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Corn productivity and topdressing application cost of nitrogen fertilizers

Produtividade de milho e custo da aplicação em cobertura de fertilizantes nitrogenados

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ABSTRACT

Nitrogen (N) is the most required nutrient in the cultivation of corn (*Zea mays* L.), also representing a significant share in the production costs. The objective was to evaluate the efficiency for one experimental year of different sources of nitrogen fertilizers applied in topdressing on the corn grain yield and their respective fertilization costs. The experiment was carried out under field conditions and without irrigation under no-tillage system, in a Red Oxissol. For sowing, 280 kg ha^{-1} of NPK fertilizer 12-30-20 was used for all treatments. In addition to the control treatment (NPK), four nitrogen formulations were applied in topdressing: Urea, Super N, Nitromag, and Sulfammo, both formulations applied 50% in the V3/V4 and 50% V7/V8 stages, in four replicates. Grain yield was determined at the physiological maturation. The type of nitrogen fertilizer did not influence corn grain yield, an average of 9016 kg ha^{-1}. The largest profits were achieved with the application of Super N, Urea and Nitromag. Nitrogen fertilizers with slow and controlled N release does not promote an increase in corn grain yield in relation to Urea. The use of Super N in topdressing has the highest profitability in corn cultivation.

KEYWORDS: economic analysis; nitrogen; nitrogen formulations; *Zea mays*.

RESUMO

O nitrogênio (N) é o nutriente mais requerido no cultivo do milho (*Zea mays* L.), ainda representa significativa participação no custo de produção. O objetivo foi avaliar a eficiência em um ano experimental de diferentes fontes de fertilizantes nitrogenados aplicados em cobertura na produtividade de grãos de milho e os seus respectivos custos da adubação. O experimento foi realizado em condições de campo e sem irrigação sob sistema plantio direto, em Latossolo vermelho. Na semeadura foi utilizado 280 kg ha^{-1} de adubo NPK 12-30-20 para todos os tratamentos. Além do tratamento testemunha (NPK), quatro formulações nitrogenadas foram aplicadas em cobertura: Ureia, Super N, Nitromag, e Sulfammo, ambas as formulações aplicadas 50% no estádio V3/V4 e 50% V7/V8, em quatro repetições. Na maturação fisiológica foi determinada a produtividade de grãos. O tipo de fertilizante nitrogenado não influenciou na produtividade de grãos de milho, média de 9016 kg ha^{-1}. Os maiores lucros foram com a aplicação de Super N, Ureia e Nitromag. O uso em cobertura de fertilizantes nitrogenados de lenta e controlada liberação de N não promovem aumento na produtividade de grãos de milho em relação a Ureia. O uso de Super N em cobertura apresenta a maior lucratividade no cultivo do milho.

PALAVRAS-CHAVE: análise econômica; nitrogênio; formulações nitrogenadas; *Zea mays*.

INTRODUCTION

Corn is one of the most important cereals in the world's economy. Different forms of use, from human and animal consumption to the high-tech industry, characterize it. The three-leading corn-producing countries are the United States, China, and Brazil, which together represent approximately 67% of world's production (FAOSTAT 2020). The use of corn grain in animal feed represents most of the consumption of this cereal. In the United States, about 50% is for this purpose, while in Brazil, it ranges from 60 to 80%, and in the world 70%, depending on the estimate source and agricultural year (TEJEDA 2019). According to CONAB (2022), in the 2021/22 harvest, Brazil sowed roughly 22.3 million hectares of corn, representing an

increase of 8.2% in relation to the 2020/21 harvest, with a total production of 112.8 million tons of grains where the State of Rio Grande do Sul had a participation of 3.9% of the Brazilian production, achieving an average productivity of 5.6 tons/ha.

Nitrogen (N) is the major element in the development of plants, as it participates in the composition of amino acids, proteins, nucleic acids, chlorophyll, and many essential enzymes that stimulates the growth and development of the aerial part and root system of the plants. It is also the nutrient applied in the greatest amount in the corn crop, as it is the most limiting factor in the growth and development of the plants, therefore making it the most expensive fertilizer in the crop production cost (SOUZA et al. 2015). Thus, studies are needed to reduce nitrogen fertilizers in topdressing and not decrease corn yield (SCHILLACI et al. 2021). However, N is a nutrient that has a more significant effect on increasing grain yield (QUEIROZ et al. 2011). For each ton of grain produced, corn requires approximately an additional 15 to 20 kg of N ha^{-1} (PAVINATO et al. 2008, CQFS 2016). Among nitrogen fertilizers, urea is the most used in Brazil (GUARINO et al. 2021) and in the world (IFA 2020) mainly because of its lower purchase cost (TASCA et al. 2011).

In Brazil, the not incorporated urea applied on the surface is the main form of nitrogen topdressing fertilization in corn crop because Brazil mainly uses no tillage in most areas and in these areas the incorporation of N is difficult due to the cultivation system. This method of application (not incorporated) combined with the conditions of low soil moisture, low soil cation exchange capacity, high soil pH, high temperature and wind, increases the losses caused by volatilization, resulting in a less efficiency of its use (ERNANI 2003, SILVA et al. 2012, VIERO et al. 2014, GUARINO et al. 2021). Nitrogen losses caused by ammonia volatilization after the application of urea on the soil surface, depending on the application conditions, vary from the lowest values of 30% (GONZATTO et al. 2013, VIERO et al. 2014, VIERO et al. 2015) to extremely high quantities, greater than 50% (ROCHETTE et al. 2009, TASCA et al. 2011). The incorporation of nitrogen fertilizers virtually eliminates the loss of N through volatilization (ROCHETTE et al. 2009). However, the process of incorporating nitrogen fertilizers in no-tillage systems and their need for N at different growth stages in Brazil is hampered, which is why it is necessary to apply it in broadcast. More recently, some studies have been experimenting with methods to minimize N losses through volatilization, for example, using nitrification inhibitors mixed with urea in different formulations to decrease the rate of urea hydrolysis, by inhibiting activity of urease (STAFANATO et al. 2013, VIERO et al. 2014, OLIVEIRA et al. 2016, GUARINO et al. 2021, ZHANG et al. 2022). Thus, adjusting the N rate and type of formulations increases crop N use efficiency in corn (NASIELSKI et al. 2019) and reduces environmental risks (CHIODINI et al. 2019).

One of the greatest challenges for corn producers is to increase their productivity combined with cost reduction to obtain greater returns and profitability with the crop. The study of production costs provides important information for decision taking, allowing the choice of the best resources in terms of types of topdressing nitrogen fertilizers be used, and aiming at better results of grain yields and financial return in the corn crop (SOUZA et al. 2012). Knowledge of the cost of production of nitrogen topdressing fertilizers covered in corn provides information for the adoption of different technological levels and expands the range of more sustainable and profitable technologies (KAPPES et al. 2015). With a view to increasing the efficiency of nitrogen fertilization, reduction in environmental contamination and production costs, and even increasing crop productivity rates, the proper use of nitrogen fertilization is of paramount importance (FAGERIA et al. 2007). Thus, the economic analysis allows the producer to make the best decision based on information on the costs of nitrogen fertilizers applied in topdressing in the production of the corn crop.

It can be found in the literature studies that compare the use of nitrogen fertilizers, but few studies have investigated the dynamics of the efficiency in conditions of local agro-ecosystems, especially only in terms of topdressing application and their economic viability. We hypothesized that higher maize productivity could be obtained at a lower cost from different sources of N. Thus, the objective of this study was to evaluate for one experimental year the efficiency of different sources of nitrogen fertilizers applied in topdressing in the productivity of corn grains and their respective fertilization costs.

MATERIAL AND METHODS

The experiment was carried under field conditions for one experimental year in the municipality of Bom Progresso, Rio Grande do Sul State (RS), (27º51’58” S, 53º50’18” W, 410 meters above sea level). According to the classification of Köppen, the climate in the region is Cfa-type, with an average annual temperature of around 19°C and rainfall between 1,800 and 2,000 mm (SILVA et al. 2014). The soil at the experiment site is classified as Red Oxissol (SANTOS et al. 2018). Prior to the experiment establishment, the area had been used for annual grain crops under no-tillage system and a soil sampling was carried out in

the 0-10 cm layer for the edaphic characterization of the area, which had the following properties: clay (54%); pH in water (6.0); SMP index (6.0); organic matter (2.8%); base saturation (76.5%); Aluminum (0 cmol / L); Calcium (7.5 cmol / L); Magnesium (3.8 cmol / L); Hydrogen + Aluminum (3.6 cmol / L); Sulfur (54 mg / L); Zinc (6 mg / L); Copper (6 mg / L); Boron (5.8 mg / L); Manganese (166 mg / L); Phosphorus (5.8 mg / L) and Potassium (166 mg / L).

Sowing was carried out on September 2, 2017 in a mechanized manner with the aid of a seeder in no-tillage system over black oat crop residues with approximately three tons of straw ha^{-1}. The corn cultivar used was the hybrid Pioneer® 32R48VYHR, with a spacing between lines of 0.48 meters and approximate density of 72,916 plants/ha^{-1}. In maize sowing, in all treatments, 280 kg ha^{-1} of chemical fertilizer 12-30-20 (N-P_2O_5-K_2O) was used as base fertilizer. Five treatments of nitrogen formulations most used in the study region applied in topdressing were evaluated: T1 - Urea (45% N), T2 - Super N (33% N), T3 - Nitromag (27% N), T4 - Sulfammo (22% N), T5 - Control (control, without N), all with four replicates in experimental units of 12 m^2 (2.4 x 5 m). The nitrogen fertilizers in topdressing at equivalent doses were 422 kg/ha in treatment T1; 575 kg/ha in the treatment T2; 703 kg/ha in treatment T3; 863 kg/ha in treatment T4 and 0 kg/ha in treatment T5. The nitrogen fertilizers were broadcast distributed shortly after the occurrence of rainfall in two steps, the first when the corn plants had three fully developed leaves (V3/V4), and the second before tasseling (V7/V8). The base and topdressing fertilization was performed according to the needs observed through chemical analysis of the soil and expectation of high grain yield, established according to the Fertilization and Liming Manual for states of RS and SC (CQFS 2016).

The corn cultivar used in the experiment allowed the chemical control of weeds in the growth stage V3. The cultivar also has resistance against insects, even so, field monitoring was still carried out weekly to verify the need for pest management. The experiment was carried out under natural conditions and without irrigation. Figure 1 presents data on rainfall, and average air temperature during the experimental period.

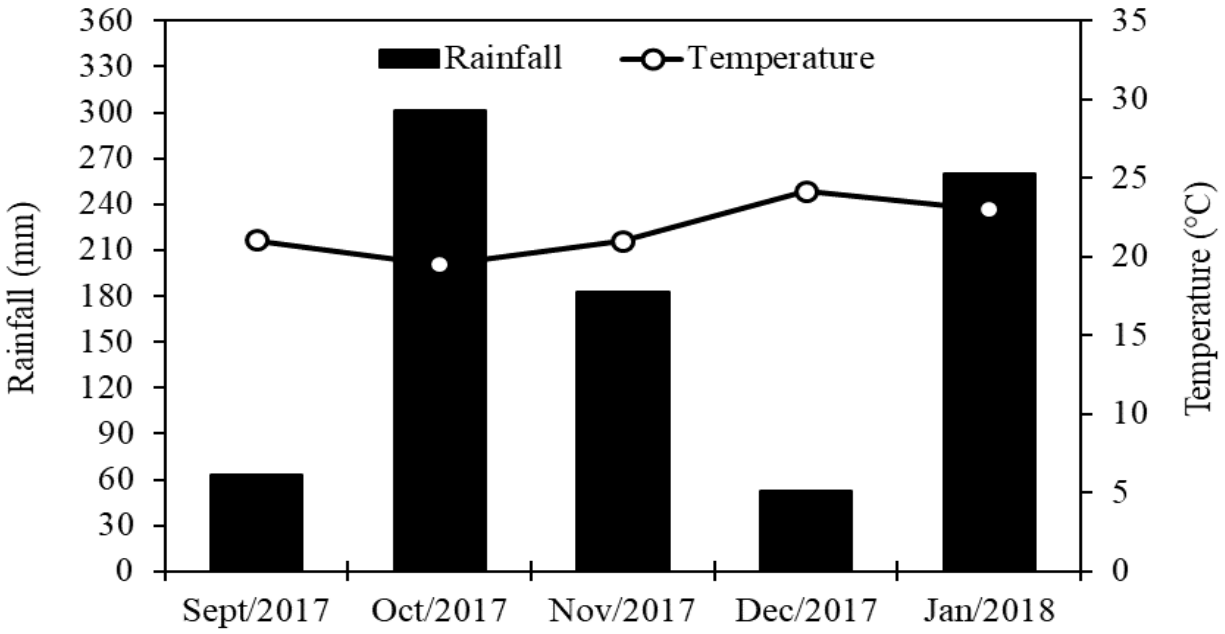

Figure 1. The rainfall, and air average temperature in the experimental period.

The corn was harvested on February 8, 2018, at the plant physiological maturation stage using a collection area of 3 m by 1.44 m (4.32 m^2) in each replicate, in three rows of each plot. Initially, the ears were evaluated for their length (EL), diameter (ED) and number of grain rows per ear (RN). Subsequently, the corn was threshed, the grains were dried weighed, and grain yield (GY) at humidity of 13% and the mass of 1,000 grains (TSW) were determined. For the purposes of economic analysis, in each treatment, the revenues and costs of nitrogen fertilizers applied in topdressing on the corn crops were determined. The economic analysis of the different sources of nitrogen fertilizers in corn production was calculated based on the work of TSUNECHIRO et al. (2006), SOUZA et al. (2012) and SOUZA et al. (2015). The analysis was adapted and performed specifically for the economic study of nitrogen fertilizers, thus, without considering other corn production costs. The cost of nitrogen fertilizers and the value of maize grains received by the rural producer, both converted into R$/kg, were in accordance with the average price traded in the experiment region, in September 2017 and February 2018, respectively, sowing and harvest time of experiment.

The data obtained were subjected to analysis of variance and, when significant, to the test of Tukey at 5%, using the procedures available in the Sisvar statistical package (FERREIRA 2011).

RESULTS AND DISCUSSION

Grain yield, length, ear diameter and weight of a thousand corn seeds showed a statistical difference between treatments (Table 1). The control treatment was the one with the lowest means in relation to the parameters GY, EL, ED and TSW, as it did not receive any dosage of any nitrogen fertilizer in topdressing. The types of nitrogen fertilizers did not significantly influence the productivity of corn grains with a mean value of 9016 kg ha^{-1}. Several authors have also not observed an increase in corn grain productivity with the use of the types of nitrogen fertilizer, including stabilized sources of N, that is, slow and controlled release (QUEIROZ et al. 2011, SOUZA et al. 2011, MOTA et al. 2015, MARTINS et al. 2018).

Table 1. Grain yield (GY), ear length (EL), ear diameter (ED), number of grain row per ear (RN) and one-thousand seed weight (TSW) of corn submitted to different nitrogen fertilizer sources.

Treatments	GY (kg/ha)	EL (cm)	ED (cm)	RN (ear)	TSW (g)
Urea	8395 a*	17.4 ab	15.2 a	14.2 a	672.2 ab
Super N	9507 a	15.5 b	14.7 ab	13.9 a	731.5 a
Nitromag	8638 a	19.2 a	15.7 a	13.8 a	643.0 b
Sulfammo	9525 a	17.9 ab	15.4 a	13.8 a	726.4 a
Control	4293 b	11.7 c	13.7 b	13.9 a	527.3 c
CV (%)	7.78	7.9	3.4	3.2	12.5

*Means followed by the same letter in the column are not different from each other by the test of Tukey 5%.

On the other hand, differently from what was observed in this study, other studies showed an increase in the productivity of corn grains using such fertilizers (ABREU et al. 2013, FRAZÃO et al. 2014, OLIVEIRA et al. 2016, ZHANG et al. 2022). Study of SCHILLACI et al. (2021) showed, however, that reducing topdressing N fertilization with variable rates does not reduce maize productivity. Despite the average increase of 828 Kg ha^{-1} in grain productivity (9.8%) promoted by the stabilized N sources, in relation to urea, the non-significant increase may be related to the high amount of rainfall that occurred in October and November (Figure 1), which may have favored N losses by leaching, in addition to the specific conditions of the local agro-ecosystem, including the good initial condition of soil fertility.

The lowest productivity was obtained in the control treatment with 4293 kg ha^{-1}, (52.4%) since no nitrogen fertilizer was applied in topdressing. In comparison with the control that did not receive N, all treatments showed statistically superior grain yield, which proves the efficiency of nitrogen fertilizers in increasing corn productivity, as observed by other authors (SOUZA et al. 2011, PISSINATI et al. 2013, OLIVEIRA et al. 2016). According to LOPES et al. (2007), productivity is directly linked to the number of corn grains $plant^{-1}$, which depends on EL, ED, RN and TSW, data that may explain, in part, the higher grain productivity in treatments with N application, compared to the control treatment.

The application of Nitromag promoted the highest EL (19.2 cm), 64% longer, when compared to the control treatment. Ear length is a characteristic that affects corn yield, because the higher the EL, the greater the potential number of grains to be formed per row in the ear. The ED increased with the application of urea, Nitromag and Sulfammo (average 15.4 cm), 13% thicker in relation to the control. Ear diameter is a characteristic closely related to grain filling and RN of grain ear^{-1}.

As for the RN, the different N sources did not cause statistical difference between them, corroborated by the study of VALDERRAMA et al. (2011), where the number of rows were not influenced by the N sources, indicating that the corn RN was dependent on the genetic potential of the hybrid used, different from that observed by COSTA et al. (2012). The TSW was higher for Super N and Sulfammo, followed by Urea, Nitromag and control, 31.4% lower than the average of nitrogen fertilizer types. MARTINS et al. (2018), when testing doses of N, associated with inoculation with *Azospirillum brasilense*, but for popcorn, observed, in addition to the significant increase in grain yield, an increase in EL, ED, TSW, in the treatments that received N. OLIVEIRA et al. (2016), also observed a response to nitrogen fertilization in the increase of EL, TSW, number of grains per row, in addition to the increase in grain yield and height of corn plants. Other studies also reported the efficiency in using nitrogen fertilizers, for example, DUETE et al. (2008) in the production of dry matter, VALDERRAMA et al. (2011) in the N content in the leaf, SOUZA et al. (2011) in the number of grains per ear, QUEIROZ et al. (2011) in grain mass increase, COSTA et al. (2012) in the number of rows per ear, ALBUQUERQUE et al. (2013) at plant height, KAPPES & ANDRADE (2013) in the length of the ear.

Thus, N is the nutrient that stands out for its ability to define the components of corn grain production and yield.

The use of nitrogen fertilizers, especially those of slow and controlled N-release, Super N, Nitromag and Sulfammo, promoted higher corn EL, ED and TSW, probably due to their gradual N-release, taking longer to be available for absorption by plants, although not reflecting significantly on GW. According to DA ROS et al. (2015), in slow and controlled-release fertilizers, the delay in hydrolysis due to the protection of granules and/or by urease inhibitors contributed to the gradual release of N according to the needs of the crop and, consequently, reducing losses and favoring the development of ears of corn. STAFANATO et al. (2013) found that the coating of nitrogen fertilizer with copper and boron significantly reduced the process of ammonia volatilization. STAFANATO et al. (2013) also found lower ammonia volatilization rate of nitrogen fertilizers in products containing NBPT (N (n-butyl) thiophosphoric amide), an inhibitor of the urease enzyme.

Nevertheless, VIERO et al. (2015) observed that, in comparison to common urea, the slow and controlled release fertilizer did not demonstrate the potential to reduce volatilization. In study of ZHANG et al. (2022), the results showed that, compared with ureia fertilizer, controlled-release urea and parceled aplication increased crop yield by 10.08% and 8.11%, respectively, and split application N use efficiency by 47.55% and 45.21%, respectively. Although the topdressing application of nitrogen fertilizers, especially those with slow and controlled release, caused an increase in EL, ED and TSW. This however did not reflect in the increase in the productivity of corn grains, which makes the economic analysis of its application, the next stage to be considered when choosing the best nitrogen fertilizer to be used in corn crops.

The results of the economic analysis referring to the costs and profitability of the crop in relation to the different sources of nitrogen fertilizers applied in topdressing in the corn crop can be seen in Table 2. In relation to the cost of nitrogen fertilization applied in topdressing the corn plants, they ranged from R$ 0.00 in the control, where no dose of N sources was applied, to R$ 1950.40 ha^{-1} with the application of 863 kg ha^{-1} of Sulfammo, at a cost of R$ 2.26 kg^{-1}.

The Nitrogen application costs showed this variation due to the difference in price and in their N concentrations in the formula of each product, which resulted in a higher or lower value for the purchase of nitrogen fertilizers. Regarding the urea dose in the present study, the dose of 422 kg ha^{-1} was equivalent to R$ 666.00 ha^{-1}, while KAPPES et al. (2015) in their study with N doses, where it was estimated the same amount of N to be applied via urea resulted in a cost of R$ 714.00 ha^{-1} in the state of Mato Grosso do Sul. This shows that in addition to the source to be chosen, the geographical location of the crop is also important from the point of view of nitrogen fertilizer costs.

Table 2. Economic analysis of the different N fertilizer sources applied in topdressing on corn plants.

Treatments	Dose (kg/ha)	Cost (R$/kg)	Cost (R$/ha)	CV[1] (R$/kg)	CGR[2] (R$/ha)	Cost[3] (%/ha)	Return[4] (R$/ha)
Urea	422	1.58	666.00	0.58	4896.60 a*	13.60 c	4229.90 ab
Super N	575	1.56	897.00	0.58	5545.40 a	16.20 c	4648.40 a
Nitromag	703	1.46	1026.40	0.58	5038.40 a	20.40 b	4012.00 ab
Sulfammo	863	2.26	1950.40	0.58	5556.20 a	35.10 a	3605.80 b
Control	0	0.00	0.00	0.58	2504.00 b	0.00 d	2504.00 c
CV (%)	-	-	-	-	7.78	10.39	9.64

[1]CV: Commercial value of corn in the region. [2]RBL: Crop gross revenue, considering only the grain yield and the commercial value practiced in the region. [3]Percentage of nitrogen cover fertilizer cost in relation to RBL. [4]Profit: Difference between RBL and Cost (R$/ha). *Means followed by the same letters in the columns are not statistically different each other by the test of Tukey.

In addition, the difference in the N concentration in each product also reflected the difference in dose to be applied so that in all treatments the same amount of N was offered to corn. This aspect also increased the cost of fertilization, especially in those treatments that used products with a lower concentration of N and sold at a higher price, such as Sulfammo and Nitromag, when compared to the price of urea application. MOTA et al. (2015), evaluating different sources of N and doses in the corn crop, also found that depending on the source of N applied, there may be a reduction in production costs, without hampering the productivity

The applications of N represented an equivalent cost ha^{-1} that varied between 13.6% and 35.1% in the urea and Sulfammo treatments, respectively (Table 2). When the significant differences were observed, it was found that the corn that received Sulfammo application showed a result in the highest percentage cost, while Nitromag obtained a median cost and Super N and Urea were those with the lowest percentage costs. ARTUZO et al. (2018) working with corn cost analysis between 1997 to 2016, found that the cost of fertilizers

corresponded to approximately 85% of the gross crop revenue, that is, a higher cost, because in the scenario of the present study it was evaluated only the cost of nitrogen fertilizers. In the study by TSUNECHIRO et al. (2006), it was found that when evaluating the effective operating costs of *safrinha (*off-season) corn fertilizers, they were 26.2% and 24.7%, for production with high and medium technology, respectively. However, today the cost of fertilizers can exceed 30% due to their high prices, especially in high technology production systems.

Based on the costs properly accounted and considering the yields obtained for each source of N tested, together with the value of corn (CV), it was possible to obtain the gross crop revenue (GCR) and the profit per hectare. The GCR ha^{-1} varied between R$ 2504.00 and R$ 5556.20 in the control and Sulfammo treatments, respectively. The corn applied with Sulfammo obtained the highest RBL, however, without presenting significant differences in relation to the other treatments also with application of nitrogen fertilization. When compared to the control that did not receive N, all treatments had a statistically higher GCR, which proves the efficiency of nitrogen fertilizers in increasing corn productivity and, consequently, delivering greater GCR ha^{-1} to the producer.

The analysis of the costs, the applied doses, the yields and GCL in the treatments that were used in the corn crop not considering the other production costs allowed to obtain the crop profit, which varied between R$ 2504.00 and R$ 4229.9 ha^{-1} in the control and urea treatments, respectively. The three N sources that promoted, in the end, the highest profits were Super N, Urea and Nitromag, where the highest profit was obtained when *nitrogen* fertilizer based on Super N was applied (R$/ha 4648.40), however, without presenting significant differences in relation to corn fertilized with Urea and Nitromag. The use of Sulfammo resulted in a profit that was statistically like the application of Urea and Nitromag and inferior to the application of Super N; however, a greater profit was obtained with Sulfammo in relation to the non-application of N (control). All the N-sources that were evaluated obtained a higher profit than the treatment that received no N-application. The positive effect of N on corn productivity has already been reported by several authors (SILVA et al. 2005, DUETE et al. 2009, SOUZA et al. 2011, PISSINATI et al. 2013, OLIVEIRA et al. 2016). However, according to SOUZA et al. (2015), it is necessary to emphasize the importance of the economic evaluation, since the analysis of the costs of using nitrogen fertilization demonstrates whether the increase in grain productivity may or may not be economically satisfactory.

The profit differences in monetary values varied among the treatments. It was possible to obtain R$ 1042.60 more per hectare when corn was produced using Super N in relation to corn production with Sulfammo (28.9%); it was also possible to obtain a profit of R$ 418.50 more when corn was produced with Super N in relation to Urea (9.9%); R$ 636.40 more when corn was produced with Super N compared to Nitromag (15.8%). All N applications resulted in a higher profit in relation to the non-application of N in corn, since the treatment with Sulfammo, which obtained the lowest profit was still able to produce R$ 1101.8 more than the control. These results demonstrate the importance of nitrogen fertilization for the corn crop, which is very responsive to N, especially in crop conditions with expectation of medium to high yields and with low levels of organic matter in the soil. In an evaluation on nitrogen fertilization in corn in Oxissol in the state of Santa Catarina, POLESE et al. (2018) using equivalent doses of N, based on urea, Nitrate, Nitromag, Sulfammo and Coper N, concluded that for their study in the 2017/18 crop, the best option for the farmer would be to use conventional urea, since it has the lowest cost kg^{-1} of N applied. These results corroborate those observed in this study, as Urea was also one of the sources of fertilizers that promoted better grain yields and profit. On the other hand, SOUZA et al. (2012), when studying sources of N based on entec® - ammonium sulphonitrate + nitrification inhibitor, ammonium sulphate and urea in the corn crop in a Red Latosol in the State of Mato Grosso do Sul, found that the response of the N sources according to the agricultural year; urea presented the most satisfactory economic results in the 2007/08 agricultural year, ammonium sulfate in the 2008/09 harvest and that the profitability indexes of each treatment varied according to the dose and source of nitrogen, due to the corn grain productivity.

Although all N sources provided better productivity and profitability than corn that did not receive fertilizer doses, from the point of view of cost reduction and better net revenue and profit, it is essential to choose the correct source of N to be used because even with higher levels of N in the formula, and consequently lower doses to be applied ha^{-1}, it is possible that due to the greater difference in the price, profitability does not compensate in the end. According to OLIVEIRA et al. (2013), the control of production costs is vital due to the narrow margin of profitability of crops, such as corn. In addition, according to ARTUZO et al. (2018), any production cost item, if not used correctly, has the potential to contribute significantly to the final cost.

The economic analysis needs to be strictly observed by the farmer when purchasing nitrogen fertilizer for the corn crop, considering that the objective of the crop, in addition to increasing productivity, is also to increase the net profit of the crop. In addition, according to MENEGATTI & BARROS (2007), it is important to select the best-input option related to nitrogen fertilizers to achieve results that maximize its use in corn (ARTUZO et al. 2018), increased crop yield and N use efficiency (ZHANG et al. 2022). Therefore, when choosing nitrogen fertilizer for corn, as found in the present study, one should not only consider grain yield, but also observe its cost, as net profit will depend on the factors of revenue versus costs farming, thus making it possible to better understand the system with the highest profit. However, further years of experiment will confirm or disagree with our results this study.

CONCLUSION

The use in topdressing fertilization of nitrogen fertilizers with a slow and controlled nitrogen release formulation, Super N, Nitromag and Sulfammo, does not promote an increase in corn grain yield in relation to Urea.

Both N sources, urea, Super N, Nitromag and Sulfammo promote increases in corn grain productivity in relation to the non-application of N in topdressing.

The use of Super N as a source of nitrogen fertilizer in topdressing has the highest profitability in corn cultivation, considering the monetary value obtained.

REFERENCES

ABREU FL et al. 2013. Loss of ammonia from nitrogen fertilizers applied to maize and soybean straw. Revista Brasileira de Ciência do Solo 37: 969-975.

ALBUQUERQUE AW et al. 2013. Plantas de cobertura e adubação nitrogenada na produção de milho no sistema de plantio direto. Revista Brasileira de Engenharia Agrícola e Ambiental 17: 721-726.

ARTUZO FD et al. 2018. Costs management in maize and soybean production. Revista Brasileira Gestão Negócios 20: 273-294.

CONAB. 2022. Companhia Nacional de Abastecimento. Acompanhamento da safra brasileira de grãos safra 2021/22 - Décimo levantamento. Companhia Nacional de Abastecimento 6: 01-126.

COSTA NR et al. 2012 Adubação nitrogenada no consórcio de milho com duas espécies de braquiária no sistema plantio direto. Pesquisa Agropecuária Brasileira 47: 1038-1047.

CQFS. 2016. Comissão de química e fertilidade do solo. Manual de adubação e calagem para os estados do Rio Grande do Sul e Santa Catarina. 1.ed. Porto Alegre: Sociedade Brasileira de Ciência do Solo. 324p.

DA ROS CO et al. 2015. Nitrogênio disponível no solo e acumulado na cultura do milho associado a fontes nitrogenadas de eficiência aumentada. Enciclopédia Biosfera 11: 1374-1385.

DUETE RRC et al. 2008. Manejo da adubação nitrogenada e utilização do nitrogênio (15N) pelo milho no Latossolo Vermelho. Revista Brasileira de Ciência do Solo 32: 161-171.

DUETE RRC et al. 2009. Viabilidade econômica de doses e parcelamentos da adubação nitrogenada na cultura do milho em Latossolo Vermelho Eutrófico. Acta Scientiarum Agronomy 31: 175-181.

ERNANI PR. 2003. Disponibilidade de nitrogênio e adubação nitrogenada para a macieira. 1.ed. Lages:Graphel. 76p.

FAGERIA NK et al. 2007. Produtividade de arroz irrigado e eficiência no uso do nitrogênio influenciadas pela adubação nitrogenada. Pesquisa Agropecuária Brasileira 42: 1029-1034.

FAOSTAT. 2020. Food and Agriculture Organization of the United Nations. Disponível em: http://www.fao.org/faostat/en/#data/QC/visualize . Acesso em: 25 mar. 2022.

FERREIRA DF 2011. Sisvar: a computer statistical analysis system. Ciência e Agrotecnologia 35: 1039-1042.

FRAZÃO JJ et al. 2014. Fertilizantes nitrogenados de eficiência aumentada e ureia na cultura do milho. Revista Brasileira de Engenharia Agrícola e Ambiental 18: 1262-1267.

GUARINO WC et al. 2021. Ammonia volatilization and agronomical efficiency of a mixture of urea with natural zeolite for rose fertilization. Pesquisa Agropecuária Brasileira 56: e01449.

GONZATTO R et al. 2013. Volatilização de amônia e emissão de óxido nitroso após aplicação de dejetos líquidos de suínos em solo cultivado com milho. Ciência Rural 43: 1590-1596.

IFA. 2020. International Fertilizer Industry Association. IFA database. Disponível em: http://www.fertilizer.org. Acesso em: 04 mai. 2020.

KAPPES C & ANDRADE JADC. 2013. Produtividade do milho em condições de diferentes manejos do solo e de doses de nitrogênio. Revista Brasileira de Ciência do Solo 37: 1310-1321.

KAPPES C et al. 2015. Análise econômica do milho em sucessão a diferentes adubos verdes, manejos do solo e doses de nitrogênio. Bioscience Journal 31: 55-64.

LOPES SJ et al. 2007. Relações de causa e efeito em espigas de milho relacionadas aos tipos de híbridos. Ciência Rural 37: 1536-1542.

MARTINS TG et al. 2018. Inoculation efficiency of *Azospirillum brasilense* on economising nitrogen fertiliser in landrace popcorn. Revista Ciência Agronômica 49: 283-290.

MENEGATTI ALA & BARROS ALMD 2007. Análise comparativa dos custos de produção entre soja transgênica e convencional: um estudo de caso para o Estado do Mato Grosso do Sul. Revista de Economia e Sociologia Rural 45: 163-183.

MOTA MR et al. 2015. 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 39: 512-522.

NASIELSKI J et al. 2019. Luxury vegetative nitrogen uptake in maize buffers grain yield under post-silkingwater and nitrogen stress: A mechanistic understanding. Frontiers in Plant Science 10: 318.

OLIVEIRA CM et al. 2013. Os custos de produção e a rentabilidade da soja nos municípios de Santarém e Belterra, estado do Pará. Acta Amazonica 43: 23-32.

OLIVEIRA FC et al. 2016. Corn development and production in function of sources of nitrogen fertilizers and doses. Revista Caatinga 29: 812-821.

PAVINATO OS et al. 2008. Nitrogênio e potássio em milho irrigado: análise técnica e econômica da fertilização. Ciência Rural 38: 358-364.

PISSINATI A et al. 2013. Management and cost of urea application in maize grown in northern Paraná State, Brazil. Revista de Ciências Agrárias 6: 235-241.

POLESE I et al. 2018. NDVI e rendimento da cultura do milho submetida a diferentes fontes nitrogenadas. Anuário Pesquisa e Extensão UNOESC 3: 1-9.

QUEIROZ AM et al. 2011. Avaliação de diferentes fontes e doses de nitrogênio na adubação da cultura do milho (*Zea mays* L.) Revista Brasileira de Milho e Sorgo 10: 257-266.

ROCHETTE P et al. 2009. Reducing ammonia volatilization in a no-till soil by incorporating urea and pig slurry in shallow bands. Nutrient Cycling in Agroecosystems 84: 71-80.

SANTOS HG et al. 2018. Sistema Brasileiro de Classificação de Solos. 5.ed. Brasília: Embrapa. 356p.

SCHILLACI C et al. 2021. Reducing topdressing N fertilization with variable rates does not reduce maize yield. Sustainability 13: 8059.

CHIODINI ME et al. 2019. The nitrification inhibitor vizura® reduces N_2O emissions when added to digestate before injection under irrigated maize in the po valley (Northern Italy). Agronomy 9: 431.

SILVA AA et al. 2012. Aplicação de diferentes fontes de uréia de liberação gradual na cultura do milho. Bioscience Journal 28: 104-111.

SILVA EC et al. 2005. Doses e épocas de aplicação de nitrogênio na cultura do milho em plantio direto sobre Latossolo Vermelho. Revista Brasileira de Ciência do Solo 29: 353-362.

SILVA RF et al. 2014. Doses de dejeto líquido de suínos na comunidade da fauna edáfica em sistema plantio direto e cultivo mínimo. Ciência Rural 44: 418-424.

SOUZA JA et al. 2015. Viabilidade econômica de fontes e doses de nitrogênio no cultivo do milho segunda safra em sistema de plantio direto. Revista de Ciências Agrárias 58: 308-313.

SOUZA JÁ et al. 2011. Adubação nitrogenada na cultura do milho safrinha irrigado em plantio direto. Bragantia 70: 447-454.

SOUZA JAD et al. 2012. Lucratividade do milho em razão das fontes, doses e épocas de aplicação de nitrogênio. Revista Ceres 59: 321-329.

STAFANATO JB et al. 2013. Volatilização de amônia oriunda de ureia pastilhada com micronutrientes em ambiente controlado. Revista Brasileira de Ciência do Solo 37: 726-732.

TASCA FA et al. 2011. Volatilização de amônia do solo após aplicação de ureia convencional ou com inibidor de urease. Revista Brasileira de Ciência do Solo 35: 493-502.

TEJEDA LHC 2019. Déficit hídrico em plântulas de milho: Aspectos morfológicos e moleculares. Dissertação (Mestrado em Agronomia). Pelotas: UFPel. 74p.

TSUNECHIRO A et al. 2006. Análise técnica e econômica de sistemas de produção de milho safrinha, região do médio Paranapanema, estado de São Paulo. Informações Econômicas 36: 62-70.

VALDERRAMA M et al. 2011. Fontes e doses de NPK em milho irrigado sob plantio direto. Pesquisa Agropecuária Tropical 41: 254-263.

VIERO F et al. 2014. Ammonia volatilization from nitrogen fertilizers in no-till wheat and maize in southern Brazil. Revista Brasileira de Ciência do Solo 38: 1515-1525.

VIERO F et al. 2015. Management of irrigation and nitrogen fertilizers to reduce ammonia volatilization. Revista Brasileira de Ciência do Solo 39: 1737-1743.

ZHANG G et al. 2022. Can controlled-release urea replace the split application of normal urea in China? A meta-analysis based on crop grain yield and nitrogen use efficiency 275: 108343.