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Planting fertilization and nitrogen doses in topdressing in second-crop corn

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ABSTRACT

The present study aimed to evaluate the influence of fertilization formulated at planting and doses of nitrogen in topdressing on the yield components of second-crop corn. The experiment was conducted between March and June 2018 on the farm of the State University of Goiás, University Unit of Ipameri-GO. The randomized block design, arranged in a 3 x 5 factorial scheme with four replications, was used. Three fertilizer formulations at planting (06-22-12; 08-20-15 and 06-22-12 + 2% organic carbon) and five doses of N (0, 50, 100, 150 and 200 kg ha^{-1}) in topdressing were evaluated. Leaf nitrogen content, fresh and dry mass of leaves, plant height, stem diameter, first ear insertion height, length and diameter of ears, 1000-grain weight, the mass of plants per hectare, extraction of nitrogen, and grain yield were assessed. Given the results, NPK formulated fertilizers can be used indifferently to grow second-crop corn. Nitrogen doses in topdressing have satisfactory results up to the estimated rate of 135 kg ha^{-1} for the cultivation of second-crop corn.

Keywords: *Zea mays* L., Nitrogen fertilization, Fertilizer of planting.

Adubação de plantio e doses de nitrogênio em cobertura no milho safrinha

RESUMO

O presente trabalho teve como objetivo avaliar a influência da adubação com formulados na semeadura e doses de nitrogênio em cobertura sobre as características produtivas do milho cultivado na safrinha. O experimento foi conduzido entre os meses de março a junho de 2018, na fazenda da Universidade Estadual de Goiás, Unidade Universitária de Ipameri-GO. O delineamento experimental utilizado foi o de blocos casualizados no esquema fatorial 3 x 5 sendo três formulações de adubos na semeadura (06-22-12; 08-20-15 e 06-22-12 + 2% de carbono orgânico) e cinco doses de N (0, 50, 100, 150 e 200 kg ha^{-1}) em cobertura, com quatro repetições. Determinou-se o teor de nitrogênio foliar, massa fresca e seca de folhas, altura de plantas, diâmetro do colmo, altura de inserção da primeira espiga, comprimento e diâmetro de espigas, massa de mil grãos, massa de plantas por hectare, extração de nitrogênio e produtividade. Diante dos resultados pode-se utilizar indiferentemente os fertilizantes formulados NPK na produção do milho safrinha. As doses de nitrogênio em cobertura apresentam resultados satisfatórios até a dose estimada de 135 kg ha^{-1} de nitrogênio para o cultivo de milho safrinha.

Palavras-chave: *Zea mays* L., Adubação nitrogenada, Adubo de plantio.

1. Introduction

Belonging to the Poaceae family, corn (*Zea Mays* L.) is a cereal of great nutritional value and socioeconomic importance since, in addition to being used in human and animal food, it is used as raw material for the industrial sector (Galvão et al., 2014). The second-crop corn cropping system, also known as off-season corn, is highly relevant in the national scenario, as it stands out in terms of use and the characterization of its peculiar production; its cultivation is in the rainfed system with the planting occurring between January and April (Cruz et al., 2010). Conab (2019), the cultivation of second-crop corn has taken on the leading role as the main corn season in the country, representing about 70% of the total corn production.

The fertilization of the corn crop must be based on the productive potential of the crop for the sowing season to replace the nutrients that will be exported by the grains (Duarte et al., 2011). Thus, fertilization with NPK-formulated fertilizers in crops such as second-crop corn in different producing regions is quite variable, being used fertilizers that contain nitrogen (N), phosphorus (P), and potassium (K). The climate of tropical regions, such as the Cerrado, favors the rapid decomposition of crop residues in the soil, but because they are poor in nutrients, it requires the use of appropriate management practices (Leal et al., 2013). One of the main factors responsible for the low yield of areas destined for corn production is soil fertility (Rodrigues et al., 2014).

Mostly, soils have a low content of available nitrogen (N), and inorganic fertilizers are the main source of nutrient addition to the soil. It is considered essential for developing and increasing crop yield as it constitutes fundamental components of the plant cell and participates in biochemical reactions (Dartora et al., 2013). However, despite being the nutrient absorbed and extracted in greater quantity by the maize crop, it is still difficult to define the most appropriate and economical dose, especially when high yields are sought (Caires and Milla, 2016).

Potassium (K) acts in the processes of photosynthesis and respiration due to the activation of several enzymes; it also participates in the transport of carbohydrates and, especially in stomatal conductance, providing greater tolerance of corn plants to the loss of soil moisture during the second crop (Parente et al., 2016; Simão et al., 2018). The nutrient phosphorus (P) becomes less available in the rhizosphere due to its occurrence in organic forms, slow diffusion rate in the solution, and its contact with some soil constituents, such as aluminum (Al), iron (Fe), and calcium (Ca). Organic matter in highly weathered soils reduces P adsorption, even in small proportions, and can increase the agronomic efficiency of phosphate fertilizers, thus enabling greater P uptake by crops (Almeida et al., 2016).

The time of application of complementary nitrogen can be carried out in installments, both at the time of sowing and in topdressing when the plants have 3 to 7 leaves (Coelho, 2006; Pöttker and Wiethölter, 2004). Results of studies carried out under different climatic conditions, cropping systems, and soil conditions have shown that, in general, the corn crop is responsive to nitrogen fertilization (Carmo et al., 2012; Santos et al., 2013). Given the above and little availability of studies on the use of formulas at sowing, the present work aimed to evaluate the influence of fertilization with formulas at sowing and doses of nitrogen in topdressing on the yield components of second-crop corn.

2. Material and Methods

The second-crop corn experiment was carried out between March and June 2018 in a field where soybeans (*Glycine max* L.) were previously grown at the State University of Goiás, Ipameri University Unit, Campus Sul, in Ipameri-GO at 17º 43' S, 48º 22' W, and altitude of 800 m. The climate, according to the Köppen-Geiger classification (Cardoso et al., 2014), is defined as a tropical climate (Aw-type) with a dry season in winter. Temperature and rainfall data collected are in Figure 1.

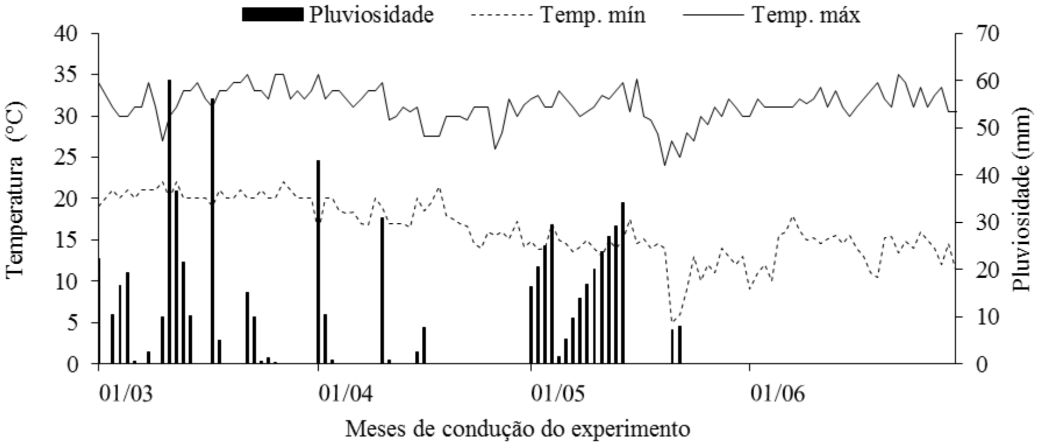

Figure 1. Maximum and minimum air temperature (°C) and rainfall (mm) accumulated between March and June 2018. Ipameri-GO, 2018.

The soil of the experimental area is classified as Latossolo Vermelho-Amarelo distrófico with a sandy texture (Embrapa, 2018). The chemical and physical attributes of the soil were evaluated before the experiment set up, according to the methodology proposed by Ribeiro et al. (1999) and presented the following results, in the 0-20 cm layer, 9.3 mg dm^{-3} of P (Melich-1); 17.1 g dm^{-3} of O.M.; pH 6.20 ($CaCl_2$); 0.26, 2.40, 0.90, and 1.70 cmol$_c$ dm^{-3} of K, Ca, Mg, and H+Al, respectively, 67.7% of base saturation, sand 510 g kg^{-1}, silt 210 g kg^{-1}, and clay 280 g kg^{-1}.

The randomized block design, arranged in a 3 x 5 factorial scheme with four replications, was used. Three fertilizers with different NPK formulations at sowing (06-22-12; 06-22-12; 08-20-15 + 2% of organic carbon + 0.70% humic acid + 0.41 fulvic acid) and five N doses (0, 50, 100, 150, and 200 kg ha^{-1}) applied in topdressing were evaluated. At sowing, 300 kg ha^{-1} of each nutrient, N, P, and K, were used. The N source used was urea with 45% N. The corn used was the 30A37PW hybrid available from Morgan®.

The sowing of the second-crop corn was carried out mechanically through direct sowing on soybean straw. The experimental plots consisted of six rows with a row spacing of 0.50 m and eight meters in length. The four central rows were considered valuable areas, excluding one meter of the border at each end. The population of plants per hectare used was 55,000, and the planting was carried out at the beginning of March due to the climatic conditions of the region. Topdressing fertilization (application of doses) was performed manually when the plants had six developed leaves (V6 phenological stage), applied along the entire row length at sowing. Crop practices were carried out according to the recommendation for corn (Borém et al., 2017).

Leaf nitrogen content was evaluated. Ten leaves were collected per plot, completely expanded (first leaf below the first ear), when the plants were at the R1 stage (silking). First, the leaves were weighed to determine the fresh mass. Soon after, the leaves were dried in an oven with forced air circulation at a temperature of 65°C for 72 hours to determine the dry mass. Afterward, the material was ground in a Wiley mill-type equipped with a mesh sieve with a 1 mm opening and placed in paper bags for later determination of leaf N levels, following the methods described by Malavolta et al. (1997).

The biometric and yield components were also determined in ten plants per plot. Plant height was measured using a tape measure in centimeters; the plant was measured from the distance from the ground to the apex of the tassel. Stem diameter was obtained with the aid of a digital caliper in millimeters. First ear insertion height was measured with a tape measure in centimeters; the plant was measured from the distance from the ground to the insertion point of the first ear. Ear length was determined using a millimeter ruler; the distance between the base and the apex of the ear was measured. Ear diameter was measured with the aid of a digital caliper in millimeters. 1000-grain weight was determined. Plant mass per hectare was evaluated after harvesting the ear; with a digital scale, five plants from each plot were weighed, and the values were extrapolated to hectare (kg ha^{-1}). Grain yield was determined with a digital scale; the values of grain mass from the evaluated area were extrapolated to hectare (kg ha^{-1}) and standardized to 13% moisture.

At the end of the harvest, the extraction of the nutrient nitrogen by the corn plants was determined, being obtained through the multiplication of the mass of plants per hectare by the nitrogen content, thus obtaining the value of nitrogen extracted by the second-crop corn (kg ha^{-1}). The data were submitted to the analysis of variance (F test). The means from three NPK formulations were compared by the Tukey test at a 5% probability. For the nitrogen doses, when significant, regression analysis was performed. Statistical analyzes were processed using the Sisvar statistical analysis program (Ferreira, 2011).

3. Results and Discussion

As shown in Figure 1, it is possible to observe the maximum, minimum temperature, and rainfall values during this experiment. The average temperature throughout the experiment was 24 °C. This temperature remained within the standards favorable to the development of corn, ranging from 24 to 30 °C (Galon et al., 2010). It was also possible to observe that rainfall distribution occurred irregularly in March, April, and May. In June, however, there was no precipitation on the corn crop.

No significant effects were observed for the interaction between NPK formulations and nitrogen doses in topdressing on the analyzed characteristics of the second-crop corn (Tables 1 and 2). The average values for leaf nitrogen content, fresh and dry mass of leaves, plant height, stem diameter, and first ear insertion height are shown in Table 1. It was possible to observe a significant effect of NPK formulations only on leaf nitrogen content, dry mass of leaves, and stem diameter.

For the foliar nitrogen content and dry mass of leaves, it was possible to observe that the NPK formulations, 06-22-12 and 06-22-12 + 2% of organic carbon, did not present a difference between them, being both superior to the 08-20-15. For the stem diameter, it was possible to observe that the 06-22-12 + 2% organic carbon had the highest averages, and the formulated 06-22-12 had the lowest values.

Table 1. Nitrogen content (TNF), fresh mass of leaves (FM), dry mass of leaves (DM), plant height (PHT), stem diameter (SD), and first ear insertion height (FEI) of second-crop corn according to different sowing fertilizers and nitrogen doses in topdressing. Ipameri-GO, 2018.

Fertilizers	TNF	FM	DM	PHT	SD	FEI
	g kg^{-1}	-----g-----		cm	mm	cm
06-22-12 + 2% C.O	33.88 a	75.20 a	32.90 a	227.57 a	20.48 a	99.52 a
06-22-12	33.53 a	70.50 a	30.90 a	226.17 a	18.89 b	99.49 a
08-20-15	29.82 b	72.00 a	26.90 b	223.90 a	19.83 ab	99.55 a
F value	28.25	1.79	22.65	0.63	4.08	0.59
Doses of N (kg ha^{-1})						
0	-(a)	67.83	28.50	-(a)	-(a)	-(a)
50	-	74.83	30.50	-	-	-
100	-	71.83	30.33	-	-	-
150	-	74.00	31.33	-	-	-
200	-	74.33	30.50	-	-	-
F value	8.01	1.55	1.59	1.99	5.22	2.41
CV (%)	5.84	11.05	9.50	4.59	8.94	9.56

Means followed by the same lowercase letter in the column for each factor studied do not differ from each other by the Tukey test at 5% probability. (a)= Significant regression for the dose effect.

Table 2. Ear length (EL), ear diameter (ED), 1000-grain weight (M1000), mass of plants per hectare (MPPH), nitrogen extraction by plants (EXTRN), and grain yield (PROD) of second-crop corn according to different NPK formulations and nitrogen doses in topdressing. Ipameri-GO, 2018.

Fertilizers	EL	ED	M1000	MPPH	EXTRN	PROD
	cm	mm	g	-------------kg ha^{-1}-------------		
06-22-18 + 2% C.O	14.15 a	43.64 a	238.26 a	4187.70 a	125.77 a	3551.01 a
06-22-18	14.59 a	43.89 a	239.38 a	3953.40 a	133.98 a	3368.11 a
08-20-15	14.92 a	48.03 a	234.01 a	3993.0 0a	133.82 a	3507.49 a
F value	2.47	1.32	0.26	0.65	0.76	0.48
Doses of N (kg ha^{-1})						
0	14.05	43.26	230.29	-(a)	-(a)	-(a)
50	14.36	50.22	237.02	-	-	-
100	14.70	44.19	240.33	-	-	-
150	14.88	44.44	241.05	-	-	-
200	14.76	43.82	237.39	-	-	-
F value	1.15	1.05	0.36	2.57	4.81	2.84
CV (%)	7.55	21.24	10.37	17.08	18.26	17.62

Means followed by the same lowercase letter in the column for each factor studied do not differ from each other by the Tukey test at 5% probability. (a)= Significant regression for the dose effect.

According to Zandonadi et al. (2014), organic matter is made up of carbon compounds and is considered to regulate various nutrients, especially micronutrients. In addition, it provides several benefits to soils, such as better aggregation and water retention, greater CEC, and the addition of beneficial microorganisms, which are present in organic matter. Thus, adding nutrients and organic carbon to the soil can result in greater availability of nutrients for plants, which can increase the production of dry matter, shoots, and roots of plants (Lourenzi et al., 2016). When evaluating the nitrogen doses in topdressing, it was possible to observe a significant effect on leaf nitrogen content, plant height, stem diameter, and first ear insertion height. For all these variables, the data presented a quadratic adjustment (Figure 2).

For the leaf nitrogen content (Figure 2A), it was possible to observe a content of 34.15 g kg^{-1} of dry matter for the estimated dose of 142.25 kg ha^{-1} of nitrogen. This result demonstrates that the plants were nourished, as the value of leaf nitrogen content observed is within the range of sufficiency recommended for corn, which is 27 to 35 g kg^{-1} of dry matter (Malavolta, 2006). Lana et al. (2017), when evaluating the same nitrogen doses in corn production, did not observe a significant difference between the doses used, but all their results for foliar nitrogen content were within the recommended sufficiency range.

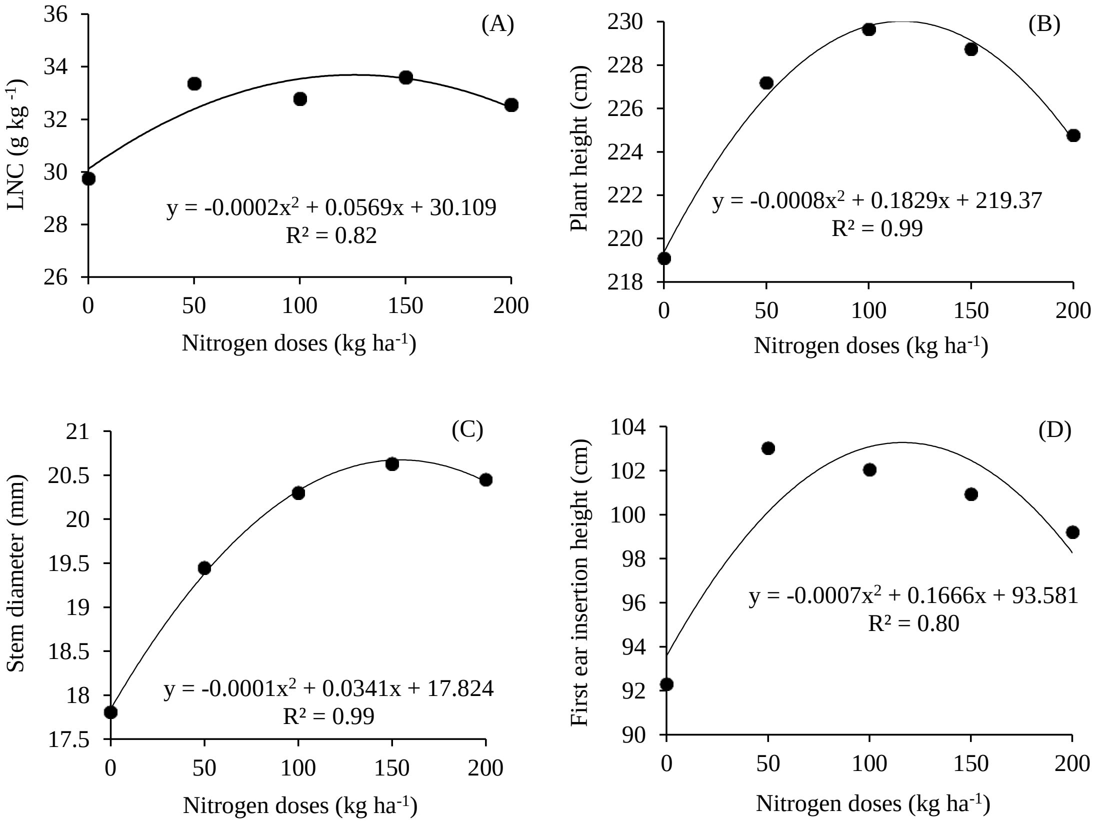

Figure 2. Leaf nitrogen content - LNC (A), plant height (B), stem diameter (C), and first ear insertion height (D) of second-crop corn according to the nitrogen doses in topdressing. Ipameri - GO, 2018.

The highest observed plant height was 229.82 cm for the estimated N dose of 114.31 kg ha^{-1} in topdressing (Figure 2B). As for the stem diameter, 20.71 mm in diameter was estimated at an N dose of 183.5 kg ha^{-1} (Figure 2C). These results corroborate with Besen et al. (2018), who, when evaluating mineral sources of nitrogen in the corn-wheat succession in a no-tillage system, observed an increase in corn plants. Variables such as plant height and stem diameter may be correlated with corn yield, as plants with larger stem diameters and heights can store a greater amount of photoassimilates, which will contribute to grain filling (Kappes et al., 2014).

When the height of insertion of the first ear was evaluated, it was possible to observe a height of 103.49 cm for the estimated dose of 119 kg ha^{-1} of nitrogen (Figure 2D). Zoz et al. (2019) did not observe significant results for the first ear insertion height in second-crop corn, but they applied nitrogen at corn sowing. Mar et al. (2003), when evaluating nitrogen doses in second-crop corn, found results similar to those observed in this work, with the highest first ear insertion height (99.54 cm) obtained with the estimated dose of 116.16 kg ha^{-1} of nitrogen. According to Li et al. (2007), first ear insertion height may be related to plant damping-off, as the higher the ear height, the greater the susceptibility to damping-off.

An essential element for corn, nitrogen, plays a role in the metabolism of corn plants, in addition to being a component of proteins and the chlorophyll molecule, which directly influences plant growth and, consequently, increases crop yield (Portugal et al., 2017). The length and diameter of ears, 1000-grain weight, the mass of plants per hectare, nitrogen extraction by plants, and grain yield of second-crop corn plants are shown in table 2. When evaluating the different NPK formulations, it was impossible to observe a significant effect.

When evaluating the nitrogen doses, it was possible to observe a significant effect of the data for plant mass per hectare, nitrogen extraction, and grain yield. No significant effect was observed for the length and diameter of ears beyond the 1000-grain weight. For plant mass per hectare, it was possible to observe data adjustment to positive linear regression, ranging from 3602 to 4279 kg ha^{-1} from the lowest to the highest dose used. (Figures 3A). Bortolini et al. (2002), when evaluating nitrogen application systems and their effects on N accumulation in the corn plant, observed significant results for plant mass production per hectare when using 150 kg ha^{-1} of nitrogen in topdressing; however, they used a population of plants superior to the one used in this work. Heinrichs et al. (2003) did not find a significant difference in total plant mass when evaluating nitrogen doses in topdressing in the corn crop.

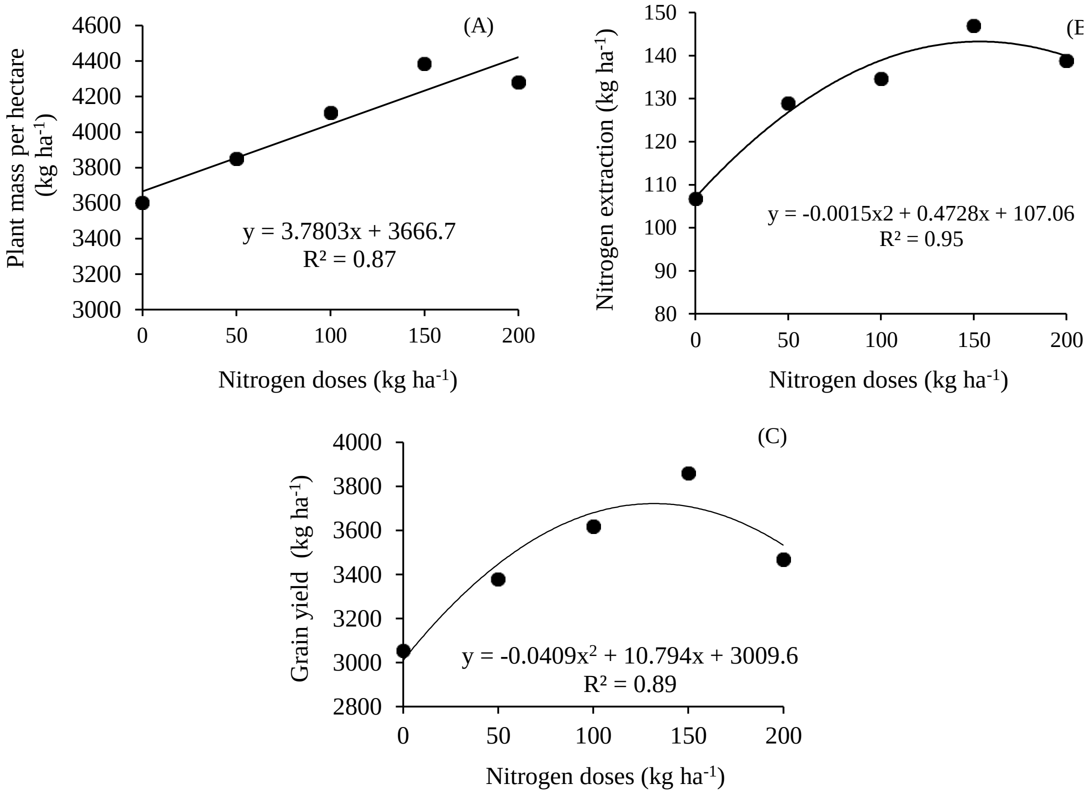

Figure 3. Plant mass per hectare (A), nitrogen extraction (B), and grain yield (C) of second-crop corn according to the nitrogen doses in topdressing. Ipameri-GO, 2018.

The works of Bortolini et al. (2002) and Heinrichs et al. (2003) presented superior results (9746 and 9597 kg ha^{-1}, respectively) than those observed in this work. This difference can be explained by the moment in which the material was collected since, in the two cited works, the collection of plants was carried out at the phenological stage R1 (silking), and in this work, the collection of the plants was carried out at harvest. When evaluating the nitrogen extraction by the corn plants, it was possible to observe the maximum extraction of 144.31 kg ha^{-1} for the estimated dose of 157.60 kg ha^{-1} of nitrogen (Figure 3B).

Menezes et al. (2018) observed superior results when evaluating nitrogen, phosphorus, and potassium extraction by corn grown with and without swine manure; they observed extraction of 162.08 kg ha^{-1} of nitrogen in the treatment without fertilization. Simão et al. (2017) state that corn sown late in the second crop, beginning of March, as occurred in this experiment (Figure 1), may suffer greater water limitation, which implies lower nutrient absorption by the crop and consequently reduces the extraction rates of corn nutrients.

As for yield, it was possible to observe data adjustment to quadratic regression, with the highest yield found being 3721.77 kg ha^{-1} for the estimated nitrogen dose of 131.95 kg ha^{-1} (Figure 3C). This result was above the national average for the time this experiment was harvested, which is 3500 kg ha^{-1} (Conab, 2019), a fact that shows that the N availability in the soil significantly influences the corn grain yield (Torres et al., 2014). Furthermore, this result was superior to Gazola et al. (2014). They evaluated nitrogen doses in topdressing in second-crop corn and observed a yield of 3107 kg ha-1 for an estimated nitrogen dose of 149.5 kg ha-1. According to Basi et al. (2011), nitrogen is considered a determining element for plant growth, development, and yield, as it influences essential physiological processes.

4. Conclusions

Given the results, NPK formulated fertilizers can be used indifferently in producing second-crop corn. Nitrogen doses in topdressing fertilization present satisfactory results up to the estimated dose of 135 kg ha^{-1} for second-crop corn cultivation.

Authors' Contribution

Luciana Maria da Silva, Rogério Lamim Silva Junior and Cecília Leão Pereira Resende contributed to the installation of the experiments, evaluations, data collection, tabulation and writing of the manuscript. Rafael Marangoni Montes contributed with the products used and correction of the manuscript. Katiane Santiago Silva Benett and Cleiton Gredson Sabin Benett helped to set up the experiment, review the data, write the manuscript, analyze the data, prepare the graphics and guided the first three authors.

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