NITROGEN COATED FERTILIZER WITH CONTROLLED RELEASE FOR THE MAIZE CROP

FERTILIZANTE REVESTIDO COM NITROGÊNIO COM LIBERAÇÃO CONTROLADA PARA A CULTURA DO MILHO

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ABSTRACT: Maize represents one of the most cultivated crops of cereals in the world, being used as a source of grain, silage and biofuel. Nitrogen is very required in the maize crop, making nitrogen fertilization a significant part of the production cost. The objective of this study was to evaluate the response of two sources of N, urea and coated urea of controlled release, regarding the productivity and the cost/benefit ratio in maize for 2nd harvest. The experiment was carried out in the field in soil classified as dystroferric Red Latosol and treatments distributed in experimental plots, following the randomized block design with four replications. The treatments were 40 kg N ha^{-1} of common urea; 60 kg N ha^{-1} of common urea; 40 kg N ha^{-1} of coated urea; 60 kg of N-coated urea and the control without application of N broadcast application in planting. The maize crop responded to the application of nitrogen at planting. However, the use of coated urea did not increase the grain yield in relation to the use of common urea. The economic analysis demonstrated a better efficiency of use of N and the best net revenues with the application of the dose of 40 kg N ha $^{-1}$ of common urea in the planting of the crop.

KEYWORDS: Efficiency of N use. Fertilization. Productivity of out-of-season maize. *Zea mays.*

INTRODUCTION

Maize (*Zea mays* L.) represents one of the most cultivated crops of cereals in the world, being used as a source of grain, silage and biofuel (RODRÍGUEZ-BLANCO; SICARDI; FRIONI, 2015; GRUJCIC et al., 2018). Specifically in Brazil, maize is cultivated in two seasons, called 1st harvest, with sowing between September and December and harvest during the months of January to May (production of 28.82 million tons) and the 2nd harvest, with sowing dates from January to March and harvest from May to August (production of 58.59 million tons) (CONAB, 2017). Among the factors that affect the productivity of this crop are the water availability, the initial population of plants, sowing time, crop practices, occurrence of diseases, pests and weeds and the availability of nutrients to the plant (FANCELLI; DOURADONETO, 2003; RODRIGUES et al., 2014; GUERRA et al., 2017).

The nitrogen (N) is considered a chemical element essential to plants required by most cultures of economic interest, being the element that most limits the corn production (FAGERIA; BALIGAR, 2005; MARINI et al., 2015; ARNUTI et al., 2017). However, the provision of this element through the use of fertilizers has presented high cost and low efficiency, due to the losses to the environment (ZHENG et al., 2017), usually attributed to the very soluble forms (CANTARELLA, 2007; ARNUTI et al., 2017). As the risks of loss of or reduction in crop yield of maze in the second season are relatively large, one of the dilemmas of this modality of cultivation is know what source to use and the quantity of applied N, since the water deficiency alters the absorption and metabolism of N in the plant, reducing the efficiency of applied fertilizer (FERREIRA et al., 2002). One of the ways to increase the efficiency of utilization of nitrogenous fertilizers is the use of slow-release or controlled fertilizer to prevent the rapid transformation of N contained in the fertilizer in forms of less stable N in certain environments (HALL, 2005; ZHENG et al., 2017). Thus, the release of nutrients in the soil solution occurs synchronously with the demand of crop (ZHENG et al., 2017) and consequently improving their efficiency of use.

Chagas et al. (2016) working with different sources of N in coffee plants, verified that it is possible to reduce up to 2 applications of N when using N sources of controlled release in relation to the conventional and applying 70% of the recommended doses for the crop. Silva et al. (2012) et al in the maize crop and Silva Junior et al. (2016)

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in the production of fruits of *Caryca papya* L., verified the effect of slow release nitrogen, when compared to urea.

Pedrinho et al. (2015) working with rapid cycle crop, as the lettuce, and with slow release and traditional urea, found no differences in productivity among the studied sources. Veçozzi et al. (2018) using N sources with urea and urea coated with polymers, in the irrigated rice crop, found no effect among the sources.

Despite the potential of slow-release fertilizer to increase the efficiency of use of nitrogenous fertilizers, the use of such products is limited by the high cost in comparison with the traditional fertilizers. The consumption of nitrogenous fertilizers in Brazil is 64% based on urea, basically due to the concentration of N (45% N). This concentration, in terms of logistics is favorable to urea, when compared to other sources (ANDA, 2015), in addition to the economic factor, presenting a lower cost per unit of N compared to the sulfate and ammonium nitrate (FERNANDES et al., 2015). The urea coated with sulfur, probably the product with lower price differential is around two times more expensive than the common urea. Still, the cost of other slow release nitrogen fertilizers can vary between 2.4 to 10 times per unit of N (SHAVIV, 2001; TRENKEL, 2010).

Due to that, this study aimed to evaluate the response of two sources of N (common urea and coated urea of controlled release) and doses (40 and 60 kg ha^{-1}) on the productivity and cost-benefit analysis in 2nd harvest maize.

MATERIALS AND METHODS

This study was conducted in an experimental area in the municipality of Maracajú, State of Mato Grosso do Sul, Brazil (21º.55'54" S and 55º.20'56"). The soil of the area was classified as dystroferric Red Latosol (featuring in the layer from 0 to 0.2 mMO=25.5 g kg^{-1}; pH=4.7; P (Mehlich^{-1})= 29 mg k^{-1}; K= 3.9; Ca= 33.9; Mg= 10.8; H+Al= 51.2, Al= 4.1 mmol$_c$ dm^{-3}; S $_{so4}$ = 35.6; Cu= 4.7; Fe=17.2; Zn= 2.5; Mn= 25.7; B= 0.3 mg k^{-1}; clay== 287 507; sand and silt 206 g kg $^{-1}$ and 0.2 to 0.4 m layer MO=16.7 g kg^{-1}; pH=4.9; P (Mehlich-1)= 5.6 mg k^{-1}; K= 2.3; Ca= 25.8; Mg= 6.3; H+Al= 40.0, Al= 3,3mmol$_c$ dm^{-3}; S $_{so4}$ = 48.4; Cu= 2.3; Fe=10.0; Zn= 0.7; Mn= 9.0; B= 0.3 mg k^{-1}; clay= 523; sand=273 and silt 204 g kg $^{-1}$, determined according to Embrapa (2011). The region's climate is tropical, with an average annual rainfall of 1312.8 mm, average annual temperature of 24°C and average annual relative humidity of the air of 67% (CEMTEC, 2015). The data of precipitation (rain) and temperatures (Figure 1) recorded during the execution of the experiment were obtained from the Monitoring Center of weather, climate and water resources of Mato Grosso do Sul (CEMTEC), which maintains a weather station 3 km away from the experimental area. During the period of the test performance the average rainfall was 461 mm, the average temperature was 24ºC.

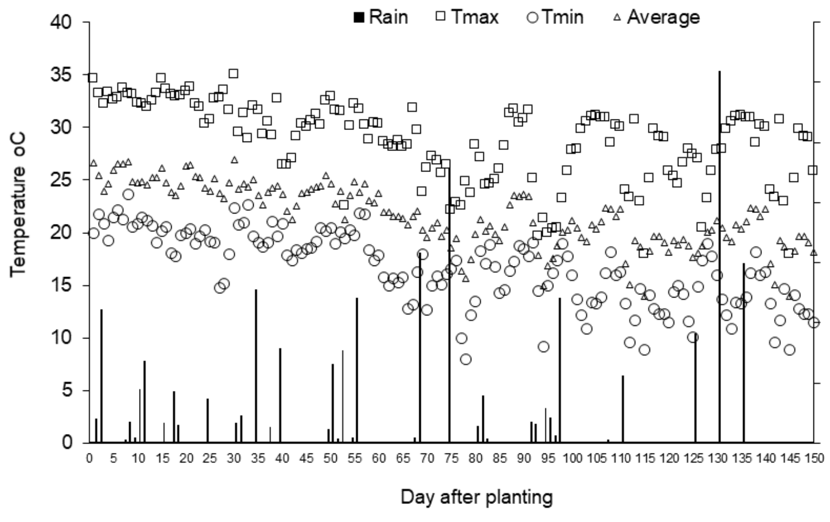

Figure 1. Average temperatures, maximum and minimum averages and rainfall in the experimental period.
Source: CEMTEC (2015).

In the area determined for the accomplishment of the experiment, soybean was used as summer crop, whose planting was conducted in September 2014. After the harvest of soybean, maize was established in February 2015, in no-tillage system, using a randomized block design with four replications for each treatment. Four treatments were used: 40 kg N ha^{-1} of common urea; 60 kg N ha^{-1} of common urea; 40 kg N ha-1 of coated urea; 60 kg of N-coated urea and the control (without application of N). For the application of coated urea the commercial product of nitrogen Polybler® was used with 40% of N-controlled release and for the traditional urea fertilizer with 45% of N was used applied at sowing of maze. In all treatments 120 kg ha -1 K_2 were applied by broadcast before planting, with the source of potassium chloride and nitrogen fertilizers applied in the furrow at planting. The experimental units were composed of 48 lines of 0.5 meters by 1000 meters in length. As useful area 30 central lines were considered (1.5 ha). For sowing seeds of corn cultivar simple hybrids (Agroceres 9040) were used, in the density of three seeds per linear meter, aiming at obtaining a population of 60,000 plants ha^{-1}.

Two months after sowing of maze (April 2015), a sampling of leaves were performed for determination of N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Zinc according to methodology from Embrapa (2011). For this reason, a leaf opposite the ear per plant was collected, using its central part, totaling 20 leaves per treatment. The collected material was dried in an oven at 65ºC, milled in mill type Wile and subjected for analysis. In addition, in July 2015, soil sampling of each plot was performed at depths of 0-20 and 20-40, with Dutch auger hole, for determination of pH, Ca, P, K, Ca, Mn, S_{SO4}, Al, H+Al, B, Cu, Fe, Zn and Mn according to the methodology proposed by Embrapa (2011).

The harvest was performed in a mechanized useful area (1.5 ha) in July 2015 and subsequently measured grain moisture with the use of a moisture meter (Motomco). The values obtained from the productivity of the area were corrected to 14% moisture and adjusted to kg ha^{-1}. Before the mechanized harvesting, at random 10 ears were withdrawn of each plot and the grains manually threshed were placed in an oven forced circulation until they reached 14% and one thousand grains were collected at random and weighed to determine the weight of one thousand grains.

To analyze the costs of production the prices of normal and coated urea were surveyed in the region, visiting establishments in August 2015 that work with fertilizers collecting the values of price charged to the producer. For the normal urea prices in 12 places were researched and it was obtained as average price the value of R$3.51 kg of N. For urea of controlled release 3 places were consulted, obtaining as average price the value of R$5.25 kg of N to obtain the price of applied N, the average value obtained from the forms of N of was multiplied by the applied dose. The application cost was considered to be the same for both sources. The increase in productivity was obtained with the productivity gap between the treated crop and the control.

For the calculation of Gross Revenue the corn prices practiced in the region was used, in the season in March 2015 - R$20.00 a bag of 60 kg, thus obtaining the value of R$ 0.33 kg of maize, which was multiplied by the increase in productivity, obtaining the gross revenue due to the applied N. The net revenue was obtained by the difference between the gross income and the price of applied N.

The nitrogen use efficiency (NUE) was determined according to Moll, Kamprath and Jackson (1982) using the following equation:

$$\text{Efficiency of N use} = \frac{(x-y)}{Z} \qquad \text{eq. 01}$$

Efficiency of N use, which represents the number of kg of maize grains produced per kg of applied N;

X is the corn grain yield in kg ha^{-1}, in the dose of N studied

Y is the corn grain yield in kg ha^{-1}, in the control; and

Z is the quantity of N applied to the soil in kg ha^{-1}.

The obtained data were statistically evaluated by analysis of variance. When the statistic in the F test was significant at 5% of probability, the means of the treatments were compared by the Tukey test at 5% probability.

RESULTS AND DISCUSSION

The fertility of the soil in the treatments, after corn harvest presented values of P, K, Ca, Mg, and S_{OS-4}, both in the layer of 0 to 0.2 m, and in the layer from 0.2 to 0.4 m (Table 1), within the ones recommended for the crop, when compared to the values suggested by Alvarez et al. (1999) and Sbcs/Nepar (2107). The micronutrient values (Table 2) were within the recommended for the crop, with the exception of B. The values of pH and B, which were below the recommended, may have limited the productive potential of the crop, but as they were virtually identical among the treatments, it was concluded that there was no interference of soil fertility in the comparison among the treatments.

Table 1. Mean values of the parameters of the fertility of the soil in the experimental area.

Treatment	Dosage Kg ha^{-1}	MO	pH	P	K	Ca	Mg	H+Al	Al	S-$_{S04}$
		g kg^{-1}	$CaCl_2$	mg kg^{-1}	------------------mmol$_+$ dm^{-3}------------------					mg kg^{-1}
0 to 20 cm										
Control	0	24.9 a	4.8 a	68.7 a	6.0 a	42.0 a	15.3 a	55.2 a	2.9 b	40.5 a
Urea	40	23.7 a	4.6 a	19.2 b	2.7 b	32.9 a	9.5 b	56.1 a	5.1 a	36.1 a
	60	25.9 a	4.7 a	24.0 b	4.1 b	30.2 a	9.8 b	49.4 a	4.1 a	33.7 a
Coated Urea	40	28.0 a	4.7 a	12.7 b	3.0 b	37.1 a	11.7 b	45.1 a	2.9 b	33.6 a
	60	25.3 a	4.6 a	20.7 b	3.9 b	27.1 a	7.8 b	50.3 a	5.3 a	34.3 a
20 to 40 cm										
Control	0	17.2 a	5.0 a	9.4 a	3.1 a	27.8 a	6.9 a	42.0 a	2.8 a	47.7 a
Urea	40	16.9 a	4.8 a	4.1 bc	1.5 b	24.3 a	6.3 a	42.3 a	3.8 a	48.5 a
	60	16.1 a	5.0 a	4.7 bc	2.3 a	25.5 a	6.0 a	37.5 a	3.1 a	50.3 a
Coated Urea	40	17.8 a	4.9 a	6.1 b	2.4 a	27.5 a	7.0 a	41.8 a	3.1 a	45.8 a
	60	15.4 a	4.7 a	3.6 c	2.1 ab	24.0 a	5.3 a	36.2 a	3.6 a	52.4 a

Averages followed by the same letters at the column, dot not differ among themselves, by the Tukey test at 5% of probability.

The average values of pH were observed in layer 0 of 4.7 to 0.2 4.9 me in the layer from 0.2 to 0.4 m, which can be considered acid to the maize crop Alvarez et al. (1999) and Sbcs/Nepar (2017). In the management of the soil fertility, liming was performed before the implementation of the soybean broadcast crop and without incorporation which may have not have result in corrective effect, thus not affecting the pH values. Ernani et al. (2005), working with the correction of the soil with limestone, found that the incorporation of liming in the soil is more effective than when it is applied at broadcast, without further incorporation. These same authors also reported that the pH neutralization reaction occurs only in the layer from 0 to 7 cm of soil depth.

The main disadvantage of urea is the possibility of high N losses by volatilization of ammonia. However, in acid soils, such as those that predominate in Brazil, the application of urea incorporated to 0.05 m or more depth in soil is enough to control these losses and to ensure that the N from its hydrolysis, is in the form of ammonia, which is stable (CANTARELLA; MARCELINO, 2007). Although the levels of P and K have shown differences among the evaluated treatments, the concentrations in the soil are above the critical level for these nutrients in the layer from 0 to 20 cm, according to Roscoe and Gitti (2013). Thus, these values considered appropriate, were not limiting factors for the response of N by the treatments. However, in the layer from 0.2 to 0.4 m, the valuesd Mg, Ca and P were below the critical level, according to Ribeiro, Guimarães and Alvarez (1999), which may have limited the potential response of the crop.

The nutrient Mg in the treatment with 60 kg ha^{-1} of coated urea, presented quantification of 0.78 cmol$_c$ dm^{-3}, below the critical level, which may have negatively influenced the response of this treatment. Out of the nutrients in the soil (Table 2), only Boron (0.3 mg dm^{-3}) was below the one recommended for the crop. Dourado Neto et al. (2004) working with dosages of B in maize found that levels of 0.35 mg dm^{-3}, were sufficient to meet the demands of the crop. The other micronutrients, even presenting significant differences among the evaluated treatments were at adequate levels (ALVAREZ et al., 1999; ROSCOE; GITTI, 2013).

Table 2. Mean values of soil micronutrients (DTPA) in the experimental area for two sources of nitrogenous fertilizers.

Treatment	Dosage Kg ha^{-1}	Cu	Fe	Zn	Mn	B
		mg dm^{-3}				
		0 to 0.2 m				
Control	0	4.6 a	17.9 a	3.3 a	22.7 b	0.4 a
Urea	40	5.2 a	19.0 a	2.3 a	31.8 a	0.4 a
	60	4.3 a	16.8 a	2.0 a	26.3 a	0.3 a
Coated Urea	40	4.9 a	17.5 a	2.5 a	21.9 a	0.3 a
	60	4.8 a	14.9 a	2.4 a	25.9 ab	0.4 a
		0.2 to 0.4 m				
Control	0	2.4 a	9.6 a	0.9 a	10.0 b	0.3 a
Urea	40	2.3 a	10.1 a	0.8 a	8.3 bc	0.3 a
	60	1.9 a	9.6 a	0.4 a	6.7 c	0.3 a
Coated Urea	40	2.8 a	11.6 a	0.9 a	14.0 a	0.3 a
	60	2.0 a	9.2 a	0.4 a	6.2 c	0.2 a

Averages followed by the same letters at the column, dot not differ among themselves, by the Tukey test at 5% of probability.

The evaluated treatments significantly influenced ($P<0.01$) the contents of K, Ca, Mg, S, Fe and Zn in dry matter of the corn leaves of the 2nd harvest (Table 3). The contents of Boron in all treatments and Ca in treatments Control, 60 of urea and 40 of Coated Urea, were below the critical level, according to Embrapa (2011). The values of B below the recommended levels may be related to low value found of this nutrient in the soil, which can be attributed to average levels of organic matter (25.5 g kg ha^{-1}) found in the present study, considering the values suggested in Alvarez et al. (1999). Coelho and Coelho Filho (2006) comment that the availability of B is associated to the levels of soil organic matter, corroborating with the result in this work. Just as for B, the low values of leaf Ca in the treatments control, urea 60 and urea 40 coated urea, seem to be related to the low availability of this nutrient in the soil (Table 1).

Table 3. Average values of the contents of macro and micronutrients in dry matter of maize leaves (2nd harvest) to two sources of nitrogenous fertilizers.

Treatment	Dosage Kg ha^{-1}	N	P	K	Ca	Mg	S	B	Cu	Fe	Zn	Mn
		g kg^{-1}						mg kg^{-1}				
Control	0	30.9b	2.5a	13.9b	0.7b	1.4b	1.5 b	7.1a	11.9a	256.8a	32.0b	62.6a
Urea	40	34.6	2.6	19.2	3.7	2.2	1.7	7.6	14.0	254.5 a	34.7	57.8
	60	35.7	2.7	18.4	1.7	1.7	1.9	6.6	14.8	153.0 b	55.2	74.4
Urea average		35.2a	2.7a	18.8a	2.7 a	2.0a	1.8a	7.1a	14.4a	203.8ab	45.0a	66.1a
Coated Urea	40	35.1	2.5	19.1	2.0	1.8	2.0	6.5	14.8	138.8b	38.0	65.0
	60	35.9	2.6	19.2	4.2	1.7	1.5	6.2	11.8	210.0a	34.2	65.2
Average of Coated urea		35.5a	2.6a	19.2a	3.1 a	1.8a	1.8a	6.4a	13.3a	174.4b	36.1b	65.1a

Averages followed by the same letters at the column, dot not differ among themselves, by the Tukey test at 5% of probability.

Although the use of nitrogen fertilization has resulted in increased productivity and weight of 1000 grains in relation to control, no significant differences were observed between the sources and dosages (Table 4). The average productivity of maize of 6,816 kg ha^{-1} was considered adequate for the region of Maracaju (MS), Brazil. Pereira et al. (2009) working with several cultivars of out-of-season maize crop in the region of Lavras, Minas Gerais, Brazil, in dosages of fertilizer high and low, verified average productivity of 3,081.9in 2005 and 4,711.4 in 2004, below the values obtained in this study.

Table 4. Average values of yield and weight of 1000 grains of maize (2nd harvest) to two sources of nitrogenous fertilizers.

Treatment	Dosage	Yield	Weight of 1000/grains
		Kg ha-^{1}	g
Control	0	5,250 b	294.00 b
Urea	40	6,805	324.00
	60	6,977	349.00
Average Urea		6,891 a	336.5 a
Urea Coated	40	6,540	355.00
	60	6,960	375.00
Average of Coated urea		6,750 a	365.0 a

Averages followed by the same letters at the column, dot not differ among themselves, by the Tukey test at 5% of probability.

Comparing the 40 and 60 kg ha^{-1} of N, regardless of the source, there was no difference, although Broch and Ranno (2008), state that the nitrogen (N) is the nutrient absorbed in greater quantity and that most limits the yield of corn. This result confirms those of Bono et al. (2009), working in the region, in the same type of soil, verified that the N source of slow release, that doses below 100 kg ha^{-1} of N, showed no difference in yield of maize upon the use of traditional and slow-release urea. These data are corroborated by Valderrama et al. (2011), working with fertilizers coated with polymer (urea), found that coating was not efficient in the studied climatic conditions, as they provided similar results to the same conventional fertilizers, for leaf contents of N, P and K, yield components and grain yield of irrigated corn. However, Mar et al. (2003), working with out-of-season maize in the region of Dourados (MS), found a significant difference in productivity between the doses of 30 and 60 kg ha^{-1}, applied in the furrow at planting.

In the economic analysis, it was found that the greatest increase in yield was for the dosage of 60 kg N ha^{-1}. However, the largest net revenue and the EUN was for the dosage of 40 kg N ha^{-1} for the source urea (Table 5). EUN average obtained was 32.1 kg of maize grains for each kg of applied N. This value corroborates with those of Cancellier et al. (2011), who working with several maize genotypes and with the index of Moll to EUN, found a mean value of 33 kg of maize grains for each kg of applied N. These values are close to those of Mota et al. (2015) who found mean values of 39 kg for 1st year and 35 for the 2nd year working with dosages of 70, 140 and 280 kg N ha^{-1} sources of ammonium nitrate, urea with urease inhibitor and with nitrification inhibitors.

Table 5. Economic analysis of two sources of nitrogen applied on maize crop (2nd harvest) for two sources of nitrogenous fertilizers.

Treatment	Dosage Kg N ha^{-1}	Price of applied N (R$ ha^{-1})	Increase in yield (kg ha^{-1})	Gross revenue due to the applied N (R$0.33/kg)	Net revenue due to the applied N (R$ ha^{-1})	EUN Kg of grains kg of N^{-1}
Urea	40	140.44	1,555.5	518.50	378.06	38.87
	60	210.67	1,724.4	574.80	364.13	28.78
Average Urea		175.6	1,640.0	546.7	371.1	33.8
Urea Coated	40	210.00	1,325.4	441.80	231.80	32.25
	60	315.00	1,710.0	570.00	255.00	28.50
Average of Coated urea		262.5	1,517.7	505.9	243.4	30.4

CONCLUSION

The maize crop for 2nd harvest in the study area responds to the application of nitrogen at planting. The use of different sources of nitrogen (common and coated urea) and dosages (40 and 60 kg N ha^{-1}) did not influence the yield and weight of 1000 grains of maize of 2nd harvest. The best economic efficiency of the use of N applied in the crop was found with common urea, at a dose of 40 kg N ha^{-1}.

RESUMO: O milho representa uma das culturas de cereais mais cultivadas no mundo, sendo utilizado como fonte de grãos, silagem e biocombustível. O nitrogênio é muito necessário na cultura do milho, tornando a fertilização nitrogenada uma parte significativa do custo de produção. Este trabalho teve como objetivo avaliar o fertilizante nitrogenado revestido de liberação controlada para a cultura do milho de 2ª safra. O trabalho foi desenvolvido na Fazenda Estância Maracaju, localizada no município de Maracaju – Mato Grosso do Sul. As parcelas experimentais foram constituídas por 48 linhas com espaçamento de 0,5 metros por 1000 metros de comprimento entre si. Como área útil considerou-se as 30 linhas centrais (1,5 ha). Os tratamentos utilizados foram T1: 40 kg ha-1 de N de ureia comum; T2: 60 kg ha-1 de N de ureia comum; T3: 40 kg ha-1 de N de ureia revestida; T4: 60 kg de N de ureia revestida e T5: sem aplicação de N. Os tratamentos foram distribuídos nas unidades experimentais segundo delineamento de blocos ao acaso com quatro repetições. A cultura de milho, respondeu aplicação de nitrogênio no plantio. O uso de ureia revestida não influenciou na produtividade de grãos em relação a ureia comum no milho de 2ª safra. A melhor eficiência de uso de N e a melhor receita líquida é com a dose de 40 kg de N ureia ha-1, de ureia comum aplicado no plantio da cultura.

PALAVRAS-CHAVE: Adubação. Eficiência de uso do N. Produtividade do milho safrinha. *Zea mays*.

REFERENCES

ALVAREZ, V. H.; NOVAIS, R. F.; BARROS, N. F.; CANTARUTTI, R. B.; LOPES, A. S. Interpretação dos resultados de análise de solo. In: RIBEIRO, A. C.; GUIMARÃES, P. T. G.; ALVAREZ, V. H. (Ed.). **Recomendações para uso de corretivos e fertilizantes em Minas Gerais:** 5a aproximação. Viçosa: Comissão de Fertilidade do Solo do Estado de Minas Gerais, 1999. p.25-32.

ANDA - Associação Nacional para Difusão de Adubos. **Anuário Estatístico do Setor de Fertilizantes**. São Paulo: Anda, 2015. 176p.

ARNUTI, F.; CECAGNO, D. MARTINS, A. P.; BALERINI, F.; MEURER, E. J.; SILVA, P. R. F. Intensidade de irrigação e manejo da adubação nitrogenada de cobertura no milho em sistema de plantio direto consolidado. **Colloquium Agrariae**, v. 13, n. 3, p. 29-40, 2017. https://doi.org/10.5747/ca.2017.v13.n3.a171

BONO, J. A. M.; SETTI, J. C. A.; TRAESEL, E. J.; RANNO, S. K.; BROCH, D. L.; MARAVIESKI, M. J. Eficiência de uma fonte de liberação lenta de nitrogênio em cobertura num Latossolo Vermelho Eutrófico de Maracaju-MS. In: Congresso Brasileiro de Ciênciad Solo, 32, 2009. Fortaleza. **Anais...** Fortaleza: Sociedade Brasileira de Ciência do Solo, 2009.

BROCH, D. L.; RANNO, S. K. Fertilidade do solo, adubação e nutrição da cultura do milho. In:____. **Tecnologia e Produção**: Soja e Milho 2008/2009. Maracajú: Fundação MS, 2008. p. 133-140.

CANCELLIER, L. J. L.; AFFÉRRI, F. S.; CARVALHO, E. V.; DOTTO, M. A.; LEÃO, F. F. Eficiência no uso de nitrogênio e correlação fenotípica em populações tropicais de milho no Tocantins, Fortaleza. **Revista Ciência Agronômica**, v. 42, n. 1, p. 139-148, 2011. https://doi.org/10.1590/S1806-66902011000100018

CANTARELLA, H. Nitrogênio. In: NOVAIS, R. F.; ALVAREZ, V. H.; BARROS, N. F.; FONTES R. L.; CANTARUTTI, R. B.; NEVES, J. C. L. (Ed.). **Fertilidade do solo**. Viçosa: Sociedade Brasileira de Ciência do Solo, 2007. P. 375-470.

CANTARELLA, H.; MARCELINO, R. O. Uso de inibidor de urease para aumentar a eficiência da ureia. In: Simpósio sobre Informações Recentes para Otimização da Produção Agrícola, 2007, Piracicaba. **Anais...** Piracicaba: International Plant Nutrition Institute, 2007. p. 15-16.

CENTRO DE MONITORAMENTO DE TEMPO, DO CLIMA E DOS RECURSOS HÍDRICOS DE MATO GROSSO DO SUL. **CEMTEC,** 2015. Avaiable in: <http://www.cemtec.ms.gov.br>. Acessed in: 18 August 2015.

CHAGAS, V. F.T.; GUELFI, D. R.; CAPUTO, A. L. C.; SOUZA, T. L.; ANDRADE, A. B.; FAQUIN, V. Ammonia volatilization from blends with stabilized and controlled-released urea in the coffee system. **Ciência e Agrotecnologia**, v. 40, n. 5, p. 497-509, 2016. https://doi.org/10.1590/1413-70542016405008916

COELHO, A. M.; COELHO FILHO, A. **Adubação foliar na cultura do milho utilizando fertilizantes multinutrientes**. Sete Lagoas: Embrapa Milho e Sorgo, 2006, 6p.

CONAB – Companhia Nacional de Abastecimento (2018). Levantamento de janeiro de 2017. Avaiable in: <http://www.conab.gov.br/OlalaCMS/uploads/arquivos/15_01_09_09_00_21_boletim_graos_janeiro_2017.pdf >. Acessed in: 15 May 2018.

DOURADO NETO, D.; FAVARIN, J. L.; MANFRON, P. A.; PILAU, F. G.; SOARES, M. A.; BONNECARRÉRE, R. A.G.; OHSE, S. Efeito do Boro e Nitrogênio na cultura do milho. **Insula**, v. 33, n. 1, p. 51-67, 2004.

EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária. **Manual de método de análise de solo**. Rio de Janeiro: Embrapa, 2011. 230 p.

ERNANI, P. R.; SANGOI, L.; LECH, V. A.; RAMPAZZO, C. A forma de aplicação da ureia e dos resíduos vegetais afeta a disponibilidade de nitrogênio. **Ciência Rural**, v. 35, n. 2, p. 360-365, 2005. https://doi.org/10.1590/S0103-84782005000200017

FAGERIA, N. K.; BALIGAR, V. C. Enhancing nitrogen use efficiency in crop plants. **Advances in Agronomy**, v. 88, n. 1, p. 97-185, 2005. https://doi.org/10.1016/S0065-2113(05)88004-6

FANCELLI, A. L.; DOURADO NETO D. **Milho**: estratégias de manejo para alta produtividade. Piracicaba: Esalq/USP/LPV, 2003. 208 p.

FERNANDES, J. C.; BUZETTI, S.; DUPAS, E.; TEIXEIRA FILHO, M. C. M.; ANDREOTTI, M. Sources and rates of nitrogen fertilizer used in Mombasa guineagrass in the Brazilian Cerrado region. **African Journal of Agricultural Research**, v. 10, n. 19, p. 1031-1042, 2015. https://doi.org/10.5897/AJAR2014.9276

FERREIRA, V. M.; MAGALHÃES, P. C.; DURÃES, F. O. M.; OLIVEIRA, L. E. M.; PURCINO, A. A. C. Metabolismo do nitrogênio associado à deficiência hídrica e sua recuperação em genótipos de milho. **Ciência Rural**, v.32, n. 1, p. 13-17, 2002. https://doi.org/10.1590/S0103-84782002000100003

GRUJCIC, D.; HANSEN, T. H.; HUSTED, S.; DRINIC, M.; SINGH, B. R. Effect of nitrogen and zinc fertilization on zinc and iron bioavailability and, chemical speciation in maize silage. **Journal of Trace Elements in Medicine and Biology**, v. 49, p. 269-275, 2018. https://doi.org/10.1016/j.jtemb.2018.02.012

GUERRA, A. M. N. M.; FERREIRA, J. B. A.; VIEIRA, T. S.; FRANCO, J. R.; COSTA, A. C. M.; TAVARES, P. R. F. Avaliação da produtividade de grãos e de biomassa em dois híbridos de milho submetidos à duas condições de adubação no município de Santarém – PA. **Revista Brasileira de Agropecuária Sustentável**, v. 7, n. 4, p. 20-27, 2017. https://doi.org/10.21206/bjsa.v7i4.431

HALL, W. Benefits of enhanced-efficiency fertilizers for the environment. In. INTERNATIONAL WORKSHOP ON ENHANCED-EFFICIENCY FERTILIZERS, 2005. Paris. **Anais…** Paris: International Fertilizer Industry Association, 2005.

MAR, G. D.; MARCHETTI, M. E.; SOUZA, L. C. F.; GONÇALVES, M. C.; NOVELINO, J. O. Produção do milho safrinha em função de doses e épocas de aplicação de nitrogênio. **Bragantia**, v. 62, n. 2, p. 267-274, 2003. https://doi.org/10.1590/S0006-87052003000200012

MARINI, D.; GUIMARÃES, V. F.; DARTORA, J.; LAMAS, M. C.; PINTO JUNIOR, A. S. Growth and yield of corn hybrids in response to association with *Azospirillum brasilense* and nitrogen fertilization. **Revista Ceres**, v. 62, n.1, p. 117-123, 2015. https://doi.org/10.1590/0034-737X201562010015

MOLL, R. H.; KAMPRATH, E. J.; JACKSON, W. A. Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. **Agronomy Journal**, v. 74, n. 3, p. 562-564, 1982. https://doi.org/10.2134/agronj1982.00021962007400030037x

MOTA, M. R.; SANGOI, L.; SCHENATTO, D. E.; GIORDANI, W.; BONIATTI, C. M.; DALL`IGNA, L. Fontes estabilizadas de nitrogênio como alternativa para aumentar o rendimento de grãos e a eficiência de uso do nitrogênio pelo milho. **Revista Brasileira de Ciência do Solo**, v. 39, n. 2, p. 512-522, 2015. https://doi.org/10.1590/01000683rbcs20140308

PEDRINHO, D. R.; BONO, J. A. M.; LUDWIG, J.; MARTINEZ, V. R.; FARIA, M. R. Cultivation of lettuce fertilized with controlled release nitrogen fertilizer and urea. **Bioscience Journal**, v. 31, n. 4, p. 997-1003, 2015. https://doi.org/10.14393/BJ-v31n4a2015-26122

PEREIRA, J. L. A. R.; PINHO, R. G. V.; BORGES, I. D.; PEREIRA, A. M. A. R.; LIMA, T. G. Cultivares, doses de fertilizantes e densidades de semeadura no cultivo de milho safrinha. **Ciência e agrotecnologia**, v. 33, n. 3, p. 676-683, 2009. https://doi.org/10.1590/S1413-70542009000300003

RIBEIRO, A. C.; GUIMARÃES, P. T. G.; ALVAREZ, V. V. H. **Recomendação para o uso de corretivos e fertilizantes em Minas Gerais:** 5ª Aproximação. Viçosa: Comissão de Fertilidade do Solo do Estado de Minas Gerais. 1999. 359 p.

RODRÍGUEZ-BLANCO, A.; SICARDI, M.; FRIONI, L. Plant genotype and nitrogen fertilization effects on abundance and diversity of diazotrophic bacteria associated with maize (*Zea mays* L.). **Biology and Fertility of Soils (2015),** v. 51, n. 3, p. 391-402. https://doi.org/10.1007/s00374-014-0986-8

RODRIGUES, M. A.; BUZETTI, S.; TEIXEIRA FILHO, M. C. M.; GARCIA, C. M. P.; ANDREOTTI, M. Adubação com KCl revestido na cultura do milho no Cerrado. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 18, n. 2, p. 127-133, 2014. https://doi.org/10.1590/S1415-43662014000200001

ROSCOE, R.; GITTI, D. C. Manejo e Fertilidade do solo para a cultura da soja. In: LOURENÇÃO, A. L. F.; GRIGOLLI, J. F. J.; MELOTTO, A. M.; PITOL, C.; GITTI, D. C.; ROSCOE, R. (Ed.) **Tecnologia e Produção**: soja 2013/2014. Maracajú: Fundação MS, 2013. p. 16-41.

SBCS/NEPAR - Sociedade Brasileira de Ciência Do Solo: Núcleo Estadual Paraná. **Manual de adubação e calagem para o Estado do Paraná**. Curitiba: Sbcs/Nepar, 2017, 482p.

SHAVIV, A. Advances in controlled-release fertilizers. **Advances in Agronomy**, v. 71, n. 1, p. 1-49, 2001. https://doi.org/10.1016/S0065-2113(01)71011-5

SILVA, A. A.; SILVA, T. S.; VASCONCELOS, A. C. P.; LANA, R. M. Q. Aplicação de diferentes fontes de uréia de liberação gradual na cultura do milho. **Bioscince Journal**, v. 28, n. 1, p. 104-111, 2012.

SILVA JUNIOR, G. B.; SANTOS, E.; SILVA, R. L.; CAVALCANTE, H. L. Nutritional status and fruit production of *Carica papaya* as a function of coated and conventional urea. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 20, n. 4, p. 322-328, 2016. https://doi.org/10.1590/1807-1929/agriambi.v20n4p322-328

TRENKEL, M. E. **Slow – and Controlled-Release and Stabilized Fertilizers**: An Option for Enhancing Nutrient Efficiency in Agriculture. 2. ed. Paris: International Fertilizer Industry Association, 2010. 160 p.

VALDERRAMA, M.; BUZETTI, S.; BENETT, C. G. S.; ANDREOTTI, M.; TEIXEIRA FILHO, M. C. M. Fontes e doses de NPK em milho irrigado sob plantio direto. **Pesquisa Agropecuária Tropical**, v. 41, n. 2, p. 254-263, 2011. https://doi.org/10.5216/pat.v41i2.8390

VEÇOZZI, T. A.; SOUSA, R. O. DE; SCIVITTARO, W. B.; WEINERT, C.; TARRILLO, V. R. C Soil solution and plant nitrogen on irrigated rice under controlled release nitrogen fertilizers. **Ciência Rural**, v. 48, n. 1, p. 1-5, 2018. https://doi.org/10.1590/0103-8478cr20170279

ZHENG, W.; LIU, Z.; ZHANG, M.; SHI, Y.; ZHU, Q.; SUN, Y.; ZHOU, H.; LI, C.; YANG, Y.; GENG, J. Improving crop yields, nitrogen use efficiencies, and profits by usingmixtures of coated controlled-released and uncoated urea in awheat-maize system. **Field Crops Research**, v. 205, n. 1, p. 106–115, 2017. https://doi.org/10.1016/j.fcr.2017.02.009