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# Topdressed nitrogen fertilization on second-crop corn in soil with improved fertility

**Clério Hickmann[1]*, Álvaro Vilela de Resende[2], Julian Junio de Jesus Lacerda[3], Silvino Guimarães Moreira[4] and Breno Henrique Araújo[5]**

[1]Universidade do Oeste de Santa Catarina, Rua Oiapoc 211, Bairro Agostini, CEP 37.200-000, São Miguel do Oeste, SC, Brazil.
[2]Embrapa Milho e Sorgo, CEP 35.701-970, Sete Lagoas, MG, Brazil.
[3]Universidade Federal do Piauí, CEP 64900-000, Bom Jesus, PI, Brazil.
[4]Universidade Federal de Lavras, CEP 37.200-000, Lavras, MG, Brazil.
[5]Rehagro - Recursos Humanos no Agronegócio, Rua Santa Fé, 100, CEP 30310-290, Belo Horizonte, MG, Brazil.

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**The aim of this study was to evaluate the performance of sources and application rates of topdressed nitrogen (N) on second-crop corn following soybean in an improved fertility *Latossolo* in the region of Campos das Vertentes, MG. Brazil. A randomized block experimental design was used in a 4 x 5 +1 factorial arrangement, with four replications. The treatments consisted of the combination of four N sources via forms of urea: conventional urea (common urea), urea coated with 16% elemental sulfur (Urea+S), urea treated with base compound urease inhibitor with a 0.4% boron and 0.15% copper (Ureia+B+Cu), urea treated with 1.060 mg kg$^{-1}$ of the urease inhibitor N-(n-butyl) thiophosphoric triamide (Urea+NBPT), and five application rates of N through urea: 30, 45, 60, 90, and 120 kg ha$^{-1}$, plus an additional treatment without N supplied in topdressing. The N concentrations in the leaves and grain, the exported N, the mineral N in the soil (nitrate and ammonium), grain yield, and profitability were evaluated. The N sources increased the N concentrations in the leaves, in the grain, and the exported N. However, the grain yield and the N concentration in the soil did not vary in accordance with the sources of urea. Increasing application rates of N increase N concentration in the leaves and in the grain, exported N, grain yield, and the mineral N concentration in the soil up to a depth of 10 cm. Application of N in topdressing is not economically beneficial considering the final yield of the second-crop corn following soybean in a soil with improved fertility.**

**Key words:** *Zea mays* L, Urea, Nitrogen, No-tillage system, N rates.

## INTRODUCTION

In recent years, there has been a considerable increase in yield in the main grain crops in Minas Gerais, Brazil. Specifically for corn, mean yield increased from 3.9 to 5.4 t ha$^{-1}$ from the 2005/06 crop year to the 2014/15 crop year. In these 10 years, production increased from 5.3 to 6.9 million tons (CONAB, 2016).

*Corresponding author. E-mail: clerioh@gmail.com.

In the 2014/15 crop year, the contribution of second-crop ("safrinha") corn was very significant. Cultivated area increased by 288% from the 2005/06 to the 2014/15 crop year. In the latter crop season, the second-crop corn was responsible for production of 54.6 million t of corn grain in Brazil, with mean grain yield of 5.7 t $ha^{-1}$ (CONAB, 2016).

Along with expansion of the soybean crop to the south of the state of Minas Gerais (MG), and specifically the region of Campos das Vertentes, MG, there has been expressive development of second cropping. These regions have become important grain production centers in the state.

Nevertheless, various agronomic technologies are being adopted that have not yet been duly consolidated for the soil and climate conditions of the region. Prominent among them is topdressing fertilization on second-crop corn.

Currently, in these regions, low N application rates are often recommended, as in other regions with second-crop corn. In general, this has been justified by the lower potential yield associated with greater climate risk factors, such as low water availability, cool weather, and less solar radiation in the central region of Brazil (Shioga et al., 2004). However, the efficiency of nitrogen (N) use is highly dependent on local soil and climate conditions and that makes regionalized studies necessary (Gott et al., 2014) as proposed here.

N is the most important nutrient in the corn crop mainly due to its role in plant growth. It is a structural component of chlorophyll and, as such, participates directly in plant photosynthetic activity and in increasing total percentage of proteins, which results in ear weight gain (Fancelli and Neto, 2004). The high export rate of N through the grain, the decreased uptake rate under water deficit conditions, and high volatilization and leaching losses make N the nutrient of highest demand in the corn crop (Soratto et al., 2010).

Volatilization of ammonia ($NH_3$) is one of the most important processes connected with reduction in N use efficiency, and volatilization increases when N is supplied by ureas. Under conditions of wet soil that is covered by crop residues and receives high solar radiation, loss of $NH_3$ through volatilization may reach values greater than 50% of the N applied via urea (Vitti et al., 2007). Under these soil and climate conditions, peak volatilization of $NH_3$ occurs on the second or third day after application of urea (Cantarella, 2007).

Additives applied to urea have reduced volatilization losses in inhibiting activity of the urease enzyme. The inhibitor occupies the site of activity of the enzyme and inactivates it. It thus delays the start and the speed of volatilization. Delayed hydrolysis of urea reduces the concentration of $NH_3$ in the surface soil, limiting its loss. Upon preventing rapid hydrolysis, the inhibitor increases the possibility of rainwater and irrigation incorporating the components of urea in the soil profile (Cantarella, 2007). Another attempt at increasing the efficacy of urea utilization consists of coating the granules with polymers or other materials, including elemental sulfur (Oliveira et al., 2014).

Some studies have shown the efficiency of urease inhibitors in reducing the speed of transformation of urea to $NH_3$, with reduced losses through volatilization of N compared to common urea. However, new studies must be performed under different soil and climate conditions (Chien et al., 2009).

Although some studies have shown reduction in N losses through volatilization with the use of urea with urease inhibitors, often crop yields have not been affected. This shows the need for new studies because these fertilizers increase production costs by 15 to 20 %.

Within this context, the aim of this study was to evaluate the performance of sources and application rates of N supplied by ureas in topdressing in second-crop corn following soybean in a soil with improved fertility in the region of Campos das Vertentes, MG, Brazil.

## MATERIALS AND METHODS

The experiment was conducted from March to June 2012 on the Santa Helena Farm at 21º15'40'' S and 44°30'30" W, in Nazareno, MG, Brazil. Altitude of the location is 1020 m. The soil was classified as a *Latossolo Vermelho Distrófico*, with clayey texture (Embrapa, 2013).

The area has a management history of high technological investment for grain production and was in *Brachiaria* pasture until 2005. From the 2005 to 2010 crop years, the area was tilled and planted to corn in the main crop season, with winter fallow. In the 2011/2012 crop year, soybean was planted in the main crop season, followed by second-crop corn. A no-tillage management system was used beginning with the planting of annual crops. The chemical characteristics of the soil with improved fertility (Kappes and Zancanaro, 2014) of the experimental area were performed prior to the experiment beginning, according to analytical procedures the 0,0-010 m layer described in Silva (2009) had the following chemical properties: clay and organic matter, 560 and 32.8 g $kg^{-1}$,respectively; pH in water, 5.0; available P and K, 6.1 and 141 mg $kg^{-1}$, respectively (extracted by Mehlich-1); exchangeable Al, Ca, and Mg, 0.0, 2.4, and 0.7 cmolc $dm^{-3}$, respectively (extracted by 1 mol $L^{-1}$ KCl); cation exchange capacity (CEC) at pH 7.0, 8.0 cmolc $dm^{-3}$, base saturation of CECpH7.0, 44.0 %; N-$NH_4$+ and N-$NO_3$-, 14.2 and 41.2 mg $dm^{-3}$, respectively, and H+Al, 4.5 cmolc $dm^{-3}$.

The corn cultivar DOW 2B587 Hx was sown with a mechanized planter (with nine planting rows spaced at 0.6 m) in dryland conditions following soybean. The crop was sown in February 2012, with a final population estimated at 60 thousand plants $ha^{-1}$.

The treatments were in a 4 x 5 +1 factorial arrangement in a randomized block design, with four replications. The plots consisted of six rows spaced at 0.6 m and 10 m length. In these plots, we compared application rates of 30, 45, 60, 90, and 120 kg $ha^{-1}$ of N supplied by the following urea sources: conventional urea (Common urea), urea coated with 16% elemental sulfur (Urea+S), urea treated with base compound urease inhibitor with 0.40% boron and 0.15% copper (Urea+B+Cu), and urea treated with 1060 mg $kg^{-1}$ of the urease inhibitor N-(n-butyl) thiophosphoric triamide (Urea+NBPT). An additional treatment without topdressed N

(Control) was evaluated.

The treatments (sources and rates of N via ureas) were applied manually in strips, around 20 cm beside the plant row, in the four expanded sheets stage ($V_4$). Fertilization at planting was that adopted by the producer in the rest of the field, for an expected yield of 7.2 t ha$^{-1}$. It consisted of application of 15 kg ha$^{-1}$ of N and 75 kg ha$^{-1}$ of $P_2O_5$ supplied by monoammonium phosphate (MAP) in the planting furrow, and 60 kg ha$^{-1}$ of $K_2O$ supplied via broadcast KCl prior to sowing.

The plant health treatments (herbicide, insecticide, and fungicide application) were performed when necessary according to the protocol of the farm (time, amount, and type of product to be applied). To monitor the climatic variations in the experimental period, a meteorological station was set up with automatic recording of data at around 1000 m from the location of the experiment.

In the tasseling stage ($V_T$), soil samples were collected for evaluation of mineral N (ammonia N + nitrate N) available in the soil in the 0-10, 10-20, 20-40 cm depth layers. Sampling consisted of five single samples per plot in the treatments: Common urea; Urea+S, and Control (without topdressed N).

The explanation for selection of the three treatments is due to the representation of mineral N in the treatments that contrast management practices without application of N, traditional application of N via conventional urea, and N applied with stabilized urea sources. The samples were air dried immediately after collection (aiming to reduce changes in the forms of N in the soil), passed through a sieve with a 2 mm diameter mesh, and refrigerated at a temperature below 1°C (Mattos et al., 1995). Ammonia N + nitrate N was determined by the semi-micro Kjeldahl steam distillation method (Tedesco et al., 1995).

Leaf samples were taken in the female flowering stage by collecting 15 leaves per plot on plants at a point opposite to and below the ear. Leaf N was analyzed using the Kjeldahl method (Tedesco et al., 1995). Grain yields were evaluated by harvesting three 4-m rows per plot after physiological maturity of the crop. Grain yields was determined after mechanical shelling, adjusting the moisture content to 130 g kg$^{-1}$. Based on calculation of N concentration in the grain, in which the same method of leaf analysis was used (Tedesco et al., 1995), N export was estimated by multiplying the concentration in the grain by the total grain weight.

The data were subjected to analysis of variance. The mean values of the treatments were compared by the F test and regression models were fitted to the dependent variables in accordance with the application rates of topdressed N. The variables of N urea sources were compared by the Scott-Knott test at the level of 0.05 probability. The Sisvar statistical program (Ferreira, 2011) was used.

An economic analysis was made based on the costs of topdressed nitrogen fertilizers in August 2013. The data were compared to the income generated from grain sales. The prices paid per kg of nitrogen fertilizer were: Urea+B+Cu = R$ 1.46, Urea+S = R$ 1.57, Urea+NBPT= R$ 1.34, and Common urea = R$ 1.20. The estimated cost of mechanized application of topdressed nitrogen was R$ 10.00 ha$^{-1}$ in 2012 (considering the mean total operational cost of the farm), and the other expenses for the crop were considered constant. The commercial value of the 60 kg bag of corn was R$ 32.62. The U.S. dollar exchange rate on August 18, 2013 was R$ 2.42 (CEPEA/ESALQ, 2013).

## RESULTS AND DISCUSSION

There was water deficit during the tasseling and flowering period of the second-crop corn (Figure 1). In this period – from Abril 10 to May 10, 2013 – there was accumulation of only 20 mm of rainfall, which hurt crop performance in the period of greatest water demand (Bergamaschi et al., 2004).

The interaction between N sources and application rates was not significant for the N concentration in the leaves. Nevertheless, the leaf N concentration varied according to the sources (Figure 2A). The sources and application rates increased the leaf N concentration in relation to the treatment without application of N (control) (Figures 2A and B).

The concentrations observed in the treatments that received N are above the reference value for leaf N concentration (30 g kg$^{-1}$), according to Cantarutti et al. (2007). This shows that modern corn genotypes extract more N to express their yield potential because the soil, which was built up (Kappes and Zancanaro, 2014), has a good nutrient reserve, including initial mineral N content.

The results of leaf N concentration in this study indicate that the favorable climate conditions at the time of N application (Figure 1) allowed efficient uptake of nitrogen fertilization by the corn crop and also a decrease in possible losses through volatilization from application of ureas. There was a rain of 28 mm, 24 hours after fertilizer application. Another relevant aspect is the contribution of organic N from the soil. The high organic matter content in the soil made considerable mineral N content available to the plants through mineralization of organic N. The leaf N concentration of 28 g kg$^{-1}$ in the control treatment confirms this hypothesis.

Although the interaction between application rates and sources of N was significant for the grain N concentration variable, the N sources affected the grain N concentrations only at the application rate of 30 kg ha$^{-1}$ (Table 1). The stabilized urea sources proved to be superior to conventional urea. Regardless of the sources, the corn plants grown with 120 kg ha$^{-1}$ of N in topdressing had higher grain N concentrations.

The grain N concentrations did not vary much among the treatments (12.9 to 15.1 g kg$^{-1}$) (Table 1). These concentrations are near those found by Duarte et al. (2005), which ranged from 13.7 to 17.5 g kg$^{-1}$ in a study conducted with different N sources applied in the main crop season in a *Latossolo* of the *Cerrado* (Brazilian tropical savanna). The narrow range of N rates (90 kg ha$^{-1}$) applied in the treatments of this study probably limited greater variations among the grain N concentrations. Cantarella and Duarte (2014) consider 15 g kg$^{-1}$ as an adequate level of grain N concentration, a value that may vary according to the genotype used.

The amount of N exported through the grain was not changed by the sources of urea (Figure 3A). Nevertheless, it increased along with an increase in the N rates applied (Figure 3B). The N exported was 94 kg ha$^{-1}$, on average, among the sources tested. Converting the N values exported by the grain produced, the mean value is 14.6 kg t$^{-1}$ of grain, which is similar to Cantarella and

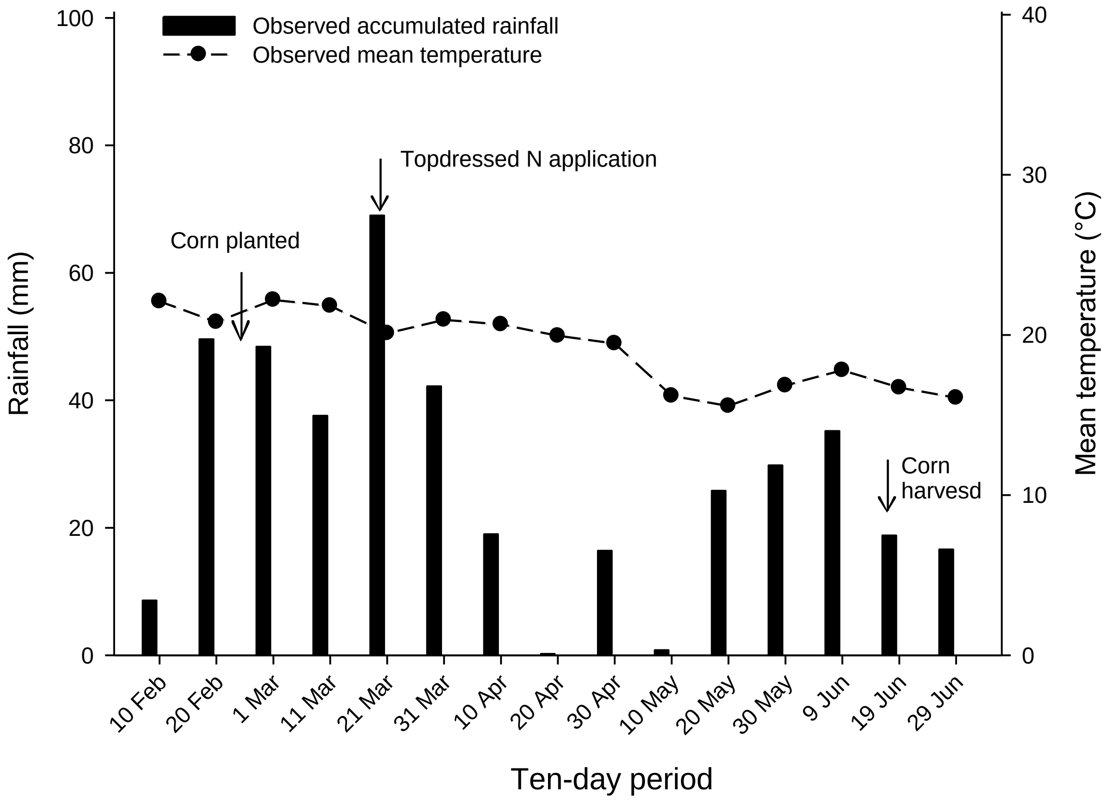

**Figure 1.** Rainfall and mean temperature observed during the experimental period, Nazareno, MG, Brazil, 2011/2012 crop season.

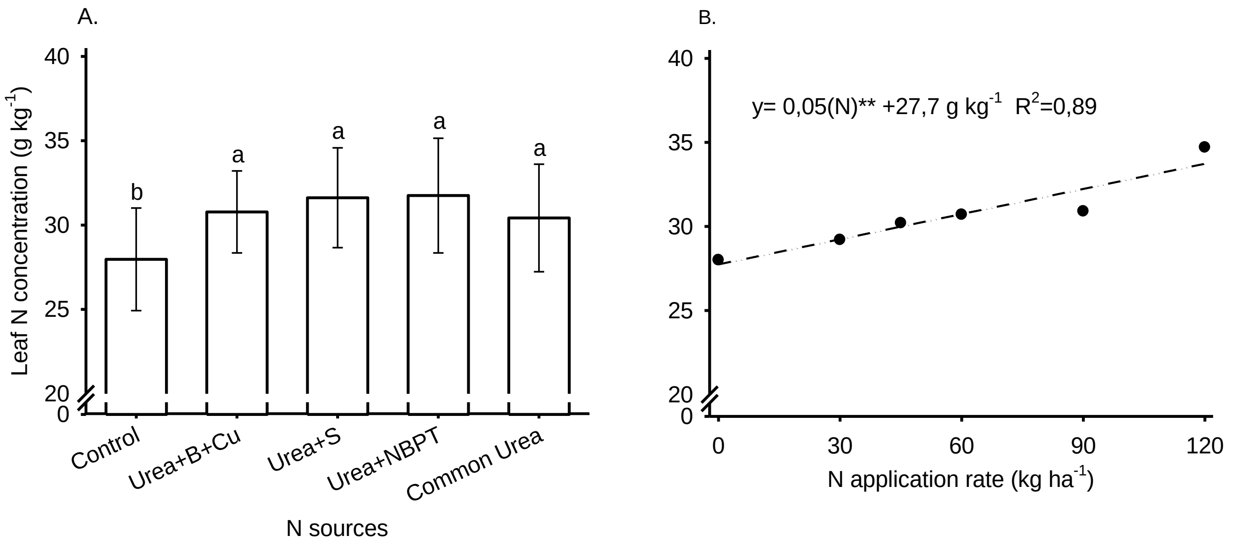

**Figure 2.** Leaf N concentration as a result of different sources (A.) and rates (B.) of N applied in topdressing via ureas in second-crop corn in rotation with soybean in an improved fertility *Latossolo*. ** significant at 1% of probability by the F test. Nazareno, MG, Brazil, 2011/2012 crop season.

Duarte (2014), who estimated a standard value of 15 kg t$^{-1}$ of N exported through grain.

In the treatment that did not receive N in topdressing, 77 kg ha$^{-1}$ of N was exported via the grain. This shows

**Table 1**. Grain N concentration (g kg$^{-1}$) in second-crop corn following soybean in an improved fertility *Latossolo*, as a result of sources of urea and N application rates in topdressing. Nazareno, MG, Brazil, 2011/2012 crop season.

| **N source** | **N application rate (kg ha$^{-1}$)** | | | | |
|---|---|---|---|---|---|
| | 30 | 45 | 60 | 90 | 120 |
| Urea+B+Cu | 13.7$^{A}$ | 14.3$^{A}$ | 15.1$^{A}$ | 14.7$^{A}$ | 14.8$^{A}$ |
| Urea+S | 13.5$^{A}$ | 14.0$^{A}$ | 14.3$^{A}$ | 14.8$^{A}$ | 15.1$^{A}$ |
| Urea+NBPT | 14.0$^{A}$ | 13.5$^{A}$ | 13.7$^{A}$ | 14.6$^{A}$ | 15.1$^{A}$ |
| Common urea | 12.9$^{B}$ | 13.8$^{A}$ | 14.0$^{A}$ | 14.1$^{A}$ | 14.9$^{A}$ |
| Mean | 13.5$^{c}$ | 13.9$^{c}$ | 14.3$^{b}$ | 14.5$^{b}$ | 15.0$^{a}$ |
| CV % | 2.5 | 3.2 | 7.2 | 2.4 | 4.3 |

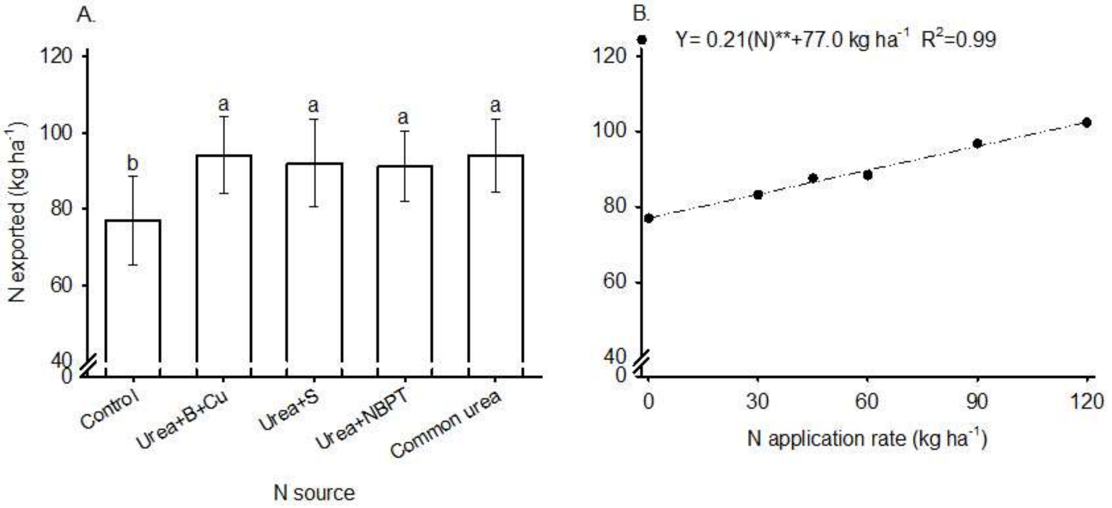

**Figure 3.** N exported as a result of different sources (A.) and rates (B.) of N applied in topdressing in second-crop corn in an improved fertility *Latossolo*. ** significant at 1% probability by the F test. Nazareno, MG, Brazil, 2011/2012 crop season.

that part of the N exported originated from mineralization of the organic matter in the soil. The other fraction of N that was exported originated from the 15 kg ha$^{-1}$ of N supplied at sowing through application of the MAP fertilizer. This shows the importance of fertilization for maintaining the soil organic matter.

The interaction between N sources and rates applied in topdressing were not significant for mineral N available in the 0 to 10, 10 to 20, and 20 to 40 cm depth layers. The common urea and sulfur-coated urea sources had higher mineral N concentrations than the control treatment only in the 20 to 40 cm layer (Figure 4A). There were probably considerable losses through leaching because rainfall of 48 mm was registered 36 hours after the application of the ureas in topdressing.

The addition of different rates of N increased the mineral N concentrations in the surface layer, and an increasing linear model was fitted. In contrast, in the 10 to 20 cm layer, the N rates applied did not modify the mineral N concentrations. In the 20 to 40 cm layer, there was a quadratic fit between the application rates and the mineral N concentration available (Figure 4B).

From the increase in the mineral N concentrations in the soil, especially in the surface layer (0 to 10 cm), it can be deduced that high rates of N applied through fertilizer in topdressing provide a good supply of the nutrient in the corn cycle when the greatest amount of N is required, given that the evaluation was made at the beginning of tasseling.

Considering the apparent density of the soil of 1.0 kg dm$^{-3}$ normally observed in the *Latossolos* of the Cerrado, the treatments that received N via ureas made a stock of around 24 kg ha$^{-1}$ of mineral N available in each layer evaluated (Fernandes and Fernandes, 2009). This value can be considered significant in the 20 to 40 cm layer since the plant concentrates around 80% of the root system in the first 40 cm of the soil profile (Silva et al., 2012).

It should be noted that organic matter is important in making mineral N available to the crop. In the first 20 cm

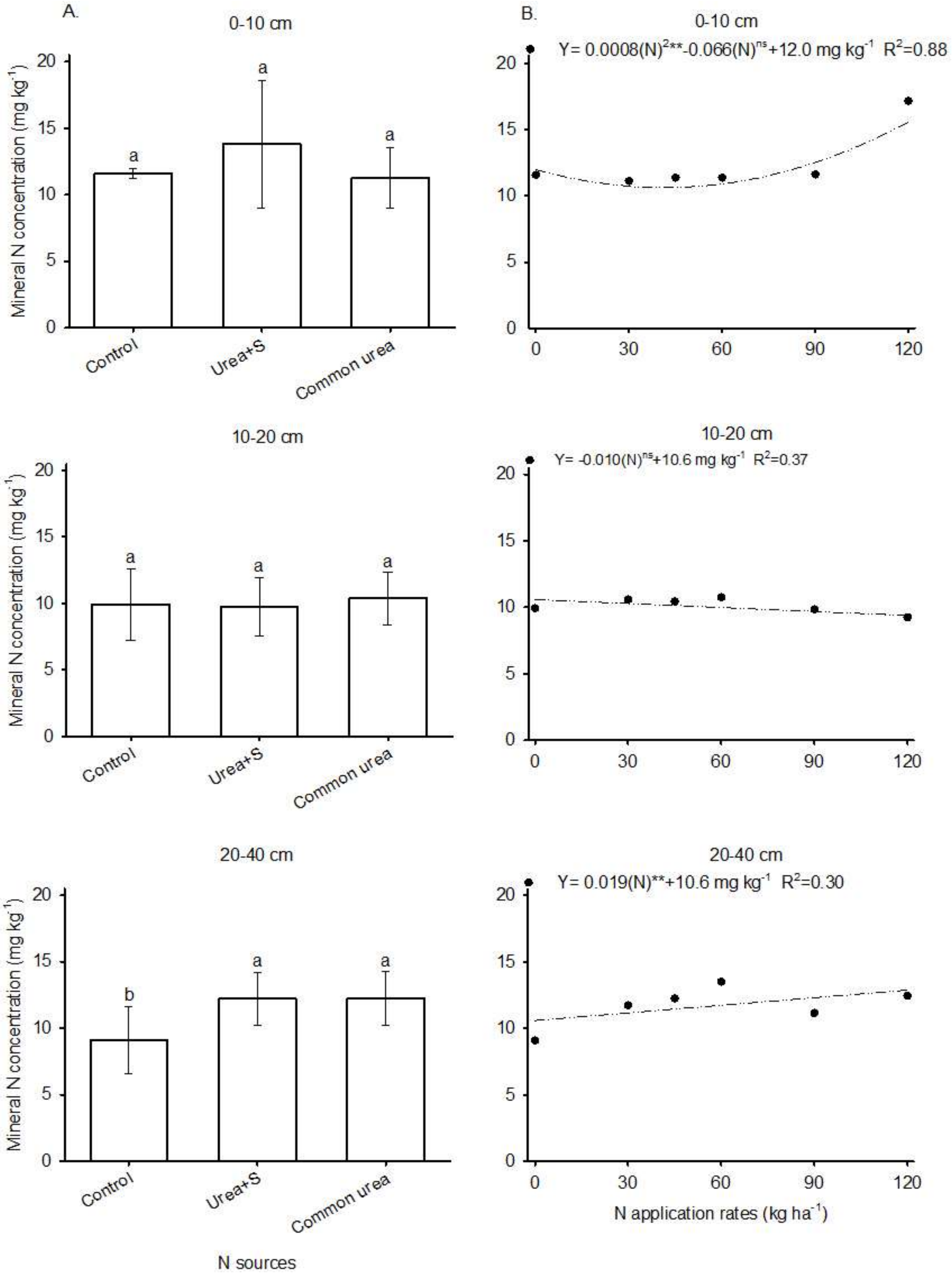

**Figure 4.** Mineral N ($NO_3^-$ + $NH_4^+$) concentration in the 0-10 cm, 10-20 cm, and 20-40 cm depth layers, as a result of different sources (A.) and rates (B.) of N applied in topdressing in second-crop corn in rotation with soybean in an improved fertility *Latossolo*. ** significant at 1% probability by the F test. Nazareno, MG, Brazil, 2011/2012 crop season.

of soil depth, the control treatment made mineral N concentrations available equal to the treatments that had received N via ureas (Figure 4A). Another important aspect is the contribution of N originating from crop

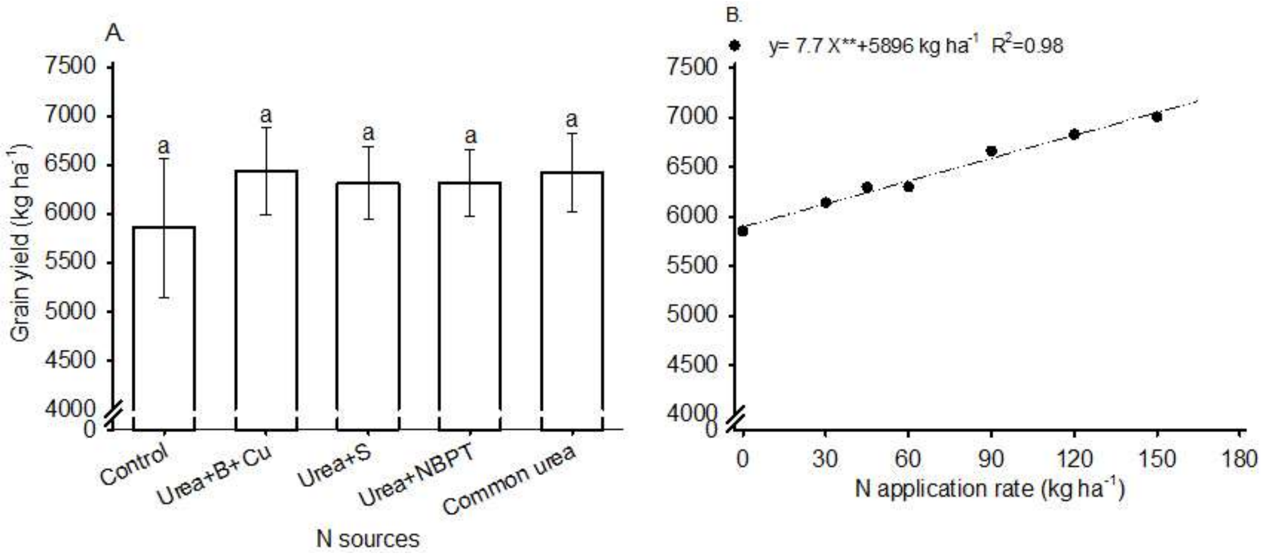

**Figure 5.** Grain yield under different sources (A.) and rates (B.) of N applied in topdressing in second-crop corn in an improved fertility *Latossolo*. ** significant at 1% probability by the F test. Nazareno, MG, Brazil, 2011/2012 crop season.

residues from previous crops, especially leguminous crops. These aspects indicate the fundamental importance of a suitable supply of N to non-leguminous species, with economic and environmental impacts, because of high response to the application of this nutrient and the high susceptibility to losses by the processes of volatilization and leaching (Aita et al., 2004; Ferreira et al., 2010).

There was no interaction between sources and rates of N applied in topdressing for grain yield. Grain yield ranged from 5853 kg ha$^{-1}$ in the treatment that did not receive N (control) to 6430 kg ha$^{-1}$ in the Urea+B+Cu treatment, and the sources evaluated did not exhibit significant difference (Figure 5A). Moreover, corn yield showed a linear increase as the N application rates increased. According to the fitted model, each kg of N supplied added 8 kg ha$^{-1}$ of grain production (Figure 5B).

Studies that show increases in grain yield with increasing application of N via nitrogen fertilizers are well known in the literature (Mar et al., 2003; Santos et al., 2013) as well as the absence of response in the use of sources of different concentrations and chemical composition (Meira et al., 2009; Lange et al., 2014).

The final stand of plants showed significant lodging as a result of the action of wind at the end of the crop cycle. This factor probably led to the low agronomic performance of the cultivar evaluated. Another factor that may have led to low grain yield was the water deficit registered in the period between tasseling and grain filling (Figure 1). Bergamaschi et al. (2004) obtained reduction of 2000 kg ha$^{-1}$ of corn grain in an experiment conducted in dryland arising from water demand of eight consecutive days when the crop was at 60 days after sowing (beginning of tasseling).

Studies performed in the Cerrado showed that second-crop corn responds in grain yield when rates from 120 to 160 kg ha$^{-1}$ of N are applied in topdressing (Mar et al., 2003; Carvalho et al., 2011). These authors obtained yield of 10,7t ha$^{-1}$ upon supplying 160 kg ha$^{-1}$ of mineral N. This implies that in the present study, rates above the maximum tested (120 kg) would increase grain yield according to the fitted model.

Only considering the costs associated with application of N in topdressing in management of second-crop corn practiced on the Santa Helena farm in the 2012/2013 crop year, economic analysis confirmed that there was no advantage in applying nitrogen fertilization in topdressing (Table 2).

The high cost of the fertilizers, the low price received for the bag of corn, and especially the atypical climate conditions that producers confronted in the region for the season brought about the loss obtained from application of nitrogen fertilizers in topdressing. However, longer term studies that consider the production system as a whole are needed. The reason for this is that, without nitrogen fertilization, the sustainability of the systems may be compromised since the supply of N to the crops will be made through oxidation of the organic matter present in the soils (Duete et al., 2009).

Increases observed in relation to standard management of the farm (without application of nitrogen fertilization in topdressing for second-crop corn). Price per kg of nitrogen source: urea+B+Cu = R$ 1.46, urea+S = R$ 1.57, urea+NBPT = R$ 1.34, Urea: R$ 1.20. Cost of mechanized application of urea in topdressing: R$ 10.00 per hectare. Value of a 60 kg bag of corn: R$ 23.62. Exchange rate of U.S. dollar on August 18, 2013 = R$ 2.42. Source: CEPEA/ESALQ (2013); Heringer fertilizantes (2013).

The low efficiency of N use is another factor associated

**Table 2.** Profitability indicators and N use efficiency in second-crop corn production as a result of application rates and sources of N via ureas in topdressing in an improved fertility *Latossolo*. Nazareno, MG, Brazil, 2011/2012 crop season.

| Source | Application rates | Grain yield | Increase | | | | Efficiencyof N |
|---|---|---|---|---|---|---|---|
| | | | Grain yield | Income | Cost | Profit | |
| | ……….kg $ha^{-1}$................. | | | .............. R\$ $ha^{-1}$ ............. | | | kg $kg^{-1}$ |
| Control | 0 | 5853 | - | - | - | - | - |
| Urea+B+Cu | 30 | 6166 | 313 | 122.00 | 438.00 | -316.00 | 10 |
| | 45 | 6304 | 451 | 176.00 | 657.00 | -482.00 | 10 |
| | 60 | 6503 | 650 | 254.00 | 877.00 | -623.00 | 11 |
| | 90 | 6597 | 744 | 290.00 | 1315.00 | -1025.00 | 8 |
| | 120 | 7158 | 1305 | 509.00 | 1753.00 | -1244.00 | 11 |
| Urea+S | 30 | 5991 | 138 | 54.00 | 471.00 | -417.00 | 5 |
| | 45 | 6165 | 312 | 122.00 | 707.00 | -585.00 | 7 |
| | 60 | 6409 | 556 | 217.00 | 942.00 | -725.00 | 9 |
| | 90 | 6642 | 789 | 308.00 | 1413.00 | -1105.00 | 9 |
| | 120 | 6816 | 963 | 376.00 | 1884.00 | -1508.00 | 8 |
| Urea+NBPT | 30 | 6229 | 376 | 147.00 | 402.00 | -255.00 | 13 |
| | 45 | 6064 | 211 | 82.00 | 603.00 | -521.00 | 5 |
| | 60 | 6330 | 477 | 186.00 | 804.00 | -618.0 | 8 |
| | 90 | 6685 | 832 | 324.00 | 1206.00 | -882.00 | 9 |
| | 120 | 6723 | 870 | 339.00 | 1608.00 | -1269.00 | 7 |
| Common urea | 30 | 6175 | 322 | 126.00 | 360.00 | -234.00 | 11 |
| | 45 | 6345 | 492 | 192.00 | 540.00 | -348.00 | 11 |
| | 60 | 6145 | 292 | 114.00 | 720.00 | -606.00 | 5 |
| | 90 | 6769 | 916 | 357.00 | 1080.00 | -723.00 | 10 |
| | 120 | 6650 | 797 | 311.00 | 1440.00 | -1129.00 | 7 |

with the negative outcome obtained in final yield of the crop. The response in grain production clearly expressed the law of diminishing increases: fertilization increased production in the beginning and then decreased in yield per unit of N added. Probably the low utilization of the N provided in topdressing is connected with the period of water deficit that occurred in the phase of greatest demand for the nutrient by the crop (tasseling and flowering).

The results reveal that the stabilized ureas did not bring about the effect that aims at controlled release of N in synchrony with the demand required by the corn plant. As already discussed, accentuated losses probably occurred through leaching since rainfall of 48 mm was registered 36 hours after application of the ureas in topdressing, a condition that is unfavorable for the stabilized ureas to express their efficacy (Zavaschi et al., 2014).

## Conclusions

The sources of N supplied via stabilized ureas does not increase the mineral N in the soil, the leaf and grain N concentration, the exported N, and grain yield. Supplying increased N rates increases the leaf and grain N concentrations, the exported N, grain yield, and mineral N available in the soil up to a soil depth of 10 cm. The application of N via stabilized ureas is not economically compensatory for second-crop corn in rotation with soybean when managed in unfavorable soil and climate conditions in a soil with improved fertility.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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