Australian Journal of Crop Science AJCS

AJCS 12(10):1668-1675 (2018) ISSN:1835-2707
doi: 10.21475/ajcs.18.12.10.pne1394

Effect of different nitrogen sources and time of application on corn grain yield

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Abstract

Alternatives to reduce N losses in soil and increasing nutrient utilization efficiency are important because of the complex dynamics of nitrogen in the soil. In this context, the objective of this study was to evaluate the mechanized application of N doses, at different times (sowing or top-dressing) and forms (surface or incorporated) using urea to evaluate N leaf concentration, production components and corn grain yield. The study was conducted in Selvíria - MS, Brazil, in an Oxisol with clay texture in Brazilian Cerrado. The experimental design was a randomized complete block design with four replicates, arranged in a 6 x 2 x 2 factorial scheme: 6 doses of N (0, 50, 100, 150, 200, 250 kg ha^{-1}), 2 application times (fully sowing or top-dressing) and 2 application forms in the soil (surface and incorporated). The evaluations were: N leaf concentration, stem diameter, plant height, height of pin insertion, spike length and diameter, number of rows per spike, grains per row, and grains per spike, 100 grains mass and corn grain yield. The N application in surface would be more beneficial due to the greater operational capacity. We recommended the application of 153 kg ha^{-1} of N in the soil without incorporation at sowing or top-dressing time in a clayey texture soil and with additional irrigation.

Keywords: Grain yield, *n*itrogen fertilization, productive components, urea, *Zea mays* L.
Abbreviations: N_Nitrogen; N-NH_3_ammonia; a.i._active ingredient; O.M._organic matter

Introduction

Brazil is the third largest corn producer in the world. However, in order to obtain high grain yields, it is necessary to apply high nitrogen (N) doses, since in general the soils do not supply the crop demand during its cycle (Galindo et al., 2016, 2017). In non-legume crops, nitrogen fertilization represents one of the highest costs of the production process (Nunes et al., 2015). Wheat, corn and rice crops consume approximately 60% of the total nitrogen fertilizer produced in the world (Espíndula et al., 2014). Therefore, N fertilization management is carried out with the aim of guaranteeing high yield, due to the dynamics of N in the soil. However, addition of large amounts of N will raise farmers' production costs (Teixeira Filho et al., 2014).

Traditionally, annual crops receive only a fraction of the total dose of N they need at sowing, and the remainder is applied between the lines at the time of greatest demand (Kaneko et al., 2015). This is due to three factors: low initial demand, possibility of leach losses and high salt content of nitrogen fertilizers.

The N application time is one of the most discussed aspects in the management of nitrogen fertilization on grasses under no-tillage system, since, in the first years of adoption of this system, the initial lack of N may occur of the immobilization caused by the microbial decomposition of the residues of the predecessor crop (Teixeira Filho et al., 2010). Thus, in some cases, the anticipation of nitrogen fertilization, in relation to conventional recommendations, or even in relation to crop sowing, may be more efficient in raising annual grain crops yield (Nascente et al., 2011). However, there is a need for further studies, in special for the corn crop in regions with dry winter and controlled irrigation.

The N can be applied to the soil by different methods, being the most commons in the haul, on the soil surface or incorporated in culture lines. The most commonly used source of N in agriculture is urea. When no rainfall occurs in the first few days after application, soil incorporation may be important to minimize ammonia formation (N-NH_3) and and its release into the atmosphere. Lara Cabezas et al. (2000) observed higher losses of urea-derived N-NH_3 when it was applied at the soil surface, compared to its incorporation into the soil in corn crop. These authors estimated that there may be a reduction in corn grain yield due to the volatilization of N-NH_3 in the proportion of 10 kg ha^{-1} of grains for each 1% of volatilized N.

However, studies on different forms and times of nitrogen application of urea have not proved significant increase in corn grain yield, even though some benefits have been observed. In addition, there are still few studies that define the best time and form of N application associated with the best dose, aiming at an adequate management of nitrogen fertilization, reducing losses and moving towards a more sustainable agriculture.

This study proposes that time and the form of nitrogen application associated with the N doses can increase the efficiency of the nitrogen fertilization, with positive effect on corn grain yield. The objective of this study was to evaluate the effect of N doses at different times (sowing or cover) and forms of application (surface or incorporated) using urea as source, evaluating the N concentration in the leaf tissue, productive components and corn grain yield in Brazilian Cerrado (Brazilian Savannah) region.

Results

Effect of forms and time of N application on N leaf concentration, productive components and corn grain yield

The times of N application only influenced the plant height, where the application of all N at sowing favored the growth of corn plants (Table 1).

The application of N incorporated in the soil provided a higher N leaf concentration and plant height. However, its application on surface without incorporation favored the 100 grains mass (Table 1).

Effect of N doses on N leaf concentration, productive components and corn grain yield

N doses influenced N leaf concentration, plant height, height of pin insertion, number of rows per spike, grains per rows and grains per spike (Table 1). There was adjustment to the increasing linear function for N leaf concentration, plant height and number of grains per row, and adjustment to the quadratic function until the doses of 162.5; 161.7 and 161.2 kg ha^{-1} for height of pin insertion, number of rows per spike and grains per spike (Fig 3).

Effect of interaction between N forms and doses on corn grain yield

The interaction between N application forms and doses was significant for grain yield. With application of 150 kg ha^{-1} of N, the application on surface provided higher grain yield. There was adjustment to the quadratic function with maximum points in 153.2 and 186.1 kg ha^{-1} with surface and incorporated application, respectively (Table 2 and Fig. 3).

Effect of interaction between N times of application and doses on corn grain yield

The interaction between N application times and doses was also significant for grain yield. With application of 100 and 200 kg ha^{-1} of N, the application in top-dressing provided greater grain yield. However, with the application of 250 kg ha^{-1}, the application of all N at the time of sowing resulted in higher yield. There was adjustment to the quadratic function until the doses of 208.8 and 147.0 kg ha^{-1} with application at sowing and top-dressing, respectively (Table 3 and Fig. 3).

Discussion

The higher plant height due to the N application at sowing time was occurred due to the initial availability of the nutrient, at the beginning of development and growth of the plants, providing greater root growth, reflecting in the aerial part, at the beginning of the vegetative corn cycle. This evidenced by 1.5% increase in plant height, when N applied at sowing time.

Regarding to the concentration of N in the foliar tissue, Santos et al. (2010), studying N application times (15 days before sowing, sowing and V4) also showed no difference in nutrient concentration. Similarly, Meira et al. (2009), did not see any difference in N leaf concentration, when 120 kg ha^{-1} of N either applied at sowing time and or totally as top-dressing. Corroborating with Kaneko et al. (2010), nitrogen management (without N, 120 kg ha^{-1} seeding 30 kg ha^{-1} seeding and 90 kg ha^{-1} at V6, 120 kg ha^{-1} at V6 and 30 kg ha^{-1} in sowing + 45 kg ha^{-1} in V4 + 45 kg ha^{-1} in V8), did not induce an difference in N leaf concentration, when applied at the time of sowing or top-dressing application. Also, according to Cantarella et al. (1997), the appropriate range for N is 27-35 g kg^{-1}, at which the N contents in the leaves were adequate (with the exception of the control) (Table 1).

The higher concentration of N leaf concentration and plant height as a function of the N incorporation indicates that ammonia volatilization may have occurred, even with irrigation in the area, especially in the initial development period of the corn, corroborating with Lara Cabezas et al. (2000). Although, higher 100 grains mass may occur with the N application on the surface, but no difference has observed in length and diameter of spikes, number of rows per spike, number grains per row and grains per spike. This indicates that under conditions of consolidated no-tillage system and clayey soil, mineralization of N-organic soil may have occurred. The no-tillage system with the maintenance of cultural residues provides soil protection, and also provides an increase in organic matter, with changes in soil chemical, physical and biological conditions (Siqueira Neto et al., 2010). That may favor the N availability throughout the corn crop cycle.

The increase in N leaf concentration as a function of applied nutrient doses demonstrates the importance of N in nutrient absorption. N is the nutrient that most interferes in the development and crop yields, especially grasses. This nutrient is found in higher concentrations in plant tissues and grains, besides being the nutrient required in greater quantity by corn. Thus, the higher availability of this nutrient to the plants favored the development of the root system, by which root can explore larger volume of soil and absorb larger amounts of nutrients such as N and water. This reflects the increase in grain yield, evolving from the synthesis of proteins, chlorophyll, coenzymes, phytohormones, nucleic acids and secondary metabolites (Marschner, 2012). Similar results were obtained by Soratto et al. (2010) and Costa et al. (2012), which verified a linear and positive effect of N doses at N leaf concentration up to the doses of 120 and 200 kg $ha-^{1}$ of N, respectively.

Castro et al. (2008) studied the plant height and height of pin insertion and reported that the plant height is influenced by the N availability in the soil, since this nutrient participates directly in the cell division and expansion and the photosynthetic process. This would explain the positive response of height and growth of the corn plant to the applied N doses. Gross et al. (2006), predicted that nitrogen fertilization positively influences growth and plant height and pin insertion, with a significant effect on corn grain yield. However, it is noteworthy that plant height does not always correlate with grain yield, since modern

Table 1. N leaf concentration, plant height and height of insertion pin, stem diameter, length and diameter of spikes of corn, influenced by nitrogen times, forms of application and N doses. Selvíria - MS, Brazil, 2013/14

	N leaf concentration	Plant height	Height of insertion pin	Stem diameter	Spike lenght	Spike diameter
Forms of application	($g\ kg^{-1}$)	--------(m)--------		----------------(cm)---------------		
Sowing	29.20 a	2.61 a	1.18 a	2.25 a	19.19 a	4.91 a
Top-dressing	28.73 a	2.57 b	1.15 a	2.22 a	19.02 a	4.89 a
Forms of application						
Surface	28.45 b	2.57 b	1.15 a	2.26 a	19.00 a	4.92 a
Incorporated	29.48 a	2.61 a	1.19 a	2.22 a	19.22 a	4.88 a
L.S.D. (5%)	0.96	0.03	0.05	0.07	0.656	0.09
N doses ($kg\ ha^{-1}$)						
0	25.67	2.50	1.09	2.17	19.61	4.83
50	27.84	2.58	1.15	2.22	18.88	4.97
100	28.43	2.58	1.23	2.20	18.80	4.98
150	29.10	2.63	1.16	2.27	18.72	4.80
200	31.15	2.63	1.19	2.29	19.56	4.97
250	31.63	2.63	1.18	2.28	19.08	4.84
C.V. (%)	6.95	2.77	8.39	6.24	8.43	4.51

	Rows per spike	Grains per row	Grains per spike	100 grains mass	Grain Yield
Forms of application				(g)	$kg\ ha^{-1}$
Sowing	15.50 a	36.60 a	571.02 a	31.14 a	8464
Top-dressing	15.25 a	36.75 a	563.72 a	30.55 a	8617
Forms of application					
Surface	15.47 a	36.54 a	568.77 a	31.26 a	8697
Incorporated	15.27 a	36.81 a	568.97 a	30.43 b	8385
L.S.D. (5%)	0.39	1.09	19.33	0.82	322
N doses ($kg\ ha^{-1}$)					
0	14.75	35.25	526.25	29.92	6460
50	15.81	36.25	579.25	30.49	8597
100	15.81	36.31	575.25	30.63	9056
150	15.31	37.37	575.87	31.07	9256
200	15.25	37.68	575.81	31.12	8947
250	15.31	37.81	571.25	31.85	8929
C.V. (%)	6.16	7.30	8.37	6.55	9.26

Means followed by the same letter in the column do not differ by the Tukey test at 5%.

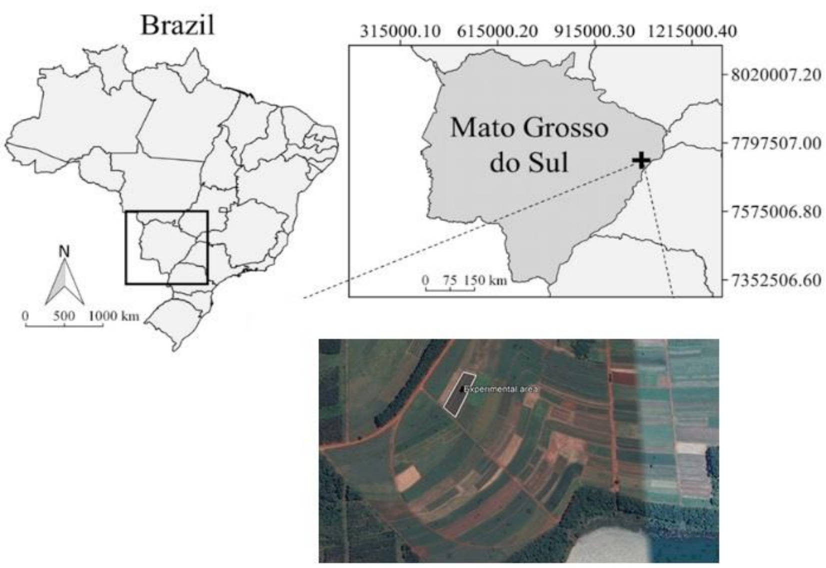

Fig 1. Study area at the Selvíria, Mato Grosso do Sul, Brazil (20°22'S, 51°22'W, altitude of 335 m).

Table 2. Interaction between N doses and forms of application in corn grain yield. Selvíria - MS, Brazil, 2013/14.

Forms	Grain Yield (kg ha^{-1})					
	N doses (kg ha^{-1})					
	0	50	100	150	200	250
Surface	6460 a	8837 a	9136 a	9878 a	9185 a	8684 a
Incorporated	6460 a	8357 a	8976 a	8634 b	8708 a	9173 a
L.S.D. (5%)	789					

Means followed by the same letter in the column do not differ by the Tukey test at 5%.

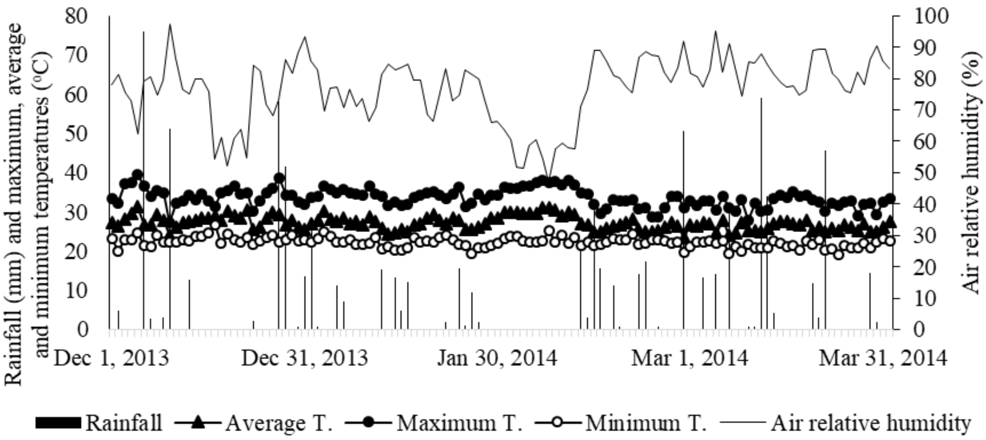

Fig 2. Rainfall, air relative humidity, and maximum, average, and minimum temperature obtained from the weather station located on the Education and Research Farm of FE / UNESP during corn cultivation in the period of December 2013 to April 2014

Table 3. Interaction between N doses and time of application in corn grain yield. Selvíria - MS, Brazil, 2013/14.

Time	Grain Yield (kg ha^{-1})					
	N doses (kg ha^{-1})					
	0	50	100	150	200	250
Sowing	6460 a	8330 a	8650 b	9260 a	8549 b	9535 a
Top-dressing	6460 a	8864 a	9462 a	9252 a	9344 a	8322 b
L.S.D. (5%)	789					

Means followed by the same letter in the column do not differ by the Tukey test at 5%.

hybrids with high productive potential are mostly of low size (Cruz et al., 2008).

The results obtained are similar to those obtained by Goes et al. (2014), who verified increase in height of pin insertion and plant height with the increase of N doses. Consistently, Souza and Soratto (2006) verified a quadratic response of plant height as a function of N doses in top-dressing (0, 30, 60 and 120 kg ha^{-1}) using urea source. According to these authors, the highest plant height value was obtained at the estimated dose of 66.8 kg ha^{-1} of N.

Regarding the height of pin insertion, the results are consistent with those obtained by Souza and Soratto (2006) and Lana et al. (2009). These investigators evaluated the corn response to the N application and verified that the height of pin insertion was higher in the treatments that received N, compared to the control. As reported by Büll (1993), a well-nourished plant in N showed greater development of leaf area and root system, as this nutrient influenced division, cell expansion and photosynthesis, leading to increased plant height and, consequently, the height of pin insertion.

In contrary, Kaneko et al. (2010) observed no response to nitrogen fertilization in height and pin insertion of corn in the first year of cultivation at Oxisol Brazilian Cerrado of Selvíria - MS. The positive result obtained in the present study is mainly due to the increase of the plant height to the increase of N doses, which culminated in the consequent increase of height of pin insertion.

For the evaluation of stem diameter, the results obtained contradict those verified by Cruz et al. (2008), Lana et al. (2009) and Kappes et al. (2013), who found an increase in stem diameter in response to N doses in corn. In contrast, similar results were verified by Costa et al. (2012) in steam diameter. However, according to the authors, N doses did not influence plant height and height of pin insertion.

In relation to the number of rows and grains per row and spike, the results differed from those obtained by Silva et al. (2005), testing combinations of times of nitrogen application and forms of urea and could did not verify increase in the number of rows of grains and number of grains per row. However, Mohammadi et al. (2003) verified that the grain mass and number of grains per spike were the most

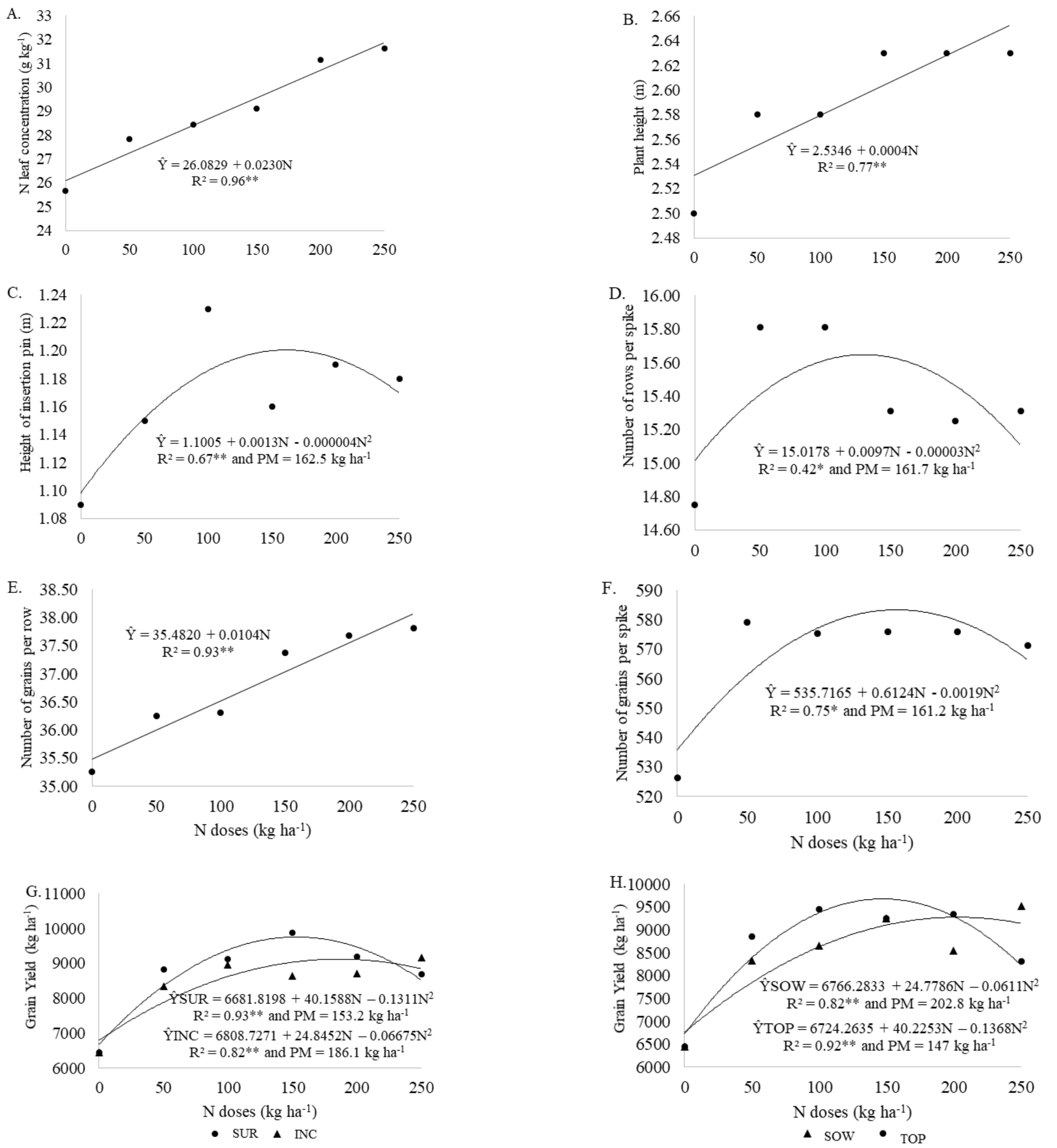

Fig 3. N leaf concentration (A), plant height (B), height of insertion pin (C), number of rows per spike (D), grains per rows (E) and grains per spike (F) in function of N doses, interaction between N doses and times of application (G) interaction between N doses and forms of application (H) in corn grain yield. Selvíria - MS, Brazil, 2013/14. ** and *: significant at $p<0.01$, $p<0.05$, respectively.

most important components in grain yield prediction, demonstrating the importance of these productive components for the corn crop. Contrasting results were obtained by Kappes et al. (2013), which also did not find increase of rows per spike. According to these authors, the increase of N doses also did not influence the diameter and length of the spike and grain mass, similar to that verified in the present study. According to Ohland et al. (2005), grain mass is a characteristic influenced by genotype, nutrient availability and climatic conditions during grain filling stages. For Ulger et al. (1995), this productive component has high dependence on the uptake of N by corn, which reaches a peak during the period between the beginning of the flowering and the beginning of the grain formation. In this period, N deficiency may contribute to the formation of grains with lower specific mass, due to non-translocation of the nutrient in adequate amounts. In the present study, we verified that the soil was not able to supply the need of the corn crop to N. In this way, the nutrient supply through fertilization becomes extremely important, directly influencing the components of the spike, such as the number of rows and number of grains, reflected in grain yield.

According to Lopes et al. (2007), the relationships between the ear characteristics are dependent on the genotypes. For Cruz and Carneiro (2003) the hybrid is responsible for 50% of the final grain yield. In this way, for the hybrid to express all its genetic potential, the factors such as water, nutrients and temperature are fundamental. The increase of N doses allowed better development of rows and grains due to the tendency of higher N accumulation, with positive reflection on the nutritional state of the plant, allowing the genetic expression of the material in number of rows and grain per spike. Similar results were obtained by Santos et al. (2010), working on urea at a dose of 150 kg ha^{-1}. They verified a difference between N application times in corn crop only when fully applied in V4, compared to treatments applied 15 days before sowing, not differing from treatments in which urea was applied at sowing. Similarly, Kaneko et al. (2010), working with urea at the dose of 120 kg ha^{-1} also did not verify difference between the N application in sowing and top-dressing of corn crop. Souza et al. (2011) also found that the application of all nitrogen fertilization in sowing time is feasible under conditions of clayey soil, irrigated by sprinkling and under no-tillage, as well as the traditional application of N in cover crops irrigated corn crop.

In contrast, Meira et al. (2009) studied N application times in corn (120 kg ha^{-1} in seeding, 30 and 90 kg ha^{-1}, 60 and 60 kg ha^{-1} and 90 and 30 kg ha^{-1} in sowing and top-dressing in V6, respectively, and 120 kg ha^{-1} in V6), verified higher grain yield, when N was applied fully in top-dressing compared to the application in sowing. However, Silva et al. (2005), evaluated the effect of N application time in the form of urea in two forms of applications (surface and incorporated) in the Cerrado region. They observed that N incorporated in sowing and N applied at 15 days after the emergence of seedlings (120 kg ha^{-1}) were the treatments that promoted higher grain yield, differently from the present study. Similar results were obtained by Kaneko et al. (2015), where they applied urea and ammonium nitrate on surface or incorporated and verified that there is no influence of the N application form.

Several studies have reported positive effect of N doses application on corn grain yield (Gomes et al., 2007, Pavinato et al., 2008; Lana et al., 2009; Souza et al., 2011; Goes et al., 2014; Kappes et al., 2014). This which can be explained by the fact of high N demand of studied hybrid in succession to a fallow area, in which natural vegetation probably has a high C/N ratio. The desiccation and mechanical disintegration were performed less than 25 days before corn sowing, evidencing the effect of N immobilization on straw.

The positive results of nitrogen fertilization (N doses) can be attributed to the fact that grain yield correlated positively with N leaf concentration (0.96**), number of grains per row (0.79**), number of grains per spike (0.75*), plant height (0.77**) and height of pin insertion (0.67**). These values also highlight the importance of N, both with regard to the nutritional status of the plant and its positive influence on the increase in the number of corn grains, resulting in higher grain yield.

Due to the obtained results, it would be more interesting to apply N on surface to minimize the costs of the nutrient incorporation. The application of all nitrogen fertilizer at sowing time in no-tillage system is possible but should be cautioned, since the area is being cultivated in crop rotation, preferably with legumes and in a soil that provides enough O.M. to that N deficiency does not occur in flowering stages and grain filling, which are critical stages for grain yield. However, it should be pointed out that the top-dressing application minimizes the risk of an eventual deficiency caused during critical periods of corn crop development.

Materials and Methods

Field sites and material description

The study was carried out in the municipality of Selvíria - MS, Brazil, located at the geographic coordinates 22º 22 'latitude S and 51º 22 'O longitude, with an altitude of 335 m (Fig. 1). The soil of the experimental area was classified as an Oxisol, clay texture, according to Embrapa (2013). The study was conducted under field conditions under a no-tillage system irrigated by sprinkling, by means of a central pivot with a water depth of approximately 14 mm and a 72 hour irrigation system. History of the area shows annual crop cultivation more than 27 years. The last 10 years has been under no-tillage system and the last year being fallow. The granulometric analysis (depth of 0-0.20 m) presented the following results: 433, 471 and 90 g kg^{-1} of clay, sand and silt, respectively.

The climate, according to Köppen's classification, is the tropical humid with a rainy season in the summer and dryness in the winter, the fundamental type Aw, and the annual average temperature of 23.5 ^{o}C, average annual rainfall of 1370 mm, with relative humidity average annual air temperature between 70 and 80%. Fig. 2 shows the climatic conditions during the corn experiment.

In September of 2013, the chemical attributes of the soil in the arable layer was determined before the installation of corn experiment, according to methodology proposed by Raij et al. (2001). The following results were obtained: 10 mg dm^{-3} of P (resin); 5 mg dm^{-3} of S-SO_4; 22 g dm^{-3} O.M. (Organic Matter).; 5.3 pH ($CaCl_2$); K, Ca, Mg, H + Al = 2.4; 21.0; 18.0 and 28.0 $mmol_c$ dm^{-3}, respectively; Cu, Fe, Mn, Zn (DTPA) = 3.2; 22.0; 24.2 and 1.2 mg dm^{-3}, respectively; 0.16 mg dm^{-3} B (hot water), CTC 51.58 mmol $_c$ dm^{-3} and 60% base saturation.

Experimental design

The experimental design was a randomized complete block design with four replicates arranged in a factorial scheme: 6 x 2 x 2: 6 doses of N (0, 50, 100, 150, 200 and 250 kg ha^{-1}), 2 application forms in the soil (surface and incorporated - both mechanically applied) and 2 application times (totally in sowing and top-dressing). The treatments were mechanically applied. The nitrogen source was granular urea (45% N). All similar treatments were applied in a uniform way, in which operations are carried out in commercial corn crops. The dimensions of the plots were 10 m in length with 4 useful lines and spacing between plants of 0.45 m, and expected population of 66 thousand plants per hectare.

Crop development

The desiccation of the area was performed 20 days before sowing with the herbicides glyphosate (1800 g ha^{-1} of active ingredient - a.i.) and 2,4-D (670 g ha^{-1} of a.i.), and 5 days before sowing the straw was managed by triton to facilitate cultural management. The sowing of the triple corn hybrid DKB 350 PRO (cartridge caterpillar resistant - *Spodoptera frugiperda*) was performed mechanically, on 12/16/2013. Afterwards, the area was irrigated to promote seed germination. Seedlings emerged 5 days after sowing.

In the sowing fertilization, 112 and 64 kg ha^{-1} of P_2O_5 and K_2O were applied, respectively, based on the soil analysis and corn yield expectation. Nitrogen fertilization was carried out according to the treatments mentioned previously, always between corn lines, at the time of sowing, or in corn V4 stage (01/08/2014). When incorporated into the soil, the urea was deposited at a depth of about 5 to 7 cm above ground level. The experimental area was irrigated by sprinkling, by means of central pivot on the following day of the top-dressing fertilization. For weed control, the herbicides tembotrione (84 g ha^{-1} of a.i.) and atrazine (1000 g ha^{-1} of a.i.) were applied, plus the addition of an adjuvant in the herbicide syrup, vegetable oil (720 g ha^{-1} of a.i.) in post-emergence, at stage V2. Pest and disease control was not necessary. Corn was harvested manually and individually per experimental unit on 18/04/2014, 118 days after plant emergence. The material was then dried in full sun and mechanically trodden.

Traits measured

The evaluations were: (a) N Leaf concentration, according to the methodology of Malavolta et al. (1997). The main stem insertion was collected in the feminine flowering of plants, according to the methodology described in Cantarella et al. (1997); (b) Stem diameter in the second internode, using pachymeter, in 5 plants per plot; (c) plant height, defined as the distance (m) from the soil level to the apex of the tassel, using a graduated ruler in 5 plants per plot; (d) Height of pin insertion, by means of a graduated ruler, in 5 plants per plot; The last 5 evaluations occurred during the corn maturation stage. From the useful area of each plot, five ears were collected randomly for manual counting and/ or evaluations of: (e) length (f) diameter of spike; (g) Number of rows per spike; (h) Number of grains per row; (i) number of grains per spike; (j) 100 grains mass, determined in a precision balance of 0.01 g with water content of the grains corrected to 13% (wet basis) and (k) Grain yield, determined by collecting the spikes contained in 10 m of each of the two lines in the physiological maturation phase and with 20% moisture in the grains. The material was subjected to drying in full sun and after the mechanical track, the grains were quantified and the data transformed in kg ha^{-1}, at 13% (wet basis).

Statistical analysis

The evaluated variables were submitted to analysis of variance (test F) and the means of the N forms and times of application were compared by the Tukey test at 5% of probability. Regression analysis was used for N doses. For statistical analysis, the SISVAR program was used (Ferreira, 2011).

Conclusion

The supply of nitrogen at the time of sowing provides higher plant height, and the urea incorporated into the soil leads to higher N leaf concentration and plant height. However, the application in surface provides greater 100 grains mass. The increase of N doses positively influences N leaf concentration, plant height and height of pin insertion, number of rows per spike, grains per row and grains per spike, with a positive reflection on corn grain yield. The urea application in surface is more interesting due to the ease of application, cost, besides propitiating similar corn grain yield compared to the incorporated application. In a soil of clay texture with additional irrigation, it is possible to anticipate all the nitrogen fertilization for the sowing occasion with the application of urea between the corn lines.

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