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Nitrogen fertilization on soybean crop over straw of forage sorghum intercropped with Urochloa ruziziensis

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The experiment was carried out to evaluate the influence of N on the agronomic characteristics of soybean crop under no-tillage system over forage sorghum intercropped with *Urochloa ruziziensis* and on straw degradation. Four treatments (nitrogen doses) were used: 0; 20; 40 and 60 kg of N ha^{-1}. N were applied at V3-V4 stage, using ammonium nitrate as the N source, containing 30% N. The experimental design was a randomized block design with four replications. The evaluation of dry matter quantity of forage sorghum and *U. ruziziensis* straw was carried out before the sowing of forage sorghum and *U. ruziziensis* and after soybean harvest. The soybean crop parameters evaluated were, as follows: first pod insertion height and plant height, final stand ha^{-1} and grain yield ha^{-1}. Evaluations were performed at the soybean crop harvest. Nitrogen fertilization did not influence the straw decomposition of *U. ruziziensis* and forage sorghum nor the first pod insertion height, plant height and final stand ha^{-1} of soybean crop. Nevertheless, fertilization showed a quadratic behavior in the 2015/2016 crop in relation to grain yield, with a reduction in yield at doses greater than 21 kg of N ha^{-1}, and a linear increase in the 2016/2017 crop.

Key words: Ammonium nitrate, *Glycine max* L., no-tillage.

INTRODUCTION

Nitrogen (N) is the most required nutrient by the soybean crop, and it can be absorbed as ammonium (NH_4^+) or nitrate (NO_3^-) in which the N sources available to the crop are the soil, non-biological fixation, biological fixation of atmospheric N_2 (BNF) and nitrogen fertilization (Domingos et al., 2015).

However, the results of works with nitrogen fertilization in soybean vary, showing increases in grain yield (Mendes et al., 2008; Boroomandan et al., 2009; Petter et al., 2012; Bahry et al., 2013a; Wilson et al., 2014) or not (Silva et al., 2011; Bahry et al., 2013b; Borges et al., 2013; Santos Neto et al., 2013; Bahry et al., 2014; Balboa et al., 2015; Ferreira et al., 2016).

Nitrogen fertilization in soybean may succeed when no-

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Table 1. Soil chemical attributes in the 0.00-0.20 m depth layer, 2015/2016 crop.

P (Resin)	OM	pH ($CaCl_2$)	K	Ca	Mg	H+Al	Al	V
mg dm^{-3}	g dm^{-3}		---------$mmol_c$ dm^{-3}--------					(%)
23	19	5.1	3.2	13	9	24	1	52

OM - Organic matter.

Table 2. Crops used in the experiment.

Sept/Mar	Apr/Aug	Sept/March	Apr/Aug	Sept/Mar	Apr/Aug
2009/2010		2010/2011		2011/2012	
Soybean	Crotalaria juncea	Maize	C. juncea	Soybean	Grain sorghum
2012/2013		2013/2014		2014/2015	
Soybean	Grain sorghum	Soybean	C. juncea	Maize	Grain sorghum + *U. ruziziensis*

Mar: March; Apr: April.

tillage is carried out in areas with a marked straw volume and with a C/N ratio of 60 to 80/1, such as after maize, sorghum or pearl millet crops and also when it no-tillage is carried out on degraded pasture areas (Câmara, 2000).

In these areas, it is common for soybean crops to show N-deficiency symptoms in the initial phase, due to the low availability of this nutrient through BNF in this phase and also due to the low levels of N in the soil caused by its use by microorganisms in the decomposition of the straw (Borges et al., 2015).

According to Da Ros and Aita (1996), to use C in biosynthesis and also as an energy source, soil microorganisms immobilize the N in straw, including part of the mineral N in the soil, therefore, decreasing its availability to the crops. Another situation in which nitrogen fertilization in soybean crops is justified is in high-yield cultivation systems, where there is a high demand for N, requiring amounts close to 300 kg of N ha^{-1} to achieve high grain yields (Lamond and Wesley, 2001). In these systems, the N supply may also not be fully met through BNF and soil supply, therefore, they will require complementary nitrogen fertilization (Petter et al., 2012). Thus, the use of nitrogen fertilization in soybean crops, in areas with large amounts of straw, could accelerate the decomposition of straw, supply this initial N deficiency and promote increases on grain yield. The objective of this study was to evaluate the influence of N on the agronomic characteristics of the soybean crop, under no-tillage system on forage sorghum straw intercropped with *U. ruziziensi*s and on straw degradation.

MATERIALS AND METHODS

The experiment was carried out in the 2015/2016 and 2016/2017 crops, at the Advanced Research Center for Rubber and Agroforestry Systems, of the Agronomic Institute (IAC), of the São Paulo Agribusiness Technology Agency (APTA), located in the municipality of Votuporanga - São Paulo State, within the geographic coordinates 20° 28 'South Latitude and 50° 04' West Longitude, with smooth relief and altitude from 410 to 490 m.

The climate in the region is tropical with dry winters (Aw in the Köppen's classification) with an average annual temperature of 24°C, with an average maximum temperature of 30°C and an average minimum temperature of 18°C. The average annual rainfall is 1448.7 mm. The soil was classified as eutrophic Dark-Red Latosol (Oxisol) with sandy texture (according to SiBCS, Santos et al., 2013).

The experimental design used was the randomized block with four replications. Four doses of N were used: 0; 20; 40 and 60 kg of N ha^{-1}. Nitrogen was applied twenty days after soybean emergence (stage V3-V4), on December 18 2015 and December 22 2016, using ammonium nitrate as the N source, containing 30% N.

Prior to the 2015/2016 soybean crop sowing, soil samples were collected for chemical analysis and determination of fertility. The samples were collected at ten random points in the experimental area, in the 0-0.20 m depth layer, giving rise to ten sub-samples. The ten sub-samples were homogenized and originated a composite sample of the area. The samples were collected with a metal probe and subsequently air-dried. The following were determined: pH in $CaCl_2$ 0.01 mol L^{-1} (1: 2.5 soil: solution ratio), potential acidity (H^+ + Al^{3+}) and the levels of P, K, Ca and Mg in the soil extracted by the exchange resin ions (van Raij et al., 2001); based on these results, the base saturation values (V) were calculated using the relationship between the content of exchangeable bases in the soil (Ca, Mg and K) and the cation exchange capacity (CEC), in $mmol_c$ dm^{-3}. The results are shown in Table 1.

The experiment was carried out in an area intended for grain production. The area was cropped with peanuts, in a conventional soil tillage system, in the 2008/2009 crop and forage sorghum over the peanut stubble. After the cultivation of sorghum, all sowing was carried out in a no-tillage system. The crops used in the period from September 2009 to August 2015 are shown in Table 2. The amount of N, P and K used during the 2009/2010 to 2014/2015 crops is shown in Table 3. On April 23, 2015, forage sorghum cultivar DOW SS 318 was sown at a spacing of 0.8 m between rows, using 12 seeds m^{-1} and 300 kg ha^{-1} of the 08-28-16 formulated fertilizer, intercropped with *U. ruziziensis*, with a seed spending of 10 kg ha^{-1} with a cultural value (CV) of 50%, mixed with the sowing fertilizer of

Table 3. Quantity of the nutrient used in the experiment.

N	P	K	N	P	K	N	P	K
kg ha^{-1}								
	2009/2010			2010/2011			2011/12	
12.0	60.0	60.0	112.2	67.2	86.4	20.0	88.0	76.0
	2012/13			2013/2014			2014/2015	
12.0	60.0	60.0	14.0	70.0	70.0	120.0	84.0	94.0

Table 4. Soil chemical attributes in the 0.00-0.20 m, 2016/2017 crop.

P (Resin)	OM	pH ($CaCl_2$)	K	Ca	Mg	H+Al	Al	V
mg dm^{-3}	g dm^{-3}		---------mmol$_c$ dm^{-3}--------					(%)
39	17	5.0	3.5	15	10	21	1	57

OM - Organic matter.

forage sorghum.On October 29 2015 a sampling of the amount of dry matter of U. ruziziensis and forage sorghum present in the area was carried out. Ten samples of 0.5×0.5 m were taken, at U. ruziziensis and forage sorghum cut close to the soil. The samples were packed in paper bags and taken to dry in a forced ventilation oven, regulated at 65-70°C for 72 h. After achieving constant weight, the dry mass of the plant material was determined, and the results were expressed in kg ha-1 of dry matter. The average amount of dry matter in the area was 10600 kg ha^{-1}. The management of *U. ruziziensis* and forage sorghum was carried out through desiccation, without mowing or cutting them. The area was desiccated on November 09 2015, using glyphosate (480 g L^{-1}), at a dose of 4 L ha^{-1} of the commercial product (c.p.) and chlorimurom-ethyl (250 g kg^{-1}), at a dose of 0.05 kg ha^{-1} of the c.p.

On November 23 2015, soybean cultivar BMX Potencia was sown, with a spacing of 0.5 m between rows, using 16 seeds m^{-1}, 300 kg ha^{-1} of the fertilizer formulated 04-20-20 and three doses ha^{-1} of liquid inoculant and 1.5 doses ha^{-1} of peat inoculant. The soybean was harvested on March 18 2016.

On 23 March 2016 a sampling of the quantity of dry matter of *U. ruziziensis* and forage sorghum on the soil was carried out to verify the effect of N on the decomposition of straw. Two samples of 0.5 × 0.5 m were taken per plot, collecting all the *U. ruziziensis* straw and forage sorghum present on the soil. The samples were packed in paper bags and taken to dry in a forced ventilation oven, regulated at 65-70°C for 72 h. After obtaining constant weight, the dry mass of the straw was determined, and the results expressed in kg ha^{-1} of dry matter.

On the same day, forage sorghum cultivar DOW SS 318 was sown, at a spacing of 0.8 m between rows, using 12 seeds m^{-1} and 300 kg ha^{-1} of the fertilizer formulated 08-28-16, intercropped with *U. ruziziensis*, mixed with forage sorghum sowing fertilizer, with a seed expenditure of 10 kg ha^{-1} and a CV of 50%. Prior to sowing the 2016/2017 soybean crop, a new soil sample was collected for chemical analysis and determination of its fertility, using the same methodology as the previous year. The results are shown in Table 4.

On October 19 2017 a new sampling of the quantity of the dry matter of *U. ruziziensis* and forage sorghum in the area was carried out, using the same methodology as the previous year. The average amount of dry matter present in the area was 11100 kg ha^{-1}. The management of *U. ruziziensis* and forage sorghum was again carried out through desiccation, without mowing or cutting them. The area was desiccated on October 19 2016, using glyphosate (720 g kg^{-1}), in the dosage of 2.5 kg ha^{-1} of c.p. + ethyl carfentrazone (400 g L^{-1}) in the dosage of 0.1 L ha^{-1} of the c.p. + mineral oil, in the dosage of 0.5% of the c.p. On November 16 2016, a sequential desiccation was performed using clethodim (240 g kg^{-1}), at a dosage of 1.0 L ha^{-1} of the c.p. + mineral oil, in the dosage of 0.5% of the c.p.

On November 17 2016, the soybean cultivar BMX Potencia was sown, with a spacing of 0.5 m between rows, using 16 seeds m^{-1} and 300 kg ha^{-1} of the 04-20-20 formulated fertilizer and three doses ha^{-1} of liquid inoculant and 1.5 doses ha^{-1} of peat inoculant. The soybean was harvested on March 09 2017. On March 16, 2017, a new sampling of the amount of dry matter of *U. ruziziensis* and forage sorghum present on the soil was carried out, using the same methodology as the previous year.

Agronomic characteristics of forage sorghum and *U. ruziziensis* in the same edaphoclimatic conditions of the study are included in Borges et al. (2014). The parameters evaluated in soybean crop were the following: first pod insertion height, plant height, final stand ha^{-1} and grain yield ha^{-1}. The evaluations were carried out at harvest of the soybean crop. Grain yield was obtained by standardizing grain moisture to 13% (wet basis). The sampling of the first pod insertion height and plant height was carried out in five plants in each plot, and the sampling of the final stand ha^{-1} and grain yield was carried out in 3 m of two central lines of each plot. The pods were threshed in a mechanical thresher. After threshing the grains were weighed and their moisture measured to calculate grain yield.

The data were submitted to the F test ($p < 0.05$), using the computer software Assistat (Silva and Azevedo, 2016) and the study of polynomial regression was performed. The monthly data on potential evapotranspiration, rainfall and average temperature in Votuporanga, São Paulo State from April 1 2015 to April 1 2017, are shown in Figure 1.

RESULTS AND DISCUSSION

No effect ($p < 0.05$) of the nitrogen fertilization was observed on the decomposition of *U. ruziziensis* straw and forage sorghum (Table 5), corroborating with Borges et al. (2013) who also did not observe any effect of

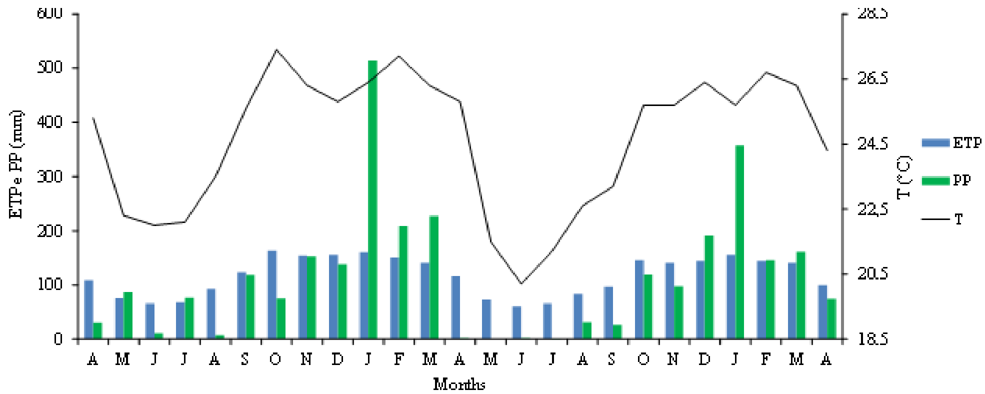

Figure 1. Data on potential evapotranspiration (ETP), rainfall (PP) and average temperature (T), in Votuporanga - São Paulo State in the experimental period, April 2015 to April 2017. Source: CIIAGRO (2020).

Table 5. Regression in the analysis of variance of the quantity of dry matter of U. ruziziensis and forage sorghum, after soybean harvest, 2015/2016 and 2016/2017 crops.

Sources of variation	F	
	2015/2016 crop	2016/2017 crop
Linear Regression	0.3211^{ns}	0.9288^{ns}
Quadratic Regression	0.0159^{ns}	0.3241^{ns}
Cubic Regression	0.0378^{ns}	0.1199^{ns}
Coefficient of variation (%)	21.29	26.20

Table 6. Regression in the analysis of variance of soybean crop agronomic characteristics, 2015/2016 crop.

Sources of variation	F			
	Insertion height	Plant height	Final stand	Yield
Quadratic regression	0.7067^{ns}	0.0454^{ns}	0.0317^{ns}	33.1865**
Coefficient of variation (%)	16.13	9.52	19.02	11.72

Insertion height - first pod insertion height; Final stand - Final stand ha^{-1}; Yield - Grain yield; ^{ns} - not significant; ** - significant at 1% by the F test.

nitrogen fertilization on the degradation of sugarcane straw due, according to the authors, to climatic conditions, with an average temperature greater than 25°C and accumulated precipitation in the period above 750 mm, which may have promoted a faster straw decomposition, even without the use of N.

On the other hand, Garcia et al. (2014) found that the amount of remaining dry matter of the forage species *Urochloa* and *Megathyrsusicum*, grown in intercropping with corn, was influenced by the nitrogen fertilization applied to the forages after the maize harvest, showing a decreasing linear effect according to the number of days after the cutting management, for all doses of N applied, with an average reduction in the dry matter of 85.3% for *U. ruziziensis*, at 150 days after NBapplication. Nevertheless, in the 2015/2016 crop, the reduction in the straw dry matter in this experiment at 146 days after N application was 21.4, 23.8, 23.8 and 28.3%, respectively for the doses of 0, 20, 40 and 60 kg ha^{-1} of N, and in the 2016/17 crop, the reduction was 44.8, 33.9, 34.2 and 32.7%, respectively for doses of 0, 20, 40 and 60 kg ha^{-1} of N at 148 days after N application.

The dry matter quantities of *U. ruziziensis* straw and forage sorghum, after soybean harvest, were 8330, 8073, 8079 and 7607 kg ha^{-1} in the 2015/2016 crop, and 6128, 7340, 7309 and 7468, in the 2016/17 crop for the doses of 0, 20, 40 and 60 kg ha^{-1} of N, respectively, greater than the average amount found by Garcia et al. (2014) for *U. ruziziensis*, which was 663 kg ha^{-1} of N, 150 days after N application. No effect (p <0.05) was observed in the nitrogen fertilization on the first pod insertion height, plant height and final stand ha^{-1} in either crop (Tables 6 and 7),

Table 7. Regression in the analysis of variance of soybean crop agronomic characteristics, 2016/2017 crop.

Sources of variation	F			
	Insertion height	Plant height	Final stand	Yield
Linear regression	0.2438^{ns}	0.5666^{ns}	0.0159^{ns}	12.5284**
Coefficient of variation (%)	15.04	11.19	9.53	10.82

Insertion height - first pod insertion height; Final stand - Final stand ha^{-1}; Yield - Grain yield; ^{ns} - not significant; ** - significant at 1% by the F test.

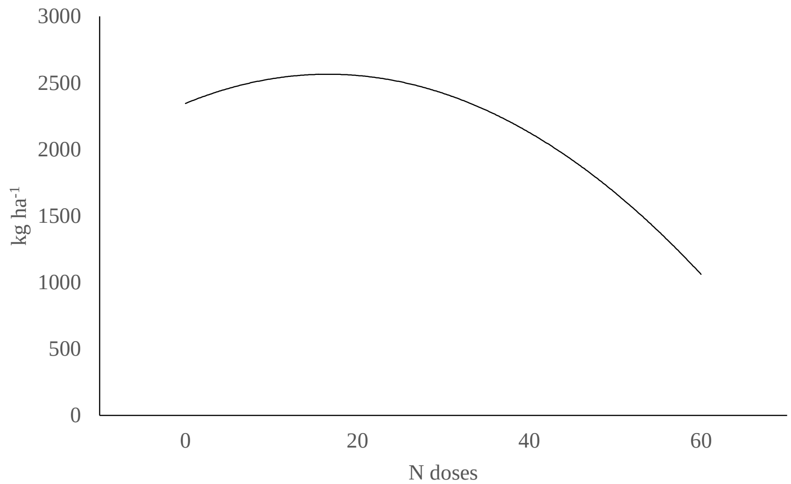

Figure 2. Grain yield of soybean crop according to the nitrogen doses (kg ha^{-1}), 2015/2016 crop.

corroborating with Bahry et al. (2013a). It should be observed that in both harvests, three doses ha^{-1} of liquid inoculant and 1.5 doses ha^{-1} of peat inoculant were used, which, according to Silva et al. (2011), may have adequately supplied the crop with this nutrient in its vegetative phase due to the adequate biological N fixation by bacteria, due to conditions conducive to this process during the crop development, such as temperature, pH, water availability , oxygen, nutrients in the soil, among other determining factors in nodulation.

Also, the experiment was developed in an area where the no-tillage system has not been used since the 2009/2010 crop. In addition, according to Silva et al. (2011), in the no-tillage system, the soil is not used very much, so there is a less mineralization effect and it is likely that the N of the soil contributed to the initial supply to the crop until the beginning of the fixation process. Thus, the BNF, associated with the N available in the soil solution was effective in providing the levels of N required by the crop in its vegetative phase, corroborating with Ferreira et al. (2016).

On the other hand, this fact was not observed in the reproductive phase of the crop as the grain yield was influenced by the application of N. Also, in the 2015/2016 crop, the N doses showed significant quadratic regression ($p < 0.01$) (Table 6). In the 2016/2017 crop, the doses of N showed significant linear regression ($p < 0.01$) (Table 7), corroborating with Santos et al. (2000), who also observed a linear response to N in terms of grain yield, in one of the two years of the experiment, where the dose of 120 kg ha^{-1} was the most favorable. It can be seen through the equation $y = 2370.639 + 40.205x - 0.949x^2$ ($R^2 = 0.99$) that the dose of 21 kg of N ha^{-1} provided the highest grain yield in the 2015/2016 crop (2796 kg ha^{-1}), decreasing up to the dose of 60 kg of N ha^{-1} (Figure 2). The dose of 20 kg of N ha^{-1} resulted in an increase of 204 kg ha^{-1} of grains; however, the dose of 40 and 60 kg of N ha^{-1} resulted in a reduction of 215 and 1289 kg ha^{-1}, respectively, corroborating with Balboa et al. (2015) who found, in the arid lands of Scandia, that the greater application of N statistically decreased grain yield in comparison to the other treatments. This reduction in grain yield indicates a likely harmful effect of N at higher doses (Bahry et al., 2013a), causing the reduction in soybean nodulation, in terms of dry matter and number of nodes per plant (Nogueira et al., 2010). This fact was reported by Mendes et al. (2008) who found that the application of 200 kg ha^{-1} of N impaired nodulation.

According to Brandelero et al. (2009), nodulation is closely related to grain yield and, according to Bahry et al.

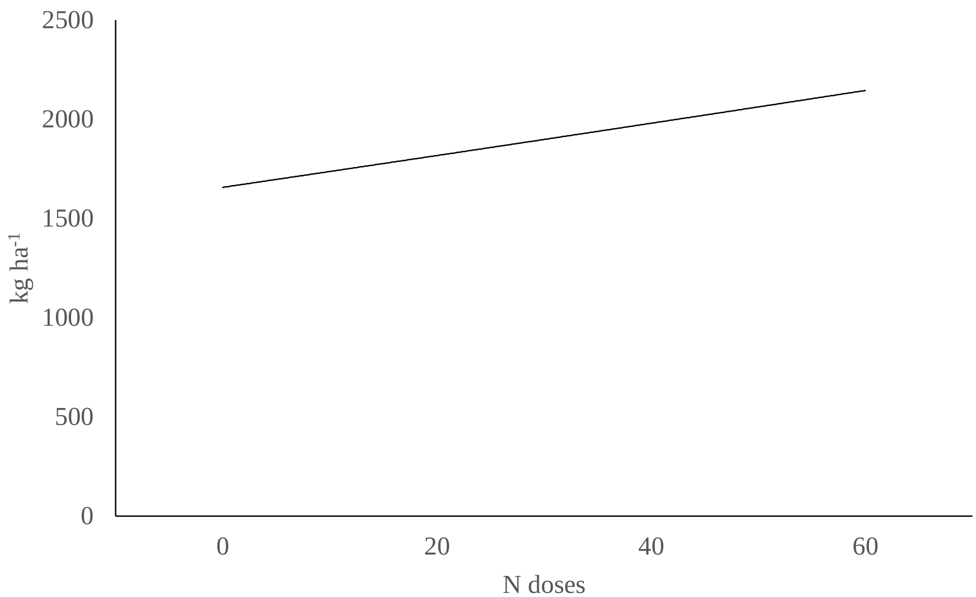

Figure 3. Grain yield of soybean crop according to the nitrogen doses (kg ha^{-1}), 2016/2017 crop.

(2013b), at the beginning of the pod formation, the rhizobia are in full operation, and any stressing factor can impair the process, in this case, the exogenous application of N, which may have negatively affected the biological fixation and caused stress in the plant itself, due to the malfunction of the rhizobia-plant interaction.

In the 2016/2017 crop, the equation y = 1656.999 + 7.946x (R^2 = 0.97) showed that the dose of 60 kg N ha^{-1} provided the highest grain yield (2134 kg ha^{-1}), as shown in Figure 3. The increases in grain yield were 100, 353 and 458 kg ha^{-1}, for the doses of 20, 40 and 60 kg of N ha^{-1}, respectively, therefore demonstrating that according to Silva et al. (2011), there was a good supply of N throughout the crop development. These results corroborate with Boroomandan et al. (2009) who found a significant increase (528.4 kg ha^{-1}) in grain yield, as the density increased from 30 to 45 plants m^{-2} and the initial fertilization of N increased from 0 to 40 kg ha^{-1} in two years.

Similar results were observed by Petter et al. (2012) who found that the late application (beginning of flowering) of 20 and 40 kg of N ha^{-1} provided an increase in grain yield in all cultivars, with increases of up to 360 kg ha^{-1}, when compared to the control. The efficiency of BNF depends on the availability of nutrients in the soil (Leite et al., 2009) and the supply of N may not be fully met by biological fixation and soil supply, thus requiring complementary nitrogen fertilization to achieve a maximum grain yield (Petter et al., 2012; Salvagiotti et al., 2009).

In high-yield soybean cultivation systems, the effect of the late application of N during the crop development period can be an important factor to be considered (Balboa et al., 2015). On the other hand, Bahry et al. (2013b) stated that, even in high-yield crops, biological fixation may be sufficient to meet the demand for N from soybean.

In Illinois and Indiana, USA, Wilson et al. (2014) found that the N-supplementation through soil and BNF provided almost all the necessary N to maximize the grain yield potential of the oldest cultivars, but it did not satisfy the quantity required by modern cultivars. Because of the N-mobility in the soil, its efficiency still raises many doubts (Costa et al., 2009). Bearing in mind that in the first year, nitrogen fertilization above 21 kg of N ha^{-1} promoted a reduction in grain yield and that in the second year, the fertilization effect was linear, it is emphasized that the use or not of nitrogen fertilization in the crop of soybean on forage sorghum straw intercropped with *U. ruziziensis*, should not exceed 21 kg of N ha^{-1}, and this fertilization will depend on its economic viability, due to the application costs, both of the product itself, and the labor and necessary equipment. Also, in years when grain prices are expected to raise and the nitrogen fertilizer prices to fall, the application of the nutrient can be a really important factor for incrementing the income of the soybean farmer (Bahry et al., 2013a). Even with average gains of 300 kg ha^{-1} in grain yield, obtained with the application of N in the soybean crop, Petter et al. (2012) concluded that nitrogen fertilization was not economically viable, when considering the prices of soybean, nitrogen fertilizer, freight and application costs.

This fact was observed by Mendes et al. (2008), who found that the increase of 4 bags ha^{-1} would not result in profit for the farmers, when considering the prices of US$

119 for 50 kg of ammonium sulfate and US$ 23 for the sack of soybean, ranked in the Federal District, in November 2007, without including the cost of transporting the fertilizer and its application. According to Salvagiotti et al. (2008), in most cases, nitrogen fertilization in soybean crops is only profitable, where the N_2 fixation is not able to meet the total N demand for high-yield crops and when the soybean price, in relation to the N, is enough to make the investment economically viable.

Conclusions

The application of nitrogen did not influence the degradation of the straw of forage sorghum and *U. ruziziensis*. Nitrogen fertilization in soybean crop over forage sorghum straw intercropped with *U. ruziziensis* increases in grain yield; however, this fertilization should not exceed 21 kg of N ha^{-1}.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Balboa GR, Hodgins DR, Ciampitti IA (2015). Late-season nitrogen fertilizer application in soybean. Kansas Agricultural Experiment Station Research Reports 1(2). https://doi.org/10.4148/2378-5977.1016

Bahry CA, Venske E, Nardino M, Fin SS, Zimmer PD, Souza VQ, Caron BO (2013). Características morfológicas e componentes de rendimento da soja submetida à adubação nitrogenada. Revista Agrarian 6(21):281-288.

Bahry CA, Venske E, Nardino M, Fin SS, Zimmer PD, Souza VQ, Caron BO (2013). Aplicação de ureia na fase reprodutiva da soja e seu efeito sobre os caracteres agronômicos. Tecnologia & Ciência Agropecuária 7(2):9-14.

Bahry CA, Nardino M, Venske E, Fin SS, Zimmer PD, Souza VQ, Caron BO (2014). Efeito do nitrogênio suplementar sobre os componentes de rendimento da soja em condição de estresse hídrico. Revista Ceres 61(2):155-160. https://doi.org/10.1590/S0034-737X2014000200019

Borges WLB, Mateus GP, Freitas RS, Tokuda FS, Hipólito JL, Tomazini NR, Cazentini Filho G, Gasparino AC (2013). Uso de nitrogênio no sistema de produção de soja sobre palhada de cana-de-açúcar. Nucleus 10(3):57-66. https://doi.org/10.3738/nucleus.v0i0.909

Borges WLB, Freitas RS, Mateus GP, Sá ME, Alves MC (2014). Absorção de nutrientes e alterações químicas em Latossolos cultivados com plantas de cobertura em rotação com soja e milho. Revista Brasileira de Ciência do Solo 38(1):252-261. https://doi.org/10.1590/S0100-06832014000100025

Borges WLB, Freitas RS, Mateus GP, Sá ME, Alves MC (2015). Produção de soja e milho cultivados sobre diferentes coberturas. Revista Ciência Agronômica 46(1):89-98. https://doi.org/10.1590/S1806-66902015000100011

Boroomandan P, Khoramivafa M, Haghi Y, Ebrahimi A (2009). The effects of nitrogen starter fertilizer and plant density on yield, yield components and oil and protein content of soybean (*Glycine max* L. Merr). Pakistan Journal of Biological Sciences 12(4):378-382. Doi: 10.3923/pjbs.2009.378.382.

Brandelero EM, Peixoto CP, Ralisch R (2009). Nodulação de cultivares de soja e seus efeitos no rendimento de grãos. Semina: Ciências Agrárias 30:581-588.

Câmara GMS (2000). Nitrogênio e produtividade da soja. In: Câmara, GMS (ed). Soja: tecnologia da produção II. ESALQ, Departamento de Produção Vegetal, Piracicaba pp. 1-25.

Centro Integrado De Informações Agrometeorológicas - Ciiagro (2020). Resenha: Votuporanga no período de 01/04/2015 a 01/04/2017.ciiagro.sp.gov.br/ciiagroonline/Listagens/Resenha/LResenhaLocal.asp. [accessed on 09.12.2020].

Costa RSS, Arf O, Orioli Júnior V, Buzetti S (2009). População de plantas e nitrogênio para feijoeiro cultivado em sistema de plantio direto. Revista Caatinga 22(4):39-45.

Da Ros CO, Aita C (1996). Efeito de espécies de inverno na cobertura do solo e fornecimento de nitrogênio ao milho em plantio direto. Revista Brasileira de Ciência do Solo 20(1):135-140.

Domingos CS, Lima LHS, Braccini AL (2015). Nutrição mineral e ferramentas para o manejo da adubação na cultura da soja. Scientia Agraria Paranaensis 14(3):132-140.

Ferreira AS, Balbinot Júnior AA, Werner F, Zucareli C, Franchini JC, Debiasi H (2016). Plant density and mineral nitrogen fertilization influencing yield, yield components and concentration of oil and protein in soybean grains. Bragantia 75(3):362-370. https://doi.org/10.1590/1678-4499.479.

Garcia CMP, Andreotti M, Teixeira Filho MCM, Lopes KSM, Buzetti, S (2014). Decomposição da palhada de forrageiras em função da adubação nitrogenada após o consórcio com milho e produtividade da soja em sucessão. Bragantia 73(2):143-152. http://dx.doi.org/10.1590/brag.2014.016

Lamond RE, Wesley TL (2001). In season fertilization for high yield soybean production. Better Crops With Plant Food 85(2):6-7.

Leite LFC, Araújo ASF, Costa CN, Ribeiro AMB (2009). Nodulação e produtividade de grãos de feijão-caupi em resposta ao molibdênio. Revista Ciência Agronômica 40(4):492-497.

Mendes IC, Reis Júnior FB, Hungria M, Sousa DMG, Campo RJ (2008). Adubação nitrogenada suplementar tardia em soja cultivada em Latossolos do Cerrado. Pesquisa Agropecuária Brasileira 43(8):1053-1060. https://doi.org/10.1590/S0100-204X2008000800015

Nogueira PDM, Sena Júnior DG, Ragagnin VA (2010). Clorofila foliar e nodulação em soja adubada com nitrogênio em cobertura. Global Science and Technology 3(2):117-124.

Petter FA, Pacheco LP, Alcântara Neto F, Santos GG (2012). Respostas de cultivares de soja à adubação nitrogenada tardia em solos de cerrado. Revista Caatinga 25(1):67-72.

Salvagiotti F, Cassman KG, Specht JE, Walters DT, Weiss A, Dobermann AR (2008). Nitrogen uptake, fixation and response to fertilizer N in soybeans: A review. Field Crops Research 108(1):1-13. https://doi.org/10.1016/j.fcr.2008.03.001

Salvagiotti F, Cassman KG, Specht JE, Walters DT, Weiss A, Dobermann A (2009). Growth and nitrogen fixation in high-yielding soybean: impact of nitrogen fertilization. Agronomy Journal 101(4):958-970. https://doi.org/10.2134/agronj2008.0173x

Santos LP, Vieira C, Sediyama CS, Sediyama T (2000). Adubação nitrogenada e molíbdica da cultura da soja em Viçosa e Coimbra. Revista Ceres 47(269):33-48.

Santos Neto JT, Lucas FT, Fraga DF, Oliveira LF, Pedroso Neto JC (2013). Adubação nitrogenada, com e sem inoculação de semente, na cultura da soja. FAZU em Revista 10:8-12. www.fazu.br/ojs/index.php/fazuemrevista/article/download/242/411

Santos HG, Jacomine PKT, Anjos LHC, Oliveira VÁV, Lumbreras JF, Coelho MR, Almeida JÁ, Cunha TJF, Oliveira JB (2013). Sistema brasileiro de classificação de solos. 3rd edn. Centro Nacional dePesquisa de Solos, Rio de Janeiro P 353. http://ainfo.cnptia.embrapa.br/digital/bitstream/item/181678/1/SiBCS-2018-ISBN-9788570358219-english.epub

Silva AF, Carvalho MAC, Schoninger EL, Monteiro S, Caione G, Santos PA (2011). Doses de inoculante e nitrogênio na semeadura da soja em área de primeiro cultivo. Bioscience Journal 27(3):404-412.

Silva FAS, Azevedo CAV (2016). The Assistat Software Version 7.7 and its use in the analysis of experimental data. African Journal of Agricultural Research 11(39):3733-3740. https://doi.org/10.5897/AJAR2016.11522

van Raij B, Andrade JC, Cantarela H, Quaggio JA (ed) (2001). Análise química para avaliação da fertilidade do solo. Instituto Agronômico,

Campinas 285 p.
Wilson E, Rowntree SC, Suhre JJ, Weidenbenner NH, Conley SP, Davis VM, Diers BW, Esker PD, Naeve SL, Specht JE, Casteel SN (2014). Genetic gain x management interactions in soybean: II. Nitrogen utilization. Crop Science 54(1):340-348.https://doi.org/10.2135/cropsci2013.05.0339