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Nitrogen accumulation and productivity of green corn in function of ways and seasons of top-dressing nitrogen fertilizer application

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Nitrogen is one of the nutrients required in large amounts by plants and mostly influences corn yield. With the objective of evaluating the best timing and methods of N fertilizer application in topdressing on corn, this experiment was carried out in Ipameri County, State of Goiás, Brazil, on a Red Yellow Latossol (Ferralsol). The treatments were distributed in a randomized complete block design with four replications. The applied treatments were: control: 100% N applied on the surface after planting; 100% N applied on the surface in V4 phase; 50% N applied on the surface at V4 and 50% N applied on the surface at V6 phases; 100% N applied on the surface in V6 phase; 100% N applied in continuous fillet at V4 phase; 100% N applied in continuous fillet at V6 phase; 50% N in continuous fillet applied at V4 and 50% N in continuous fillet applied at V6 phases. The data were subjected to variance analysis by test 'F' and the means were compared by Tukey test (P <0.05). The nitrogen fertilization increased the length of ears with and without husk, the diameter of ear without husk, ears green yield with and without husk, number of grains per row and grain yield. The N application mode in continuous fillet provided greater averages for the characteristics evaluated. The N application time influences the absorption and accumulation of N in the shoots of corn.

Key words: Absorption, nitrogen fertilization, application methods, nutrition.

INTRODUCTION

The culture of green maize has become an alternative of great economic value to the producer because of good market price and of the demand for the product in nature (Matos, 2007), mainly, for subsistence agriculture. It is intended for consumption in the green stage of maturation, both in the form of cooked or roasted ear, juice, cooked and canned grains, among others, differentiating its characteristics from common corn. In Brazil, the production of green maize is intended mainly for canning (Sawazaki et al., 1990; Oliveira Junior et al., 2006). To meet requirements of the consumer, the ears should be large, cylindrical and with husk (Freire et al., 2010).

One of the aspects of great importance in the

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production of green maize is the management of nutrition, mainly in terms of nitrogen (N), nutrient required in great quantity. The management of nitrogen fertilization in the production of green maize is crucial, because it is directly related to the increased productivity and improved quality, with numerous relevant functions in its physiological activities, as photosynthesis, respiration, protein synthesis and ionic absorption. The recommendations of the nitrogen fertilization are 80 and 120 kg.ha^{-1} of N, and m is based on the fact that culture requires about 20 kg.ha^{-1} of N for each ton of grain produced, and for green maize, is based on information relating to grains production (Borin et al., 2010). In Brazil, the regional recommendations of N, presented variations, with doses that vary from 20 to 180 kg ha^{-1} (Almeida and Sanches, 2012). Higher doses are associated with larger productivity, but the energy efficiency has great interference in the results. According to Matos (2007), 70 to 90% of the assays with maize in Brazil respond to N.

The availability of N, in many production systems, is almost always a limiting factor, along the crop cycle, influencing the growth of the plant more than any other nutrient (Carmo et al., 2012). In addition, N presents high mobility in the soil and can be easily lost, mainly, by the immobilization, denitrification, leaching and volatilization. For this reason, it is important to minimize the losses, maximize the absorption and metabolism of N in the interior of the plants (Almeida and Sanches, 2012).

The phenological stage of application can interfere with the efficiency of the use of nitrogen fertilizers by crops. On one hand, early applications can favor losses by leaching, due to longer exposure to rain and lower rate of nutrient uptake by the crop from sowing to the first days after emergence. Late fertilization may not make plant to produce more due to plant productive potential in the early stages, depending on the availability of nutrients. Better grain productivity was obtained by Silva et al. (2005a), with the incorporation of N during planting or 15 days after the emergency. However, Rambo et al. (2004) obtained an increase in productivity of grains by applying N in the emergency of ear stage. According to Silva et al. (2005b), response to late fertilizing depends on the cultivar. For this reason, it is of fundamental importance to search for more precise information on the requirements for the production of green maize, as well as determine the application modes and phenological stage, in which the fertilizer is more required, according to the absorption and the accumulation of nutrient in different stages of plant development (Borin et al., 2010).

Thus, the objective of this work was to evaluate the accumulation of N and the productivity of green maize in function of modes and phenological stages of application of N.

MATERIALS AND METHODS

The work was conducted in the experimental field of State University of Goiás, Campus Ipameri, Goiás (Lat. 17° 43’ 19’’ S, Long. 48° 9’ 35’’ W, Alt. 773 m) in the agricultural year of 2014/2015. According to the classification of Köppen, the climate of the region is tropical humid (AW) with annual rainfall of 1,447 mm, average temperature of 21.9°C, relative humidity ranging from 58 to 81%. In Figure 1, the climate data corresponding to the period and the year of development of field work is shown.

The soil of the experimental area is classified as Red Yellow Latossol (Ferralsol) (EMBRAPA, 2013), whose physical-chemical attributes are presented in Table 1. The experimental design was randomized blocks, with 8 treatments and four repetitions. The treatments were composed of: control (without application of N in coverage); 100% N applied to the surface after sowing; 100% N applied to the surface in V4 phase; 50% N applied to the surface at V4 and 50% N applied to the surface at V6 phases; 100% N applied to the surface in V6 phase; 100% N applied in continuous fillet at V4 phase; 100% N applied in continuous fillet at V6 phase; 50% N in continuous fillet applied at V4 and 50% N in continuous fillet applied at V6 phases.

The sowing of maize for "*in natura*" consumption, Agroceres 1051, was performed on 12/17/2014 under no-tillage, with the aid of a seeder with tractor traction, with eight rows spaced 0.80 m, by distributing five seeds per linear meter. The useful area of the experimental plot constituted of four central rows, with 3.0 m length, removing a meter at each end. The fertilizing was based on the chemical analysis of the soil and in the demands of culture, with the application of 27.5 kg ha^{-1} of N, 137.5 of kg ha^{-1} of P_2O_5 and 82.5 kg ha^{-1} of K_2O, using the fertilizer with formulated NPK 05-25-15. The nitrogen fertilization application was 120 kg ha^{-1} using urea as source.

The nitrogenous fertilization was performed with the soil at field capacity, according to the treatment mentioned, using urea as source of nitrogen (N). The weed control was performed by means of the applications of atrazine in pre-emergence and Tembrotiona® in post-emergence. The control of pests was performed with application of insecticide provided and ingestion of Premio® with concentration of 125 mL ha^{-1}, plus the growth regulator insecticide, Intrepid 240SC with 180 mL ha^{-1} volume of 200 L ha^{-1}syrup.

During the reproductive phase in stage R_3 (grain pasty), 10 plants were evaluated in the useful area of each plot: I- height of insertion of the first ear (IFE), measured from the stem base to the point of insertion of the first ear; then, the plants were harvested manually following the evaluations of: II- husked ear length (HEL) and unhusked (CED) and were obtained by measuring the distance between the base and the apex of the ear in cm; III- husked ear diameter (DED), a digital pachymeter with precision to 0.1 cm, measured at the point corresponding to the center of ear was used; IV - Productivity of husked (PEE) and unhusked cob (PED) in Mg.ha^{-1} obtained with the mass of the ears harvested and extrapolated to 1 ha; V - row number per ear (relation); VI - Number of grain per row (NGF); VII - grain yield (PG), the grains were separated with cut close to the surface of cob, these were weighed and the quantity obtained was extrapolated to 1 ha (Mg ha^{-1}).

For the determination of N content, they were collected in the aerial part of four plants per plot, in stages V_{12} and R_3. Subsequently, the plants were washed and weighed to determine the wet mass, then stored in paper bags and placed to dry in an oven with forced air circulation and the temperature was kept in the range of 65 to 70°C, until the samples reached constant weight. Subsequently, the samples were milled and subjected to chemical analyzes, for the determination of concentrations of N, according to the procedures described by Malavolta et al. (1997). In these results, the cumulative quantities of this nutrient per plant and the quantity obtained extrapolated to 1 ha (kg ha^{-1}) were estimated.

The data were subjected to analysis of variance by test 'F' at the level of 0.05 of probability and the averages were compared by the Tukey test with the aid of the Statistical Program System for Analysis of Variance - SISVAR®.

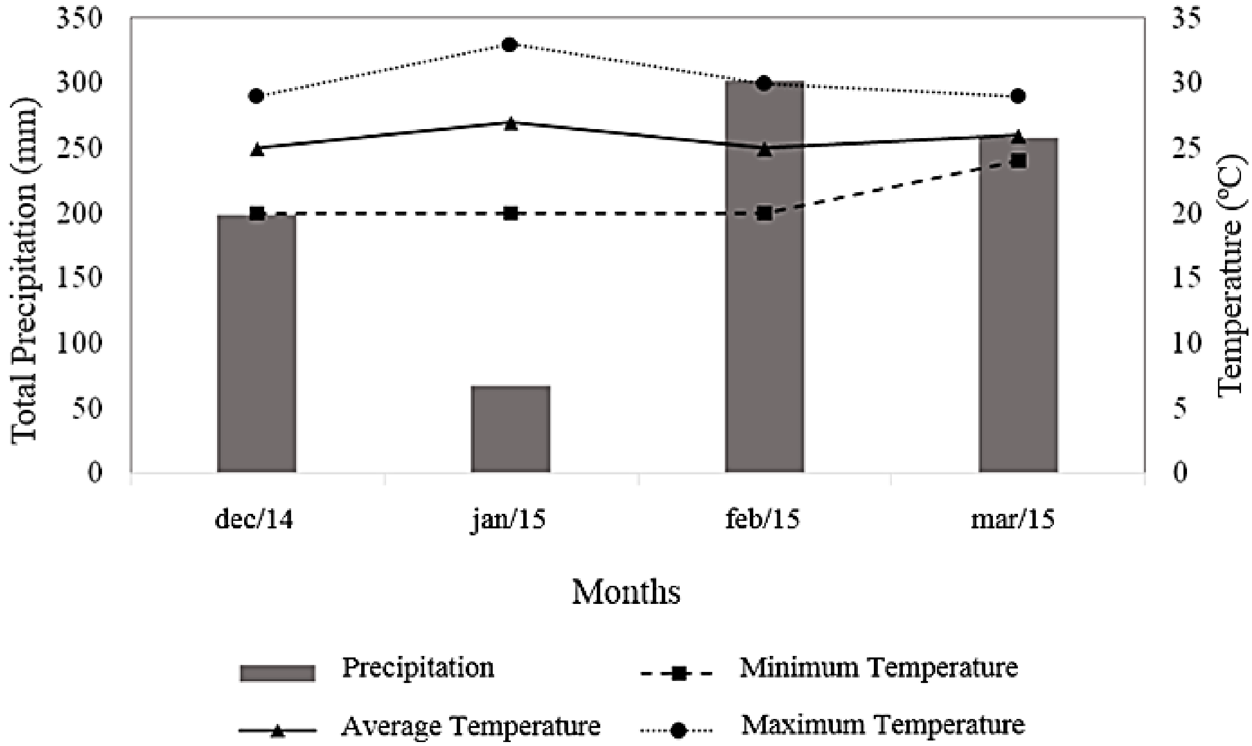

Figure 1. Pluviometric data of the meteorological station of Ipameri-GO, 2014/15, relating to the precipitation and temperature of the air during the months of development of the crop of sweet maize.

Table 1. The chemical characteristics of the soil, in a depth of 00 to 05 cm and 05 to 20 cm, sampled before the installation of the experiment.

Depth	pH	O.M.	P-Mehlich1	Macronutrients (cmol dm^{-3})							Micronutrients (mg dm^{-3})					V (%)
(cm)	$CaCl_2$	(g dm^{-3})	(mg dm^{-3})	K	Ca	Mg	Al	H+Al	SB	CTC	B	Fe	Mn	Zn	Cu	
00 to 05	5.2	3.5	12.6	0.1	1.8	0.6	0.0	2.8	1.7	5.29	0.61	24	3.4	3.0	0.5	47
05 to 20	4.8	2.9	5.6	0.1	1.2	0.4	0.1	3.8	1.7	5.53	0.34	43	2.3	1.4	0.5	31

O.M. = Organic matter; V% = saturation of bases; SB = sum of bases.

RESULTS AND DISCUSSION

The modes and phenological stages tested with nitrogen fertilization in green maize differed statistically (P<0.05), for all the variables, except for the row number per ear (relation), which shows the variability in the treatments in the study. According to the classification proposed by Scarpin et al. (1995), it may be inferred that the experiment had experimental accuracy within the normality standards, with coefficients of variation oscillating between 3.19%, for the husked ear diameter (DED) and 19.46% for N accumulated in the area (NPA) of sweet corn in stage V_{12} (Tables 2, 3 and 4).

The maximum height of insertion of the first ear (IFE) was observed in treatment with 50% N with total area in the stages V_4 to V_6, with an average of 1.20 m, differing statistically from the control and treatment with 100% N after planting, presenting a mean of 1.05 and 1.07 m, respectively (Table 2). The IFE is an important characteristic, because plants with higher values present advantages during harvest. The mode and phenological stage also influenced the height of insertion of the first ear in the work of Silva et al. (2005a), and the highest values were obtained in the treatments in which N was applied 15 days after emergence (DAE), the whole N at sowing and standard system of experimental farm. These results differ from those obtained by Neumann et al. (2005), who found no significant responses on plant height with regards to N fertilization in the maize for silage.

The length of husked cob (HEL) showed significant difference, and all the treatments were higher than the

Table 2. Average values of insertion of the first ear (IFE), husked ear length (HEL), unhusked ear length (CED), husked ear diameter (DED), husked ear productivity (PEE) and productivity of unhusked ear (PED).

Mode and season of application of N in coverage	IFE (m)	HEL (cm)	CED (cm)	DED (cm)	PEE (Mg ha^{-1})	PED (Mg ha^{-1})
Witness	1.05^{b}	18.9c	16.6c	4.1^{b}	22.9^{b}	12.3^{b}
100% N to launch after planting	1.07^{b}	20.2^{b}c	17.7^{b}c	4.4^{a}	28.3^{ab}	17.3^{ab}
100% N to launch total area V_4	1.11^{ab}	22.3^{ab}	19.6^{ab}	4.5^{a}	27.3^{ab}	17.4^{a}
50% N to launch total area V_4 and V_6	1.20^{a}	22.2^{ab}	19.4^{ab}	4.6^{a}	30.3^{a}	17.2^{ab}
100% N to launch total area V_6	1.11^{ab}	21.7^{ab}	19.1^{ab}	4.5^{a}	28.6^{a}	17.4^{a}
100% N continuous thread V_4	1.15^{ab}	22.8^{a}	19.9^{a}	4.6^{a}	32.7^{a}	19.5^{a}
100% N continuous thread V_6	1.14^{ab}	21.7^{ab}	19.1^{ab}	4.6^{a}	29.6^{a}	17.7^{a}
50% N continuous thread V_4 and V_6	1.12^{ab}	22.4^{ab}	19.6^{ab}	4.6^{a}	29.6^{a}	17.9^{a}
CV (%)	4.38	5.12	5.04	3.19	8.25	12.26

Averages followed by the same letter in the column do not differ by Tukey test (P<0.05).

Table 3. Average values of number of rows per ear (relation, NFE), number of grains per row (NGF) and grain yield (PG) evaluated in the culture of sweet corn.

Mode and season of application of N in coverage	NFE	NGF	PG (Mg ha^{-1})
Witness	16.18^{a}	28.87^{b}	5.48^{b}
100% N to launch after planting	16.87^{a}	36.72^{a}	8.73^{ab}
100% N to launch total area V_4	17.18^{a}	37.17^{a}	9.25^{a}
50% N to launch total area V_4 and V_6	17.12^{a}	36.86^{a}	8.94^{ab}
100% N to launch total areaV_6	16.50^{a}	36.39^{a}	9.20^{a}
100% N continuous thread V_4	16.62^{a}	38.14^{a}	10.57^{a}
100% N continuous thread V_6	16.81^{a}	36.15^{a}	9.38^{a}
50% N continuous thread V_4 and V_6	16.25^{a}	36.59^{a}	9.72^{a}
CV (%)	6.87	5.08	17.15

Averages followed by the same letter in the column do not differ by Tukey test (P<0.05) significant at 5% level of significance.

control, except the treatment with 100% N at the launching after planting. This is a very important characteristic in selling of green maize, when it is to be used for free fairs and greengrocery. However, the highest average HEL was with application of 100% nitrogen (N) in continuous thread in stage V_4, with 22.85 cm (Table 2). Similar results were obtained by Cardoso et al. (2011), when the performance of sweet maize cultivars in the municipality of Teresina, Piauí was evaluated, classifying unhusked green ears with lengths of 26.4 cm, as appropriate for marketing *in natura*.

The phenological stages and modes of application of nitrogen (N), influenced the unhusked ear length (CED), and the diameter of the husked ear (DED), presenting averages of 18.87 cm and 4.5 cm, respectively (Table 2). Almost all the treatments presented values of CED of preference by industry which is for ears that have length of about 20 cm. Only the control presented lower mean, with 16.62 cm, not differing statistically from treatment with 100% N, applied to launching after planting. For DED, there was no statistical difference between the control and all other treatments; however, all of them presented values higher than 4 cm, while the minimum value for trade is 3 cm. Significant results were also found by Oktem et al. (2010), when the authors evaluated the effects of different doses of N from 0 to 360 kg ha^{-1} applied at sowing and stage V_6, showing higher values of CED and DED, with 21.8 and 5.15 cm, respectively.

The productivity of husked cob (PEE) showed significant difference and five treatments were higher than the control (Table 2). The treatment with 100% N in continuous thread, in stage V_4, was higher with greater PEE, 32.7 Mg ha^{-1}, which is 30% greater than the control. These yields were higher than those of Freire et al. (2010), with the supply of urea, obtaining maximum productivity of 14.8 Mg ha^{-1} of green ears with straw. PEE is an important parameter considered in the marketing of green corn, due to the greater conservation of grain by husk protection.

Another important characteristic, directly related with

Table 4. Cumulative quantity of N in the aerial part at the stage V_{12} (NPA), in the aerial part without the grains in stage R_3 (NPASG), on grain (NG) and in the aerial part total (NPAT) of plants of sweet maize, depending on the mode and season of application of N in coverage.

Mode and season of application of N in coverage	N accumulated			
	NPA (V_{12}) ($kg\ ha^{-1}$)	NPASG (R_3) ($kg\ ha^{-1}$)	NG (R_3) ($kg\ ha^{-1}$)	NPAT (R_3) ($kg\ ha^{-1}$)
Witness	74.27^{b}	136.45^{b}	35.54^{b}	171.99^{b}
100% N to launch after planting	133.49^{a}	266.38^{a}	68.53^{a}	334.91^{a}
100% N to launch total area V_4	124.59^{ab}	258.48^{a}	66.65^{a}	325.13^{a}
50% N to launch total area V_4 and V_6	143.66^{a}	245.74^{a}	64.15^{a}	309.89^{a}
100% N to launch total area V_6	115.82^{ab}	286.59^{a}	66.27^{a}	352.86^{a}
100% N continuous thread V_4	129.75^{a}	254.32^{a}	79.77^{a}	334.09^{a}
100% N continuous thread V_6	120.37^{ab}	301.89^{a}	68.81^{a}	370.70^{a}
50% N continuous thread V_4 and V_6	118.59^{ab}	274.62^{a}	70.62^{a}	345.24^{a}
CV (%)	19.46	17.85	18.46	16.02

Averages followed by the same letter in the column do not differ by Tukey test ($P<0.05$).

the quality of the ear, is the productivity of unhusked ear (PED), considered as a commercial factor crucial both for the fresh market and for industry. For these characteristics, five treatments were higher than the witness, not differing statistically from the other two treatments with nitrogen fertilization. The treatment with 100% N in continuous thread, in stage V_4, stood out with greater PED, 19.47 $Mg\ ha^{-1}$, which is 37% greater than the control (Table 2).

The number of rows of grains per ear (relation, NFE) showed no statistical difference between the treatments, with lower mean of 17.18 rows (Table 3). Now, for the number of grains per row (NGF) and grain yield (PG), all the treatments were higher than the control; however, for PG treatment with 100% N applied after planting, and with 50% N applied in total area in the stages V_4 and V_6, significantly differ from the witness (Table 3). Souza et al. (2013) found similar results, when studying the yield components of sweet maize in different population densities, and the NFE also had no statistical differences; however, for the NGF, there was no statistical differences differentiating the results found in this work.

The three treatments that stood out for grain yield were the same as those that stood out in the productivity of unhusked corn ears, with 100% N applied in continuous thread in phase V_4, 50% N applied in continuous thread in stages V_4 and V_6 and 100% N applied in continuous thread in phase V_6, showing PG of 10.57, 9.72 and 9.38 $Mg\ ha^{-1}$, PED 19.5, 17.9 and 17.7 $Mg\ ha^{-1}$, respectively.

When the N was divided and applied in continuous thread, this provided greater productivity as compared to application in total area, probably, in function of minor losses by leaching due to fragmentation, less volatilization by less contact with the ground and, consequently, with the enzyme urease, as well as greater efficiency of absorption, when applied next to plants.

For the variable accumulation of N in the area of green maize in the stage V_{12}, it is observed in Table 4 that there was significant difference and three treatments were higher than the control. The treatments with: 50% N launching in stages V_4 and V_6; 100% N launching after planting; and 100% N in continuous thread in the stage V_4, highlighted and exhibited greater averages of N accumulated with 143.66, 133.49 and 129.75 $kg\ ha^{-1}$, respectively. In this way, the period of application of N soon after the planting and the V 4 stage V_4 promoted the highest absorption and accumulation of N in the stage V_{12}, probably, in function of this nutrient which is available to the plants for a longer period of time.

The accumulation of N in the stage R_3 for the various parts of plants of sweet maize (vegetative parts, grains and total plant) were significant and all treatments differed statistically from witness, as shown in Table 4. The largest mean values of N, accumulated in the aerial part without the grain and in the total aerial, were observed in the treatments with: 100% N in continuous thread and 100% N in total area in the stage V_6, with an average of 1.89 and 286.59 $kg\ ha^{-1}$, for N accumulated in the aerial part without the grain, and 370.70 and 352.86 $kg\ ha^{-1}$, for the aerial part total, respectively. The application of N in the V stage$_6$ was crucial and provided the largest accumulation of N in stage R_3, both for the air without grains as compared to the aerial part total, in culture of sweet maize.

The results of this study do not correspond with the results obtained by Borin et al. (2010), when absorption and accumulation of N was assessed in the culture of sweet-maize grown in field conditions, in which total extraction of N by aerial part was of 123,05 $kg\ ha^{-1}$.

The treatments with: 100% N in continuous thread in the stage V_4; 50% nitrogen (N) in continuous thread in stageV_4 and V_6; and 100% N in continuous thread in stage $V_{6,}$ showed the highest average values of N accumulated in the grain with 79.77, 68.81 and 70.62 kg ha^{-1}, respectively. When the N was divided and applied in continuous thread, this provided greater accumulations of N in grains in relation to application in total area.

Conclusions

The mode (in-line application, in total area) and season (after planting, V_4 and V_6 stage) of application influenced the quality of ears and the productivity of corn maize. The application of nitrogen (N) in continuous thread offered the highest averages for the characteristics evaluated.

The season of application of nitrogen (N) influences the absorption and the accumulation of nitrogen (N) in the aerial part of green maize. The mode of application in continuous thread allows greater accumulation of nitrogen (N) in grains as compared to application in total area.

Conflict of interest

The authors have not declared any conflict of interest.

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