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Plant cover management and nitrogen fertilization in maize crop in a dystrophic red Latosol Brazilian Cerrado (Savannah)

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An experiment was conducted in the agricultural year 2014/2015, aiming to evaluate the management of anticipated nitrogen fertilization, applied with a slow-release source in maize crop with two plant covers, in a Dystrophic Red Latosol. Matching the Oxisols in Soil Taxonomy and Ferralsols FAO/United States WRB (Unesco soil classification and the World Reference Base for Soil Resources. *Pennisetum glaucus* (*Pennisetum glaucum* (L.) R. Br.) and *Raphanus sativus* (*Raphanus sativus* L.) were used as green cover, keeping a fallow area. In the areas with vegetal cover, N was applied anticipatedly, during planting and in top-dressing, while in the fallow area it was applied during the planting process and in top-dressing. The treatments were distributed according to a random block design with four replicates. The anticipated N application was made 38 days before planting and top-dressing application 27 days after planting. Leaves were collected for foliar analysis during the tasselling stage of the plants. The harvest and threshing were done manually, and the grains were weighed. Grain yield and leaf N contents were evaluated. The maize crop responded to nitrogen fertilization regardless of the cover used. Nitrogen fertilization using a slow-release N source can be managed in an anticipated stage, without damaging crop yield.

Key words: Soil, slow-release nitrogen, *Zea mays* L.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most cultivated and consumed grains in the world, it is grown on more than 10 million hectares, producing around 50 million tons (Conab, 2017). This culture has a high economic value,

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given its great importance in human and animal nutrition, serving as raw material especially in the pork and poultry production chain, which consumes approximately 70 to 80% of the Brazilian maize production (Duarte et al., 2010). Even though it represents a significant part of the grain harvest in Brazil, its productivity is still threatened by many factors, such as soil fertility, water availability, plant population, seed sowing periods, cultural practices and diseases, pests and weeds (Fancelli and Dourado, 2003).

Nitrogen (N) is an essential chemical element to plants in general, and maize has a high extractive capacity of this nutrient from the soil (Granato et al., 2014; Coelho and França, 2007). During fertilization, N has an important role due to its participation in several processes of the plant metabolism (Andrade et al., 2003). Its presence is crucial in the initial stage of development of the plant, a period in which the absorption is more intense (Basso and Ceretta, 2000). The N supply through nitrogen fertilizers has a high cost because of its low use efficiency, mostly due to the losses to the environment which are usually attributed to very soluble forms, that facilitates the transformations occurring in the soil (Cantarella and Duarte, 2007).

As the risks of crop loss or decrease in production yield in the second crop are relatively large, one of the dilemmas of this cultivation mode is to know which source to use and the amount of N to apply, since water deficiency changes the absorption and the metabolism of N in the plant (Ferreira et al., 2002), diminishing the applied fertilizer´s efficiency. The management of nitrogen fertilization can be difficult in practice, considering that nitrogen is very dynamic in the soil because of its transformation processes, which causes losses by volatilization, leaching and denitrification. In this sense, alternatives have been sought to improve its efficiency (Souza et al., 2001; Kluthcouski et al., 2006; Fernandes and Libardi, 2007).

Studies with slow-release nitrogen fertilizers (Setti et al., 2006) detected an alternative to reduce nitrogen losses. Since it is a protected product, the slow-released N provides a controlled release in the soil, allowing applications of higher doses during planting and even before that, which results in a greater flexibility in the use of N in production systems. Motta et al. (2015) have also verified that the use of stabilized sources with inhibiting polymers of enzyme urease, and the nitrification of ammonium, does not increase grain yield or the agronomic efficiency of N use, when compared to common urea and ammonium nitrate, irrespective of the dose of N applied in the cover. Studies carried out by Research Foundation of state Mato Grosso do Sul (Brasil) have shown good results in the anticipation of the recommended N dose in soils with low loss potential of N by leaching, which allows application of the N doses by instalments (Broch and Ranno, 2008).

The anticipation of N application in non-revolved soils and the cultivation of cover crops provide changes in nutrient cycling, with nitrogen being the most affected, mainly due to the slower decomposition of the vegetal residues left on the soil surface to influence the processes of immobilization, mineralization, leaching, volatilization and denitrification (Sá, 1996; Sallet et al., 1997; Cabezas et al., 2004). The quality of the vegetal residue, mainly its C/N ratio, and the availability of mineral N in the soil solution, can influence the decomposition rate (Ceretta et al., 2002) and the N utilization of these residues by the maize (Cabezas et al., 2004, Ernani et al., 2005).

Grasses have been frequently used as cover plants on cerrado conditions, with emphasis on *Pennisetum americanum*, due to their greater resistance to water deficit, higher biomass production and lower seed cost. In addition, high temperatures and high humidity during summer, result in a rapid decomposition of plant residues with low C/N ratio (Cabezas et al., 2004). Heinz et al. (2013) in their work with *Raphanus sativus,* have confirmed that 5,7 t ha^{-1} of dry matter is the adequate quantity for soil coverage in a no-till maize plantation. Pedrotti et al. (2015) verified that *Raphanus sativus* have influenced the productivity and leaf N content of the maize crop, and that they are related to the elevation of the nitrogen doses.

Therefore, the objective of this work was to evaluate the management of the anticipated nitrogen fertilization, with a slow-release source in a maize crop with two plant covers, in a Dystrophic Red Latosol.

MATERIALS AND METHODS

The trial was conducted in a field on the following geographical coordinates: latitude 19º30'52.71 "S, longitude 54º29'23.17" O. At an altitude of 670 meters, in the agricultural year 2014/15. The predominant climate in the region is Aw, according to Köppen classification, defined as tropical humid with wet summers and dry winters.

The average annual rainfall is 1700 mm and the average annual temperature 27 °C. The experimental area´s soil was classified as Dystrophic Red Latosol, matching the Oxisols in Soil Taxonomy. Physical and chemical characteristics, from the 0 to 20 cm layer, are shown in Table 1. The area had a record of summer soybean cultivation followed by maize from the second harvest. The coverages for the experiment were implemented in March 2014.

Soil preparation in the experimental area was done through subsoiling, followed by a levelling grader and base fertilization with 250 kg of NPK, using the formulated 10-15-15, applied in the groove, and 54 kg P_2O_5 (Single superphosphate) and 90 kg K_2O (potassium chloride) applied before planting. The experimental treatments consisted of two plant coverages (*P. glaucus and R. sativus*) and an uncovered area considered as fallow. Nitrogen fertilization was managed anticipatedly before planting, during planting and as top-dressing, as it can be observed in Table 2.

The experimental design consisted of completely randomized blocks, with 9 treatments and 4 replicates, and each experimental plot consisted of 10 spaced lines of 0.5m with 5m length. The coverages of *P. glaucus* and *R. sativus* were seeded on September 10th, 2014, accounting for 15 kg ha^{-1} each. The anticipated nitrogen fertilization in treatments with *P. glaucus* and *R. sativus* were

Table 1. Results of the chemical and physical soil analysis of the experimental area, from the 0 to 0.2 m layer, according to Embrapa (2011).

Chemical analysis									Physical analysis		
pH		P	K^+	Ca^{++}	Mg^{++}	Al^{3+}	$H^{++}Al^{3+}$	MO	Clay	Silt	Sand total
H_20	$CaCl_2$	mg dm^{-3}		cmolc dm^{-3}				g dm^{-3}	g kg^{-1}		
6.41	5.60	20	76	3.10	0.60	0.0	2.97	18.4	376	238	386

Table 2. Treatment description for the experiment with nitrogen fertilization management with two vegetation covers, in a Dystrophic Red Latosol, in the region of São Gabriel do Oeste - MS.

Vegetation cover	N dosage (kg ha^{-1})		
	Anticipated	Planting	Top-dressing
	0	0	0
Pennisetum glaucum	30	80	70
	30	60	90
	0	0	0
Fallow area	0	90	90
	0	30	150
	0	0	0
Raphanus sativus	30	80	70
	30	60	90

carried out manually on October 10th, 2014, 30 days after the coverage sowing, in the quantities that were mentioned in Table 2. On November 3rd, 2009, the coverage of *P. glaucus and R. sativus*, as well as the fallow area, were desiccated with glyphosate.

The sowing of maize was performed with a seeder, spaced 0.6 m, on November 17th, 2014, with a density of 3 to 4 seeds per linear meter, with a target population of 60,000 plants ha^{-1}. The maize cultivar that was used, is the hybrid Simple Modified 2B604 (Dow AgroSciences). At this stage, the nitrogen fertilization was applied in the planting process. Top-dressing was manually done on December 14th, when maize had 4 to 5 fully expanded leaf pairs.

The productivity and leaf sample evaluations were based on the two centerline portions of 5 m long. Leaf sampling was according to Malavolta (2006). After the leaf samples were gathered, they were stored in paper bags and dried at 65°C in a greenhouse with forced air system for 48 hours. Afterwards, they were shredded, and grinded in a Wille mill, and submitted to sulfuric and distilled digestion in order to obtain the N content by the Kjeldahl method, according to Embrapa (2011).

For the productivity evaluation, the spikes of all the plants on the two central lines of the experimental plot were collected manually on February 26th, 2015, and later destrawed. Afterwards, the grains were also manually threshed. The plants harvested from the two central lines were counted, in order to correct the productivity stand of 60,000 ha^{-1} plants. In order to determine the moisture content, 100 grams of the threshed grains were used, which were oven dried at 105°C.

The temperature and precipitation data were obtained from Cemtec, whose metrological station is 5 km away from the experimental area (Figure 1). The data from leaf N content and grain yield were submitted to variance analysis, followed by a mean test, using the SAS statistical program in PROC GLM procedure.

RESULTS AND DISCUSSION

Table 3 shows the results of average square and value of variance significance, for grain yield and leaf N content. There was a significant outcome for both grain production and leaf N, for grain yield 1% and foliar contents 5%. The coefficient of variation (CV) for this experiment was 7.65 and 13.09% respectively for grain yield and leaf N. Researchers often use the coefficient of variation in order to estimate the precision of the experiments. The coefficient expresses the standard deviation as a percentage of the mean (Clemente and Nuniz, 2002).

In practice, the lower the CV the more homogeneous is the data of the variable. Gomes (2000) considers a CV as low, when it is lower than 10%, average when it is in between 10 a 20%, and high when between 20 and 30%. Therefore, the coefficient of variation for grain yield in this experiment is considered low and leaf N as medium. The average levels of foliar N, for treatments that received nitrogen fertilization, were in average 27.43 g kg^{-1}, whereas the treatments without nitrogen application remained with 24.01 g kg^{-1}. This shows that the maize crop responded to nitrogen fertilization (Table 4).

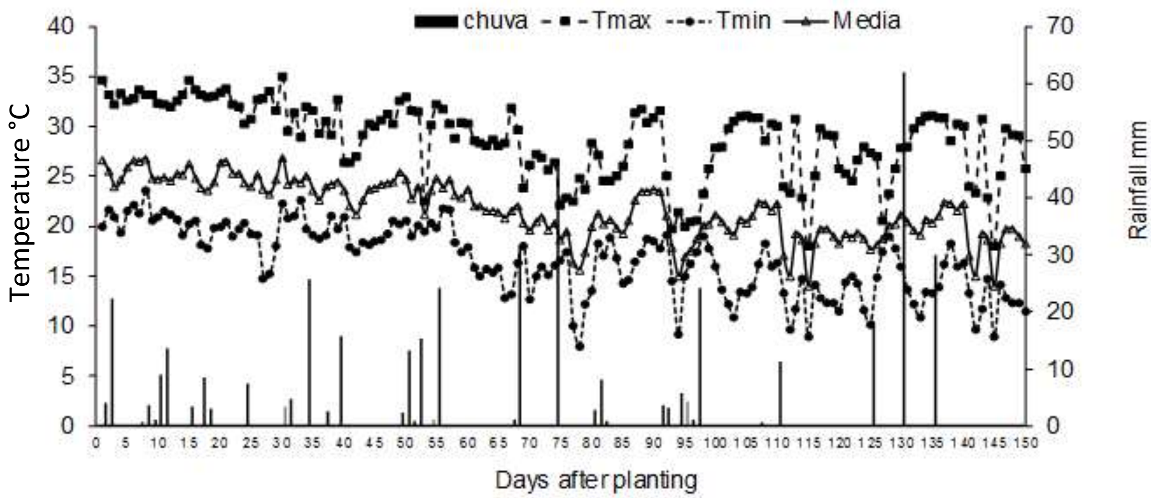

Figure 1. Average, maximum and minimum temperatures and rainfall precipitation during the experimental period. Source: Cemtec (2015).

Table 3. Results of the average square and statistical value of F for the variance analysis of the production of maize grains and foliar contents, in a Dystrophic Red Latosol, in the region of São Gabriel do Oeste - MS.

Sources of variation	GL	Average square		F	
		Production	Foliar N	Production	Foliar N
Treatments	8	2492221.01	39.18775	9.78**	3.09*
Repetition	3	1150686.62	0.915393	4.52*	0.07^{ns}
Residues	24	254786.59	12.697443	-	-
Coef. of variation (%)		7.65	13.09	-	-

** significant 1%; * significant 5% and ns = not significant.

Table 4. Average values of foliar nitrogen in maize crop with different vegetation covers and N fertilization management in a Dystrophic Red Latosol.

Cover	N dosage (kg ha^{-1})				
	Anticipated	Planting	Top-dressing	N (g kg^{-1})	
Pennisetum glaucum	0	0	0	22.08	B
Rafhanus sativus	0	0	0	22.93	AB
Fallow area	0	0	0	27.02	AB
Average				24.01	
Pennisetum glaucum	30	60	90	30.24	AB
Rafhanus sativus	30	60	90	30.66	A
Average				30.45	
Pennisetum glaucum	30	80	70	30.42	AB
Rafhanus sativus	30	80	70	27.20	AB
Average				28.81	
Fallow area	0	90	90	26.18	AB
Fallow area	0	30	150	28.35	AB
Average	-	-	-	27.27	-

Values followed by the same letter do not differ by Tukey test at 5% probability.

Table 5. Average values of maize grain yield in different vegetation covers, and N fertilization management, in a Dystrophic Red Latosol in the region of São Gabriel do Oeste - MS.

Cover	N dosage (kg ha^{-1})			Grain yield (kg ha^{-1})	
	Anticipated	Planting	Top-dressing		
Pennisetum glaucus	0	0	0	5622.5	BC
Raphanus sativus	0	0	0	5552.1	C
Fallow	0	0	0	5685.0	BC
Average	-	-	-	**5619.9**	
Pennisetum glaucus	30	60	90	6649.0	ABC
Raphanus sativus	30	60	90	7436.7	A
Average	-	-	-	**7042.9**	
Pennisetum glaucus	30	80	70	7487.2	A
Raphanus sativus	30	80	70	7286.6	A
Average				**7386.9**	
Fallow	0	90	90	6915.1	A
Fallow	0	30	150	6782.1	AB
Average	**-**	**-**	**-**	**6848.6**	**-**

Values followed by the same letter do not differ by Tukey test at 5% probability.

Malavolta (2006) suggests that foliar N values of 28 to 35 g kg^{-1} are critical, and Fontes (2001) defends that 27.5 g kg^{-1} is a critical value. According to Roscoe and Gitti (2013) these values are adequate. Therefore, we can assess that the average values of the treatments, without nitrogen fertilization, were below the critical level. For the other treatments, we can consider that the values were at the critical level or very close to it.

The treatments with *P. glaucus and R. sativus*, that received nitrogen fertilization in advance (30kg of N), showed no significant differences ($p > 0.05$) because of its plant coverage, even when compared to the fallow area, in which there was no previous fertilization treatment (Table 4). Although statistically similar, the leaf N contents are higher when a slow-release nitrogen fertilization is performed. A possible cause for the lack of response of foliar N between the cover and fallow areas, is that the dilution or concentration factors may have interfered in the foliar N content values, that is, the nutrient content dilutes as plants grow (Faroni et al., 2009).

As the soil in the fallow treatment was not stirred and the desiccation of the planted crop lasted 54 days, invasive plants grew in the area, which might have caused the absorption of N from the organic matter mineralization. Another fact that could have explained this non-response, would be the N supply by organic matter mineralization in the soil. Souza et al. (2002) consider that every 10 g of O. M./dm^{-3} can provide about 20 kg ha^{-1} of N to plants. In this case, taking into account 18.4 g dm^{-3} of organic matter, the soil would be able to provide 36.8 kg ha^{-1} of N, a greater quantity than what was applied in advance.

The treatments that received nitrogen in advance, during planting and top-dressing, presented an average productivity of 7093 kg ha^{-1}, while the treatments without nitrogen fertilization had an average of 5620 kg ha^{-1} (Table 5). This confirms the response of nitrogen fertilization nitrogen for grain yield, as well as foliar N. The treatments which received anticipated slow-released nitrogen fertilization, showed an average grain yield of 7214.86 kg ha^{-1}, whereas treatments that did not receive an anticipated nitrogen fertilization had an average of 6848.6 kg ha^{-1} (Table 5). It indicates that the maize crop positively responded to the anticipated fertilization. Sá et al. (2007) while working in the state of Paraná in 3 localities, also found the early fertilization of the maize crop effective.

The treatments with *P. glaucus* and *R. sativus* coverage that received the anticipated nitrogen fertilization (30 kg ha^{-1} N), did not show any significant difference because of the plant coverage (Table 5). In these treatments, those that received 80 kg ha^{-1} of N during planting, presented a slightly higher average than the treatments of 60 kg ha^{-1} of N. This was also observed in the fallow treatment, where the 90 kg ha^{-1} dose of N during planting presented higher values than the dose of 30 kg ha^{-1} of N. Borges et al (2015) on a study with *P. americanum* with densities 10, 15 and 20 kg of seed ha^{-1}, proved it to be a good coverage option for maize crop, regardless of the N dose for top-dressing, giving academic support for these data.

It can be affirmed that an anticipated nitrogen fertilization of 30 kg ha^{-1} on green cover, plus 80 kg ha^{-1}

at planting in the form of slow-release N, and 90 kg ha^{-1} at planting in the fallow area, which corresponds to 50% and 61.6% respectively of the total of the 180 kg of N required for the desired crop yield, showed better productivity results. Although they are still not significant in comparison with the treatments that did not receive the anticipated N fertilization.

It can be observed a better use of N by the plants when the slow-released N is applied in their system in advance. A fact that is reflected in their foliar N and grain yield.

Conclusion

Maize crop responded to the nitrogen fertilization regardless of its plant coverage. The vegetation coverages *P. glaucus* and *R. sativus* did not affect the maize grain yield. The nitrogen fertilization with a slow-release N source can be managed in advance, when applied on green coverages such as *P. glaucus* and *R. sativus,* without damaging productivity.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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