Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
http://periodicos.ufersa.edu.br/index.php/sistema

ISSN 0100-316X (impresso)
ISSN 1983-2125 (online)
http://dx.doi.org/10.1590/1983-21252016v29n116rc

WINTER BEAN PRODUCTIVITY UNDER *UROCHLOA* STRAW FERTILIZED WITH NITROGEN[1]

NÍDIA RAQUEL COSTA[2*], MARCELO ANDREOTTI[3], KENY SAMEJIMA MASCARENHAS LOPES[3], KAZUO LEONARDO ALMEIDA YOKOBATAKE[4], CÉSAR GUSTAVO DA ROCHA LIMA[5]

ABSTRACT - An experiment was conducted during the years 2009 and 2010 to evaluate the effects of *Urochloa* forage straw and nitrogen fertilization on soil properties, nutritional foliar content, index of foliar chlorophyll (IFC) values, production components, and grains yields of winter bean (*Phaseolus vulgaris* 'Pérola') in the Cerrado lowlands region of Brazil. The treatments consisted of planting bean crops under straw of *Urochloa brizantha* 'Xaraés' and *Urochloa ruziziensis,* fertilized with urea-sourced N (0, 50, 100, 150, and 200 kg N ha^{-1}). The experimental design was randomized blocks with four replications, and a factorial scheme of 2 × 5. The greater yield of *U. brizantha* dry matter in the two years of evaluation increased bean leaf nutrient levels. The nutritional increase with increasing N application rates showed that the straw produced by the forages had a positive effect on bean nutrition. The grain yield was satisfactory but was not affected by the forage species nor by changes in the N application rates. The *Urochloa* straw increased the soil organic matter (SOM), Ca, and Mg content in both evaluated years, affected the decomposition and mineralization of organic residues, and ensured the proper development of the bean plants.

Keywords: Nitrogen fertilization. *Urochloa spp. Phaseolus vulgaris*. No-tillage system. Soil fertility.

PRODUTIVIDADE DO FEIJOEIRO DE INVERNO EM PALHADA ANTECESSORA DE BRAQUIÁRIAS ADUBADAS COM NITROGÊNIO

RESUMO - Um experimento foi realizado durante os anos de 2009 e 2010 para avaliar os efeitos da palhada de espécies forrageiras do gênero *Urochloa* e da adubação nitrogenada nos atributos químicos do solo durante duas safras (2009 e 2010) e nos teores foliares nutricionais, leituras ICF, os componentes da produção e produtividade de grãos do feijoeiro de inverno na região de Cerrado de baixa altitude. Os tratamentos foram constituídos da semeadura da cultura do feijão cv. Pérola sobre a palhada de *Urochloa brizantha* cv. Xaraés e *Urochloa ruziziensis*, adubadas com N (0, 50, 100, 150 e 200 kg N ha^{-1}) - fonte uréia. O delineamento experimental foi o de blocos casualizados com 4 repetições, em esquema fatorial 2x5. A maior produtividade de massa seca da *U. brizantha* nos dois anos em avaliação incrementou os teores de nutrientes foliares no feijoeiro. O incremento nutricional, com o aumento das doses de N foi verificado, demonstrando que a palhada produzida pelas espécies forrageiras foi determinante na boa nutrição do feijoeiro de inverno. A produtividade de grãos do feijoeiro foi satisfatória, entretanto, não houve efeito das doses de N e das espécies forrageiras cultivadas em antecessão. As espécies de *Urochloa* utilizadas aumentaram os teores de MO, Ca e Mg nos dois anos avaliados, efeito este da decomposição e mineralização dos resíduos vegetais, garantindo assim o bom desenvolvimento do feijoeiro.

Palavras-chave: Adubação nitrogenada. *Urochloa spp. Phaseolus vulgaris.* Sistema plantio direto. Fertilidade do solo.

---

[*] Corresponding author

[1] Received for publication in 06/22/2014; accepted in 12/21/2015.
Paper extracted from the masters dissertation of the first author.

[2] Department of Crop Science, College of Agricultural Science, Universidade Estadual Paulista, Botucatu, SP, Brazil; nidiarcosta@gmail.com.

[3] Department of Soil Science, College of Engineering, Universidade Estadual Paulista, Ilha Solteira, SP, Brazil; dreotti@agr.feis.unesp.br, keny.samejima@gmail.com.

[4] College of Animal Science and Food Engineering, Universidade de São Paulo, Pirassununga, SP, Brazil; kazuo.yokobatake@gmail.com.

[5] Department of Civil Engineering, College of Engineering, Universidade Estadual Paulista, Ilha Solteira, SP, Brazil; cesarlima@dec.feis.unesp.br.

INTRODUCTION

The common bean (*Phaseolus vulgaris*) is the most widely cultivated species of *Phaseolus* in the world, and Brazil is the largest producer (CONAB, 2015). Despite the low average grain yields in the country (approximately 850 kg ha^{-1}), the common bean has been tested in a variety of production systems, and productivity levels higher than 3000 kg ha^{-1} have been obtained, especially by winter crops in irrigated systems (KLUTHCOUSKI et al., 2005; CONAB, 2015). This crop is among the annual species that are well adapted to a no-tillage system (NTS), and it been the most important crop in terms of acreage in irrigated systems in the off-season (KLUTHCOUSKI; AIDAR, 2003).

The adoption of no-tillage systems is highly dependent on the production and maintenance of straw on the soil surface (MACEDO, 2009). The development of this cropping system has comparative advantages over traditional systems in agronomic, economic, and environmental terms. In tropical conditions, the major concerns in NT systems have been maintaining straw on the soil surface, and recycling the nutrients provided by the straw. Many studies have therefore searched for forage species that can serve this dual purpose, especially in Brazilian Cerrado conditions (KLUTHCOUSKI et al., 2007; PARIZ et al., 2011; COSTA et al., 2014a,b). According to Macedo (2009), any rational agriculture system should include species rotation as a basic priority for production stability. Furthermore, it is necessary to alternate plants with root systems that remove nutrients from the deeper layer of the soil profile, leaving them on the surface after straw decomposition and after harvesting so that the dead roots can increase water infiltration into the soil.

Different crops have been used as ground cover, and among the most promising are corn, sorghum, millet, and tropical perennial grasses (CRUSCIOL; BORGHI, 2007; MENEZES et al., 2009; PARIZ et al., 2011), intercropped or monocropped, including the species of the genus *Urochloa* (KLUTHCOUSKI et al., 2007; MACEDO, 2009; COSTA et al., 2014a,b). Growing these ground cover species with fertilization, especially with nitrogen, can increase dry matter yield, nutritional quality, and nutrient cycling in the growing area (PARIZ et al., 2011; COSTA et al., 2014a,b).

Crop residue decomposition is essential for nutrient cycling in NTS. Knowledge of decomposition dynamics in different growing conditions and under a variety of climate and soil conditions is therefore fundamental. Nutrients cycling in agricultural ecosystems results in more efficient nutrient use by crops and reduces negative impacts on the environment (KLIEMANN et al., 2006). The straw of grasses is also a supplier of nutrients, especially in the topsoil, to the succeeding crop over the medium and long term (SILVEIRA et al., 2005).

Research involving winter bean intercropping systems in the lowland Cerrado region is scarce, especially in succession or rotation with tropical grasses. It is known that the common bean is demanding of nitrogen, and the supply of that element can be influenced by the type of plant residue on the soil surface (straw), since waste with a high carbon/nitrogen ratio (C/N) can contribute to the immobilization of microbial N, and so interfere with crop yields (ANGHINONI, 2007; MINGOTTE et al., 2014). Thus, the correct management of nitrogen fertilization in current agriculture systems, especially in intercropped systems and their off-season forages that can later be used as straw under NTS, is relevant in order to meet the demand for nutrients in successive crops through the decomposition and mineralization of plants residues.

This study aimed to evaluate the effect of *Urochloa* straw fertilized with N on soil chemical properties, nutritional foliar content, index of foliar chlorophyll (IFC), the components of production, and the yield of winter beans grown in succession under irrigated conditions in the Brazilian Cerrado lowlands over two growing seasons (2009 and 2010).

MATERIAL AND METHODS

This experiment was conducted over two consecutive growing seasons (2009 and 2010) in Selvíria in the State of Mato Grosso do Sul, Brazil (20°18′S, 51°22′W, elevation 370 m), at a site belonging to the University of Engineering, Campus of Ilha Solteira (SP) – UNESP. The study site had been cultivated with annual crops and semi-evergreens (corn, soybeans, sorghum, dwarf pigeon pea, *Urochloa brizantha* 'Marandu', beans, rice, and corn) for 8 years using an NTS. The previous crop was composed of species of *Urochloa* intercropped with corn in the summer harvests of 2008-2009 and 2009-2010.

The soil in the study region was classified as a typic haplorthox (FAO 2006) clay soil containing 482, 140, and 378 g kg^{-1} of clay, silt, and sand, respectively, with soil density = 1.31 kg dm^{-3}, and macroporosity, microporosity, and total porosity = 0.147, 0.334, and 0.481 m^3 m^{-3}. Before initiating the experiment (September 2008), the soil chemical characteristics were evaluated at 20 points per hectare (0-0.20 m) according to the methods of Raij et al. (2001). The results showed pH values of 5.1; total soil organic matter of 28; P (resin) of 18 mg kg^{-1}; exchangeable K, Ca, Mg, and total acidity values at pH 7.0 (H + Al) of 3.2, 19.0, 11.0, and 22.2 mmol$_c$ kg^{-1}, respectively; and base saturations of 59.9%. The soil pH was determined in a 0.01 mol L^{-1} $CaCl_2$ suspension (1:2.5 soil/solution). P and exchangeable

Ca, Mg, and K were extracted using an ion exchange resin and then quantified using atomic absorption spectrophotometry. The base saturation values were calculated from the exchangeable base content, and the total acidity results were obtained at pH 7.0 (H + Al). The soil organic matter content was determined using a calorimetric method.

Irrigation was performed using center-pivot sprinklers when necessary throughout the experimental period. According to the Koppen climate classification system, the climate in the study region is classified as Aw, which is a tropical and humid climate with a rainy summer season and a dry winter. Figure 1 shows the minimum, mean, and maximum temperatures, monthly rainfall, and photoperiod during the experiment. These climate data are consistent with the historical averages for the region, which has a mean annual rainfall of 1370 mm, a mean temperature of 23.5°C, and relative humidity (RH%) between 70-80%.

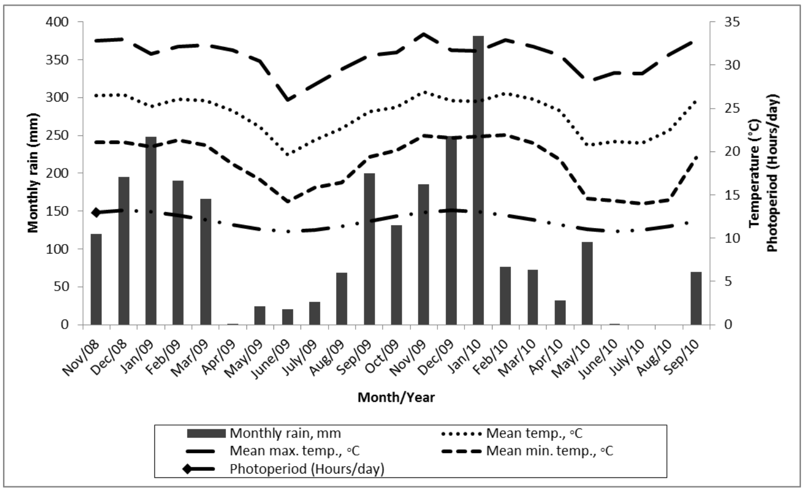

Figure 1. Climate data obtained from the UNESP weather station in Selvíria, Mato Grosso do Sul State, Brazil, from November 2008 to September 2010.

The experiment was conducted using a randomized complete block design with four replicates, and the treatments were distributed in a 2 × 5 factorial scheme. The treatments consisted of common bean crops (cultivar 'Pérola') sown on straw of two species of *Urochloa* (*Urochloa brizantha* 'Xaraés' and *Urochloa ruziziensis*) that was fertilized at rates of 0, 50, 100, 150, and 200 kg N ha^{-1} (45% urea-based N). The plots were 3.6 meters wide by 10 meters long, totaling 36 m^2. The usable area of plots was the four central rows; 0.5 m at the end of each plant row constituted the edge.

The sowing of forage species was done on the occasion of the corn intercropping on 18 November 2008 in the first growing season, and 4 November 2009 in the second growing season. After the corn was harvested on 25 March 2009 and 11 March 2010, corresponding to 121 days after emergence (DAE), the forage species was mechanically mowed to a height of approximately 0.25 m in relation to the soil surface. This management method aimed to stimulate tillering and standardize the phenological stage of grasses without removing any material; the remaining straw was left on the soil surface.

On 29 April 2009 and 15 April 2010, the forage species were fertilized with 0, 50, 100, 150, and 200 kg N ha^{-1}, applied manually, and then the area was irrigated in order to avoid excessive losses by volatilization of NH_3.

Sampling to determine forage dry matter production (FDMP) was carried out approximately 40 days after nitrogen fertilization in the two years evaluated (8 June 2009 and 25 May 2010). One square meter of forage was collected in three different locations in the plots with the aid of a metal square (1.00 m × 1.00 m), and 0.05 m of the soil surface was used as a reference to determining the residual dry matter (straw). A representative sample was dried using forced-air circulation at 65°C for 72 hours to determine the FDMP, and the resulting values were extrapolated into kilograms per hectare (kg ha^{-1}).

The plants were dried on 12 June 2009 and 2 June 2010 by applying glyphosate [isopropylamine salt of N-(phosphonomethyl) glycine] (1.44 g acid-equivalent ha^{-1}) at a spray volume of 200 L ha^{-1}, and on 22 June 2009 and 12 June 2010 the plants were crushed using a plant residue crusher. Subsequently, the common bean crop was sown on 19 June 2009 and 11 June 2010 using a no-till drill with a density of 15 seeds m^{-1} and a row spacing of 0.45 m. For all of the treatments and during both growing seasons, the basic fertilization in the sowing furrows consisted of 20 kg ha^{-1} N, 70 kg ha^{-1} P_2O_5, and 40 kg ha^{-1} K_2O in an 08-28-16 formula; assessments of soil fertility were made following the recommendations of Cantarella et al. (1997). The fungicide carboxin (5,6-dihydro-2-methyl-1,4-oxathiin-3-carboxamide) + thiram (tetramethylthiuram disulfide) was applied to the bean seeds at a dose of 60 g of active ingredient (a.i.) per 100 kg of seeds. The topdressing fertilization was between the common bean rows without incorporation (50 kg ha^{-1} of N as urea) during both growing seasons, approximately 30 days after emergence (DAE).

The insecticide lambda-cyhalothrin [α-cyano-3-phenoxybenzyl3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2-dimethylcyclopropanecarboxylate, a 1:1 mixture of the (Z)-(1 R, 3 R), S-ester and (Z)-(1S, 3S), R-ester] was applied at 7.5 g a.i. ha^{-1} at 32 and 64 DAE in both years. In the final application, the insecticide was mixed with the fungicide tebuconazole (α-[2-(4-chlorophenyl)ethyl]-α-(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol) at a dose of 200 g a.i. ha^{-1}.

At the time of common bean flowering about the V4-R5 growth stage, we determined the index of foliar chlorophyll (IFC) using portable digital chlorophyll equipment (CFL 1030, Falker) that allows instantaneous measurements on the leaf. Readings were taken on the third trifoliate leaf that was fully developed, with an average of 10 readings per leaflet from five plants per plot.

Petioles from 30 plants per plot were collected, washed, and then dried under forced air circulation at 65°C for 72 h before grinding and chemical composition analysis. Concentrations of N, P, K, Ca, Mg, and S were determined using the methods described by Malavolta et al. (1997). Nitrogen was extracted with H_2SO_4, and the other nutrients were extracted with a nitro-perchloric solution. The N concentration in the digested solution was determined by Kjeldahl analysis. The P, K, Ca, Mg, and S concentrations were determined by atomic absorption spectrophotometry.

The bean plants were harvested from the four central rows using a mechanical harvester for to determining the plot yields, on 17 September 2009 and 10 September 2010. The harvested plants were weighed and grain yields (GY) were corrected to a moisture content of 130 g kg^{-1}. The agronomic characteristics calculated included the final plant population (PP) (calculated per ha from the number of plants in the usable area in each plot), height of the first pod insertion (HFP), number of pods per plant (NPP), number of grains per pod (NGP) (evaluated for 10 randomly chosen plants per plot), and the 100-seed weight (W100) (calculated from eight random samples per plot). The final characterization of soil chemical attributes was conducted 50 days after drying the forage species in order to evaluate the effect of *Urochloa* straw decomposition on soil fertility from 0.0 to 0.20 m depth. Five simple soil samples were collected per plot in the bean crop interlines using the methodology of Raij et al. (2001).

The results were analyzed using an analysis of variance (ANOVA), and when the F-test indicated a significant result ($p \leq 0.05$), the means were compared using the least significant difference (Student's *t*-test) ($p \leq 0.05$). The effects of N application rates (prior to bean cultivation) were assessed by analysis of polynomial regression. The data for all of the variables were analyzed using an ANOVA and the statistical software package SISVAR (FERREIRA, 1999).

RESULTS AND DISCUSSION

Overall, there was no interaction between treatments in any attribute analyzed during the two growing seasons. Only foliar P and K differed significantly compared to the forage species in the first year (2009) and only the P, Ca, and IFC values differed significantly in the second year (2010) (Table 1). The highest values for the foliar nutrients were obtained when the common bean was grown on *U. brizantha* straw in both growing seasons, and in particular in 2009. This is probably due to the higher FDMP provided by this forage grass, ensuring a greater amount of nutrients are released by the straw, and thereby favoring the nutrition of the common beans in succession.

When increasing N was supplied to the forage species prior to the cultivation of common beans, there was an increase in foliar nutritional content of Ca and Mg in the first growing season (2009), and in N, Ca, and Mg in the second growing season (2010) (Table 1). This is due in part to the better nutritional quality by straw production related to nitrogen fertilization by foragers of *Urochloa* genus used in this study, as stated in the study conducted by Costa et al. (2014), under the same soil and climatic conditions as our experiment. Thus, due to the decomposition of the plant residues, nutrients are released and can be absorbed by the winter beans cultivated in succession.

The beneficial effects of tropical forages, especially the *Urochloa* species used in NTS, have been demonstrated in several studies in the literature under a variety of cropping systems (CRUSCIOL; BORGHI, 2007; GOMES JUNIOR et al., 2008; MENEZES et al., 2009; PARIZ et al., 2011; COSTA et al., 2014a,b; COSTA et al., 2015a,b). Its effects range from improvements in the physical and chemical attributes of the soil (COSTA et al., 2015b), better nutrition and development in succeeding crops (CRUSCIOL; BORGHI, 2007; GOMES JUNIOR et al., 2008; COSTA et al., 2015a), protection of the soil against erosion through the presence of the straw on the soil surface, control of pests and diseases (KLUTHCOUSKI et al., 2007), and general improvements in the cropping systems making them more sustainable (MACEDO, 2009).

Table 1. Common bean leaf concentrations of N, P, K, Ca, Mg, and S (g kg^{-1}), and index of foliar chlorophyll (IFC) and forage dry matter production (FDMP) during the 2009 and 2010 growing seasons.

Treatments	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**IFC**	**FDMP**
			(g kg^{-1})					(kg ha^{-1})
Forage species				**Growing season 2009**				
U. brizantha	40.3 a§	7.2 a*	25.1 a*	12.5 a	3.7 a	1.3 a	44.2 a	6000 a
U. ruziziensis	40.3 a	6.6 b	23.8 b	12.2 a	3.7 a	1.2 a	44.7 a	5600 a
N rates (kg ha^{-1})								
0	40.7	7.2	24.4	11.0$^{*\ (1)}$	3.5$^{**\ (2)}$	1.3	45.5	5575
50	38.8	7.0	24.9	10.8	3.3	1.3	44.0	5675
100	41.1	7.1	25.4	12.4	3.8	1.3	44.6	6050
150	39.3	6.5	24.0	13.6	3.9	1.2	43.9	5950
200	41.7	6.6	23.5	13.8	4.1	1.3	44.1	5900
VC (%)†	6.0	10.9	7.1	16.6	9.1	10.1	8.3	2.9
Forage species				**Growing season 2010**				
U. brizantha	23.9 a	1.9 a*	14.7 a	17.8 b*	3.7 a	1.5 a	47.9 a**	5650 a
U. ruziziensis	24.1 a	1.8 b	16.3 a	19.4 a	4.0 a	1.5 a	41.8 b	4995 a
N rates (kg ha^{-1})								
0	21.9$^{*\ (3)}$	1.9	15.5	15.1$^{**\ (4)}$	2.8$^{**\ (5)}$	1.4	43.0	5130
50	23.4	1.8	16.9	16.2	3.2	1.4	46.3	5255
100	25.5	1.9	13.7	19.3	4.3	1.5	44.1	5900
150	24.6	1.9	14.9	20.1	4.3	1.5	45.2	5420
200	24.9	1.9	16.5	22.2	4.8	1.5	45.6	5375
VC (%)	8.2	8.8	18.1	11.2	12.7	9.2	9.5	19.3

§ Values followed by the same letter are not significantly different at $p \leq 0.05$ according to Student's *t*-test.

**, * are $p < 0.01$ and $p < 0.05$, respectively.

†VC = Variation coefficient.

$^{(1)}Ca = 10.65 + 0.0166N$ ($r^2 = 0.901^{**}$)

$^{(2)}Mg = 3.32 + 0.0039N$ ($r^2 = 0.831^{**}$)

$^{(3)}N = 22.54 + 0.01457N$ ($r^2 = 0.761^{**}$)

$^{(4)}Ca = 14.96 + 0.0363N$ ($r^2 = 0.972^{**}$)

$^{(5)}Mg = 2.85 + 0.01023N$ ($r^2 = 0.923^{**}$)

The bean leaf nutrient content (Table 1) was higher than recommended by Malavolta et al. (1997). This shows that even in the absence of nitrogen fertilizer, the grass straw was able to provide nutrients to the common bean crop grown in succession. This may be due to the increased availability of organic matter as a result of forage plant decomposition and an increase in nutrient availability in the soil. Also because the common bean coverage was fertilized with 50 kg N ha^{-1}, and this it was performed because there was a lots of straw (Table 1) on the soil surface (grasses high C/N relationship), which could lead to nutrient deficiency by microbial immobilization N.

According to Volpe et al. (2008), N deficiency is greater in NTS than in conventional systems, and crop rotation involving legumes or grasses (lower C/N) reduces the intensity of nutritional disabilities, providing improved productivity and reduced fertilizer costs. Silveira et al. (2005) report that although large amounts of N may be contained in the shoots of crops referred to as ground cover, the actual amount of N taken advantage of by the successor crop will depend on the timing of the biomass decomposition and the demand rates of the successor crop.

The IFC in bean leaves was not influenced by nitrogen fertilization or forage grass, nor was foliar N (Table 1). Chlorophyll content (IFC) constitutes a promising alternative for assessing the nutritional status of N in plants and it can support more efficient management of nitrogen fertilization. In addition, it can allow for the synchronization of N application with the nutritional demands of the plants.

Usually there is a high correlation between N content and chlorophyll in common bean leaves, because N is part of the chlorophyll molecule. Thus, a leaf nitrogen increase may reflect directly on the IFC values. This shows the potential for non-destructive indirect measurement of chlorophyll as a means to estimate the need for N by common bean plants. However, in this study we did not find a significant influence of N application rates or a linear correlation between leaf N content and IFC readings, nor between these values and bean grain yield. This fact is probably due to the history of this agricultural area under NTS (8-9 years), during which time there has been an increase in soil organic matter and nutrients, including N, as a result of straw accumulation and the mineral fertilizer application (possible residual effect, in a clay soil), can be adequately provided this nutrient for common bean, reducing the effect fertilization on the IFC values, because not every N absorbed is allocated for the chlorophyll production.

Research by Mingotte et al. (2014), evaluating the effect of straw in different production systems (corn, *U. ruziziensis,* and corn + *U.*

ruziziensis intercropped) with beans in succession, also did not verify the effect of straw on IFC values in common bean leaves. According to these authors, the indirect measurement of chlorophyll content is less able to identify possible deficiencies of N in bean leaves in comparison to direct chemical analysis (foliar N content). Thus, further studies are recommended with this equipment in different cropping systems to ensure more efficient nitrogen fertilization management in cash crops.

In relation to forage dry matter production (FDMP) prior to common bean cultivation (Table 1), we found no significant differences between treatments. After five years under NTS with crop rotation (mainly legumes and forage grasses with large straw production potential, such as *Urochloa*), soil N immobilization and mineralization are similar (ANGHINONI, 2007). According to the same authors, after ten years under NTS, as in our study, the immobilization becomes smaller than the mineralization, thereby providing suitable nutrient cycling in the soil. The lack of effect of nitrogen fertilization on FDMP is due to the management history of the experimental area (8-9 years under NTS), which underwent rotation of corn, soybeans, sorghum, dwarf pigeon pea, *Urochloa brizantha*, and beans, and had a supply of mineral fertilizers (with probable residual effects) added to the cropping system throughout the year.

According to Pariz et al. (2011) and Costa et al. (2014a,b), in intercropping systems of production and in integrated crop-livestock systems (ICLS), the use of nitrogen fertilizer after the harvest of grain-producing crops may increase the availability of the element in the system, providing faster pasture establishment and increased FDMP over a cut/grazing system in the off-season. However, the FDMP depends upon weather conditions and crop management under NTS, as seen in the present study (Table 1).

According to Kluthcouski et al. (2007), the presence of straw on the soil surface benefits the cultivation of crops in succession, mainly due to improvement in chemical, physical, and biological soil attributes, and it also increases the water storage capacity and improves coverage on the surface.

The plant population (PP), number of grains per plant (NGP), and height of the first pod (HFP) were not changed by the cultivation of *Urochloa* species, but the number of pods per plant (NPP) and the weight of 100 seeds (W100) in the first growing season did change (Table 2). With respect to the N supplied to the forage prior to common bean cultivation, this had a significant influence only during the second year of evaluation (2010) and only on the number of pods per plant (NPP).

Table 2. Plant population (PP), number of pods per plant (NPP), number of grains per plant (NGP), height of first pod (HFP), weight of 100 seeds (W100), and grain yield (GY) of common bean during the 2009 and 2010 growing seasons.

Treatments	**PP** (n × 1000)	**NPP** (n)	**NGP** (n)	**HFP** (cm)	**W100** (g)	**GY** (kg ha^{-1})
Forage species			**Growing season 2009**			
U. brizantha	277.8 a[§]	9.8 b[*]	46.5 a	9.7 a	20.9 b[**]	3971 a
U. ruziziensis	274.4 a	11.6 a	52.2 a	9.2 a	22.6 a	4250 a
N rates (kg ha^{-1})						
0	286.4	12.2	57.0	9.1	21.8	3850
50	287.5	10.5	44.5	9.1	21.7	4309
100	272.2	10.5	46.4	9.5	22.3	4115
150	276.4	10.2	47.6	9.9	21.5	4216
200	258.3	11.1	51.2	9.7	21.3	4062
VC (%)[†]	11.5	23.6	26.5	20.3	7.5	13.2
Forage species			**Growing season 2010**			
U. brizantha	267.5 a	13.0 a	63.1 a	9.7 a	23.9 a	3254 a
U. ruziziensis	263.1 a	12.5 a	60.0 a	9.6 a	24.1 a	3454 a
N rates (kg ha^{-1})						
0	264.0	10.3[*] (1)	49.3	8.5	23.2	3632
50	273.7	12.3	55.9	8.9	24.5	3284
100	274.0	12.2	61.1	9.3	23.6	3330
150	270.1	14.8	73.7	9.0	23.8	3830
200	269.4	14.4	67.8	9.1	24.9	3693
VC %	13.1	21.1	21.4	8.3	6.7	22.3

[§] Values followed by the same letter are not significantly different at $p \leq 0.05$ according to Student's *t*-test.
[**], [*] are $p < 0.01$ and $p < 0.05$, respectively.
[†] VC = Variation coefficient.
(1) NVP = 10.64 + 0.0215N ($r^2 = 0.858$**).

The number of pods per plant (NPP) and the weight of 100 seeds (W100) in the first growing season (2009) were influenced by the choice of forage grass, and the best results were obtained when the bean was grown on *U. ruziziensis* straw (Table 2). This forage species showed better nutritional composition than *U. brizantha* (COSTA et al., 2014a,b) and produced greater nutrient cycling, thus favoring the development of the subsequent bean crop.

Nitrogen application did not significantly alter the production results of common bean grain yield in either cropping season (Table 2), except with respect to NPP. This can be attributed in part to the straw decomposition process of these cover crops combined with nitrogen fertilization, which probably supplied the beans' demand for this nutrient and ensured high productivity. Gomes Junior et al. (2008) reported a return of 17 kg N per megagram of straw from *Urochloa brizantha* 'Xaraés'. The nutrient recycling process may therefore have provided sufficient amounts of N to the bean plants, to the point of canceling the effects of mineral N application.

Bean plants cultivated in the NTS under straw increased in productivity. Soils under continuous cultivation, especially in NTS, tend, over time, to accumulate nutrients that can be exploited by the roots, making responses to fertilization with other macro and micronutrients less frequent (KLUTHCOUSKI et al., 2005). Therefore, after a history of eight years under NTS in the experimental area, the grain yield at this site was satisfactory (3254 to 4309 kg ha^{-1}) and above the winter-crop national average of 1284 kg ha^{-1} (CONAB, 2015) in the two growing seasons evaluated. However, there was no effect from either previous N application or forage species (Table 2), even with the *U. ruziziensis* having provided increments in the number of pods per plant (NPP) and weight of 100 seeds (W100), one since the components of production shall have general additive effect and not just some of them.

Several studies have evaluated winter bean production under NTS and reported on the benefits of this system with respect to the components of production and grain yield, as we also found in this study. Silveira et al. (2005) obtained a common bean yield with cultivar 'Pérola' of 1504 kg ha^{-1} on *Urochloa* straw. Valderrama et al. (2009), evaluating the effect of N and P_2O_5 rates on the components of production and grain productivity with 'Pérola' under NTS in an area where rice was previously cultivated, and with similar soil and climatic conditions to those in our study, obtained production levels of 2016-2312 kg ha^{-1}. Mingotte et al. (2014) evaluated the effects of cropping systems with corn, *Urochloa ruziziensis,* and intercropping between both species on subsequent bean production under different levels of nitrogen application, and they found a positive effect of straw under the intercropping system, giving the beans an average grain yield of 2979 kg ha^{-1}. It should be noted that these results are lower than those obtained in this study (Table 2), demonstrating once again the efficiency of the production system in the Cerrado lowlands region.

Soil fertility plays an important role in plant development, productivity, and nutrient concentration in the leaves (leaf blade). We found that during the development of the bean crop (Table 3), after fertilization of the *Urochloa* species and straw decomposition (around 50 days after grass harvesting, in both growing seasons), there was a positive effect of forage plants in improving the levels of some soil nutrients, especially calcium (Ca) and magnesium (Mg), compared to the conditions existing prior to the experiment.

We also observed a significant effect of forage species on soil organic matter (SOM); this was due to straw decomposition, which influenced the CEC (cation exchange capacity) values. The best results were found in soil where the cover crop was *U. brizantha* (Table 3), most probably due to the FDMP provided by this forage species (Table 1). In a study conducted by Costa et al. (2015), in similar soil and climatic conditions as the present study, the authors evaluated three species of forage crops (sorghum, millet, and xaraés grass) at different sowing times and concluded that forage species used as cover crops (straw) influenced the productivity of soybean in succession and improved soil chemical quality, increasing the CEC and SOM values in the soil.

The nitrogen application rates used on the forages prior to bean planting did not have any significant effect on soil chemical properties in the two years evaluated (Table 3). The main relationship between soil fertility and nitrogen availability derives from an increase in soil organic matter (ANGHINONI, 2007). The straw decomposition of forage species probably provided adequate amounts of this nutrient to the succeeding bean plants through the decomposition process. In addition, nitrogen fertilization in pastures can improve the performance of crops sown in succession due to the utilization of residual N, especially in clay soils similar to those present at our experimental site.

Table 3. Soil chemical characteristics at the experimental site at 0-0.20 m depth, 50 days after cutting of forages fertilized with nitrogen and prior to common bean cultivation, during the 2009 and 2010 growing seasons.

Treatments	P (resin)	SOM‡	pH	K_{ex}	Ca_{ex}	Mg_{ex}	H + Al	CEC††	BS‡‡
	(mg dm^{-3})	(g dm^{-3})	($CaCl_2$)			(mmol$_c$ dm^{-3})			(%)
Forage species					**Growing season 2009**				
U. brizantha	16.2 a§	23.2 a**	5.0 a	2.3 a	21.5 a*	13.3 a*	34.0 a	71.1 a**	51.8 a
U. ruziziensis	13.1 a	21.0 b	4.9 a	2.2 a	17.8 b	11.6 b	33.7 a	65.3 b	48.2 a
N rates (kg ha^{-1})									
0	13.4	22.9	5.1	2.1	20.6	13.4	33.5	69.6	51.5
50	12.5	22.1	5.0	2.4	19.5	12.8	33.0	67.4	51.0
100	13.3	22.1	4.9	2.2	16.9	11.0	35.3	65.3	46.0
150	13.6	21.6	5.1	2.1	21.5	12.8	33.0	69.3	51.8
200	20.6	21.9	4.9	2.2	19.9	12.4	34.7	69.2	49.9
VC (%)†	49.8	7.7	4.5	31.4	23.2	21.4	14.0	6.7	15.9
Forage species					**Growing season 2010**				
U. brizantha	19.2 a	23.1 a**	4.9 a*	1.5	22.9 a*	12.1 a*	34.3	70.9 a**	51.4a*
U. ruziziensis	21.9 a	21.3 b	4.8 b	1.8	17.7 b	10.7 b	36.2	65.9 b	44.9b
N rates (kg ha^{-1})									
0	22.9	22.4	4.9	1.9	19.8	11.4	36.1	69.1	47.2
50	27.4	22.8	4.9	1.6	21.3	11.6	36.1	70.7	48.4
100	19.0	21.5	4.9	1.6	19.0	10.9	34.5	65.9	47.6
150	18.6	21.6	4.8	1.5	20.6	11.0	35.8	68.9	47.6
200	15.0	22.8	4.9	1.7	20.6	11.9	33.5	67.4	50.1
VC (%)	48.2	7.2	4.8	45.3	25.8	19.0	13.9	5.7	17.9

[§] Values followed by the same letter are not significantly different at $p \leq 0.05$ according to Student's *t*-test.

**,*are $p < 0.01$ and $p < 0.05$, respectively.

[†] VC = Variation coefficient.

[‡] Soil organic matter.

[††] Cation exchange capacity.

[‡‡] Base saturation.

According to Kluthcouski et al. (2005), the N that can be made available to most legume species cultivated in succession, and which defines in part their productive potential, comes from soil organic matter that is generated through the recycling of straw from previous crops and the residual effect of nitrogen fertilizer (mineral or organic). Therefore, the maintenance or improvement of physical and chemical soil attributes in NTS, and the choice and use of cover crops, is of fundamental importance, since they generate the waste that contributes to soil erosion protection, root growth, straw decomposition, soil modification, and the recycling of nutrients that can be used by plants in succession (KLUTHCOUSKI; AIDAR, 2003).

According to the results obtained in this study, when the cultivated area had been under NTS for eight years at the implementation time of the experiment, the N was probably being mineralized (ANGHINONI, 2007), and SOM, phosphorus, and straw were accumulating on the soil surface. The *Urochloa* species used as cover crops in this research thus provided satisfactory nutrients for the common beans, since after management, was time to occur straw decomposition by forages, which together with the SOM mineralization was increment nutrients in the soil, thus contributing to good growth and higher grain yields in winter beans.

CONCLUSIONS

The greater yield of *U. brizantha* dry matter in the two years of evaluation increased leaf nutrient content and IFC values in winter bean. There was a nutritional increase in the bean leaf, depending upon previous N application rates, especially with respect to N, Ca, and Mg content, demonstrating that the straw produced by the forage grass was decisive for the good nutrition of the winter bean.

The grain yield was satisfactory and above the national average, and it was not affected by N application rates or the previously grown forage species.

The *Urochloa* species studied improved soil fertility and increased the SOM, Ca, and Mg levels derived from straw decomposition and mineralization, thus ensuring the appropriate development of the bean plants. There was no effect of different N application rates applied to the forage species prior to bean cultivation.

REFERENCES

ANGHINONI, I. Fertilidade do solo e seu manejo em sistema plantio direto. In: NOVAIS, R. F. et al.

(Ed.). **Fertilidade do solo**. Viçosa: SBCS, 2007. p. 873-928.

CANTARELLA, H.; RAIJ. B. van.; CAMARGO, C.E.O. Cereais. In: RAIJ, B. van.; CANTARELLA, H.; QUAGGIO, J.A.; FURLANI, A.M.C. (Eds.). **Boletim Técnico 100: Recomendação de Adubação e Calagem para o Estado de São Paulo.** 2.ed. Campinas: Instituto Agronômico; IAC, 1997. p. 43-71.

COMPANHIA NACIONAL DE ABASTECIMENTO (CONAB). **Acompanhamento da safra brasileira de grãos,** v. 2 – Safra 2014/15, n. 4 – Quarto Levantamento, jan. 2015. 1 Disponível em: <http://www.conab.gov.br>. Acesso em: 14 jun. 2015.

COSTA, N. R. et al. Acúmulo de macronutrientes e decomposição da palhada de braquiárias em razão da adubação nitrogenada durante e após o consórcio com a cultura do milho. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 38, n. 4, p. 1223-1233, 2014a.

COSTA, N. R. et al. Adubação nitrogenada em capins do gênero *Urochloa* implantados em consórcio com a cultura do milho. **Revista Brasileira de Ciências Agrárias**, Recife, v. 9, n. 3, p. 376-383, 2014b.

COSTA, N. R. et al. Produtividade da soja sobre palhada de forrageiras semeadas em diferentes épocas e alterações químicas no solo. **Revista Brasileira de Ciências Agrárias**, Recife, v. 10, n. 1, p. 8-16, 2015a.

COSTA, N. R. et al. Atributos do solo e acúmulo de carbono na integração lavoura-pecuária em sistema plantio direto. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 39, n. 3, p. 852-863, 2015b.

CRUSCIOL, C. A. C.; BORGHI, E. Consórcio de milho com braquiária: produção de palhada para o plantio direto. **Revista Plantio Direto**, Passo Fundo, v. 1, n. 100, p. 10-14, 2007.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA – EMBRAPA. **Sistema brasileiro de classificação de solos**. 2.ed. Rio de Janeiro, RJ: CNPS, 2006. 306 p.

FERREIRA, D.F. **SISVAR:** Sistema de análise de variância. Lavras: UFLA/DEX, 1999.

GOMES JUNIOR, F. G.; SÁ, M. E.; VALÉRIO FILHO, W. V. Nitrogênio no feijoeiro em sistema plantio direto sobre gramíneas. **Acta Scientiarum: Agronomy**, Maringá, v. 30, n. 3, p. 387-395, 2008.

KLIEMANN, H. J.; BRAZ, A. J. B. P.; SILVEIRA, P. M. Taxa de composição de resíduos de espécies de cobertura em Latossolo Vermelho Distroférrico**. Pesquisa Agropecuária Tropical**, Goiânia, v. 36. n. 1. p. 21-28, 2006.

KLUTHCOUSKI, J.; AIDAR, H. Implantação, condução e resultados obtidos com o sistema santa fé. In: KLUTHCOUSKI, J.; STONE, L. F.; AIDAR, H. **Integração lavoura-pecuária.** Santo Antônio de Goiás: Embrapa Arroz e Feijão, 2003. v. 1, cap.15, p. 409-441.

KLUTHCOUSKI, J. et al. **Manejo antecipado do nitrogênio nas principais culturas anuais**. 21. ed. Santo Antônio de Goiás: Embrapa Arroz e Feijão, 2005. 63 p. (Documentos / Embrapa Arroz e Feijão, 188).

KLUTHCOUSKI, J.; AIDAR, H.; COBUCCI, T. Opções e vantagens da integração lavoura-pecuária a produção de forragens na entressafra. **Informe Agropecuário**, Belo Horizonte, v. 28, n. 240, p. 16-29, 2007.

MALAVOLTA, E.; VITTI, G. C.; OLIVEIRA, S. A. **Avaliação do estado nutricional das plantas: princípios e aplicações.** 2.ed. Piracicaba, SP: Associação Brasileira para Pesquisa da Potassa e do Fosfato, 1997. 319 p.

MACEDO, M. C. M. M. Integração lavoura e pecuária: o estado da arte e inovações tecnológicas. **Revista Brasileira de Zootecnia**, Viçosa, v. 38, n. especial, p. 133-146, 2009.

MENEZES, L. A. S. et al. Produção de fitomassa de diferentes espécies, isoladas e consorciadas, com potencial de utilização para cobertura do solo. **Bioscience Journal**, Uberlândia, v. 25, n. 1, p. 7-12, 2009.

MINGOTTE, F. L. C. et al. Sistemas de cultivo antecessores e doses de nitrogênio em cobertura no feijoeiro em plantio direto. **Bioscience Journal**, Uberlândia, v. 30, n. 5, p. 696-706, 2014.

PARIZ, C. M. et al. Straw decomposition of nitrogen -fertilized grasses intercropped with irrigated maize in integrated crop livestock system. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 35, n. 6, p. 2029-2037, 2011.

SILVEIRA, P. M. et al. Adubação nitrogenada no feijoeiro cultivado sob plantio direto em sucessão de culturas. **Pesquisa Agropecuária Brasileira**, Brasília, v. 40, n. 4, p. 377-381, 2005.

VALDERRAMA, M. et al. Fontes e doses de nitrogênio e fósforo em feijoeiro no sistema plantio direto. **Pesquisa Agropecuária Tropical,** Goiânia, v. 39, n. 3, p. 191-196, 2009.

VOLPE, E. et al. Renovação de pastagem degradada com calagem, adubação e leguminosa consorciada em Neossolo Quartzarênico. **Acta Scientiarum Agronomy,** Maringá, v. 30, n. 1, p. 131-138, 2008.