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Research Article

Maize cropping systems and response of common bean in succession subjected to nitrogen fertilization[1]

Stefany Silva de Souza[2], Pedro Afonso Couto Júnior[2], Jordana de Araujo Flôres[2], Fábio Luiz Checchio Mingotte[2], Leandro Borges Lemos[2]

ABSTRACT

The common bean succession to intercropped crops in the no-tillage system is beneficial, especially in the search for sustainability. In addition to the straw production, the intercropping can supply nitrogen (N) to the common bean grown in succession, reducing the use of mineral fertilizer, which is pollutant and has a high cost. The present study aimed to evaluate the response to N fertilization of common bean in succession to maize cropping systems, as well as the viability of these systems in the no-tillage system. The experimental design was randomized blocks, in a split-plot arrangement, with four replicates. The plots consisted of the following systems: maize as a single crop, maize intercropped with brachiaria and maize intercropped with crotalaria. The subplots were five N doses (0 kg ha^{-1}, 50 kg ha^{-1}, 100 kg ha^{-1}, 150 kg ha^{-1} and 200 kg ha^{-1}), applied as topdressing fertilization in winter common bean, in succession to the maize cropping systems. For the maize cultivation systems, the grain yield and N amount and accumulation in the straw were evaluated. As for the common bean in succession, the grain yield and grain quality attributes were assessed. Although the three cropping systems were viable for maize grain yield, the intercropping of maize with crotalaria led to a higher N accumulation in the straw and a larger quantity of straw dry mass. The increase of the N doses promoted an increase in the grain yield of common bean grown in succession to intercropped maize. Maize intercropped with crotalaria resulted in grains with a higher size and, concerning the grain yield, an equivalent effect to that of a topdressing application of more than 200 kg ha^{-1} of N was observed for the common bean in succession.

KEYWORDS: *Crotalaria spectabilis*, *Phaseolus vulgaris*, *Urochloa ruziziensis*, nitrogen dynamics, straw production.

RESUMO

Sistemas de consórcio de milho e resposta de feijoeiro em sucessão submetido a adubação nitrogenada

A sucessão de feijoeiro com culturas consorciadas, no sistema plantio direto, é benéfica, sobretudo na busca por sustentabilidade. Além da produção de palhada, o consórcio de culturas pode fornecer nitrogênio (N) ao feijoeiro em sucessão, diminuindo o uso de adubo mineral, que é poluente e tem custo elevado. Objetivou-se avaliar a resposta à adubação nitrogenada de feijoeiro em sucessão a sistemas de cultivo de milho, bem como o desempenho agronômico destes sistemas no plantio direto. O delineamento experimental foi em blocos casualizados, com arranjo de parcelas subdivididas e quatro repetições. As parcelas consistiram de sistemas de cultivo de milho exclusivo, em consórcio com braquiária e com crotalária. As subparcelas foram cinco doses de nitrogênio (0 kg ha^{-1}, 50 kg ha^{-1}, 100 kg ha^{-1}, 150 kg ha^{-1} e 200 kg ha^{-1}), aplicadas em adubação de cobertura no feijoeiro de inverno, em sucessão aos sistemas de cultivo de milho. Nos sistemas de cultivo de milho, avaliaram-se a produtividade de grãos e quantidade e acúmulo de N da palhada. Quanto ao feijoeiro em sucessão, foram avaliados a produtividade e atributos de qualidade de grãos. Embora os três sistemas de cultivo tenham sido viáveis quanto à produtividade de grãos de milho, o consórcio de milho com crotalária proporcionou palhada com maior acúmulo de N e maiores quantidades de massa seca produzida. A elevação das doses de N promoveu aumento na produtividade de grãos de feijoeiro em sucessão ao milho consorciado. O consórcio milho e crotalária proporcionou grãos de maior tamanho e, em relação à produtividade de grãos, observou-se efeito equivalente à aplicação de mais de 200 kg ha^{-1} de N em cobertura para o feijoeiro em sucessão.

PALAVRAS-CHAVE: *Crotalaria spectabilis*, *Phaseolus vulgaris*, *Urochloa ruziziensis*, dinâmica de nitrogênio, produção de palhada.

INTRODUCTION

Crops in a no-tillage system, associated with adequate management practices, are strategies for a sustainable agricultural production. The no-tillage system stands out especially for mitigating the three major threats to the soil functions, namely erosion, changes in the soil organic carbon and nutrient imbalance (FAO 2016).

Thus, through a minimal soil disturbance, presence of vegetation cover and use of crop rotation/succession, the system favors a greater particle

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aggregation, lower impact of raindrops on the soil surface (Almeida et al. 2016), moisture conservation (Ribeiro et al. 2016) and increase of the organic matter in the soil (Melo et al. 2016).

However, the positive effect with the use of the no-tillage system depends on the correct choice of the crops grown, what may influence the preservation of the crop residues on the soil surface (Amaral et al. 2016). In addition, it can be a strategy for supplying nutrients to crops in succession/rotation (Maluf et al. 2015), through green manure.

In this context, to compose the scheme of alternating crops, cover crops belonging to the families Poaceae and Fabaceae, represented by brachiaria and crotalaria, respectively, are widely indicated (Oliveira et al. 2010, Kappes & Zancanaro 2015). However, the use of these crops as soil cover and/or green manure is not adequate to most the production systems, due to the lack of immediate economic return with agricultural products. Hence, one way of growing them in the production systems is through the intercropping of different species, especially the intercropping of maize with brachiaria (Costa et al. 2012, Flôres et al. 2017), called “Santa Fé System” (Oliveira et al. 2010), and maize with crotalaria (Arf et al. 2018), known as “Santa Brígida System” (Oliveira et al. 2010).

Brachiaria plants have residues with a high C/N ratio, which promotes the permanence of straw on the soil for a longer period, favoring the no-tillage system. However, this may be unfavorable for the subsequent crop, in relation to nutrient supply by mineralization, since the decomposition occurs more slowly (Maluf et al. 2015) and there may be a microbial immobilization of nitrogen (N).

Crotalaria plants, on the other hand, have a low C/N ratio and, consequently, a rapid decomposition of crop residues and release of nutrients (Gitti et al. 2012) through mineralization. Hence, these plants act as green manure for the production system, especially in relation to N. This occurs due to the high content of the nutrient in the tissues of crops in the Fabaceae family, promoted by their capacity to associate with atmospheric N-fixing bacteria (Quérnea et al. 2017) and incorporate them into their metabolism.

Although the common bean crop also belongs to the Fabaceae family, its biological N fixation is inefficient and unable to meet its high demand for the nutrient, so it is necessary to use high doses of mineral fertilizer. Mineral N fertilization is a high-cost, polluting management (Souza et al. 2011), and techniques that promote its reduction are economically and environmentally important.

The use of cropping systems with green manure may be a strategy to reduce the supply of mineral N fertilizer to common bean grown in succession, ensuring a high quality and yield of grains. Thus, this study aimed to assess, in a no-tillage system, the agronomic performance of maize intercropped with brachiaria and crotalaria, grain yield and quality attributes of common bean cultivated in succession, subjected to topdressing N doses.

MATERIAL AND METHODS

The experiment was conducted in an experimental area (21º14’33”S, 48º17’10”W and 565 m of altitude) owned by the Universidade Estadual Paulista, in Jaboticabal, São Paulo state, Brazil. According to the Köppen’s classification, the region has a climate characterized as Aw, humid tropical with a rainy season in the summer and a dry season in the winter (Rolim et al. 2007).

The soil of the experimental area is a Latossolo Vermelho Eutroférrico (Oxisol) with a clayey texture (533 g kg^{-1} of clay), which has been under no-tillage since the summer of 2008, in a scheme of crops succession as described in Table 1. The experiment was carried out on the dried straw of millet (5 t ha^{-1}), in the 2014/2015 agricultural year.

The experimental design was randomized blocks, in a split-plot arrangement, with four replicates. The plots consisted of three maize cropping systems: single, intercropped with brachiaria and intercropped with crotalaria. The subplots were five N doses (0 kg ha^{-1}, 50 kg ha^{-1}, 100 kg ha^{-1}, 150 kg ha^{-1} and 200 kg ha^{-1}), using urea as source, applied as topdressing in a continuous line close to the crop row, at the phenological stage V_{4-4} of the common bean (Fernández et al. 1985). The subplots (27.0 m² area) consisted of 12 rows of common bean with length of 5 m, and the eight central rows were used as useful area (14.4 m² area) for the evaluations, disregarding 0.5 m at the ends of each row.

Before sowing the maize cropping systems and common bean in the 2014/2015 agricultural year, soil samples were collected to analyze their chemical attributes in the 0-20 cm layer (Table 2).

The maize and cover crops were sown simultaneously (December 15, 2014), using a seeder-

Table 1. Chronological order of the crops and fertilizers used in the experimental area.

Agricultural year	Season	Crops	Fertilization (kg ha^{-1})				
			Sowing			Topdressing	
			N	P_2O_5	K_2O	N	K_2O
2008/2009	Summer	Maize and brachiaria	30.0	50	50	140	-
	Spring	Common bean	10.0	30	20	90	-
2009/2010	Summer	Maize and brachiaria	28.0	70	70	120	-
	Spring	Common bean	4.9	49	49	90	-
2010/2011	Summer	Maize and brachiaria	24.0	84	48	160	80
	Spring	Common bean	15.0	45	45	90	-
2011/2012	Summer	Maize and brachiaria	13.0	46	26	180	80
	Spring	Common bean	13.0	52	30	90	-
2012/2013	Summer	Maize and brachiaria	26.0	92	53	160	80
	Spring	Common bean	17.0	59	34	90	-
2013/2014	Summer	Crotalaria	-	-	-	-	-
	Spring	Millet	-	-	-	-	-

Table 2. Soil chemical attributes in the 0-20 cm layer before sowing the maize cropping systems and common bean.

Attributes	Before maize cropping systems	Before common bean		
		Maize	Maize + brachiaria(1)	Maize + crotalaria(2)
pH ($CaCl_2$)	5.5	5.6	5.6	5.7
OM (g dm^{-3})	21.0	25.0	24.0	26.0
P (mg dm^{-3})	57.0	58.0	53.0	60.0
K ($mmol_c$ dm^{-3})	5.4	5.2	3.5	5.0
Ca ($mmol_c$ dm^{-3})	48.0	39.0	43.0	41.0
Mg ($mmol_c$ dm^{-3})	33.0	39.0	43.0	41.0
H + Al ($mmol_c$ dm^{-3})	24.0	31.0	28.0	25.0
CEC ($mmol_c$ dm^{-3})	110.0	92.0	92.0	88.0
V (%)	78.0	66.0	70.0	72.0

(1) Maize intercropped with *Urochloa ruziziensis*; (2) maize intercropped with *Crotalaria spectabilis*.

fertilizer for intercropping under no-tillage. The early maize hybrid Impacto was sown at a spacing of 0.90 m between rows, with a final population of 65,000 plants ha^{-1}. The crops intercropped with maize were sown in double rows, spaced at 0.22 m, using 11 kg ha^{-1} and 12 kg ha^{-1} of *Urochloa ruziziensis* and *Crotalaria spectabilis* seeds, respectively. The maize was fertilized at sowing with 16 kg ha^{-1}, 33 kg ha^{-1} and 58 kg ha^{-1} of N, K_2O and P_2O_5, respectively, and topdressed with 90 kg ha^{-1} of N and 45 kg ha^{-1} of K_2O, when it had six well developed leaves (January 12, 2015). The fertilizations were calculated based on the results of the soil chemical analysis (Table 2) and on recommendations by Raij & Cantarella (1997). The cover crops were not fertilized.

At 18 days after the emergence (DAE) of the maize, in order to avoid weeds, the following herbicides were applied: bentazone (720 g ha^{-1} of a.i.) and nicosulfurom (12 g ha^{-1} of a.i.) in the maize/crotalaria intercropping, as well as atrazine (1,000 g ha^{-1} of a.i.) and nicosulfurom (6 g ha^{-1} of a.i.) in the maize as a single crop and intercropped with brachiaria. During the crop cycle, average temperatures between 18 ºC and 29 ºC were recorded, with a total precipitation of 819 mm (Figure 1). The total area cultivated with the maize crop (May 25, 2015) was mechanically harvested. Subsequently, the area was desiccated (May 26, 2015) with glyphosate (1,860 g ha^{-1} of a.i.) and 2,4 D (960 g ha^{-1} of a.i.).

The common bean IAC Alvorada cultivar was mechanically sown under no-tillage on June 15, 2015, at a spacing of 0.45 m between rows, with a final population of 230,000 plants ha^{-1}. Fertilization at sowing was performed with 40 kg ha^{-1} of K_2O and P_2O_5. The crop was maintained under conventional sprinkler irrigation, with an irrigation interval of 4 to 6 days, using a water depth of 10-50 mm per event, depending on the development stage. During the common bean development, there was a total precipitation of 146 mm, and the average temperature ranged between 16.4 ºC and 28 ºC (Figure 2). Weeds were controlled with the herbicides tepraloxydim (80 g ha^{-1} of a.i.), clethodim (108 g ha^{-1} of a.i.) and bentazone + imazamox (628 g ha^{-1} of a.i.). The common bean harvest was carried out on Sep. 20, 2015.

Prior to harvesting the total area of the maize crop, single and intercropped, the grain yield (t ha^{-1}) was evaluated by manually harvesting the spikelets from 2 rows of each subplot, followed by mechanized threshing. After that, the grains were weighed and their moisture was determined, in order to correct the mass to 13 % of moisture content. The result was extrapolated from the area corresponding to the two rows harvested per hectare.

In addition to the grain yield, the maize cropping systems were evaluated for the quantity (t ha^{-1}) and N accumulation (kg ha^{-1}) of the straw produced after the crops were desiccated. A sample of crop residues, previously desiccated, was collected in each subplot (June 08, 2015), using a square with area of 0.25 m². The samples were washed to remove soil particles, dried in a forced air ventilation oven at 65-70 ºC until constant weight and weighed, with values extrapolated to 1 hectare, in order to determine the quantity of straw. After this, the weighed material

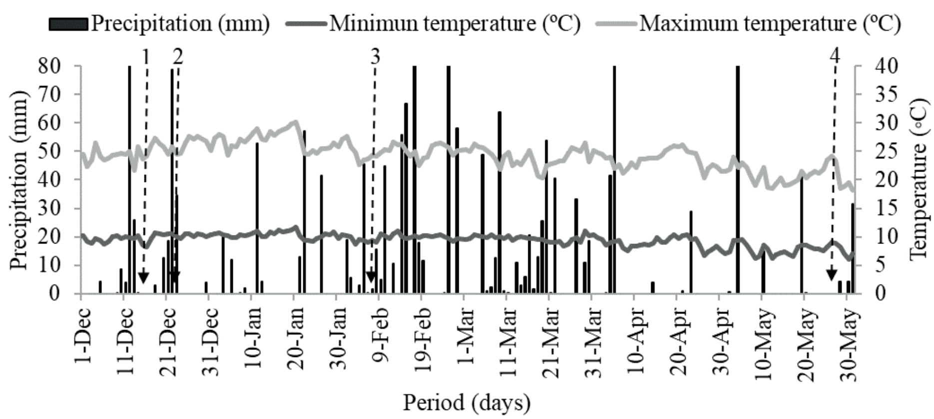


Figure 1. Precipitation (mm) and maximum and minimum temperatures (ºC), every ten days, from December 2014 to May 2015, comprising the maize cycle: 1 = sowing (December 15, 2014); 2 = emergence (December 22, 2014); 3 = flowering (February 6, 2015); 4 = harvest (May 25, 2015). Source: weather station of the Universidade Estadual Paulista (Jaboticabal, São Paulo state, Brazil).

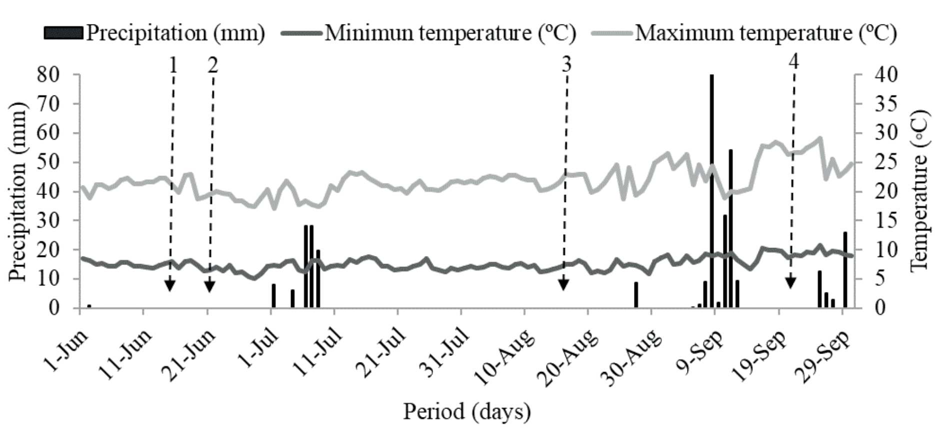


Figure 2. Precipitation (mm) and maximum and minimum temperatures (ºC), every ten days, from June to September 2015, comprising the common bean cycle: 1 = sowing (June 15, 2015); 2 = emergence (June 21, 2015); 3 = flowering (August 16, 2015); 4 = harvest (September 21, 2015). Source: weather station of the Universidade Estadual Paulista (Jaboticabal, São Paulo state, Brazil).

was ground and the N content was determined by the semi-Micro Kjeldahl method (Carmo et al. 2000). The nitrogen accumulation was calculated as the product of N content by the quantity of straw.

The common bean crop was evaluated for leaf N content (g kg^{-1}), production components through the number of pods per plant, grains per pod and 100-grain weight (g), grain yield (kg ha^{-1}) and qualitative attributes, with grain size and crude protein content (%).

The leaf N content was determined by collecting the third trifoliate leaf from the middle third portion of thirty plants at the full flowering stage (R_6) (Fernández et al. 1985), drying them in a forced air ventilation oven at 65-70 ºC until constant weight, and determining the N content by the semi-micro Kjeldahl method (Carmo et al. 2000).

After collecting ten mature plants in one row of each subplot of common bean, the numbers of pods per plant and grains per pod were counted, and the 100-grain weight was determined based on the average weight of 4 samples of 100 grains of each subplot.

The common bean grain yield was obtained as previously described for the maize crop, differing only in the number of rows harvested, because plants from four central rows of the useful area of each subplot were manually uprooted and mechanically threshed.

The samples used to determine the common bean grain yield were placed in paper bags and stored in a dry chamber, at a temperature of 20 ºC and relative humidity of 40 %, for 30 days, when the following qualitative attributes were evaluated: grain size, crude protein content, hydration capacity and maximum hydration ratio.

For grain size, the grains were classified by size when retained after agitation for 1 min on a set of sieves with oblong holes, referred to as 11, 12, 13 and 14, whose dimensions are, respectively, 11/64" x 3/4 (4.37 mm x 19.05 mm), 12/64" x 3/4 (4.76 mm x 19.05 mm), 13/64" x 3/4 (5.16 mm x 19.05 mm) and 14/64" x 3/4 (5.56 mm x 19.05 mm). The percentage of grains was calculated based on the relationship between the mass of the grains retained on each sieve and the mass of the total sample. The sum of the percentage of grains retained on the sieves 12, 13 and 14 represented the value for sieve larger than or equal to 12 (≥ 12). After determining the grain size, the samples of common bean grains from the sieve 12 were used to determine the other qualitative attributes.

The crude protein content was determined by the formula CP = Total N × 6.25, where Total N is the N content in the grains determined by the semi-micro Kjeldahl method (Carmo et al. 2000). A Mattson cooker apparatus was used to determine the cooking time, with previous hydration of the grains in deionized water for 12 h. The maximum hydration capacity and ratio of the common bean were analyzed after an immersion period of 20 h (Farinelli & Lemos 2010).

The data were subjected to analysis of variance by the F test and the means compared by the Tukey test at 5 % of probability. Significant effects of the N doses and interaction between the cropping systems and N doses were evaluated by polynomial regression analysis.

RESULTS AND DISCUSSION

The maize/brachiaria and maize/crotalaria intercropping systems did not affect the grain yield of this cereal (Table 3). It is suggested that the conditions of soil (Table 2) and climate (Figure 1), along with the management carried out in the maize crop, were efficient in minimizing the effects of competition between the maize and cover crops. This demonstrates the possibility of a sustainable cultivation of maize intercropped with these crops, combining the production of grains and formation of soil cover for the no-tillage system. Kappes & Zancanaro (2015) emphasized that the intercropping viability depends on factors such as the species used, management of cover crops and edaphoclimatic conditions, after observing a reduction of grain yield justified by an interspecific competition of maize intercropped with forage grasses and with leguminous species, in comparison to the maize as a single crop.

As for the straw production and N accumulation (Table 3), the system of maize intercropped with crotalaria stood out. The straw production in this system was 19 % and 10 % higher than in maize as a single crop and maize intercropped with brachiaria, respectively. Since there is a greater N accumulation, it is believed that plants of the system produce more dry matter and, consequently, the straw production increases. This N accumulation in the maize/crotalaria intercropping is justified by the capacity of the leguminous species to insert the nutrient in the system through biological N fixation (Aita & Giacomini 2003) and make it available to the intercropped maize through root exudates (Dick et al. 2009).

For the common bean crop, the maize cropping systems caused differences in the leaf N content, number of pods per plant and grain yield (Table 4). These variables increased when the common bean was grown after the maize/crotalaria intercropping (Table 5), and it was found that the highest N accumulation (Table 3), associated with straw mineralization in the intercropping with the leguminous species, allowed a greater N availability to the common bean crop in succession. Arf et al. (2018), analyzing the straw produced in maize cropping systems, found lower C/N ratio values for maize intercropped with crotalaria (36 to 56), when compared to maize intercropped with brachiaria (40 to 63) and maize as a single crop (36 to 56), which promotes a greater decomposition, mineralization

Table 3. Maize grain yield, quantity of straw, straw nitrogen accumulation and F test for the maize cropping systems, as a single crop and intercropped with *Urochloa ruziziensis* and *Crotalaria spectabilis*.

Treatments	Grain yield (t ha^{-1})	Quantity of straw (t ha^{-1})	Straw nitrogen accumulation (kg ha^{-1})
Cropping systems (S)			
Maize	10.64	6.02 c[(1)]	31.61 b
Maize + brachiaria[(2)]	9.93	6.67 b	42.76 ab
Maize + crotalaria[(3)]	9.99	7.45 a	48.43 a
CV (%)	11.61	6.01	21.63
F test	2.25^{ns}	62.48**	6.82**

[(1)] Means followed by equal letters in the columns, for each factor, do not differ by the Tukey test at 5 % of probability. ^{ns} Not significant by the F test at 5 % of probability. ** Significant by the F test at 1 % of probability. * Significant by the F test at 5 % of probability. [(2)] Maize intercropped with *Urochloa ruziziensis*. [(3)] Maize intercropped with *Crotalaria spectabilis*.

Table 4. Mean value, F test and coefficient of variation (CV) for the leaf nitrogen content (LN), number of pods per plant (NPP), number of grains per pod (NGP), 100-grain weight (100GW) and grain yield (GY) of common bean (IAC Alvorada cultivar), as a function of topdressing nitrogen doses and succession to cropping systems with maize as a single crop and intercropped with *Urochloa ruziziensis* and *Crotalaria spectabilis*.

Treatments	LN (g kg^{-1})	NPP	NGP	100GW (g)	GY (kg ha^{-1})
Overall mean	31.80	9.30	4.60	28.03	2,470.78
Cropping systems (S)					
F test	55.56**	166.46**	4.88^{ns}	2.64^{ns}	309.73**
CV (%)	6.04	4.26	13.70	2.89	8.24
Nitrogen doses (N)					
F test	8.45**	30.21**	2.30^{ns}	0.74^{ns}	22.17**
CV (%)	5.03	6.49	9.82	3.01	5.93
Interaction S x N					
F test	1.09^{ns}	3.44**	0.20^{ns}	0.07^{ns}	4.36**

** Significant by the F test at 1 % of probability. * Significant by the F test at 5 % of probability. ^{ns} Not significant by the F test at 5 % of probability.

Table 5. Leaf nitrogen content (LN), number of pods per plant (NPP) and grain yield (GY) for common bean (IAC Alvorada cultivar), in succession to cropping systems with maize as a single crop and intercropped with *Urochloa ruziziensis* and *Crotalaria spectabilis*.

Treatments	LN (g kg^{-1})	NPP	GY (g)
Cropping systems (S)			
Maize	30.1 b[(1)]	8.1 c	2,125.29 c
Maize + brachiaria[(2)]	30.0 b	9.3 b	2,402.61 b
Maize + crotalaria[(3)]	35.4 a	10.4 a	2,884.44 a

[(1)] Means followed by different letters in the columns, for each factor, differ by the Tukey test at 5 % of probability. [(2)] Maize intercropped with *Urochloa ruziziensis*. [(3)] Maize intercropped with *Crotalaria spectabilis*.

and, consequently, nutrient availability to the crop in succession.

In addition, the variables leaf N content, number of pods per plant and grain yield responded positively to the increase in the N fertilization (Figure 3), what indicates that these variables are favored by the crop nutrition. Carmeis Filho et al. (2014) and Cunha et al. (2015) also observed an increase in the leaf N contents of common bean with the increase of N doses in topdressing fertilization.

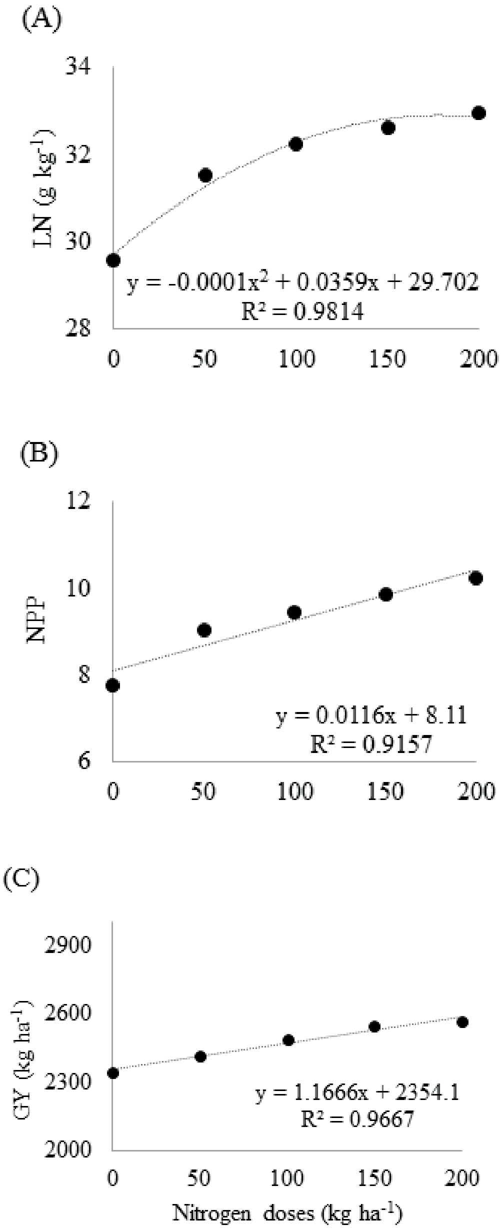
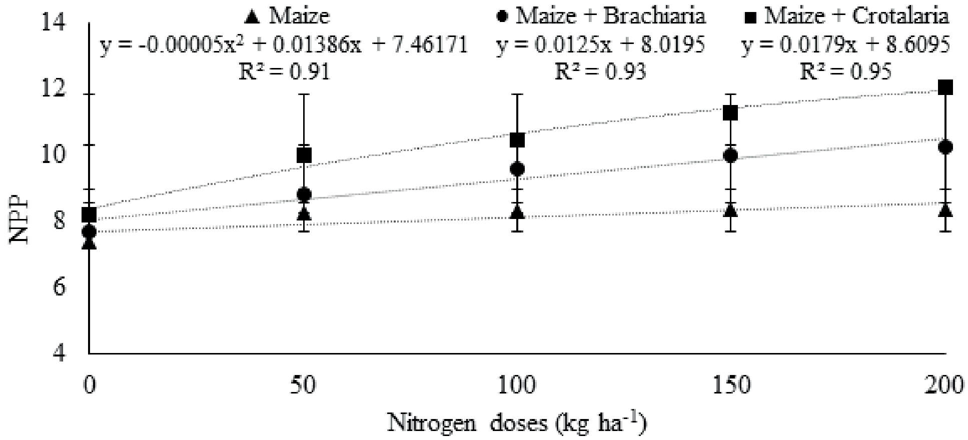


Figure 3. Leaf nitrogen content - LN (A), number of pods per plant - NPP (B) and grain yield - GY (C) for common bean (IAC Alvorada cultivar), as a function of topdressing application of nitrogen doses (common bean phenological stage V_{4-4}).

Although the common bean showed linear increments with the increase of N doses for number of pods per plant and grain yield (Figure 3), its behavior in succession to each cropping system was different, as a function of the increase of the nutrient (Figure 4). After the maize single crop, there was no response of the crop to fertilization, and the mean values were 8 kg ha^{-1} and 2,125 kg ha^{-1}, respectively for the number of pods per plant and grain yield. However, in succession to the intercropping, there were increments of approximately 0.013 to 0.018 in the number of pods per plant and 1.10 kg ha^{-1} to 1.86 kg ha^{-1} of grains for every 1 kg ha^{-1} of N supplied in the fertilization for the common bean.

Additionally, it was found that the previous cropping system factor had a greater influence than the N fertilization, because, in the absence of topdressing N (0 kg ha^{-1} of N), the grain yield of common bean in succession to maize intercropped with crotalaria (2.774 kg ha^{-1}) was higher than the values obtained with the application of the highest N dose (200 kg ha^{-1}), for common bean cultivated after the other cropping systems. Thus, the use of maize/crotalaria intercropping for this study was equivalent to the topdressing application of more than 200 kg ha^{-1} of N in the common bean crop, using urea as the nutrient source. It is suggested that, under edaphoclimatic conditions similar to those of the present experiment, the farmer could obtain a high grain yield and reduced costs with agricultural inputs through the succession of maize/crotalaria intercropping with common bean. Considering only the cost with the urea application (Farmfutures 2019), when using *Crotalaria spectabilis* seeds on the system it is possible to save about 25 USD ha^{-1}. This fact is explained by the greater supply of mineralized N from the straw produced in the intercropping with leguminous species (Table 3), promoting a greater expansion of the vegetative parts of common bean and, consequently, an increase in photosynthesis, what causes a higher grain yield (Cruz et al. 2007). Silva et al. (2016) found that the use of leguminous species as cover crops promoted an effect proportional to that of fertilization with 60 kg ha^{-1}, in the form of urea, on rice grain yield.

Regarding the qualitative attributes of the common bean grains, the cropping system factor caused variation in grain size (Table 6), and the



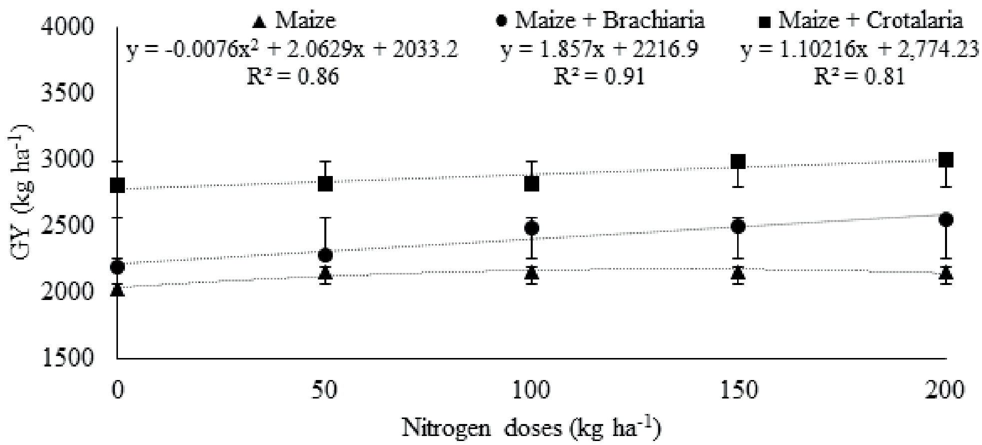


Figure 4. Analysis of the interaction between the cropping systems and nitrogen doses for the number of pods per plant - NPP (A) and grain yield - GY (B) of common bean (IAC Alvorada cultivar), as a function of the topdressing application of nitrogen doses (common bean phenological stage V_{4-4}) and succession to the cropping systems with maize as a single crop (▲), maize intercropped with *Urochloa ruziziensis* (●) and maize intercropped with *Crotalaria spectabilis* (■).

Table 6. Mean value, calculated F and coefficient of variation (CV) of the percentage of grains retained on the processing sieves, for the common bean IAC Alvorada cultivar, as a function of topdressing nitrogen doses and succession to cropping systems with maize as a single crop and intercropped with *Urochloa ruziziensis* and *Crotalaria spectabilis*.

Treatments	Processing sieves				
	11[(1)]	12	13	14	≥ 12
Overall mean (%)	21.40	31.28	24.92	14.54	77.61
Cropping system (S)					
F test	20.18**	2.69^{ns}	7.08*	11.44**	15.33**
CV (%)	23.29	14.46	10.24	30.48	8.24
Nitrogen doses (N)					
F test	1.21^{ns}	0.44^{ns}	1.28^{ns}	1.73^{ns}	2.52^{ns}
CV (%)	20.92	13.28	6.10	20.51	5.93
Interaction S x N					
F test	0.69^{ns}	0.62^{ns}	0.73^{ns}	0.21^{ns}	0.44^{ns}

* Significant by the F test at 5 % of probability. ** Significant by the F test at 1 % of probability. ^{ns} Not significant by the F test at 5 % of probability. [(1)] Sieves with mesh sizes equal to 11/64" x 3/4 (4.37 mm x 19.05 mm), 12/64" x 3/4 (4.76 mm x 19.05 mm), 13/64" x 3/4 (5.16 mm x 19.05 mm) and 14/64" x 3/4 (5.56 mm x 19.05 mm) refer to 11, 12, 13 and 14, respectively. The sum of the percentage of grains retained on the sieves 12, 13 and 14 represents ≥ 12.

highest percentages retained on sieves with larger mesh dimensions occurred when the maize/crotalaria intercropping was the previous system (Figure 5). The common bean in succession to this intercropping showed a greater expansion of grains, but with no effect on the 100-grain weight (Table 4). The greater retention of grains on the sieves 13 and 14 contributed for more than 80 % of the grains to be retained on the sieves corresponding to larger than or equal to 12 (Figure 5). This is important for the farmer, because it indicates that higher prices are paid for these grains by the packing companies, which recommend that the lot should have 70 % of grains on sieves larger than or equal to 12 (Carbonell et al. 2010).

The other variables of qualitative attributes were not influenced by the factors cropping systems and topdressing N doses (Table 7), possibly because these are characteristics associated with the genetics of the crop and climatic conditions at the harvest time. Thus, the mean values for these characteristics agree with those reported in the literature. Carbonell et al. (2008), analyzing the common bean IAC Alvorada cultivar in the São Paulo state, found crude protein contents within the range of 17.52 % to 25.68 %. The cooking time was within the range recommended as acceptable by Ramalho & Abreu (2006), which is less than 30 min. For the hydration ratio close to 2, it can be stated that, after the hydration period, the grains absorbed a mass of water similar to their initial mass, agreeing with the results of Farinelli & Lemos (2010) and Carmeis Filho et al. (2014). As for the time for maximum hydration, the ideal is that it should be less than 12 h, because soaking beans at the night before the preparation is a common practice in the Brazilian cuisine.

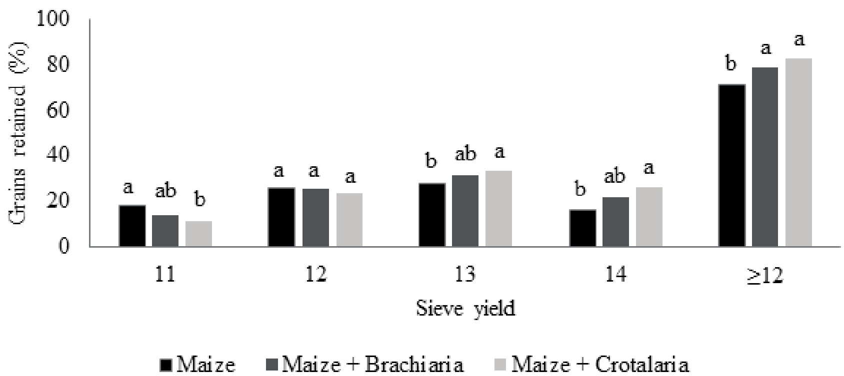


Figure 5. Grain size for the common bean IAC Alvorada cultivar grown in succession to maize as a single crop, maize intercropped with *Urochloa ruziziensis* and maize intercropped with *Crotalaria spectabilis*. Means followed by equal letters, for each sieve, do not differ by the Tukey test at 5 % of probability. Sieves with mesh sizes equal to 11/64" x 3/4 (4.37 mm x 19.05 mm), 12/64" x 3/4 (4.76 mm x 19.05 mm), 13/64" x 3/4 (5.16 mm x 19.05 mm) and 14/64" x 3/4 (5.56 mm x 19.05 mm) refer to 11, 12, 13 and 14, respectively. The sum of the percentage of grains retained on the sieves 12, 13 and 14 represents ≥ 12.

Table 7. Mean value, test F and coefficient of variation (CV) for crude protein content (CP), cooking time (CT), time for maximum hydration (TMH) and hydration ratio (HR) of the common bean IAC Alvorada cultivar, as a function of topdressing nitrogen doses and succession to cropping systems with maize as a single crop and intercropped with *Urochloa ruziziensis* and *Crotalaria spectabilis*.

Treatments	CP (%)	CT (min)	TMH (h:min)	HR
Overall mean	20.35	9.30	4.60	28.03
Cropping systems (S)				
F test	0.18^{ns}	9.45^{ns}	1.13^{ns}	4.63^{ns}
CV (%)	13.91	4.84	4.79	1.54
Nitrogen doses (N)				
F test	1.05^{ns}	1.00^{ns}	0.73^{ns}	2.20^{ns}
CV (%)	9.25	6.55	3.45	1.33
Interaction S x N				
F test	0.81^{ns}	0.01^{ns}	0.96^{ns}	1.03^{ns}

** Significant by the F test at 1 % of probability. * Significant by the F test at 5 % of probability. ^{ns} Not significant by the F test at 5 % of probability.

CONCLUSIONS

1. The maize grain yield is not affected by the intercropping with crotalaria and brachiaria, when compared to its cultivation as a single crop. However, the maize/crotalaria intercropping promotes a greater quantity of straw and nitrogen accumulation, if compared to maize intercropped with brachiaria and maize as a single crop;
2. The maize/crotalaria intercropping leads to higher grain yields of the common bean grown in succession, even in the absence of topdressing nitrogen application;
3. The grain yield of common bean increases with the addition of N doses applied as topdressing, when in succession to maize intercropped with brachiaria and crotalaria;
4. Common bean cultivated after maize/crotalaria intercropping produces large grains;
5. Using maize/crotalaria intercropping is the best option, when common bean is sown in succession, considering the edaphoclimatic conditions of the experiment and the cultivation after six years of implementation of a no-tillage system.

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