão Preto, São Paulo State, Brazil, Email dbolonhezi@gmail.com, branco@apta.sp.gov.br,
[B]Centro de Grãos e Fibras, Insituto Agronômico, APTA, Campinas, São Paulo State, Brazil, Email carbonell@iac.sp.gov.br

Abstract
The no-tillage of crop rotation and intercropping are sustainable practices to reduce the impact of sugarcane to produce bioethanol on food safety. The objective of this research was to study the effect of side dressing nitrogen application on dry bean (IAC-Alvorada) grown as intercropped crop with green harvested sugarcane ratoon in no-tillage, named "*sweet common bean system*". Field experiment was carried out in a commercial area (Oxisol), at Sao Jose Farm (Sertãozinho, Sao Paulo State, Brazil), planted with genotype RB865536, on the 3rd ratoon. Five treatments of side dressing nitrogen rates (0, 40, 80, 120, and 160 kg/ha of N, as Urea) were arranged in a complete randomized block, with 6 replications. Evaluations (dry matter, LAI) were done from 30 to 90 days after planting (DAS). A quadratic response was observed for dry biomass and grain yield, with 120 and 80 kg/ha, respectively the best N-rate. LAI increasing with N-rates until the maximum of 5.5 at 75 DAS IAC-Alvorada can be considered responsive (12.8 kg of grains per kg of N) to increasing N-rates.

Key Words
Conservation tillage, *Phaseolus vulgaris*, *Saccharum officinarum*, food and biofuel.

Introduction
In recent years, the demand for bioethanol production is rapidly increasing worldwide, and in many countries, debates have already started concerning the competition for land use between energy and food crops. According to Lal (2009), the projected global energy demand will increase a rate of 2.23% per year by 2025; therefore it is extremely important adoption of sustainable production systems, such as the no-tillage, which is practiced only on 6.4% of world's cropland. Brazil has had a long time tradition in the use of renewable energy and is the second largest area under no-till farming (more than 40% of cropland). In some parts of Brazil, previous areas of grain crops are now cultivated with sugarcane, which is grown on more than 8.2 million of hectares. The widespread adoption of no-tillage soybean on sugarcane straw has achieved tremendous success in enhancing soil quality, preventing soil erosion, and weed control (Christoffoleti *et al.* 2007, Bolonhezi 2008). However, the practice of crop rotation with leguminous crop (estimated to be 1 million hectares available every year) is only possible after 5 or 6 ratoons of sugar cane. Intercropping of sugarcane with grain crops, is one possibility to associate energy and food production and has been used in commercial fields since the late 1960's, especially with common bean (Tokeshi 1980; Govinden 1991). In Sao Paulo State, annually there are accessible more than 600 thousand hectares of sugarcane with irrigation, which it would be possible to grow common bean with sugarcane, during the winter. Common bean (*Phaseolus vulgaris* L.) is one of the most important sources of plant protein for a large part of the world population and nitrogen is a main constituent. Nowadays, there are available modern no-tillage planters, which may provide suitable planting under sugarcane straw (average 15 Mg/ha of dry matter biomass). Nevertheless, it is important to point out that, in this condition, the recommended N rate (from 30 to 60 kg/ha of N) can be insufficient to supply the requirement of this crop. In this context, we hypothesize that growth of common bean between sugarcane ratoon rows is feasible, but it is necessary to increase the nitrogen rate in no-tillage systems. The aim of this research was to evaluate different levels of side dressed N in no-tillage on grain yield, leaf area index, and macronutrients content all long of several growth stages of common bean.

Materials and Methods
Location, Soil characteristics and Experimental Design
The trial was carried out in a commercial sugarcane area situated at São José Farm, in Sertãozinho city, São Paulo State, Brazil. Chemical attributes of the Dark Red Latosol are presented in the Table 1. The experiment was set up in a green harvested sugarcane field of the RB865536 on the 3rd ratoon. The amount of dry biomass on the soil surface was estimated at 20 Mg/ha. Approximately 30 days after harvesting the sugarcane, two rows of the common bean cv. IAC-Alvorada (erect growth habit and maturity range around 92 days after planting) were sown (08/14/2008) between sugarcane rows. Five treatments of side dressed nitrogen rates (0, 40, 80, 120, and 160 kg/ha of N, as Urea) were arranged in a complete randomized block,

with 6 replications. Each plot contained 4 rows of bean spaced 0,5 m and with 8 m of length, divided per one (1) row of sugarcane. A planter model COP-CA® (Tatu Marchesan), was used which has special cutter disk. Fertilization was done according to recommendations of Ambrosano *et al.* (1996), and consisted of 10, 50 and 50 kg/ha of N, P_2O_5 and K_2O. The side-dress N-rates were applied in 09/05/2008. Irrigation was done using a water-spraying system, from sowing (08/14/2008) to the peak of flowering (10/15/2008).

Table 1. Chemical properties of surface and subsurface soil (0.0-0.20 and 0.20-0.40 m). Sao Jose Farm, Sertaozinho city, Sao Paulo State, Brazil.

Depth (m)	pH	O.M.	P (resin.)	K	Ca	Mg	S	CTC	V
	$CaCl_2$	g/dm	mg/dm	--------------mmol$_c$/dm-------					%
0-0.20	5.9	23	30	1.8	53	10	18	86	76
0.20-0.40	5.5	21	47	2.3	46	8	20	82	69

Evaluations

Plant samples were taken every 15 days, from emergence to harvest. Each sample was composed by aboveground biomass collected in 1 meter of row. Simultaneously, Leaf Area Index (LAI) data collection was performed using indirect measurements with a LAI-2000. In each replication were evaluated 3 different points. This aboveground biomass was oven-dried at 65^o C, weighed and ground to determine the concentration of macronutrients (N, P, K, Ca, Mg, and S) at the Soil Research Centre of Agronomic Institute of Campinas according to Bataglia (1993). Pods were harvested (4 rows with 5 meters in each plot) 90 days after planting and the grain yield was expressed in kg/ha. Data were subjected to ANOVA and regression analysis.

Results

Concerning effects of nitrogen rates on plant dry matter yields, a significant increase was observed at 45 and 60 days after sowing (DAS), and the data fitted a quadratic regression equation (Figure 1). The highest dry matter of aboveground biomass, was observed with the N-rate of 120 kg/ha, while Silva *et al.* (2004) reported that in no-tillage the highest dry biomass was obtained with the N-rate of 75 and 100 kg/ha. High levels of nitrogen are important in no-tillage on sugarcane straw, because there are large amounts of residue on the soil surface (high N-immobilization by microorganisms) and due to the competition with sugarcane plant for nutrients and water. In Figure 2, shows the variation of LAI from 30 to 90 days after planting for each N-rate. The difference increase until 60 days after sowing and practically disappeared at the last evaluation. The highest LAI (5.4) was measured at 55 days after sowing, for N-rate of 160 kg/ha, which was 2 times higher than the control. Pavani *et al*. (2009) observed the maximum LAI (4.4) in no-tillage at 69 days after sowing. The high LAI in the control at 75 days after sowing, could be explained by the BNF (Biological Nitrogen Fixation) or nitrogen stock in the soil. According to Luca *et al.* (2008) after three harvests of sugarcane, the decomposition of accumulated aerial residue biomass (40 t/ha) could release up to 0.022 t/ha of nitrogen. Moreover it is important to consider that the N_2 fixation is stimulated under great amount of straw, as well as the mineral N can be deleterious to nodulation (Cardoso *et al*. 2007). Even though, there were significant differences in the N-concentration at the first evaluation, no significant variations were found in the second and third evaluations. However, the amount of nitrogen extracted by aboveground biomass was significantly lower in the control. At the first evaluation, the response was linear and at second and third evaluations, the responses were quadratic, with the highest extraction at the N-rate of 120 kg/ha. This result is important because farmers need to reduce the cost of nitrogen (in average 100 kg/haof N) applied in the sugarcane ratoon, given that the residue of IAC-Alvorada can return to the soil after harvest, at least 30 kg/ha of nitrogen. Nevertheless, Araujo *et al.* (2009) mentioned that some genotypes were more efficient than others based on harvest index, which is the dry matter of the pods divided by the total dry matter. The quadratic effect was observed for grain yield (Figure 4) and the highest yield was obtained with the N-rate of 80 kg/ha. These results agree with research carried out by Silva *et al*. (2004) and Junior *et al*. (2009), both in no-tillage systems. An increase of 12,8 kg/ha grain was observed per kg/ha of nitrogen used. The cultivar IAC-Alvorada could be considered a responsive genotype, according to Araujo *et al.* (2009).Overall, the results emphasize that intercropping of bean and sugarcane ratoon was viable because, it can use the same area to produce food and energy, can reduce the application of herbicide, can supply part of the nitrogen requirement of sugarcane, and can improve the profit of farmers. Therefore, this system could be named "*sweet common bean*", due to the success of this first attempt. In future researche it would be important to study the residual effect of nitrogen applied on the stalk yield of sugarcane.

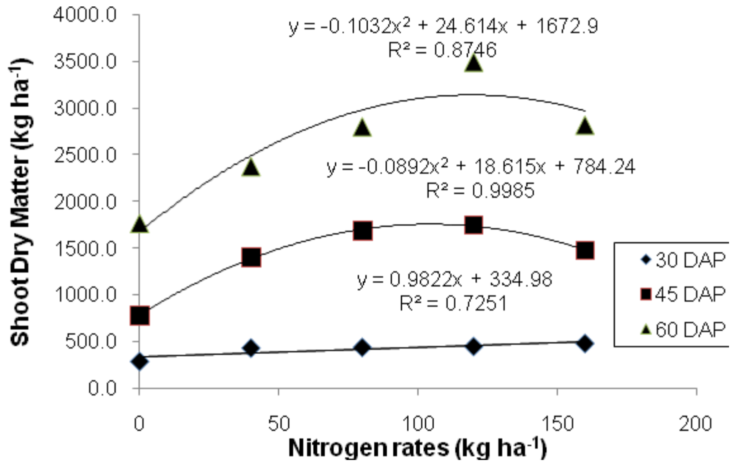

Figure 1. Variation of shoot dry matter of cv. IAC-Alvorada, with increasing nitrogen rates.

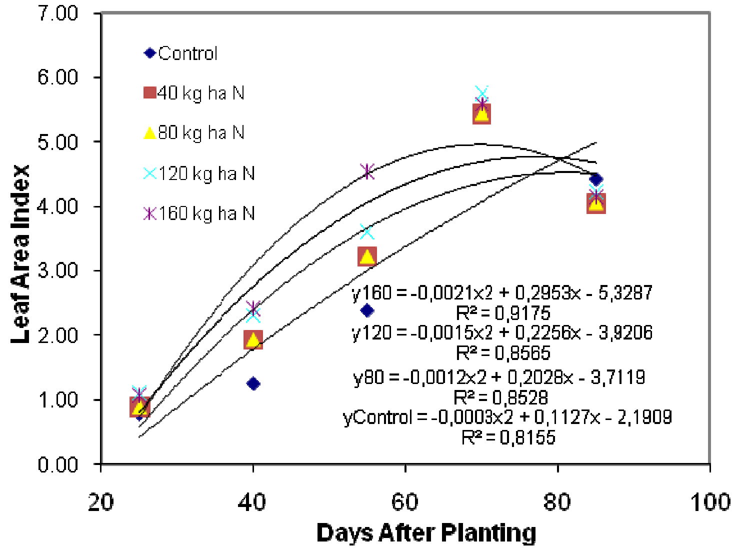

Figure 2. Leaf area index in different growth stages and nitrogen rates.

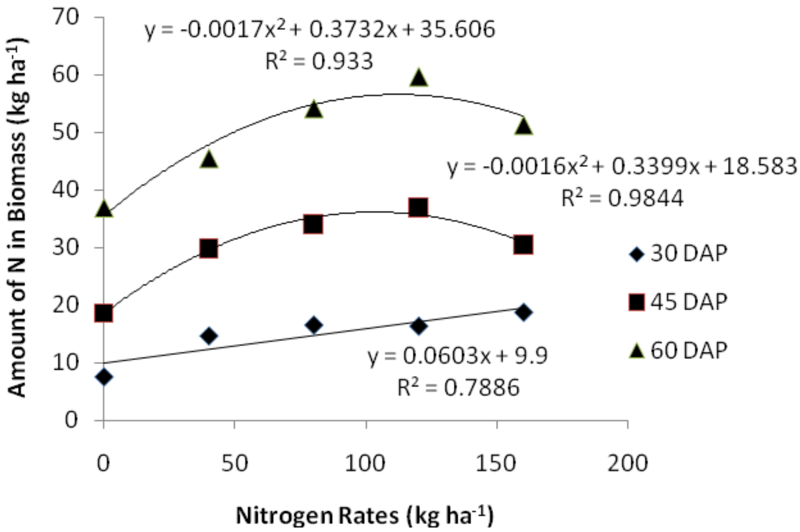

Figure 3. Extraction of nitrogen in the biomass of common bean cv. IAC-Alvorada.

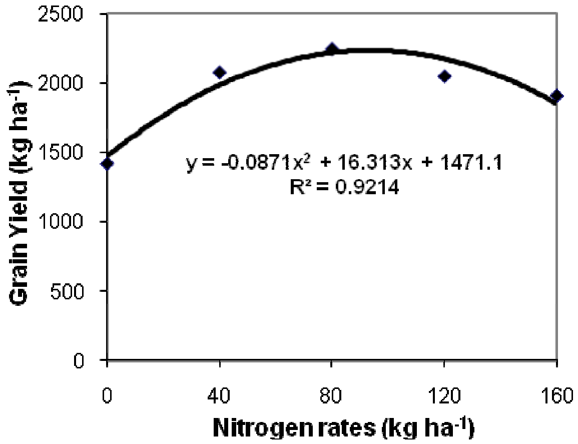

Figure 4. Grain yield of common bean cv. IAC-Alvorada grown with sugarcane for several N-rates .

Conclusion

At 45 and 60 DAS, the highest dry biomass and amount of nitrogen extracted were for the N-rate of 120 kg/ha. The LAI increased with increasing N-rate until the maximum of 5.5 at 75 DAS. A quadratic response was verified for grain yield with the highest (2244 kg/ha) at the N-rate of 80 kg/ha. The cultivar IAC-Alvorada can be considered responsive (12.8 kg of grain per kg of N) to increasing N-rates.

Acknowledgements

The authors wish to thank Tatu Marchesan and Mr. José Luis Balardin for their support. Appreciation is also expressed to the staff (specially Mr. Odair) at Fazenda São José, Sertãozinho, Brazil.

References

Araujo JR, Ramalho MAP, Bruzi AT, Abreu AFB (2009) Dry matter accumulation in genotypes of bean submitted to different levels of nitrogen. *Ciênc. Agrotec.* **33**, 985-992.

Bataglia OC, Furlani MAC, Teixeira JPF, Furlani PR, Gallo JR, Métodos de análise química de plantas, Campinas, *Instituto Agronômico*, 48 p, 1983. (Boletim Técnico, 78).

Bolonhezi D (2008) Expansão da produção de matéria-prima para energia e implicações na produção de grãos. In' IX CONAFE, Documentos IAC 85, pp. 1640-1650. (IAC)

Cardoso EJBN, Nogueira MA, Ferraz SM (2007) Biological N_2 fixation and mineral N in common bean-maize intercropping or solo cropping in southeastern Brazil. *Experimental Agriculture* **43**, 319-330.

Christoffoleti PJ, Carvalho SJP, Lopez-Overejo RF, Nicolai, M., Hidalgo E, Silva JE (2007) Conservation of natural resources in Brazilian agriculture: implications on weed biology and management. *Crop Protection* **26**, 383-389.

Goviden N (1991) Intercropping of sugarcane with beans in Mauritus research needs in relation to constraints to production. In' An Ecorregional Frame Work for Bean Germoplasm Development and natural resources research. pp. 203-211. (CIAT).

Junior JA, Andrade MJB, Carvalho, JG, Vieira NMB, Morais AR (2009) Adubação nitrogenada do feijoeiro, em plantio e cobertura, em plantio direto e convencional. *Ciênc. Agrotec* **33**, 943-949.

Lal R (2008) Soil quality impacts of residue removal for bioethanol production. *Soil and Tillage Research* **102**, 233-241.

Luca EF, Feller C, Cerri CC, Barthes B, Chaplot V, Campos DC, Manechini C (2008) Avaliação de atributos físicos e estoques de carbono e nitrogênio em solos com queima e sem queima de canavial. *R. Bras. Ci. Solo* **32**, 789-800.

Pavani LC, Lopes AS, Pereira GT (2009) Desenvolvimento da cultura do feijoeiro submetida a dois sistemas de manejo de irrigação e de cultivo. *Acta Scientiarum Agronomy* **31,** 453-459.

Silva MG, Arf O, Sá ME, Rodrigues RAF, Buzetti S (2004) Nitrogen fertilization and soil management of winter common bean crop. *Sci. Agric.* **61**, 307-312.

Tokeshi H (1980) Cultivos consorciados com a cana-de-açúcar em Taiwan. In: CANA-DE-AÇÚCAR E PRODUÇÃO DE ALIMENTOS E FIBRAS. Anais...Piracicaba, 1980. Instituto do Açúcar e do Álcool. 13-28