DOI: 10.5433/1679-0359.2018v39n6p2501

Maize silage intercropped with grass and pigeon pea subjected to different N rates and pasture development in the offseason

Silagem de milho consorciado com capim e feijão guandu submetidos a doses de N e desenvolvimento da pastagem na entressafra

Stephanie Vicente de Bessa[1]; Clarice Backes[2]; Alessandro José Marques Santos[2]; Lucas Matheus Rodrigues[3]*; Arthur Gabriel Teodoro[3]; Danilo Augusto Tomazello[4]; Paulo Renato de Rezende[1]; Adriana Aparecida Ribon[2]; Lorrayne Lays Ferreira Leite[1]; Pedro Rogério Giongo[2]

Abstract

The objective of this study was to evaluate the effect of the rates of nitrogen topdressing applied to an intercrop of maize (M) with paiaguás grass (G) and pigeon pea (P) on silage production and pasture development in the offseason. The treatments consisted of two simultaneous intercropping systems (M + G; and M + G + P) and four rates of N topdressing (0, 80, 160, and 240 kg ha^{-1}). The introduction of pigeon pea to the system and the increasing N rates resulted in increased yield and protein density. Pigeon pea responded to nitrogen fertilization with good regrowth and good dry matter yields in the intercrop. N rates of 240 kg ha^{-1} N for M+G and 120 kg ha^{-1} for M+G+P can be recommended for making silage. Nitrogen rates promote an increase in the dry matter yield of the grass and pigeon pea, resulting in improvements in the pasture during the offseason.
Key words: Fertilization. Forages. Integrated System. Legumes.

Resumo

Objetivou-se com este trabalho avaliar o efeito da aplicação de doses de nitrogênio em cobertura do milho em consórcio do capim-paiaguás e feijão guandu na produção de silagem e no desenvolvimento da pastagem na entressafra. Os tratamentos foram constituídos por dois sistemas de consórcio simultâneos (milho + capim-paiaguás e milho + capim-paiaguás + feijão guandu) e quatro doses de N aplicadas em cobertura (0, 80, 160 e 240 kg ha^{-1}). A introdução do guandu no sistema e o aumento das doses de N proporcionam ganhos em produtividade e densidade protéica. O feijão guandu respondeu a adubação nitrogenada produzindo boa rebrota e boa produção de matéria em consórcio. A forrageira se desenvolveu menos quando o guandu foi adicionado no sistema. Para produção da silagem podem ser recomendadas as doses de 240 kg ha^{-1} de N para M+C e 120 kg ha^{-1} para M+C+G. As doses de N

[1] Mestres em Desenvolvimento Rural Sustentável, Universidade Estadual de Goiás, UEG, São Luís de Montes Belos Goiás, Brasil. E-mail: stephaniebessa86@gmail.com; pr.rezende89@gmail.com; lorraynnelays@hotmail.com;
[2] Profs. Drs., Pós-Graduação em Desenvolvimento Rural Sustentável, UEG, São Luís de Montes Belos, GO, Brasil. E-mail: clarice.backes@ueg.br; alessandro.santos@ueg.br; adriana.ribon@ueg.br; pedro.giongo@ueg.br
[3] Discentes, Curso de Mestrado do Programa de Pós-Graduação em Desenvolvimento Rural Sustentável, UEG, São Luís de Montes Belos Goiás, Brasil. E-mail: lucasmrzoo@gmail.com; arthur_teodoro@hotmail.com
[4] Discente, Curso de Doutorado do Programa de Pós-Graduação em Zootecnia, UFG, Goiânia, Brasil. E-mail: tomazello@yahoo.com.br
* Author for correspondence

Received: Dec. 01, 2017 - Approved: July 06, 2018

promovem aumento da matéria seca do capim e do feijão guandu resultando em melhorias na pastagem na entressafra.
Palavras-chave: Adubação. Leguminosas. Forrageiras. Sistemas integrados.

Introduction

Integrated crops provide economic and environmental improvements and increase production efficiency, which is particularly notable in the intercropping of maize and grasses. During silage production, the maize plant shoots are removed to prevent the accumulation of straw. However, the intercropping with grasses makes it possible to supply feed to grazing animals during the offseason and roughage material for the system (CECCON, 2013). Up to 12 t ha^{-1} of dry matter is accumulated after the harvest of maize (CRUSCIOL et al., 2009).

The literature presents positive results from the intercropping of maize with forage plants for both grain yield and silage production. Almeida et al. (2017) evaluated an intercropping system of maize with two cultivars of *Panicum maximum*: cv. Massai and cv. Tanzania. They observed no differences in growth, grain yield, or N concentration in the maize leaves. Pariz et al. (2017) pointed out that the intercropping of maize and marandu grass leads to an increase in silage production and the forage itself when compared with monocrops. The optimal values were obtained at a harvest height of 0.45 m. Seidel et al. (2014) studied the intercropping of maize and *Urochloa brizantha* cv. MG-4 and did not observe differences from the maize monocrop. According to Borghi et al. (2013), the development and production of forage are favored by intercropping with maize.

Nitrogen fertilization has a positive effect on the yield of maize crops in that it improves vegetative growth and grain development (AFSAR et al., 2017). For the *Cerrado* region, the recommended rates for seeding range from 20 to 30 kg ha^{-1} as topdressing, which may reach up to 180 kg ha^{-1} (SOUSA; LOBATO, 2004; ALVES et al., 1999). Fertilizer rates may vary with the introduction of grass in an intercropping with maize when taking into account the nutritional requirements and the form of growth of the forage. No information is available to define a recommended rate for the system. Costa et al. (2012a) found positive responses from intercrops of maize and forage with N rates of up to 200 kg ha^{-1}.

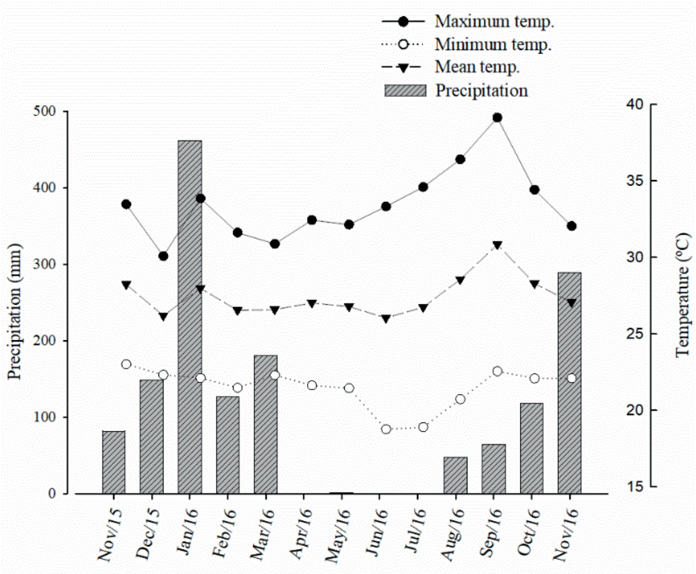
Maize silage has advantages as animal feed in terms of preservation and storage for use during the dry period of the year, when forage is scarce. However, maize silage may have limitations such as low crude protein (CP) content. An alternative to address this problem is intercropping grasses with legumes to increase the nutritional value of silage, which depends on the species and quantity of mass produced. Costa et al. (2012b) observed that introducing legumes did not influence the CP contents of maize silage because of the low proportions used in the process: 4.3% *Calopogonium mucunoides*, 2.8% *Macrotyloma axillare*, and 1.2% *Stylozanthes capitata*. Evangelista et al. (2005) intercropped sorghum with leucaena and found that the CP contents rose from 4.5 to 10.3% with the inclusion of 40% leucaena in the ensiled mass.

In addition to possibly improving the silage quality, legumes also provide nitrogen to the system through N-fixing bacteria. According to Hungria et al. (2010), there is increasing interest in the use of symbiotic bacteria with the rising costs of fertilizers, in addition to the remarkable sustainability appeal and reduction of environmental impact. Of the many legume species, pigeon pea stands out for its nutritional qualities with CP contents ranging from 16 to 20% in the leaves, as well as its finer branches (COSTA et al., 2001). The objective of this study was to evaluate the effect of nitrogen topdressing rates applied to maize intercropped with paiaguás grass and pigeon pea on silage production and pasture development during the offseason.

Materials and Methods

Experiments were carried out in São Luís de Montes Belos, Goiás, Brazil (16º32'30" S, 50º25'21" W; 569 m asl). The region has an Aw-type climate according to the Köppen classification, as well as an average temperature of 23.5ºC and temperature range of 20.7ºC (June) to 25.0ºC (December). The average annual precipitation is 1785 mm with 87% concentrated between October and March and an average of four months of rain scarcity (ALVARES et al., 2013). Precipitation and temperature data were collected during the experimental period (Figure 1).

Figure 1. Temperature and precipitation in the municipality of São Luís de Montes Belos during the experimental period (November 2015 to November 2016).



The soil in the experimental area is a dystrophic red latosol (EMBRAPA, 2013) with a mild wavy relief. The original vegetation in the area was a *strictu sensu Cerrado* biome, and the area was lying fallow. The soil chemical analysis had the following results before the establishment of the experiment: pH 5.1 ($CaCl_2$). 30 g dm^{-3} of organic matter, 4 mg dm^{-3} of P (resin), 32, 1.3, 32, and 6 mmol$_c$ dm^{-3} of H^++Al^{+3}, K, Ca, and Mg, respectively, and 55% base saturation. The soil particle sizes were 260, 450, and 290 g kg^{-1} for sand, clay, and silt, respectively.

A randomized-block design with a 2 × 4 factorial arrangement was adopted with four replicates. The treatments consisted of two simultaneous intercropping systems (maize [M] + paiaguás grass [G] and M + P + pigeon pea [P]), as well as four N rates applied as topdressing (0, 80, 160, and 240 kg ha^{-1}). The plots had a total area of 21 m^2 with six 5-m-long rows of maize. The usable plot area was considered the four center rows while disregarding half a meter at each extremity.

The single-cross maize hybrid Agroeste was used for making silage, which included the whole plant. The forage species used was paiaguás grass cv. BRS Paiaguás {*Urochloa brizantha* (Hochst. ex A. Rich.) R. D. Webster cv. Paiaguás [syn. *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf cv. Paiaguás]}, and the legume was pigeon pea cv. BRS Mandarim. The soil in the experimental area was conventionally prepared with two harrowing sessions. Limestone was applied manually on the soil surface and incorporated in the second harrowing event. The area received 1.2 t ha^{-1} of calcitic limestone (PRNT 92.54%) to elevate the base saturation to 70%.

The maize crop was sown mechanically by a seeder-fertilizer machine with 0.70-m spacing and five seeds per meter to reach a final stand of 60,000 plants per hectare. Seeds of the forage plant were mixed with the fertilizer and placed in the fertilizer compartment of the seeder to be deposited at a depth of 0.08 m beneath the maize seeds at 5.2 kg ha^{-1} with a percentage of pure live seed of 46%. The pigeon pea was planted manually in the maize inter-row using 10 seeds per meter.

For base fertilization in the seeding furrow, the 05-25-15 NPK formulation was used at a rate of 400 kg ha^{-1}. Nitrogen topdressing at rates of 0, 80, 160, and 240 kg ha^{-1} was applied in two steps when the maize plants reached phenological stages V4 and V8 (with four and eight developed leaves, respectively). The nitrogen fertilizers adopted were urea (45% N) and ammonium sulfate (20% N) in the first application, and the aim was to provide 30 kg ha^{-1} of sulfur. In the second application, only urea was used. The applications were done manually near the maize row on the soil surface, and the material was later incorporated to prevent excess N loss by volatilization. In the first topdressing, potassium fertilizer was also applied at a K_2O rate of 60 kg ha^{-1} using potassium chloride (60% K_2O).

In the flowering period after the appearance of the female inflorescence, the green color intensity (GCI) of the leaves was read using a Falker digital chlorophyll absorbance meter. The readings were taken from the middle third of the leaves from the base of the ear at two points in the central part using 10 leaves per plot. For the leaf diagnosis, the middle third of the 10 evaluated leaves was collected and used in the determination of the concentrations of N, P, K, Ca, Mg, and S (MALAVOLTA et al., 1997).

The plants were harvested for silage production during the dent reproduction stage of maize. The cycle up to the collection of the maize crop for ensiling was 83 days after emergence. At that point, we measured agronomic traits of maize such as plant height (cm), height of ear insertion (cm), stem diameter (mm), final stand, and ear index. After these assessments, the maize plants, grass, and pigeon pea were cut manually at a height of approximately 0.45 m in the center rows at lengths of 2 m long per plot using the usable area of the plots. The cut plants were ground, and a representative sample was dried in a forced-air oven at 65ºC for 72 h to determine the total dry matter yield of forage extrapolated to kg ha^{-1}.

A part of the ground mass was kept in mini-silos made of PVC tubes (55-cm length × 15-cm diameter) at a density of 600 kg m^{-3}. After 31 days, the silos were opened, and the central samples were removed and analyzed for their chemical properties. We determined the fiber (neutral and acid detergent fiber) ether extract, CP, ash, dry matter, organic matter, and non-nitrogen extract contents in the silage. The total CP was determined by calculating the concentrations in the dry mass of the silage.

The following variables were determined during the harvest of the maize. The dry matter of paiaguás grass shoots was determined by collecting the plants at 0.20 m from the soil surface from two meters of the usable area. The dry matter of maize plants was determined by collecting five random plants from the usable area of the plot at 0.45 m from the soil surface. The dry matter of the pigeon pea shoots was determined by randomly collecting 10 plants per plot at 0.45 m from the soil surface. These determinations for the pigeon pea were performed on another two occasions during the offseason period at 72 and 245 days after the harvest of maize (DAH).

We also determined the dry matter of shoots of paiaguás grass at 72 and 245 DAH (0.20 m from the soil surface in 1 m^2 per plot), as well as the number of tillers. To obtain the dry matter of the entire harvested material (pigeon pea and grass), it was dried in a forced-air oven at 65ºC for 72 h, and the result was extrapolated to kilograms per hectare. The number of tillers was determined after lowering the forage in an area of 0.0625-m^2 at three points per plot.

The data obtained were subjected to an analysis of variance. The means from the intercropped treatments were compared using Tukey's test (DMS) at the 5% probability level, and the effects of N rates were evaluated by regression analysis using the magnitude of the regression coefficients (significant at 5% probability) as a criterion for the choice of the model. The software Sisvar version 5.6 (FERREIRA, 2011) was used for the statistical analyses.

Results and Discussion

There was no significant effect of the intercrops on the nutrient content and GCI in the maize leaves, and there was no interaction effect between the intercropping and N rates (Table 1). The N rates applied as topdressing significantly influenced the N, Ca, Mg, and S contents in the leaves and the GCI values. Both N and GCI had positive linear responses to the increasing N rates. Their similar responses are a result of the relationship between N and chlorophyll since 50 to 70% of the total N is associated with chloroplasts (CHAPMAN; BARRETO, 1997). This similarity corroborates the findings reported by Godoy et al. (2007), who indicate the use of a chlorophyll absorbance meter to help in the evaluation of N availability to the maize crop.

Table 1. Foliar nutrient contents (g kg^{-1}) and green color index (GCI) in the leaves of maize (M) intercropped with paiaguás grass (G) and pigeon pea (P) and in the topdressing nitrogen.

Treatment	N	P	K	Ca	Mg	S	GCI
Intercrop	ns	ns	ns	ns	ns	ns	ns
M+G	29	1.5	17	6.8	2.0	1.9	60.3
M+G+P	29	1.4	16	6.6	1.9	1.9	60.4
N (kg ha^{-1})	**	ns	ns	*	**	*	**
0	27	1.5	16	7.2	2.2	1.8	58.8
80	29	1.3	16	6.5	1.8	1.8	59.0
160	30	1.6	17	6.5	1.9	1.9	61.4
240	29	1.5	17	6.6	1.9	1.9	62.3
CV (%)	3.18	8.28	7.74	7.45	10.17	5.14	2.34

CV - coefficient of variation; ns - not significant.
** significant at the 5% probability level.
$N = 27.012 + 0.0356N - 0.000114N^2$ ($R^2 = 0.90^{**}$); $Ca = 7.126 - 0.0923N - 0.00003N^2$ ($R^2 = 0.91^{**}$); $Mg = 2.18062 - 0.004773N - 0.000015N^2$ ($R^2 = 0.91^{**}$); $S = 1.822 + 0.000464N$ ($R^2 = 0.80^{*}$); $GCI = 58.446 + 0.016047N$ ($R^2 = 0.91^{**}$).

The foliar S contents also increased linearly as the N rates increased. A part of the N applied as topdressing was provided with ammonium sulfate, and there is a relationship between N and S where an increase in S coupled with nitrogen fertilization promotes the development of maize (AFSAR et al., 2017), resulting in greater absorption of this nutrient. Despite their quadratic response, the foliar Ca and Mg decreased as the N rates were elevated, which can be explained by the dilution effect since higher N rates also led to a higher yield of dry plant matter. Irrespective of the treatments used, the average macronutrient contents in the leaf blades were within the adequate range for the maize crop (RAIJ et al., 1996; OLIVEIRA, 2004).

The growth of maize plants was not influenced by the introduction of pigeon pea to the system, although the legume was sown simultaneously in the maize inter-row (Table 2). Intercrops may lead the species to compete for light, nutrients, and water, thus changing their distribution of leaves and height (MACIEL et al., 2004). However, these effects depend on the intercropped species. Pigeon pea has a slow initial growth (REDDY et al., 2016), which explains the results obtained. Chieza et al. (2017) intercropped maize with another legume, *Crotalária juncea*, in the summer crop. They found that when the legume was kept in the system, the maize yield decreased by 47%, which was associated with initial rapid growth and good climatic conditions.

Table 2. Agronomic variables of shoots of maize plant as a function of the intercropping of maize with paiaguás grass and pigeon pea and nitrogen topdressing fertilization.

Treatment	FPS (plants ha^{-1})	HEI (m)	PH (m)	SD (mm)	EI	DM kg ha^{-1}
Intercrop	ns	ns	ns	ns	ns	ns
M+G	63,836	1.17	2.18	18.8	1.1	12.1
M+G+P	64,952	1.17	2.18	18.8	1.1	11.8
N (kg ha^{-1})	ns	ns	ns	**	ns	**
0	62,050	1.19	2.17	17.8	1.1	10.6
80	66,068	1.17	2.16	18.5	1.0	11.7
160	65,175	1.17	2.22	19.7	1.0	12.6
240	64,282	1.15	2.18	19.3	1.1	12.9
CV (%)	6.19	5.94	4.09	2.43	11.18	4.12

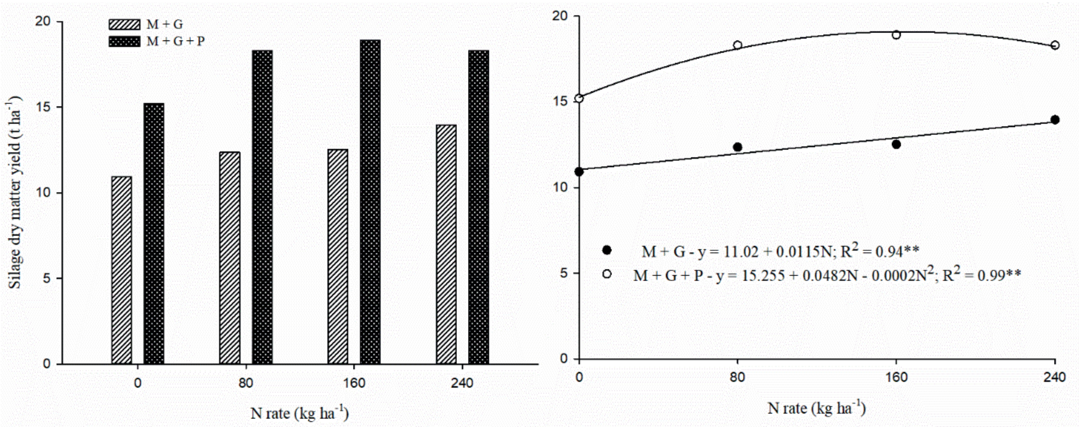
FPS - final plant stand; HEI - height of ear insertion; PH - plant height; SD - stem diameter; EI - ear index; DM - dry matter.
CV - coefficient of variation; ns - not significant.
** significant at the 5% probability level.
$SD = 17.6779 + 0.017841N - 0.000045N^2$ ($R^2 = 0.92^{**}$); $DM = 10.5944 + 0.017921N - 0.000030N^2$ ($R^2 = 0.99^{*}$).

The N rates influenced only the stem diameter and the dry matter of the maize shoots (Table 2). According to the adjusted equation, an estimated N rate of 198 kg ha^{-1} resulted in the highest stem diameter. The dry matter of the shoots had a quadratic response, and the estimated N rate of 298 kg ha^{-1} led to the highest values. According to Liu et al. (2014), nitrogen fertilization is essential to obtain high yields of dry matter from maize, especially in the post-flowering stage.

The dry matter yield of silage was affected by the interaction between the intercrops and N rates. The highest yields were obtained when the pigeon pea was introduced to the system. Increases of 39, 49, 51, and 32% were obtained based on the means of the M+G+P intercrop in relation to M+G at N rates of 0, 80, 160, and 240 kg ha^{-1}, respectively (Figure 2A). These increases are explained by the elevated quantity of dry matter produced by pigeon pea.

Yields increased linearly for the M+G intercrop with respect to the N rates and reached 13.9 t ha^{-1} at an N rate of 240 kg ha^{-1}. For the M+G+P intercrop, the response was quadratic, and the maximum yield (18.1 t ha^{-1}) was obtained at an estimated N rate of 120 kg ha^{-1} (Figure 2B). The quadratic response of the M+G+P intercrop to the applied N rates was directly related to the response of pigeon pea to dry matter nitrogen fertilization.

Figure 2. Dry matter yield of silage of maize intercropped with paiaguás grass (M+G) and with paiaguás grass and pigeon pea (M+G+P) as a function of nitrogen topdressing.



A - decomposition of intercrops within each N rate; B - decomposition of N rates within each intercrop.

These results suggest that the introduction of pigeon pea contributed to reducing the N rate in the system as a function of the produced mass. The uptake of N in the soil fixed by the legume does not occur immediately and results from the decomposition of the remaining dry matter in the area. Therefore, the reduction of the N rate may not be attributed to the biological fixation of the legume as a direct source of N to the established grasses. Salmi et al. (2006) found that pigeon pea can contribute 188 to 261 kg ha^{-1} of N to the soil, but at three months after the management of these plants, only 40% of this total had been released.

The CP contents in the silage and the amount of protein produced (kg ha^{-1}) were also affected by the interaction between the intercrops and N rates (Table 3). In the intercrop with pigeon pea in the system, higher CP contents and thus larger amounts of CP per area were found. When considering only the contents, a CP increase of only 9% was observed when pigeon pea was introduced to the system, shifting from 7.3 to 8.0%. Considering the dry matter produced, the increase in quantity was 34%. Silage is a roughage feed that is commonly used in periods of forage scarcity. Thus, the greater dry matter yield and CP content directly ensure a larger volume of feed and CP for the herd in this period, as well as indirectly ensure a lower need for supplementation with concentrates.

Table 3. Concentration and quantity of crude protein (CP) in silage of maize intercropped with paiaguás grass (M+G) and with paiaguás grass and pigeon pea (M+G+P) as a function of nitrogen topdressing.

	CP (%)		CP (kg ha^{-1})	
N (kg ha^{-1})	Intercrop		Intercrop	
	M+G	M+G+P	M+G	M+G+P
0	6.9b	7.7a	751b	1167a
80	7.2b	7.9a	886b	1446a
160	7.4a	7.9a	932b	1494a
240	7.5b	8.4a	1041b	1351a
CV (%)	4.44		5.82	

CV - coefficient of variation.
Common letters in a row do not differ according to Tukey's test at the 5% probability level.

In both intercropping systems, the CP response to N rates fit a linear model, and the highest concentrations of 7.5 and 8.4% were obtained in M+G and M+G+P, respectively (Figure 3). Costa et al. (2012b) tested an intercropping of brachiaria grass and legumes and obtained low CP contents (5.1%). They observed no differences between the associations due to the low mass production of the legumes *Calopogonium mucunoides*, *Macrotyloma axillare*, and *Stylozanthes capitata* (439, 233, and 95 kg ha^{-1}, respectively). Leonel et al. (2008) obtained 5.9% CP in maize silage with the grass *U. brizantha* cv. MG5.

The amount of CP per hectare increased linearly with the N rates for the M+G intercrop and quadratically in M+G+P. A maximum value of 1,505 kg ha^{-1} was obtained at an estimated N rate of 143 kg ha^{-1} (Figure 3), which also demonstrates a reduction in the topdressing N level when the legume is introduced in the system. The types of intercropping and the N rates did not influence the contents of Ca, P, moisture, fiber, ether extract, mineral matter, total digestible nutrients, and total dry matter of the produced silage. The respective mean values were 0.44, 0.11, 69, 22.0, 2.0, 4.0, 64, and 30%, as shown in Table 4. These values are within the recommended ranges for silage (KIRCHOF, 2004).

Figure 3. Content and quantity of crude protein in silage of maize intercropped with paiaguás grass (M+G) and with paiaguás grass and pigeon pea (M+G+P) as a function of nitrogen topdressing.

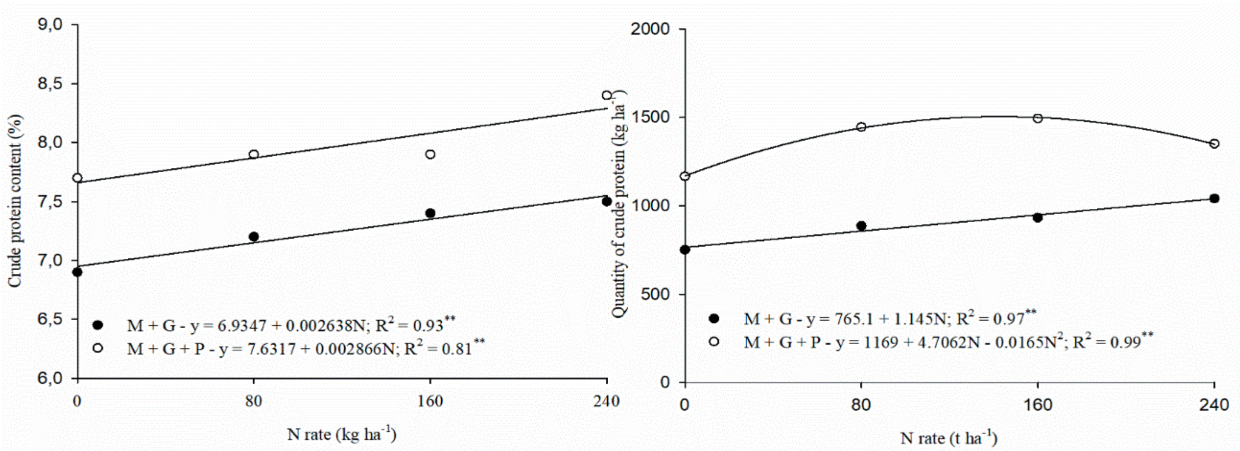


Table 4. Mean contents of calcium (Ca), phosphorus (P), moisture (M), fiber, ether extract (EE), mineral matter (MM), total digestible nutrients (TDN), and total dry matter (TDM) in silage of maize intercropped with paiaguás grass (M+G) and maize intercropped with paiaguás grass and pigeon pea (M+G+P) as a function of nitrogen topdressing.

Treatment	Ca	P	M	Fiber	EE	MM	TDN	TDM
	--			%----------------------------------				
Intercrop	ns	ns	ns	ns	ns	ns	ns	ns
M+G	0.40	0.11	70	21.8	2.0	4.1	64	30
M+G+P	0.45	0.10	70	22.2	1.9	3.9	64	30

continue

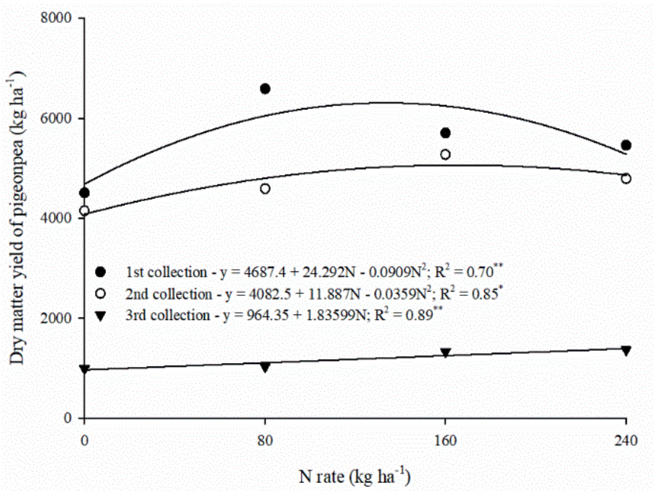
continuation

N (kg ha^{-1})	ns	ns	ns	ns	ns	ns	ns	ns
0	0.42	0.12	70	21.5	2.0	3.8	65	30
80	0.41	0.10	70	22.9	2.0	4.2	64	30
160	0.44	0.10	69	22.1	2.0	4.2	64	31
240	0.44	0.10	69	21.5	1.9	3.9	65	31
CV%	15.56	20.37	2.09	9.25	8.26	10.54	1.97	4.82

M - maize, G - paiaguás grass, G - pigeon pea.

Pigeon pea intercropped with maize and grass had a quadratic adjustment for dry matter yield as a function of nitrogen fertilization in the first two evaluations. This occurred when the silage was harvested and at 72 DAH. There was also a linear adjustment for the third evaluation at 245 DAH (Figure 4). The response of this legume plant to nitrogen fertilization demonstrates that biological fixation was not sufficient to meet the requirements of the plant, which was first introduced in an area with no history of legume growth and no inoculation of seeds. The highest yields of pigeon pea in the first and second evaluations were 6,310 and 5,066 kg ha^{-1}, which occurred with N rates of 134 and 166 kg ha^{-1}, respectively. In the third evaluation, however, the legume produced 1,405 kg ha^{-1} up to the highest tested rate. The decreasing production after the first evaluation may be associated with a loss of vigor of the plant and climatic characteristics since the area is located in a *Cerrado* biome region, which is characterized by dry winters (Figure 1).

Figure 4. Dry matter yield of pigeon pea intercropped with maize and paiaguás grass as a function of nitrogen topdressing at three evaluation times.



1st evaluation - at the harvest of the silage; 2nd evaluation - at 72 days after harvest (DAH); and 3rd evaluation - at 242 DAH.

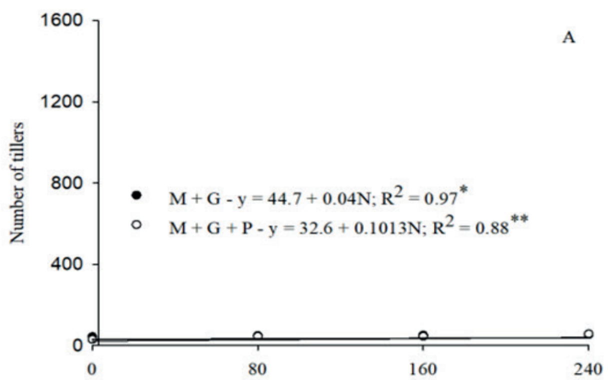
According to Costa et al. (2001), pigeon pea has a production potential of up to 8,000 kg ha^{-1} in the rainy period and 6,000 kg ha^{-1} in the dry period. Therefore, the yield obtained in the current experiment denotes the response of the legume to nitrogen fertilization and its behavior when inserted in an intercropping system, and the dry matter yields are very close to those of the monocrop. Veras et al. (2016) showed the capacity of pigeon pea and other cover crops to add N to the system in topsoil. Thus, non-exported mass may contribute N to the soil.

For the grass, the number of tillers responded to the interactions at the three evaluation times (when the maize was harvested and at 72 and 245 DAH). In the decomposition of the intercrops within N rates (Table 4), the M+G intercrop provided the highest number of tillers only with zero N when the maize was harvested. At 72 DAH, the intercrops showed no significant differences at an N rate of 0 kg ha^{-1}. However, they did show significant differences at the other rates, and the M+G intercrop resulting in the highest means. At 245 DAH, the intercrops differed from each other at all rates, and M+G provided higher means than M+G+P. The differences between intercrops were more pronounced at 72 and 245 DAH, which may be associated with the appearance of lateral shoots of pigeon pea after the first evaluation, which thus occupied a larger area. The lower tillering is due to the competition among plants (mainly for space).

In the decomposition of rates within each intercrop, when the maize was harvested, the M+G and M+G+P systems elicited a linear response in the number of tillers, which reached 54 and 57 tillers m^{-2} up to the highest N rate evaluated (Figure 5). Soon after the harvest of maize, Bottega et al. (2017) found 229 tillers m^{-2} of *U. ruziziensis*, 149 of *U. brizantha* cv. Marandu, and 60 of *U. brizantha* cv. Xaraés when the grasses were sown simultaneously in the same row of the cereal. This demonstrates the existence of differences even between cultivars of *U. brizantha*. Based on the present results, the paiaguás grass displayed a similar tillering pattern to that of Xaraés grass when intercropped with maize.

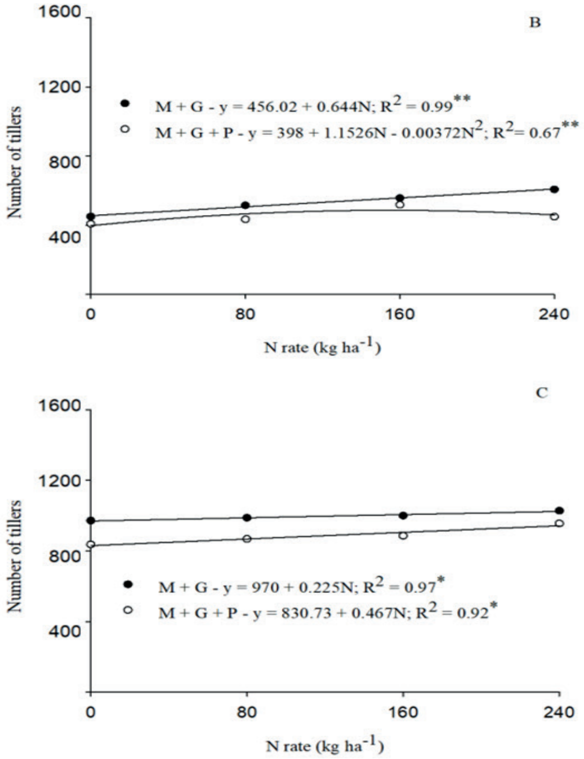
At 72 DAH, the response in the M+G intercrop was linear, and the grass reached 620 tillers at the highest tested N rate. For M+G+P, however, the response was quadratic, and the N rate of 155 kg ha^{-1} provided the highest number of tillers (487 m^{-2}). At 245 DAH, the response in both intercrops was linear, and the highest N rate tested generating 1,024 tillers m^{-2} for the M+G intercrop and 943 tillers m^{-2} for M+G+P. The number of tillers is an important trait, since the pasture DM production is directly related to this variable.

Figure 5. Number of tillers in paiaguás grass intercropped with maize (M+G) and with maize + pigeon pea (M+G+P) as a function of nitrogen topdressing.



continue

continuation



A - at the harvest of maize, per m^2; B - at 72 days after harvest (DAH), per m^2; C - at 245 DAH, per m^2.

As shown in Table 5, at harvest with N rates of 0 and 80 kg ha^{-1}, M+G resulted in the highest dry matter yield of paiaguás grass, but the other rates did not lead to differences between the intercrops. It can thus be inferred that higher rates mainly reduced the competition between plants for N, resulting in similar dry matter yields. At the other evaluated times, without maize in the area, the highest means were obtained in the grass with the M+G intercrop as compared with M+G+P at N rates of 80, 160, and 240 kg ha^{-1}.

Table 5. Number of tillers in paiaguás grass intercropped with maize (M+G) and maize + pigeon pea (M+G+P) as a function of nitrogen topdressing at three evaluation times.

N (kg ha^{-1})	Number of tillers (n/m^2)					
	At harvest		72 days after harvest		245 days after harvest	
	Intercrop		Intercrop		Intercrop	
	M+G	M+G+P	M+G	M+G+P	M+G	M+G+P
0	44a	30b	452a	409a	972a	837b
80	49a	46a	516a	435b	988a	868b
160	51a	46a	558a	519b	1000a	886b
240	54a	57a	608a	450b	1028a	956b
CV (%)	13.30		8.56		4.81	

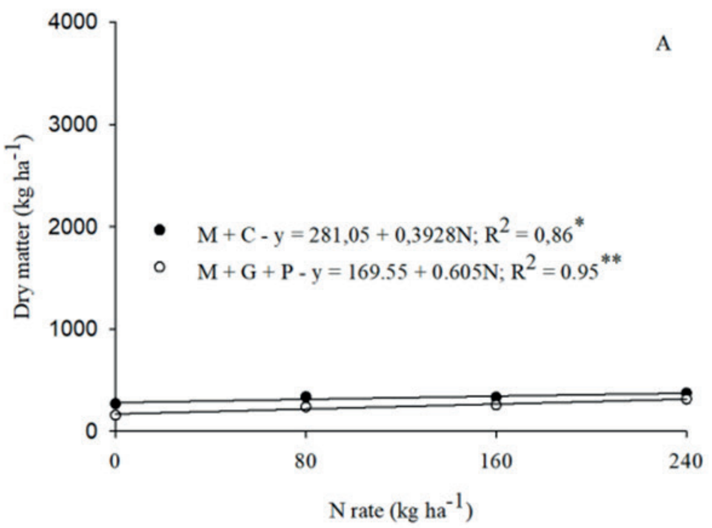
CV - coefficient of variation.
Common letters in a row do not differ according to Tukey's test at the 5% probability level.

At 242 DAH, when no N was applied as topdressing, there was no difference between the intercrops for the dry matter production of the grass (Table 5). The smaller space occupied by the grass might have been offset by the uptake of N left in the soil from the decomposition of the pigeon pea remnants in the area. The introduction of legumes in grazing contributes to reducing the use of fertilizers and thus fertilization costs, in addition to benefiting animal performance (PINHEIRO et al., 2014). Cecato et al. (2014) also observed that the grass intercropped with the legume may provide similar gains to those obtained with mineral fertilization.

In view of the produced means, the pigeon pea reduced the dry matter of the grass by 32 and 18% at 72 and 245 DAH in the offseason, respectively. Although the grass production was lower in the M+G+P intercrop, the mass produced by the pigeon pea in the system would be present for the animals to graze on, which is basically a high-protein source in comparison with the grass, in addition to contributing N to the system. If we add up the mean values of the masses of grass and pigeon pea, the total amount of forage produced in the M+G+P intercrop would be 6,722 and 4,152 kg ha^{-1} at 72 and 245 DAH, respectively, whereas the M+G intercrop generated averages of 2,974 kg ha^{-1} at 72 and 3,632 kg ha^{-1} at 245 days after the maize was harvested.

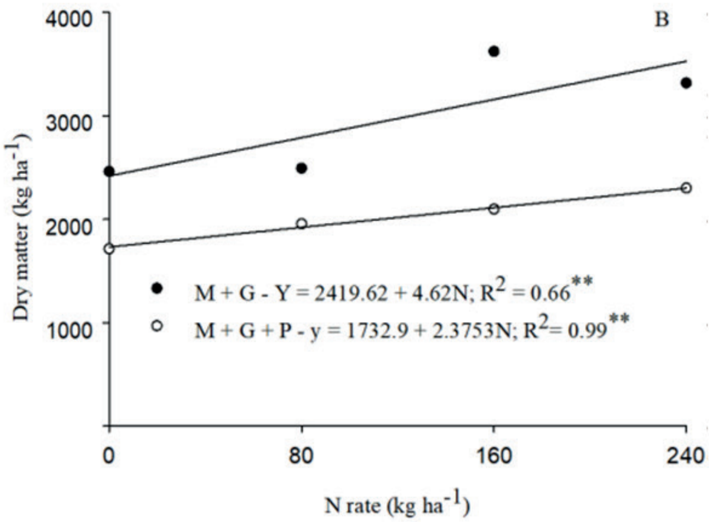
In the decomposition of the rates within each intercrop, at harvest and 72 DAH, both intercropping systems tested had a linear increase in dry grass matter as the N rates were elevated (Figures 6A and 6B). At 242 DAH, these variables responded quadratically, and 3,868 kg ha^{-1} for M+G and 3,086 kg ha^{-1} for M+G+P were obtained at estimated N rates of 164 and 163 kg ha^{-1}, respectively (Figure 6B). DM values greater than 2,500 kg ha^{-1} are satisfactory for yields of forages intercropped with maize (PARIZ et al., 2011).

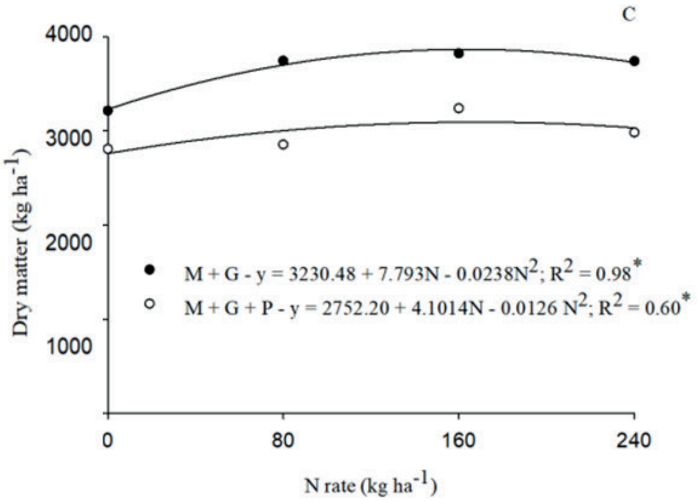
Figure 6. Dry matter of paiaguás grass intercropped with maize (M+G) and with maize + pigeon pea (M+G+P) as a function of nitrogen topdressing.



continue

continuation





A - at the harvest of maize; B - at 72 days after harvest (DAH); C - at 245 DAH.

Introducing pigeon pea to the system and increasing N rates promote gains in yield and protein density. Paiaguás grass develops less when pigeon pea is added to the system. For silage production, N rates of 240 and 120 kg ha^{-1} are recommended for the maize + paiaguás grass and maize + paiaguás grass + pigeon pea intercrops, respectively. Nitrogen rates promote an increase in the dry matter of the grass and pigeon pea, resulting in pasture improvements during the offseason.

References

AFSAR, M. A.; KHALIL, S. K.; WAHAB, S.; KHALIL, I. H.; KHAN, A. Z.; KHATTAK, M. K. Impact of Various ratios of nitrogen and sulfur on maize and soil ph in semiarid region. *Communications in Soil Science and Plant Analysis*, Athens, v. 48, n. 8, p. 825-834, 2017.

ALMEIDA, R. E. M. de; GOMES, C. M.; LAGO, B. C.; OLIVEIRA, S. M. de; PIEROZAN JUNIOR, C.; FAVARIN, J. L. Maize yield, forage production and quality affected by methods of intercropping maize and *Panicum maximum*. *Pesquisa Agropecuária Brasileira*, Brasília, v. 52, n. 3, p. 170-176, 2017.

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; MORAES, G. de; LEONARDO, J.; SPAROVEK, G. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, Stuttgart, v. 22, n. 6, p. 711-728, 2013.

ALVES, V. M. C.; VASCONCELLOS, C. A.; FREIRE, F. M.; PITTA, G. V.; FRANÇA, G. E.; RODRIGUES FILHO, A.; ARAÚJO, J. M.; VIEIRA, J. R.; LOUREIRO, J. E. Milho. In: RIBEIRO, A. C.; GUIMARÃES, P. T. G.; ALVAREZ V. H. (Ed.). *Recomendações para o uso de corretivos e fertilizantes em Minas Gerais:* 5º Aproximação. Viçosa, MG: Comissão de fertilidade do solo do estado de Minas Gerais, 1999. p. 314-316.

BORGHI, E.; CRUSCIOL, A. C.; MATEUS, G. P.; NASCENTE, A. S.; MARTINS, P. O. Intercropping time of maize and palisadegrass or guineagrass affecting grain yield and forage podruction. *Crop Science*, Madison, v. 53, n. 2, p. 629-636, 2013.

BOTTEGA, E. L.; BASSO, K. C.; PIVA, J. T.; MORAES, R. F. Cultivo de milho em consórcio com capins tropicais. *Revista de Ciências Agroveterinárias*, Lages, v. 16, n. 1, p. 18-25, 2017.

CECATO, U.; IWAMOTO, B. S.; PELUSO, E. P.; MARI, G. C.; PEREIRA, V. V.; SAUTE, J. M. Animal performace on Tanzânia grass pasture intercropped with estilozantes campo grande or fertlized with nitrogen. *Tropical Grasslands - Forrajes Tropicales*, Palmira, v. 2, n. 1, p. 29-30, 2014.

CECCON, G. *Consórcio milho-braquiária*. Brasília: EMBRAPA Agropecuária Oeste-Livros Técnicos (INFOTECA-E), 2013. 175 p.

CHAPMAN, S. C.; BARRETO, H. J. Using a chlorophyll meter to estimate specific leaf nitrogen of tropical maize during vegetative growth. *Agronomy Journal*, Madison, v. 89, n. 4, p. 557-562, 1997.

CHIEZA, E. D.; GUERRA, J. G. M.; ARAÚJO, E. S.; ESPÍNOLA, J. A.; FERNANDES, R. C. Produção e aspectos econômicos de milho consorciado com *Crotalária juncea* L. em diferentes intervalos de semeadura, sob manejo orgânico. *Revista Ceres*, Viçosa, MG, v. 64, n. 2, p. 189-196, 2017.

COSTA, N. de; TOWNSEND, C. R.; MAGALHAES, J. A.; PEREIRA, R. G. A. *Formação e manejo de pastagens de Guandu em Rondônia*. Rondônia: EMBRAPA, 2001. 2 p.

COSTA, N. R.; ANDREOTTI, M.; GAMEIRO, R. de A.; PARIZ, C. M.; BUZETTI, S.; LOPES, K. S. M. Adubação nitrogenada no consórcio de milho com duas espécies de braquiária em sistema plantio direto. *Pesquisa Agropecuária Brasileira*, Brasília, v. 47, n. 8, p. 1038-1047, 2012a.

COSTA, P. M.; VILLELA, S. D. J.; LEONEL, F. de P.; ARAÚJO, S. A. do C.; ARAÚJO, K. G.; RUAS, J. R. M.; COELHO, F. S.; ANDRADE, V. R. Intercropping of maize, brachiaria grass and leguminous plants: productivity, quality and composition of silages. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 41, n. 8, p. 2144-2149, 2012b.

CRUSCIOL, C. A. C.; SORATTO, R. P.; BORGHI, E.; MATEUS, G. P. Integração lavourapecuária: benefícios das gramíneas perenes nos sistemas de produção. *Informações Agronômicas*, Peachtree Corners, v. 1, n. 125, p. 2-15, 2009.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA. Centro Nacional de Pesquisa de Solos. Sistema Brasileiro de Classificação de Solos. 3. ed. Rio de Janeiro: CNPS, 2013. 353 p.

EVANGELISTA, A. R.; ABREU, J. G.; AMARAL, P. N. C.; PEREIRA, R. C.; SALVADOR, F. M.; LOPES, J.; SOARES, L. Q. Composição bromatológica de silagens de sorgo (*Sorghum bicolor* (L.) Moench) aditivadas com forragem de leucena (*Leucaena leucocephala* (Lam.) Dewit). *Ciência e Agrotecnologia*, Lavras, v. 29, n. 2, p. 429-435, 2005.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. *Ciência e Agrotecnologia*, Lavras, v. 35, n. 6, p. 1039-1042, 2011.

GODOY, L. J. G.; SOUTO, L. S.; FERNANDES, D. M.; VILLAS BÔAS, R. L. Uso do clorofilômetro no manejo da adubação nitrogenada para milho em sucessão a pastagem de *Brachiaria decumbens*. *Ciência Rural*, Santa Maria, v. 37, n. 1, p. 38-44, 2007.

HUNGRIA, M.; CAMPO, R. J.; SOUZA, E. M.; PEDROSA, F. O. Inoculation with selected strains of *Azospirillum brasiliense* and *A. lipoferum* improves yields of maize and wheat in Brazil. *Plant and Soil*, Crawley, v. 331, n. 1-2, p. 413-425, 2010.

KIRCHOF, B. *Tabelas para cálculos da alimentação de bovinos leiteiros*. 7. ed. Porto Alegre: EMATER/RS-ASCAR, 2004. 23 p.

LEONEL, F. P.; PEREIRA, J. C.; COSTA, M. G.; MARCO JÚNIOR, P.; RIBEIRO, M. D.; SILVA, C. J. Consórcio capim-braquiária e milho: produtividade das culturas e características qualitativas das silagens feitas com plantas em diferentes idades. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 37, n. 12, p. 2233-2242, 2008.

LIU, J.; BU, L.; ZHU, L.; LUO, S.; CHEN, X.; CUI, Z.; LI, S.; HILL, R. L.; ZHAO, Y. Understanding dry matter and nitrogen accumulation for high-yielding filmmulched Maize. *Agronomy Journal*, Madison, v. 106, n. 2, p. 390-396, 2014.

MACIEL, A. D.; ARF, O.; SILVA, M. G.; SÁ, M. E. de; RODRIGUES, R. A. F.; BUZETTI, S.; SOBRINHO, E. B. Comportamento do feijoeiro em cultivo consorciado com o milho em sistema de plantio direto. *Acta Scientiarum Agronomy*, Maringá, v. 26, n. 3, p. 273-278, 2004.

MALAVOLTA, E.; VITTI, G. C.; OLIVEIRA, S. A. *Avaliação do estado nutricional das plantas*. 2. ed. Piracicaba: POTAFOS, 1997. 319 p.

OLIVEIRA, S. A. Análise foliar. In: SOUSA, D. M. G.; LOBATO, E. *Cerrado:* correção do solo e adubação. Planaltina: EMBRAPA Cerrados, 2004. p. 245-256.

PARIZ, C. M.; ANDREOTTI, M.; AZENHA, M. V.; BERGAMASCHINE, A. F.; MELLO, L. M. M.; LIMA, R. C. Produtividade de grãos de milho e massa seca de braquiárias em consórcio no sistema de integração lavoura-pecuária. *Ciência Rural*, Santa Maria, v. 41, n. 5, p. 875-882, 2011.

PARIZ, C. M.; COSTA, C.; CRUSCIOL, C. A. C.; MEIRELLES, P. R. L.; CASTILHOS, A. M. de; ANDREOTTI, M.; COSTA, N. R.; MARTELLO, J. M. Silage production of maize intercropped with tropical forages in an integrated crop-livestock system with lambs. *Pesquisa Agropecuária Brasileira*, Brasília, v. 52, n. 1, p. 54-62, 2017.

PINHEIRO, A. A.; CECATO, U.; LINS, T. O. J. D.; BELONI, T.; PIOTTO, V.; RIBEIRO, O. L. Produção e valor nutritivo da forragem, e desempenho de bovinos Nelore em pastagem de capim-Tânzania adubado com nitrogênio ou consórcio em estilosantes Campo Grande. *Semina: Ciências Agrárias*, Londrina, v. 35, n. 4, p. 2147-2158, 2014.

RAIJ, B. V.; CANTARELLA, H.; QUAGGIO, J. A.; FURLANI, A. M. C. *Recomendações de adubação e calagem para o estado de São Paulo.* Campinas: Instituto Agronômico, 1996. 285 p. (IAC. Boletim Técnico, 100).

REDDY, A. S.; RAO, P. V.; BABU, J. S.; RAO, Y. K. Response of integrated weed management practices on growth and yield of pigeonpea (*Cajanus cajan* (L.) Mill sp.). *International Journal of Current Microbiology and Applied Sciences*, Kancheepuram, v. 5, n. 3, p. 610-616, 2016.

SALMI, G. P.; SALMI, A. P.; ABBOUD, A. C. S. Dinâmica de decomposição e liberação de nutrientes de genótipos de guandu sob cultivo em aléias. *Pesquisa Agropecuária Brasileira*, Brasília, v. 41, n. 4, p. 673-678, 2006.

SEIDEL, E. P.; GERHARDT, I. F. S.; CASTAGNARA, D. D.; NERES, M. A. Efeito da época e sistema de semeadura de *Brachiaria brizantha* em consórcio com o milho, sobre os componentes de produção e propriedades físicas do solo. *Semina: Ciências Agrárias*, Londrina, v. 35, n. 1, p. 55-66, 2014.

SOUSA, D. M. G.; LOBATO, E. Calagem e adubação para culturas anuais e semiperenes. In: SOUSA, D. M. G.; LOBATO, E. *Cerrado:* correção do solo e adubação. Planaltina: EMBRAPA Cerrados, 2004. p. 283-316.

VERAS, M. S. de; RAMOS, M. L. G.; OLIVEIRA, D. N. S.; FIGUEREDO, C. C.; CARVALHO, A. M. de; PULROLNIK, K.; SOUZA, K. W. de. Cover crops and nitrogen fertilization on nitrogen soil fractions under maize cultivation in no-tillage system. *Revista Brasileira de Ciência do Solo*, Viçosa, MG, v. 40, n. 1, p. 1-12, 2016.