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Application of nitrogen in different phenological states of the corn crop

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Corn is a crop of high productive potential, but to achieve this, it is essential to apply production technologies, especially fertilizers with a high level of nitrogen. The objective of this work was to evaluate the influence of nitrogen fertilizer in different phenological stages on corn production. The experiment was installed in the experimental plot of the Facultad de Ciencias Agrarias, Universidad Nacional de Concepción, Concepción Department, Paraguay. The experimental design was randomized blocks, with 5 treatments and 4 repetitions. The treatments consisted of the application of nitrogenous fertilizer in the phenological stages V0, V3, V5, V7 and V9. Number of leaves on and below the spike, number of seed lines per spike, plant height, spike height and yield were evaluated. The obtained data was subjected to the analysis of variance by Fisher's test at 5%, when significant differences was detected, it was proceeded to compare the means obtained by the effect of the treatments using the Tukey test at 5% of significance. The results indicate that the application of nitrogen in different phenological stages of corn cultivation influenced the height of the plant, height of insertion of the spike and yield; not so, for: number of leaves above and below the spike and number of seed lines per spike. It is concluded that the application of nitrogen in different phenological stages of corn, has influence on productive characteristics of the crop. It was recommended that it should be done in phenological stage V5, to achieve maximum efficiency.

Key words: *Zea mays* L., phenological stages, nitrogen, fertilization.

INTRODUCTION

Corn (*Zea mays* L.), is the cereal with the highest volume of production on the planet, with about 960 million tons; and of the 5 main world producers, 3 of them are in America: the United States, Argentina and Brazil (FAO, 2012).

It is a crop that requires adequate supply of nitrogen from the early stages of growth, as it is one of the most limiting nutrients for obtaining high productivity, and fertilization recommendations depend on various factors, such as plant support, extraction/export of nutrient by the crop,

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capacity of supply of nitrogen by the soil and index of use of nitrogen fertilizer by the plants (Sousa and Lobato, 2004).

The criteria to define the quantity of N to be supplied normally are based on the expectation of yield, the history of the area, soil type, organic matter content, N mineral content or potentially mineralized, previous crops and in the use or not of green fertilizers (Amado et al., 2002; Cantarella and Duarte, 2004).

The definition of time of application of N and the dose that coincide with the needs of corn in different environmental conditions and soil types are very important since these factors improve nutrients, absorption and decrease N losses (Androski et al., 2000).

The productive potential of corn cultivation is defined around the phenological stages V4 and V5, of four and five expanded leaves, respectively, due to the floral differentiation, in this period the plant originates the primordia of the banner and the spike, and differentiation of all leaves also occurs (Ritchie et al., 1993).

In state V3, the apex of the stem (point of growth) is still below the surface of the soil. In state V5, the apical meristem is still below the surface of the soil, which allows the plant to recover from the damage caused in the aerial part (Ritchie et al., 1993; Magalhães and Durães, 2006). In the V7 state, the adventitious roots are the main functional system, some tillers are visible. In the V9 state, the panicle develops rapidly and the stem continues a rapid elongation through the elongation of its internodes. Each internode will start the elongation before the one that is above it on the stem, similar to the initial development of the spike primordia (Magalhães and Durães, 2006).

The objective of this work was to evaluate the influence of nitrogenous fertilizer in different phenological stages.

MATERIALS AND METHODS

The experiment was installed in the experimental plot of the Faculty of Agricultural Sciences, National University of Concepción, Concepción Department, Paraguay, at the coordinates (230 40'13 "South, 570 41'85" West, elevated 160 m above sea level). The experiment was conducted between the months of March and July 2017.

The climate of the area is characterized by an average temperature of 26 and 14°C, depending on the season, with maximum that can reach 45°C in summer and minimum of up to 4°C in winter, with slight incidences of frost (DMH - DINAC, 2016).

According to the analysis performed, the soil of the experimental area, presents the following chemical and physical characteristics in the depth of 0 to 0.20 cm: pH (H_2O) 5.67; organic matter (Walkley Black): 1.67%; Ca + 2, Mg^{2+} and K^+: 5.06, 1.27 and 0.19 cmol/LS, respectively; P (Mehlich) and S: 28.94 and 11.73 mg/LS, respectively; Al + 3: 0.05; CIC: 9.71 cmol/LS; V: 67.21%. The soil texture is sandy loam (CETAPAR, 2017).

The experimental design used was randomized complete block with 5 treatments and 4 replications. The treatments consisted of five moments of application of nitrogen (N) in coverage (phenological stages V0, V3, V5, V7 and V9). The phenological stages V0, V3, V5, V7 and V9 correspond to the periods in which the plant presents 0, 3, 5, 7 and 9 fully expanded leaves, respectively (Magalhães and Durães, 2006).

The soil preparation was carried out prior to planting, with a light harrow. Subsequently, the experimental area was delimited, each unit had 14.4 m^2 (4 m × 3.6 m), and it composed of four 4 m long rows and the spacing of 0.90 m between rows and 0.4 between plants. The seed used was the hybrid DKB 7910 VT3 PRO (DEKALPAR, 2017).

The dose used was 77 kg ha^{-1} of N for all treatments, according to soil analysis, using urea as a source of the nutrient. The fertilizer application was made by incorporating it in a localized way at a distance of 0.10 m from the plant. The crop was kept free from weeds by an herbicide application. Glyphosate was used according to recommendations of the Technical Guide DEKALB (2012).

For data collection, the two central rows of each experimental unit were considered. The following variables were evaluated:

(1) Number of leaves above the spike and number of leaves below the spike: the corn leaves were counted at the end of the crop cycle, in 6 plants randomly chosen from the selected area; according to the methodology used by Ángeles et al. (2010).
(2) Number of seed lines per spike: 10 spikes of each experimental unit were selected and the lines of each spike counted; according to the methodology used by Gott et al. (2014).
(3) Height of plant: This was obtained with a metric belt, whose measurements were made in 6 plants randomly chosen from the selected area; according to the proposal of Mar et al. (2003).
(4) Spike height: This was determined in the final cycle of the crop, measuring from the base of the plant until the insertion of the first spike, obtaining the value in cm according to Mar et al. (2003).
(5) Yield: This was obtained by means of weighing the harvested grains in the selected area, with humidity of 13.0% and the data were expressed in kg ha^{-1}; based on the methodology employed by Gott et al. (2014).

The obtained data were subjected to analysis of variance by the Fisher test at 5% of significance, when significant differences were detected, it was proceeded to compare the means obtained by the effect of the treatments using the Tukey test at 5% of significance.

For the statistical analysis, the AgroEstat System was used (Barbosa and Maldonado, 2015).

RESULTS AND DISCUSSION

Table 1 shows the average values of the analyzed variables whose data indicate that there were no statistical differences in any of the evaluated characteristics. The highest values of number of leaves above the spike occurred with the application of N in stage V3; for the variable of number of leaves underneath the spike was observed more leaves with the application of nitrogen fertilizer in the V5 phenological stage, with averages of 5.90. In the variable, number of seed lines per spike was obtained. The highest result with 15.85 grain lines per spike, with nitrogen fertilization in the V0 stage.

Gott et al. (2014), evaluating the sources and times of application of nitrogen in late summer - early fall corn production, observing that the number of seed lines per spike was not affected by the factors, reaching an average of 15.5 with similar results obtained in the present work with an average of 15.52. In contrast, Kappes et al. (2009), worked with corn in late summer - early fall production, in soybean succession, evaluated

Table 1. Means of the characteristics of number of leaves above the spike, number of leaves underneath the spike and number of seed lines per spike of the evaluated corn crop.

Phenological stage	Characteristics		
	Number of leaves above the spike$^{(ns)}$	**Number of leaves underneath the spike**$^{(ns)}$	**Number of seed lines per spike**$^{(ns)}$
V0	5,75	5,65	15,85
V3	5,85	5,70	15,05
V5	5,80	5,90	15,80
V7	5,55	5,35	15,50
V9	6	5,10	15,40
GM	5,79	5,54	15,52
CV	7,05	7,73	5,71
LSD	0,52	0,96	1,99

(ns): Not significantly by Fisher test at 5% of significance; GM: general mean; CV: coefficient of variation; LSD: least significant difference by Tukey test at 5% of significance.

Table 2. Means of the characteristics of plants height, spike insertion height and yield, of corn crop submitted to the application of nitrogen fertilizer in different phenological stages.

Phenological stage	Characteristics		
	Plant height (**)	**Spike insertion height** (**)	**Yield**(**)
	cm	**cm**	**kg ha^{-1}**
V0	153.10^{b}	65.5^{b}	5885.38^{c}
V3	160.10^{ab}	71.15^{b}	6557.48^{b}
V5	177.46^{a}	86.15^{a}	7359.26^{a}
V7	165.90^{ab}	73.75^{b}	6448.24^{bc}
V9	157.05^{b}	68.15^{b}	6097.44^{bc}
GM	162.72	72.94	6469.56
CV	5.28	5.92	3.89
LSD	19.38	9.73	568.24

(**)Significant by Fisher test at 5% of significance; GM: general mean; CV: coefficient of variation; LSD: least significant difference by Tukey test at 5% of significance.

the performance of the crop in the function of different times of nitrogen application when the plants have three, seven and ten fully expanded leaves and sources of nitrogen (urea, ammonium sulfate and Entec®) in cover, whose results influenced, in terms of time, on the number of seed lines per spike.

As shown in Table 2, there are differences in the function of nitrogen fertilizer in different phenological stages, both for the plant height, spike insertion height and yield of corn.

As shown in Table 2, based on the determinations evaluated in the V5 phenological stage, the best behavior was obtained in relation to the other phenological stages. In the plant height characteristic, the V3, V5 and V7 stages are statistically equal and superior to V0 and V9 stages; while V0 stage presented the lowest value.

Cazetta (2010), evaluating the influence of the times of application of N on the agronomic characteristics and efficiency of nutrient use in the corn crop, concludes that V4-V5 stages with 120 kg ha^{-1} of nitrogen application was the best for plant height, as well as spike insertion height.

Marschner (1995), reports that the application of ideal doses of N in the initial stages of development (2 to 4 leaves), in cereal crops, it increase the production of growth promoting phytohormones and responsible for the development by the processes of division and cellular expansion (gibberellins, auxins and cytokinins), increasing the size of the stem and consequently, the height of the plants.

The best performances were obtained in V3, V5 and V7 stages; these results differ from those found by Mar et al. (2003), who evaluating some components of corn crop production (AG 3010) as a function of doses of N (30, 60, 120 and 150 kg ha^{-1}) in Urea form and application times (1/3 at planting and the remaining 2/3 when the crop presented four, eight and ten fully expanded leaves, respectively). They demonstrated that the best period of application of N in coverage was in the state with four to eight fully expanded leaves with doses of 90 to 120 kg ha^{-1} of N for the variables of number of rows per spike and grain productivity.

According to Gott et al. (2014), evaluating the sources and times of application of nitrogen in late summer - early fall corn, obtained the best results in V10 phenological stage with 6,183.9 kg ha^{-1}; however, in this investigation it was found that 7359, 26 kg ha^{-1} in V5 stage. Ritchie et al. (2002), mention that the formation of the total number of grains per corn cob is defined during vegetative V6 and V12 stages. The nutritional level, particularly of N, that is present during this period is an important regulator of the total number of grains and consequently of the total accumulation of yield.

Sangoi et al. (2007), investigating corn response at the time of application of nitrogen fertilizer in two systems of cultivation in a soil with high content of organic matter, achieved an increase in corn yield with the treatment where it was applied in V5 stage, coinciding with the results obtained in this work.

CONCLUSIONS AND RECOMMENDATIONS

The application of nitrogen in different phenological stages of corn has influence on productive characteristics of the crop. It is recommended to do it in phenological stage V5, to achieve maximum efficiency. Work is currently being done on organic and mineral fertilization in the corn crop, which will be subject to review and evaluation in a short time.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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