

Ammonia volatilization from Nitrogen topdressing fertilization in second-crop corn cultivated under two management systems

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Abstract

Controlled-release fertilizers are possible strategies to reduce losses through fertilization and increase nitrogen (N) use efficiency. In this context, this study aimed to evaluate the efficiency of N sources applied to second-crop corn cultivation. The experiment was carried out in a randomized block design in a 2 x 4 factorial scheme. Two cultivation systems (conventional and no-tillage) and four N fertilizers (urea pearls pure, urea+Cu+B, NBPT-treated urea and complex mineral fertilizer) with four replications were studied. Losses of N-NH₃ by volatilization were evaluated up to 14 days after corn N fertilization. The data were subjected to analysis of variance and the means were grouped by the Scott-Knott test at 5% probability. Under the conditions in which the study was carried out, it was observed that urea pearls pure was the least efficient N fertilizer in restricting N-NH₃ through volatilization losses. The most efficient fertilizer was NBPT-treated urea. Losses of N-NH₃ by volatilization in the no-tillage system were higher than in the conventional cultivation system.

Keywords: Nitrogen. Urea. Fertilizing.

Introduction

Worldwide, the cultivation of corn is largely carried out to produce corn-based products. Since corn productivity increases with the application of additional doses of nitrogen (N), it considerably increases the consumption of such fertilizers (ARGENTA; SILVA, 2003). The use of N fertilizers has increased over the years, especially in developing countries such as Brazil. However, the efficiency in the use of N by crops has contrasting values of around 50% related to the total applied in the soil due to large losses (LAMA, 2012). Among the main processes of N losses are volatilization, nitrification and denitrification, which contribute to the release of NH₃, N₂O and N₂ into the atmosphere (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS - FAO, 2001; SHAVIV, 2005; TRENKEL, 2010).

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Urea stands out as the main mineral source of N fertilizers used in agriculture, due to its affordable price and high N content (SOUZA et al., 2017), which makes transportation and storage economical. However, the application of urea without soil incorporation can generate significant N losses due to ammonia volatilization. In this case, the losses of ammonia (NH_3) can reach up to 80% with the superficial application in no-tillage systems and up to 30% in conventional cultivation systems (LARA CABEZAS, 1998).

Lately, in response to the widespread use of the no-tillage system and the changes in soil management, N losses through volatilization have been intensified due to mulching. According to Cancellier et al. (2016), this is due to the higher activity of the enzyme urease and the lower diffusion of urea into the soil, leading to a localized increase in soil pH, causing ammonium to transform into ammonia. In the case of no-tillage systems, the non-revolving of the soil at the time of lime application makes the surface layer of the soil alkaline, favoring the loss of N by ammonia volatilization. Although the volatilization losses are higher in no-tillage systems, there are numerous benefits involved in this kind of cultivation, such as soil temperature, increases in moisture and organic matter contents, nutrient cycling, reduction of soil compaction, minimizing the erosion process. Thus, technologies to increase fertilizer utilization efficiency ought to be improved, especially regarding N fertilizers.

Several techniques can be used to reduce N losses and to increase the efficiency in the use and recovery of N applied via fertilizer. For example, the use of slow or controlled-released fertilizers can increase their application efficiency, since they are covered or encapsulated by substances that cause nutrients to be gradually released, or have substances that prevent some stage of N transformation after application in the soil (TRENKEL, 2010). Thus, N losses by volatilization are minimized and the N availability follows the plant needs.

This technology has been commercially produced since 1961 (TRENKEL, 2010). However, the cost for its production is still high (MAESTRELO et al., 2014), limiting their use in low value-added crops. The combination of the low cost of sulfur coating and its uniform distribution in the granule generates more competitive and efficient fertilizers that improve N utilization by reducing volatilization losses (CANCELLIER et al., 2016). In addition, this technology makes it possible to increase the yield of agricultural machinery, since fertilization can be performed in a single application and without the need for incorporation.

In this context, this study aimed to evaluate ammonia losses by volatilization of urea, stabilized and slow release nitrogen fertilizers when applied to conventional tillage and no-tillage systems in second-crop corn cultivation.

Material and methods

The experiment was carried out in Medeiros, state of Minas Gerais, in a relief characterized as soft undulating. The soil of the area is characterized as dystroferic red latosol (EMBRAPA, 2013).

The experiment was carried out using a randomized block design in a 4x2 factorial scheme, with four N sources (urea pearls pure (46% N), urea+Cu+B (0.3% B; 0.3% Cu; 43% N), NBPT-treated urea (46% N) and complex mineral fertilizer (221% N; 2% P_2O_5 ; 9% K_2O ; 5% S; 0.2% B and 0.2% Zn) and two cultivation systems (no tillage and conventional tillage), with 4 replications, totaling 32 experimental plots.

Each experimental plot consisted of five meter long corn lines sown manually. Collectors for N- NH_3 losses through volatilization were installed in the center of each experimental plot.

The area was cultivated under two tillage systems: conventional and no-tillage. For the simulation of the conventional system, plant residues were removed from the area and the soil was revolved to approximately 20.0 cm deep. This operation was performed 30 days before the crop was implanted. As for the no-till plots, no intervention was carried out, since the area had already been cultivated under no-till system for eight years.

The experimental area in the previous crop was occupied by soybean. The results of the soil analysis (TABLE 1) refer to the year 2015, prior to the last soybean crop cultivation. The soybean crop was fertilized with 22.5 kg ha⁻¹ of N and 120.0 kg ha⁻¹ of P₂O₅ using monoammonium phosphate fertilizer - MAP (9.0% N and 48.0% P₂O₅). For second-crop corn cultivation, 200.0 kg ha⁻¹ of the formulated fertilizer 4-30-16 distributed in advance in the planting area were used.

Table 1 – Result of soil analysis (0-20 cm) of the experimental area (soil sampling was carried out in 2015)

Variable		Variable	
pH (H ₂ O)	6.2	V	66.2 %
P ⁽¹⁾	6.4 mg dm ⁻³	m	0 %
K ⁽¹⁾	98 mg dm ⁻³	O.M	2.41 dag kg ⁻¹
Ca ⁽²⁾	2.73 cmol _c dm ⁻³	P (rem)	14.3 mg L ⁻¹
Mg ⁽²⁾	0.69 cmol _c dm ⁻³	Mn ⁽¹⁾	12 mg dm ⁻³
Al ⁽²⁾	0 cmol _c dm ⁻³	Zn ⁽¹⁾	2.5 mg dm ⁻³
H+Al ⁽³⁾	1.87 cmol _c dm ⁻³		
SB	3.7 cmol _c dm ⁻³		
CEC (t)	3.7 cmol _c dm ⁻³		
CEC (T)	5.5 cmol _c dm ⁻³		

P-K-Fe-Zn-Mn-Cu: Mehlich-1 Extractor; (2) Ca-Mg-Al: 1 mol L⁻¹ KCl Extractor; (3) H + Al - SMP Extractor; SB = Sum of Exchangeable Bases; CEC (t) = Effective Cation Exchange Capacity; CEC (T) = Cation Exchange Capacity at pH 7.0; % V = Base Saturation Index; m = Aluminum Saturation; O.M = organic matter (Oxidation with 4N Na₂Cr₂O₇ + 10 N H₂SO₄); P (rem) = remaining soil phosphorus content.

Source: Elaborated by the authors (2018).

The hybrid AS1575 from Agroeste, which is characterized as medium size, resistant stalk, good stuffing, semi-grain texture used for grain production was used in this study. A plant population density of 60,000 plants ha⁻¹ was used. To guarantee the final stand of the experiment, 120,000 plants ha⁻¹ were sown and at 15 days after sowing (DAS) thinning was carried out, leaving the desired number of plants.

For weed control, herbicides based on Atrazine and Nicosulfuron, both selective to the crop, were applied at 30 DAS. Potassium fertilization was carried out according to soil analysis: the first application was performed at 54 DAS, applying 100.0 kg ha⁻¹ of potassium chloride fertilizer (58% K₂O) and the second at 69 DAS, using the same source and dose. Fertilization was delayed due to the lack of significant precipitation for seed germination, which delayed the entire production process.

Nitrogen fertilization was performed on different sources of N (urea pearls pure, urea+Cu+B, NBPT-treated urea and complex mineral fertilizer). Nitrogen fertilization was performed on 73 DAS of second-crop corn, using 200.0 kg ha⁻¹ of N in a single application. This dose was converted to the collector area, so each collector base received 10.0 g of N.

Ammonia losses were quantified using the semi-open collector method developed by Nonmik (1973) and adapted by Lara-Cabezas et al. (1999).

For the evaluation of NH_3 losses in the experimental plots, the bases of the chambers were installed on the same day as the N application. Two bases were used for each experimental plot aiming at the alternation of the chambers, so that while one base was being occupied by the chamber, the other remained exposed to the natural conditions of the environment.

The chambers were coupled to 20.0 cm high bases fixed at a depth of five centimeters in the soil. Two sponges were placed inside each chamber with a density of approximately 0.02 g cm^{-3} soaked in 40 mL of phosphoric acid solution (60.0 mL L^{-1}) and glycerine (50.0 mL L^{-1}). The sponge located at the top of the chamber was designed to prevent contamination of the lower sponge while it captured the lost ammonia (LARA CABEZAS; TRIVELIN, 1990).

After each collection, new sponges soaked in phosphoric acid and glycerin solution were placed in the lower chamber supports. Samples were collected on the first, second, third, fifth, ninth and fourteenth days after fertilization. In each collection, the sponges were placed in plastic bags and identified for further analysis.

The ammonium phosphate was extracted by 5 successive washes with distilled water. Each washing was carried out with 40.0 mL of water, over a porous plate Büchner funnel coupled to a kitassate by suction using a vacuum pump. After sample extraction, an aliquot of approximately 80.0 mL was stored.

For the distillation, 20.0 mL of the solution was pipetted and transferred to the digestion tube and distilled by the Kjeldahl semimicro method, by adding 10.0 mL of 40.0% sodium hydroxide solution, and then titrating the samples with hydrochloric acid solution (MALAVOLTA et al., 1997).

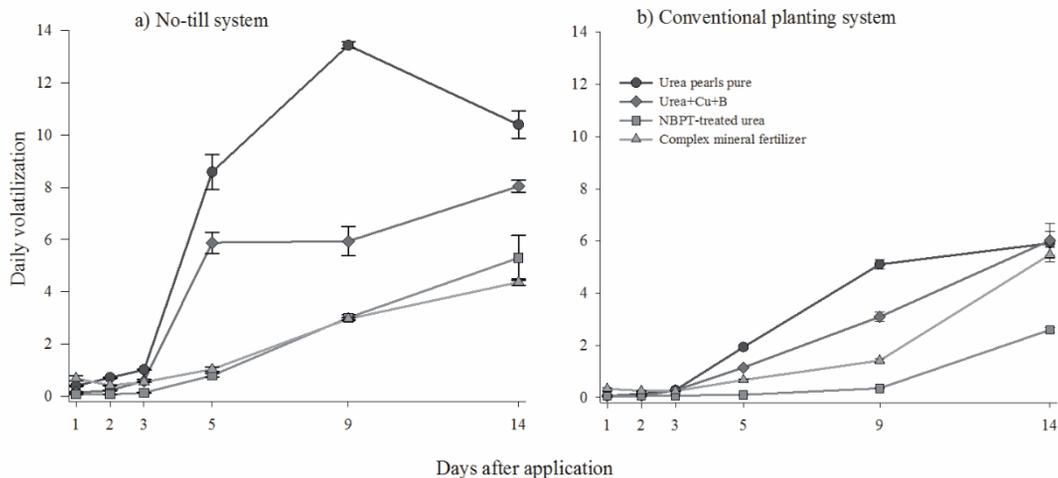
The data of NH_3 losses through volatilization were subjected to analysis of variance (F-Test) and the means were grouped using the Scott-Knott test at 5% probability, using "System for Analysis of Variance" - SISVAR software (FERREIRA, 2011).

Results and discussion

Interactions between cultivation systems (no-tillage or conventional tillage) and sources of N used in the fertilization of second-crop corn were significant for the NH_3 losses through volatilization and for the accumulated loss of NH_3 in this study, period of fourteen days ($p \leq 0.05$).

In the evaluation of NH_3 losses performed one day after fertilization, the complex mineral nitrogen fertilizer presented higher ammonia loss when compared with the other N fertilizers, regardless of the cultivation system (Figure 1b). In the evaluation carried out on the second day after fertilization, it was observed in the no-tillage system higher ammonia losses by urea pearls pure, while in the conventional system the complex mineral nitrogen fertilizer was less efficient (Figure 1a). In the evaluations performed one and two days after the application of fertilization, it was verified that the urease inhibitor fertilizer, NBPT-treated urea, was more efficient, avoiding higher volatilization ammonia losses (Figure 1), regardless of the cultivation system.

Figure 1 – Daily losses of N-NH₃ (%) after N-fertilizers application on second-crop corn cultivation under (a) no-tillage and (b) conventional cultivation systems.



Source: Elaborated by the authors (2018).

In the evaluation performed three days after fertilization, in the no-tillage system, the source urea pearls pure had the largest ammonia losses (FIGURE 1a), while NBPT-treated urea was the most efficient source in reducing the losses. This source presented similar behavior in the conventional cultivation system (FIGURE 1b). As for the fifth day after fertilization, it was observed that urea pearls pure provided greater losses of ammonia in both cultivation systems (FIGURE 1). In the evaluations carried out on the third and fifth days after fertilization, the source NBPT-treated urea was more efficient in avoiding larger losses of ammonia by volatilization, regardless of the cultivation system.

For the evaluation performed on the ninth day after fertilization, urea pearls pure remained less efficient in controlling ammonia losses, regardless of the cultivation system (FIGURE 1). NBPT-treated urea was the most efficient in restricting losses in the conventional tillage system (FIGURE 1 b). In the no-tillage system, both NBPT-treated urea and the complex mineral nitrogen sources were efficient (FIGURE 1a).

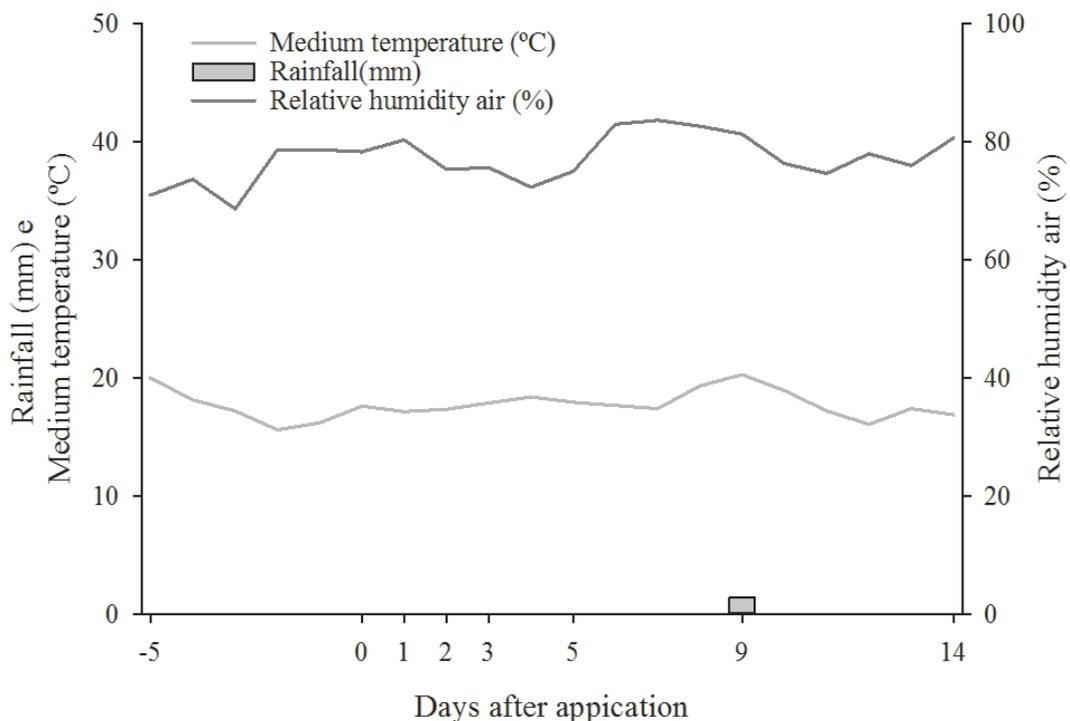
At fourteen days after fertilization, in the no-tillage system (FIGURE 1 a), urea pearls pure remained less efficient in controlling ammonia losses, while the sources NBPT-treated urea and complex mineral nitrogen were the most efficient in restricting losses. In the conventional tillage system, urea pearls pure, urea+Cu+B and complex mineral nitrogen were the least efficient sources regarding the reduction of volatilization, while NBPT-treated urea was the most efficient one (FIGURE 1 b).

In general, urease inhibitor urea was more efficient in reducing ammonia losses from volatilization. In stabilized nitrogen fertilizers, such as NBPT-treated urea, the additive added to urea in the production process (urease inhibitor) promotes delayed conversion of the amide form [(NH₂)₂CO] present in the ammonia fertilizer (NH₃), providing a decrease in volatilization (SOUZA et al., 2017). According to Cantarella (2007), NBPT inhibits urease and with consequent reduction

of urea hydrolysis for a period that can vary from 3 to 14 days, depending on the environmental conditions at the application site.

According to Jones et al. (2007), ammonia losses from ammonia volatilization are influenced by factors related to soil temperature and humidity, relative air humidity, wind speed, rainfall, among others (WATSON et al., 2008). However, after the nitrogen fertilization of second-crop corn cultivation, no significant precipitation occurred (FIGURE 2). Only on the ninth day after fertilization, there was a precipitation of 1.4 mm, which contributed to the peak of ammonia loss due to urea volatilization in the no-tillage system (FIGURE 1 a). This behavior did not occur in the conventional cultivation system, probably due to the rapid incorporation of the fertilizer into the soil, reducing its exposure. In the case of no-tillage, as the fertilizer is applied on the mulch, more precipitation would be necessary to incorporate it into the soil.

Figure 2 – Climate data collected five days before fertilization and during field sponge sampling.

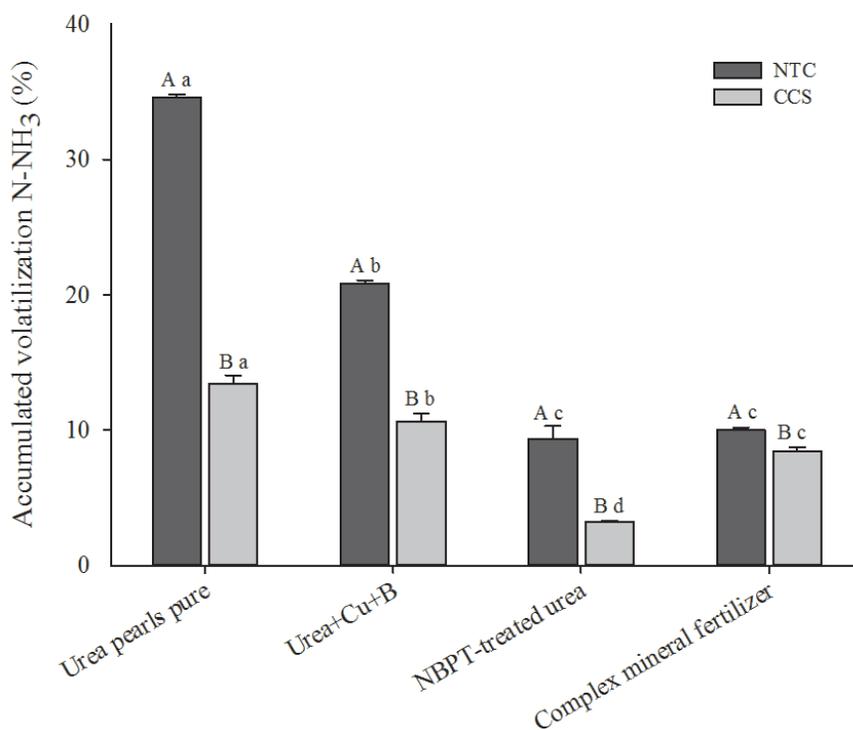


Source: Elaborated by the authors (2018).

During the experimental period, the relative humidity was prone to losses, as well as the average daily temperature, and due to the low rainfall, the loss peaks were delayed until the ninth day of evaluation (FIGURE 1).

The accumulated losses of ammonia recorded at fourteen days after fertilization are shown in Figure 3. The sequence of restriction efficiency of ammonia losses presented by the evaluated fertilizers in the conventional system followed the decreasing order: urea pearls pure < urea+Cu+B < complex mineral nitrogen < NBPT-treated urea.

Figure 3 – Accumulated NH_3 losses (% of the total applied dose) after 14 days of N fertilizers application in the second-crop corn cultivation.



Averages followed by the same letter, upper case for different systems - NTC (no-tillage cultivation system) and CCS (conventional cultivation system), and lower case for fertilizer sources - urea pearls pure, urea+Cu+B, NBPT-treated urea and complex mineral fertilizer - do not differ by the Scott-Knott test at 5% probability.

Source: Elaborated by the authors (2018).

For the no-tillage system, the sequence of restriction efficiency of ammonia losses presented by the evaluated fertilizers showed the following decreasing order: urea pearls pure < urea+Cu+B < complex mineral nitrogen = NBPT-treated urea (FIGURE 3).

The use of urea with urease inhibitor, NBPT-treated urea, has been shown to be efficient in reducing NH_3 losses due to volatilization, and one of the main gains obtained with NBPT is the increased time to incorporate urea by rain action at depths at which it is less susceptible to volatilization losses (MIKKELSEN, 2009; DAWAR et al., 2011).

Pereira et al. (2009) evaluated the volatilization of N-NH_3 fertilizers applied to second-crop corn using different N sources and found that urea with urease inhibitor reduced N volatilization by up to 50.0% when compared with common urea, which reflected in higher productivity.

In the no-tillage system, ammonia losses reached up to 34.55% of N applied in when the source used was urea pearls pure and 9.36% when the source was NBPT-treated urea (FIGURE 3). In the conventional cultivation system, the highest losses were observed when using urea pearls pure (13.41%), and the lowest when NBPT-treated urea (3.22%) was applied (FIGURE 3). The loss of N-NH_3 by urea applied to the soil surface in the no-tillage system is close to the values observed

in southeastern Brazil, ranging from 38.0% to 78.0% of the total N applied to the crops (LARA CABEZAS et al., 1997; LARA CABEZAS et al., 2000; Costa et al., 2003).

The values for the extremes of losses in the no-tillage system corresponded to a lost amount of 69.1 kg ha⁻¹ (urea pearls pure) and 18.7 kg ha⁻¹ (NBPT-treated urea) of N-NH₃ related to the dose of 200.0 kg ha⁻¹ of N. As for the accumulated losses of N-NH₃ in the conventional cultivation system, it ranged between 13.41% and 3.22% of N applied as urea pearls pure and NBPT-treated urea, respectively (FIGURE 3). These values correspond to an amount of 26.8 and 6.4 kg ha⁻¹ of N-NH₃ lost, relative to the total of 200.0 kg ha⁻¹ of N applied in the soil.

The reduction percentages of N-NH₃ losses by the nitrogen fertilizers when compared with urea pearls pure in the no-tillage system were: 39.7, 72.9 and 71.1% for urea+Cu+B, NBPT-treated urea and complex mineral fertilizer, respectively. The percentages of reduction of N-NH₃ losses by the nitrogen fertilizers when compared with urea pearls pure in the conventional cultivation system were: 20.6, 76.0 and 37.4% for urea+Cu+B, NBPT-treated urea and complex mineral fertilizer, respectively. Therefore, NBPT-treated urea obtained the largest reductions in N-NH₃ losses when compared with urea pearls pure.

The results of the present study show the potential of nitrogen fertilizers with urease inhibitor in reducing N-NH₃ losses by volatilization even when used in no-tillage cultivation systems. However, the urease inhibitor urea should be evaluated with caution, as highlighted by Otto et al. (2017), considering the price of these fertilizers in relation to urea and its effects on yield, which was not evaluated in the present study.

Conclusions

Under the conditions in which the present study was carried out, it can be concluded that urea pearls pure was the least efficient nitrogen fertilizer in the restriction of N-NH₃ losses by volatilization. The urease inhibitor urea, NBPT-treated urea, was the most efficient source regarding the reduction of N-NH₃ losses by volatilization. Losses of N-NH₃ by volatilization in the no-tillage cultivation system were higher than in the conventional cultivation system.

Volatilização de amônia por fertilizantes nitrogenados aplicados em cobertura no milho sob dois sistemas de cultivo

Resumo

Uma das tecnologias mais promissoras para o aumento da eficiência de aproveitamento do N é a utilização de fertilizantes de liberação lenta ou controlada que reduzem as perdas do N por volatilização. Neste contexto, o trabalho teve por objetivo avaliar a eficiência de fontes nitrogenadas aplicadas na adubação de cobertura do milho safrinha. O experimento foi instalado em blocos casualizados em esquema fatorial 2x4, sendo dois sistemas de cultivo (convencional e plantio direto) e quatro fertilizantes nitrogenados aplicados em cobertura (ureia perolada, ureia+Cu+B, ureia NBPT e fertilizante complexo) e quatro repetições. Foram avaliadas as perdas de N-NH₃ por volatilização no período de quatorze dias após a adubação nitrogenada de cobertura do milho. Os dados foram submetidos à análise de variância e as médias agrupadas pelo teste de Scott-Knott a 5% de

probabilidade. Nas condições em que o trabalho foi desenvolvido, observou-se que a ureia perolada foi o fertilizante nitrogenado menos eficiente na restrição das perdas de $N-NH_3$ por volatilização em relação aos demais e a ureia+NBPT o mais eficiente. As perdas de $N-NH_3$ por volatilização no sistema de plantio direto foram superiores às quantificadas no plantio convencional.

Palavras-chave: Nitrogênio. Ureia. Adubação.

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