Effect of nitrogen doses and grass crop residue on common bean in no-tillage

Efeito de doses de nitrogênio e resíduos culturais de gramíneas no feijão-comum em plantio direto

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Camila Baptista do Amaral
Doutora em Agronomia (Genética e Melhoramento de Plantas) pela Universidade Estadual Paulista (Unesp), Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal, São Paulo
Instituição: Coordenadoria de Defesa Agropecuária do Estado de São Paulo
Endereço: Avenida Brasil, 2340, Campinas - SP - CEP 13070-178
E-mail: camila.agro07@gmail.com

Fábio Luiz Checchio Mingotte
Doutor em Agronomia (Produção Vegetal) pela Universidade Estadual Paulista (Unesp), Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal, São Paulo
Instituição: Universidade Estadual Paulista (Unesp), Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal, São Paulo
Endereço: Via de Acesso Prof.Paulo Donato Castellane s/n - Jaboticabal/SP - CEP 14884-900
E-mail: flcmingotte@gmail.com

Jordana de Araujo Flôres
Doutor em Agronomia (Produção Vegetal) pela Universidade Estadual Paulista (Unesp), Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal, São Paulo
Instituição: Instituto Federal de Educação, Ciência e Tecnologia de Rondônia, IFRO, Brasil
Endereço: Avenida Lauro Sodré, 6500 - Censipam - Aeroporto, Porto Velho - RO, 76803-260
E-mail: jordana_flores@hotmail.com

Carolina Cipriano Pinto
Doutora em Ciência e Tecnologia de Sementes, Universidade Federal de Pelotas, UFPEL, Rio Grande do Sul
Instituição: Universidade Federal de Pelotas, UFPEL, Rio Grande do Sul
Endereço: Rua Gomes Carneiro, 1 - Centro, Pelotas - RS, 96010-610
E-mail: carolina.ccp@hotmail.com

Anderson Prates Coelho
Doutor em Agronomia (Produção Vegetal) pela Universidade Estadual Paulista (Unesp), Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal, São Paulo
Instituição: Universidade Estadual Paulista (Unesp), Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal, São Paulo
Endereço: Via de Acesso Prof.Paulo Donato Castellane s/n - Jaboticabal/SP - CEP 14884-900
E-mail: anderson.coelho@unesp.br

Leandro Borges Lemos
Prof. Dr. em Agronomia pela Universidade Estadual Paulista (Unesp), Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal, São Paulo
Instituição: Universidade Estadual Paulista (Unesp), Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal, São Paulo
Endereço: Via de Acesso Prof.Paulo Donato Castellane s/n - Jaboticabal/SP - CEP 14884-900
E-mail: leandro.lemos@unesp.br

ABSTRACT
Nitrogen (N) is the most absorbed nutrient by the common bean, and the availability of this element changes according to the crop residues present on the soil surface. The aim of this study was to assess the effect of top-dressed doses of N and crop residue (maize alone, maize intercropped with brachiaria and brachiaria alone) on the performance of irrigated common bean. The experiment was conducted in a split-plot arrangement, where the plots consisted of residues of maize crop alone, maize intercropped with brachiaria, and brachiaria alone and the subplots consisted of doses of top-dressed N applied to common bean (0, 40, 80, 120, and 160 kg ha^{-1}). Brachiaria alone and maize intercropped with brachiaria provided full coverage of the soil surface. The C/N ratio in the maize crop residue was higher than that in the brachiaria crop residue. This result characterizes maize as a material with slower and more gradual decomposition compared to brachiaria, which had a higher N content because it was desiccated at the time of its full vegetative vigor. Crop residue affected grain yield, particularly the cultivation on brachiaria alone. The maximum grain yield was achieved at an estimated dose of 136 kg ha^{-1} of N. These results demonstrate the effect of crop succession and nitrogen fertilization on the common bean agronomic performance in the no-tillage system, helping farmers and technicians in decision making.

Keywords: crop succession, nitrogen fertilization, *Phaseolus vulgaris* L., *Urochloa ruziziensis*, *Zea mays*.

RESUMO
O nitrogênio (N) é o nutriente mais absorvido pelo feijão-comum e a disponibilidade desse nutriente varia de acordo com os resíduos culturais presentes na superfície do solo. O objetivo foi avaliar o efeito de doses de N em cobertura e restos culturais (monocultivo de milho, milho consorciado com braquiária e monocultivo de braquiária) sobre o desempenho do feijão-comum irrigado. O experimento foi conduzido em esquema de parcelas subdivididas, onde as parcelas consistiram de resíduos culturais de monocultivo de milho, milho consorciado com braquiária e monocultivo de braquiária e as subparcelas consistiram de doses de N em cobertura aplicadas no feijão-comum (0, 40, 80, 120 e 160 kg ha^{-1}). O monocultivo de braquiária e o milho consorciado com braquiária proporcionaram cobertura total da superfície do solo. A relação C/N da palhada de milho foi maior comparado à palhada de braquiária. Esse resultado caracteriza o milho como um material com decomposição mais lenta e gradual em relação à braquiária, que apresentou maior teor de N, pois foi dessecada no momento de seu pleno vigor vegetativo. O resíduo cultural afetou a produtividade de grãos do feijão-comum, principalmente o monocultivo de braquiária. A produtividade máxima de grãos foi alcançada na dose estimada de 136 kg ha^{-1} de N. Esses resultados demonstram o efeito da sucessão de culturas e da adubação nitrogenada no desempenho agronômico do feijão-comum em sistema de plantio direto, auxiliando agricultores e técnicos na tomada de decisão.

Palavras-chave: sucessão de culturas, adubação nitrogenada, *Phaseolus vulgaris* L., *Urochloa ruziziensis*, *Zea mays*.

1 INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) has been explored in several agricultural production systems, most notably the no-tillage system (NTS). For no-tillage to be viable, grass species with high carbon nitrogen ratio (C/N) should be considered, especially in regions with tropical savanna climate where the prevailing conditions of high humidity and temperature allow a high decomposition rate of crop residues (Butenschoen et al. 2011). In this context, brachiaria and maize, both grown alone and in intercropping cultivation systems, are the best suited crops for successful no-tillage into crop residue because they are more efficient in releasing nutrients and persist on the soil surface for longer (Calonego et al. 2012). They are therefore a good choice to soil coverage, an essential factor for improving the physical, chemical, and biological properties of the soil in NTS (Cardoso et al. 2012).

In addition to the agricultural production system, the adequate management of organic matter and nutrients, in particular N, has enable higher yields on common bean (Ribeiro et al. 2018; Silva et al. 2020). Although this specie establishes a symbiotic relationship with bacteria of the *Rhizobium* genus, which fix atmospheric N and make it available to the plant, the amount of N provided by this process is not sufficient to satisfy total crop demand (Brito et al. 2011). Therefore, it is necessary to supply N through fertilization.

Even with the supply of N from crop residue mineralization and soil organic matter, microbial immobilization still occurs in a NTS, with N becoming unavailable for plants, especially when the C/N of the crop residues is higher than 50 (Cantarella et al. 2007). Thus, in the NTS with large amount of crop residue, the dose of applied N should be adjusted according to the type of crop residue. In their studies, Fiorentin et al. (2012) concluded that common bean yield is higher when it is planted after maize intercropped with brachiaria or brachiaria alone. Mingotte et al. (2014) observed that in the second year of NTS, N fertilization affected the bean yield only when it was planted after a maize monoculture, and the highest yields were obtained for crop residues with brachiaria alone or intercropped, with no effect from N fertilization.

The aim of this study was to assess the effect of top-dressed doses of N and crop residue on the performance of irrigated common bean in the fifth year of NTS.

2 MATERIAL AND METHODS

The experiment was conducted in the 2012/2013 crop season, in Jaboticabal, São Paulo, Brazil (latitude 21°14′33″’S, longitude 48°17′10″’W, 565m asl). The climate category is Aw, according to the Köppen classification, and the soil is a eutrophic Red Latosol (Oxisol) with clay texture (500 g kg^{-1} clay). The experimental area was managed under NTS, with a succession of maize alone/common bean, maize intercropped with brachiaria/common bean, and brachiaria alone/common bean since the 2008/2009 agricultural year.

A chemical analysis of the top 0,00–0,20 m soil layer was performed before the experiment was set up and the following results were obtained: pH ($CaCl_2$) = 5.6; organic matter = 26 g kg^{-1}; available P (resin) = 55 mg dm^{-3}; exchangeable H + Al = 28 $mmol_c$ dm^{-3}; available K = 5.1 $mmol_c$ dm^{-3}; exchangeable Ca = 44 $mmol_c$ dm^{-3}; exchangeable Mg = 30 $mmol_c$ dm^{-3}; cation exchange capacity (CEC) = 107.1 $mmol_c$ dm^{-3}; and base saturation (V) = 74%.

A randomized block experimental design was used, with split-plot arrangement and three replicates. The plots consisted of a residue of maize alone, maize intercropped with brachiaria, and brachiaria alone. The subplots consisted of top-dressed N doses corresponding to 40, 80, 120, and 160 kg ha^{-1} of N and one control without top-dressed N.

The topdressed N was applied manually at the $V_{4\text{-}4}$ stage (fourth completely developed trifoliate leaf) in a continuous strip at 10 cm from the bean plant row. The source of N was urea, which was incorporated by applying 10 mm irrigation after the fertilizer deposition. Each subplot consisted of eight 5-meter-long rows, and the usable area was composed of six central rows, leaving 0.5 m on each side.

Maize (hybrid AG 7088 VTPRO2), grown alone or intercropped, was sown mechanically on 07 December 2012 spaced by 0.90m, and with 5–6 seeds m^{-1}. Brachiaria (*Urochloa ruziziensis*) was sown on the same day and between the rows of maize, in a double row spaced by 0.22 m. Brachiaria alone was sown in a similar way, and a density of 400 points of cultural value ha^{-1} was used.

The plots with maize alone or intercropped with brachiaria received 330 kg ha^{-1} of commercial 08-28-16 NPK fertilizer at sowing, 400 kg ha^{-1} of commercial 20-0-20 NPK fertilizer and 170 kg ha^{-1} of urea in at the V_4 and V_8 stages respectively. Brachiaria grown alone was not top-dressed. After the maize harvest, all plots were desiccated with glyphosate-potassium (1.860 g ha^{-1} of a.i.) and carfentrazone-ethyl (40 mL ha^{-1} of a.i.) on June 13, 2013.

The common bean cultivar IPR Andorinha was sown mechanically on 02 August 2013, spaced by 0.45 m with 15 seeds m^{-1} to ensure a density of 260,000 plants ha^{-1}. The plots received 210 kg ha^{-1} of commercial 08-28-16 NPK fertilizer applied at sowing. The crop was irrigated throughout the growth cycle at 10 to 50 mm every 4 to 6 days.

Shoot dry mass, N content and N accumulation were determined at the flowering stage (R_6). Nitrogen content was determined according to the method by Ambrosano et al. (1997). To measure shoot dry mass, 10 plants were collected per subplot, washed, and dried in an oven at 65°C for 72 h. To determine the N content, the plants were ground in a Willey-type mill and digested in sulphuric acid. Ten bean plants per subplot were collected at the physiological maturation stage (R_9) to determine the number of pods, grains per pod, and mass of 100 grains.

Data were tested for normality (Cramer-von Mises normality test), and no transformation was needed. Analysis of variance(F Test) were performed, and the means obtained for each crop residue were compared using the Tukey's test ($p < 0.05$). The effects of the N doses and interaction were assessed by regression analyses. All these statistical analyses were performed using R software.

3 RESULTS AND DISCUSSION

The dry plant mass produced in the monoculture of brachiaria was greater than that produced by maize intercropped with forage, which, in turn, was greater than that in maize monoculture (Table 1).

Table 1. Total amount of crop residue (CR), coverage, N content and C/N ratio in crop residue of maize, maize + brachiaria intercropping and brachiaria before common bean sowing at Jaboticabal, São Paulo, 2013[(1)]

Treatment	Total amount of CR ($t\ ha^{-1}$)	Coverage (%)	N content (%)	C/N ---
Crop residue (CR)				
Maize	6.81 c	82 b	0.52 c	76
Maize + brachiaria	7.95 b	100 a	1.05 b	35
Brachiaria	10.87 a	100 a	1.41 a	26
CV (%)	7.66	3.85	12.49	-
F test	153.79^{**}	115.95^{**}	194.29^{**}	-
MSD	0.99	2.28	0.12	-

[(1)]Means followed by the same letter do not differ by Tukey ($p<0.05$). ** - significant at 1% by F test

Both the brachiaria alone and the intercrop cultivation resulted in total soil coverage, whereas in maize monocultures soil coverage was partial at 82%. Similar results were found by Carmeis Filho et al. (2016) and Mingotte et al. (2020), that observed adequate soil coverage when brachiaria were intercropped with maize. Soil coverage, which is recommended for adoption of no-tillage system, prevents the impact of rain drops, and thus decreases soil loss caused by erosion (Silva et al. 2005). For tropical regions, is recommended a soil coverage above 60% (Mingotte et al., 2020).

The C/N ratio in the maize crop residue was higher than that in the brachiaria crop residue. This result characterizes maize as a material with slower and more gradual decomposition compared to brachiaria, which had a higher N content because it was desiccated at the time of its full vegetative vigor. According to Cantarella et al. (2007), the values of C/N ratio between 12 and 25 favor mineralization and the ratios higher than 50 favor immobilization; a balance between the two is attained at a ratio between 25 and 30.

The dry mass of the aerial parts of bean plants, when grown on the brachiaria residue alone or on brachiaria intercrop, was 2,031 and 1,907 kg ha^{-1} respectively. These values were higher than those obtained for maize crop residue (Table 2).

Table 2. Leaf N content, dry mass, and N content in the aerial part of common bean depending on crop residue and top-dressed N doses at Jaboticabal, São Paulo, 2013[1]

Treatment	Dry mass (t ha^{-1})	N content (kg ha^{-1})	Leaf N content (g kg^{-1})
Crop residue (CR)			
Maize	1.5 b	43.64	52.5
Maize + brachiaria	1.9 a	44.89	64.7
Brachiaria	2.0 a	44.75	65.8
CV(%)	12.75	5.34	19.53
MSD	0.3	-	-
N doses (kg ha^{-1}) (D)			
0	1.6[2]	41.83[3]	52.8[4]
40	1.8	43.32	56.4
80	1.9	44.12	60.8
120	2.0	45.83	68.6
160	1.8	47.03	66.6
CV (%)	10.89	2.851	12.85
F test			
CR	20.51**	5.64^{ns}	1.24^{ns}
D	2.97*	6.59**	23.54**
CRxD	0.64^{ns}	2.10^{ns}	1.22^{ns}

[1]Means followed by the same letter do not differ by Tukey ($p<0.05$). *, ** - significant at 5 and 1% respectively and ^{ns} – non-significant by F test. [2] $y= -0.00009x^2 + 0.01957x + 6.29457$, $R^2= 0.91^{**}$; [3] $y= 0.032x + 41.844$, $R^2= 0.99^{**}$; [4] $y= -0.0004x + 0.02042$, $R^2= 0.89^{**}$

Janegitz et al. (2017) observed that brachiaria has potential to improve phosphorus availability and cycling in the soil, which among others advantages, could explain the higher mass accumulation. The dry mass of bean plants at the flowering stage was also affected by N topdressing; the maximum accumulation was achieved with a dose of 109 kg ha^{-1}. According to the report by Arf et al. (2008), the observed increase in dry mass of the plants under N topdressing is due to the involvement of this element in photosynthesis and its direct relation to chlorophyll. The application of increasing doses of N promoted a linear increase in leaf N content (Table 2). The obtained values were within the 30–50 g kg^{-1} range, which is considered adequate for the common bean plant (Ambrosano et al., 1997), even without N topdressing. Moreover, the doses of N affected its total accumulation in plants following an increasing linear model. Because N is a constituent of chlorophyll, a greater accumulation of this nutrient in plants sustains yield gains. Silveira and Gonzaga (2017) assessed the effect of N doses on the N sufficiency index and grain yield and observed that the N doses had a linear effect on the N sufficiency index, that represent a normalized valor of chlorophyll, and a quadratic effect on grain yield, supporting the idea that crescent N doses increases N content and consequently has potential to increase grain yield.

There was no effect of the different types of crop residues on the yield components of bean plants, although crop yield was higher when bean was sown on the residue of brachiaria grown alone than when it was grown on the other residues (Table 3).

Table 3. Number of pods, grains per pod, and mass of 100 grains and grain yield of common bean depending on crop residue and top-dressed N doses at Jaboticabal, São Paulo, 2013[(1)]

Treatment	Pods per plant (nº)	Grains per pod (nº)	Mass of 100 grains (g)	Grain yield (kg ha^{-1})
Crop residue (CR)				
Maize	8.6	4.6	25.3	2235 b
Maize + brachiaria	9.5	4.6	24.9	2362 b
Brachiaria	9.4	4.8	24.4	2820 a
CV(%)	8.54	4.39	4.87	6.39
MSD	-	-	-	195
N doses (kg ha^{-1}) (D)				
0	7.7[(2)]	4.7	24.9	2318[(3)]
40	8.6	4.6	24.8	2384
80	9.7	4.6	25.3	2514
120	10.4	4.7	24.8	2614
160	9.4	4.6	24.3	2530
CV (%)	15.68	6.10	3.96	9.56
F test				
CR	5.88^{ns}	3.87^{ns}	2.29^{ns}	56.86^{**}
D	4.77^{**}	0.31^{ns}	1.06^{ns}	6.42^{**}
CRxD	1.61^{ns}	1.32^{ns}	1.34^{ns}	1.49^{ns}

[(1)]Means followed by the same letter do not differ by Tukey ($p<0,05$). ** - significant at 1% and ns – non-significant by F test. [(2)] $y= -0.0002x^2 + 0.043x + 7.52$, $R^2= 0.91^{**}$; [(3)] $y= -0.0147x^2 + 3.9921x + 2294.1$, $R^2= 0.89^{**}$

There was no interaction between crop residues and N doses for any of the assessed factors (Tables 2 and 3), indicating that there was no effect of crop residue on the response of common bean to nitrogen fertilization.

The higher grain yield obtained with crop residue of brachiaria alone is probably related to the amount of plant mass produced by the forage plant, the coverage rate, and, most of all, the high capacity of nutrient turnover. Pacheco et al. (2011) assessed the production of plant mass and nutrient turnover in several cover plants and concluded that the *U. ruziziensis* species stands out regarding nutrient accumulation and release, mainly N, phosphorous, and potassium. In addition, the presence of brachiaria crop residue favors microbial activity in the soil (Carvalho et al., 2013). Assessing the effect of the same crop successions evaluated in the present study on common bean, Mingotte et al. (2021a) did not observe differences in common bean yield as a function of the previous crop. This may have occurred because the authors evaluated these effects in an area with short no-tillage, also verifying the effects of soil N immobilization by straw. However, the authors found that the common bean technological quality was increased after cultivation with *U. ruziziensis* sole, with increases in the crude protein content (Mingotte et al., 2021b).

Regarding the doses of top-dressed N, the number of pods per plant and grain yield varied with increasing dose of N (Table 3). According to the adjusted regression equation, maximum grain yield (2,565 kg ha^{-1}) would be achieved with the application of 136 kg ha^{-1} of N, regardless of the crop residue (Table 3). Souza and Soratto (2012) observed a response of the bean plant to the doses of N only when it was planted after maize intercropped with *Urochloa brizantha*, with the maximum yield obtained with the application of 113 kg ha^{-1} of N. In contrast, Binotti et al. (2010), who studied the effect of N doses of up to 80 kg ha^{-1} on bean yield, reported a linear response. Damian Junior et al. (2018) obtained a quadratic response of bean yield to N topdressing at doses of up to 180 kg ha^{-1}, and the maximum yield were obtained under the application of 106 kg ha^{-1}.

4 CONCLUSIONS

The C/N ratio in the maize crop residue was higher than that in the brachiaria crop residue. This result characterizes maize as a material with slower and more gradual decomposition compared to brachiaria, which had a higher N content because it was desiccated at the time of its full vegetative vigor. The highest grain yield was achieved when the common bean was cultivated on crop residue of brachiaria grown alone. The maximum grain yield in all those crop residues was obtained at a dose of 136 kg ha^{-1} of top-dressed N. These results demonstrate the effect of crop succession and nitrogen fertilization on the common bean agronomic performance in the no-tillage system, helping farmers and technicians in decision making.

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