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Production Components and Agricultural Productivity of Corn under Nitrogen Doses and Planting Times

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Authors' contributions

This work was performed in collaboration among all authors. Authors MASS, SS and IT designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ALDC, GNR, JLXLC, ABAM and AHM managed the study analyzes. Authors ACAM and JGF managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objective of this study was to evaluate the best time for planting and nitrogen dose during the dry season that provides better yield to corn crop in the Alagoas Coastal Tablelands region.
Study Design: The experimental design was in randomized blocks, in the split plot scheme with four repetitions.

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Place and Duration of Study: The experiment was developed at the Center of Agrarian Sciences of the Federal University of Alagoas in 2016.
Methodology: The plots consisted of 20 lines with seven meters in length and received the four sowing seasons (E1: 28/05/16, E2: 11/06/16, E3: 25/06/16, E4: 22/07/16). The subplots contained 5 lines of 7 meters each and received the nitrogen doses (0, 75, 150 and 225 kg ha^{-1}). The variables analyzed were: Number of grains per ear (NGE), grain mass per ear (GME) and agricultural yield obtained from the weighing of all grains harvested in the useful area of each plot.
Results: The variables agricultural productivity and number of grains per ear of corn adjusted to the quadratic regression model, while for the mass of 1,000 grains the linear was better. Grain mass per cob, number of grains per cob, weight of 1,000 grains and yield are influenced by nitrogen rates. The E1 season was the one that provided the highest grain mass per turn (235 g), number of grains per ear (675) and agricultural yield (9.6 t ha^{-1}). For the mass of 1,000 grains, season E2 obtained the highest result (263 g).
Conclusion: Maximum corn yield can be achieved by applying 209 kg ha^{-1} of N, which corresponds to a yield of 9.55 t ha^{-1} if planted until 06/11/16.

Keywords: 1,000 grain mass; water deficit; number of grains per ear; Zea may L.

1. INTRODUCTION

Corn (Zea mays L.) is one of the most relevant crops in the national and international market and is the most produced cereal in the world [1]. It is mainly used as a human and animal food source, consumed in the form of grains, inature, cornmeal, silage or processed into feed [2].

The [3] survey (2016) points out that the American continent produces 51% of the world total corn grain, followed by Asia, Europe, Africa and Oceania with respectively 29.6%, 12.1%, 7.2% and 0.1%. Brazil in the 2017/18 harvest produced 81.35 million tons, with average yield of 4.89 tons hectare. The states with the highest corn yields in the Northeast are: Bahia (2.29 million tons and 3.75 t ha^{-1}), Maranhão (1.88 million tons and 3.89 t ha^{-1}) and Piauí (1.48 million tonnes 3.04 t ha^{-1}). The State of Alagoas occupies eighth place, with annual production of 28.6 thousand tons and average yield of approximately 1.09 t ha^{-1} [4]. This low agricultural yield compared to the other NE states is due to improper management of fertilizers, especially nitrogen and poor distribution of rainfall during the growing season that even during the rainy season there are small summer [5,6].

Knowledge of the relationships between the submitted production variables and different soil fertility levels and planting times in specific climatic regions is essential to increase agronomic yields of agricultural crops. Among fertilizers, nitrogen (N) is the nutrient most extracted by corn crop and the one that costs the most production, but it has the greatest influence on grain yield and quality [5,7].

The most suitable sowing season is when the flowering period coincides with the longest days of the year and the grain filling stage with the period of higher temperatures and high solar radiation availability. This, considering the water needs met by the plant. Research work shows that the times when grain yields were highest and most stable were those at which the fully developed four-leaf developmental stages and flowering occurred under good soil water conditions. In tropical conditions, due to less variation in temperature and day length, rainfall distribution generally determines the best sowing time [8].

Most crops in the Northeastern semi-arid region are rainfed, thus rainfall is the main limiting factor for agricultural production [9], mainly due to irregular rainfall distribution during crop cycle, affecting plant development and causing a productive deficit [10]. Choosing the best sowing time can maximize the yield potential of the crop without significantly changing the cost of production.

Given the above, the present study aimed to evaluate the yield components (grain mass per ear, number of grains per ear, mass of 1000 grains) and agricultural yield of maize subjected to nitrogen doses and planting time in the region. of the Alagoas Coastal Boards.

2. MATERIALS AND METHODS

The experiment was carried out at the Center for Agricultural Sciences of the Federal University of Alagoas, Rio Largo, AL (09°28'02 ”S and 35° 49'43” W, 127 m altitude), in an area of 3,040.0

m^2 of an Oxisol cohesive Yellow Latosol, with medium / clayey textures and slope less than 2%. The statistical design used was randomized blocks, in split plot scheme, with four sowing dates (E1: 28/05/16, E2: 11/06/16, E3: 25/06/16, E4: 22/07 / 16), in the plots of 20 lines with 8.0 m in length and spacing of 0.80 m (128.0 m^2). In the 8-line subplots of 8.0 m, 32 m^2, four nitrogen doses (0, 75, 150 and 225 kg ha^{-1}) were placed.

The soil preparation was carried out with two harrows: one heavy and deep (± 30 cm) and another leveler. The foundation fertilization (level = 115 kg of P_2O_5 and 192 kg of K_2O per hectare) was based on the chemical analysis of the soil, aiming at an average agricultural yield of 10.0 t ha^{-1} of grains, according to [11], nitrogen fertilization was performed at 15 days after planting (DAP), based on the treatments of each subplot and urea was used as source.

The planting was done by placing 2 seeds every 25 cm and when the plants had 4 fully expanded leaves, thinning was done to the density of 50,000 plants per hectare. Native plants were controlled with the herbicides Soberan (260 mL ha^{-1}) and Atrazine (2.5 L ha^{-1}), both applied after planting with manual costal sprayer.

The agrometeorological variables: Precipitation (P), wind speed (U), relative air humidity (HR) and reference evapotranspiration (ETo) were provided by the Irrigation and Agrometeorology Laboratory (LIA), which maintains an acquisition station. automatic water. Data close to the experiment.

The water balance was made by the method of [12] according to the methodology recommended by [13]. Culture evapotranspiration (ETc) was calculated by multiplying ETo by the culture coefficient (Kc).

The Kc used was the Food Agriculture Organization (FAO), whose initial, intermediate and final phase values were 0.40, 1.2 and 0.6, respectively. The initial Kc was corrected by the graphical method, as a function of the ETo and the irrigation frequency. The Intermediate Kc and final Kc were corrected according to Equation 1: Final Kc = Final Kc (Tab) + [0.04 (U2 -2) - 0.004 (RHmin - 45)] $(H / 3)^{0.3}$ where: Kc final (Tab) is the value given in the FAO-56 bulletin, U2 is the average value for daily wind speed measured at 2 m above the grass during the last growth phase, RHmin is the value of average daily minimum relative humidity during the last growth phase [%], to 20% ≤ RHmin ≤ 80%, H is the average plant height during the last growth phase [m], to 0.1 m ≤ H ≤10 m [14].

Plant development was monitored with daily observations that began shortly after sowing and the date of occurrence of each phenological stage was considered when 50% +1 of the plants presented the predefined characteristics of that stage, based on the scale proposed by [15].

The harvests were carried out on 10/22/2016 (E1), 04/11/2016 (E2), 25/11/2016 (E3) and 11/12/2016 (E4) in the three central subplot rows (useful area). Forty ears of corn were then selected for the analysis of the variables: number of grains per ear (NGE) and grain mass per ear (MGE) and agricultural yield was obtained from the weighing of all grains harvested in the usable area. Each parcel, according to Equation 2: PA = 10,000 (M / C ϵ), where: PA is the agricultural yield (kg ha^{-1}), M is the harvested mass in the sampled area (kg), C is the total length of harvested rows (m), ϵ is the row spacing (m) and 10,000 is the conversion factor to hectare.

The obtained data were subjected to analysis of variance by the Sisvar statistical program, and the data adjusted by linear and quadratic polynomial regression ($P < 0.05$).

3. RESULTS AND DISCUSSION

The water deficit in maize crop, accounted for by the [16] water balance in the Rio Largo, AL region, from May 18 to October 31, 2016, was 45, 40, 46, 95 mm and water excess were 148, 182, 174, 264 in treatments E1, E2, E3 and E4, respectively (Fig. 1).

Seed germination is one of the most critical stages of the plant life cycle and is an irreversible process that is directly affected by the occurrence of water deficit [17]. In E1, the crop suffered a water deficit of 27.4 mm in the vegetative phase and 17.5 mm in the reproductive phase, but 15.4 mm of deficiency occurred from planting until V4 (phenological stage to which the plant has four expanded leaves), causing a delay in corn seed germination (8 DAP) [18] stated that of the various environmental factors that can influence germination, water availability is one of the most important, since it is the main factor in most biochemical and physiological processes. The water excess of this same sowing season was 55.6 mm in the vegetative phase (05/28 to

28/07/2016) and 92.0 mm in the reproductive phase (29/07 to 01/10/2016).

The E2 was the least total water deficit, and at that time the deficit was smaller in the vegetative phase (17.5 mm) and higher in the reproductive phase (22.9 mm). In the first phase the deficits were concentrated from V4 to VT (panicle emission), so it did not have much influence on plant emergence velocity (6 DAP), however approximately 7 mm of the total occurred in the transition period from vegetative to reproductive phase (31 / 07-05 / 08/2016), which according to [19], the occurrence of water deficit before the emission of stigmas can cause a decrease in productivity of up to 25%, because maize is relatively tolerant to water deficit during the vegetative phase, the same author mentions that this reduction is 50% if water stress occurs in the flowering and grain filling phase, due to the extreme sensitivity to lack of water during this period. In E2 occurred the third largest total rainfall, however it was the second that suffered the most total water excess, in which the largest excess water was in the vegetative phase (110.9 mm) and lowest in the reproductive phase (70.8 mm).

The highest water deficit of the total was registered at E3, being 27.5 mm in the tearing phase the grain filling, critical period of the crop, resulting in the low grain yield in this sowing season.

Ferreira et al. [20] observed that water stress from tassel emission up to two weeks after ear appearance causes the greatest reduction in grain yield. Water excess at this time was the second lowest at 27.4 mm and 17.5 mm in the vegetative and reproductive development phase, respectively.

E4 was the second time most affected by water deficits and excesses, because in the critical period it had about 40 mm of water stress in the grain filling phase, causing poor plant performance. However, compared to E3, there was 132.3 mm of water excess in the vegetative phase and 131.3 mm in the reproductive phase, and approximately 50% (131.3 mm) of the total water excess occurred in just 4 days.

The average value of grain mass per ear (MGE) at different N rates and at planting time was estimated by the quadratic regression equation with the observed averages, which was obtained for seasons 1, 2, 3 and 4. The coefficients of determination (R^2) 96%; 96%; 99% and 88% respectively (Fig. 2). According to R^2, the 3rd planting season was the most suitable for the regression equation (99%), while in the 4th

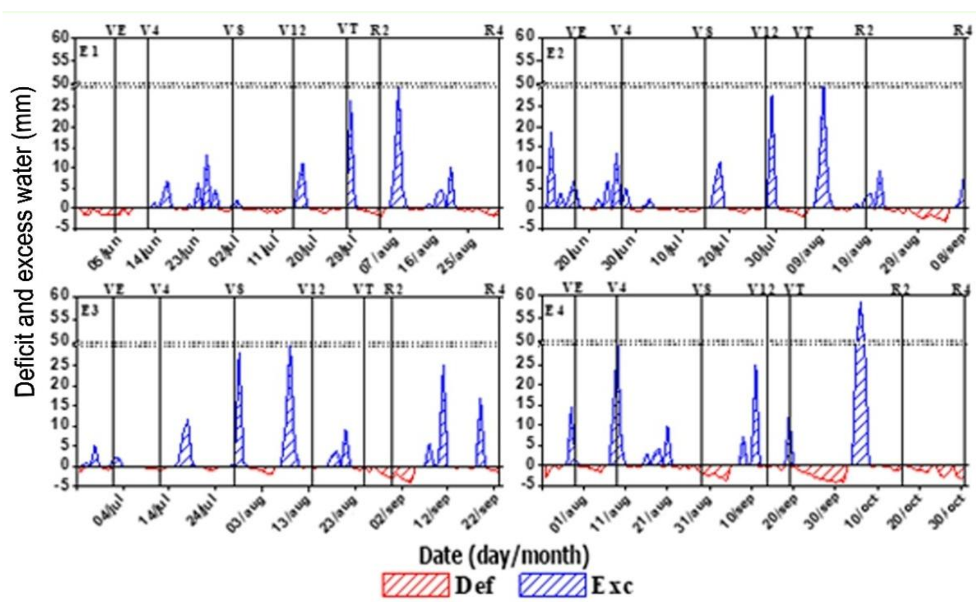

Fig. 1. Water balance of maize crop with water deficits and excesses at planting times: E1 (05/28/2016 to 09/01/2016), E2 (06/11/2016 to 08/09/2016), E3 (06/25/2016 to 09/23/2016) and E4 (07/23/2016 to 10/31/2016), in the region of Rio Largo, AL

season R^2 was the smallest (88%). Soares [21] also observed quadratic response to the application of increasing doses of N in corn crop.

The maximum observed MGE values in E1, E2, E3 and E4 were 235, 203, 179 and 172 g, respectively, obtained with the dose of 225 kg N ha^{-1}, following the same order, the lowest observed values were 130, 101, 90 and 145 g, respectively, in the treatments in which they did not receive nitrogen fertilization. This reduction in MGA in plants with nitrogen deficiency occurs because plants with this deficiency presented early leaf senescence, which caused a reduction in absorbed radiation, CO_2 fixation, organic compound production, total biomass and ear grain mass.

Souza et al. [22], studying irrigation depths and nitrogen rates in corn crop, in the Alagoas Coastal Tablelands region, observed that the largest grain mass per ear was 203 g, obtained with the dose of 225 kg N ha^{-1} and the lowest MGE was 161 g, obtained with the control without nitrogen. Raasch et al. [23] and Pavinato et al. [24], also found a significant effect of N rates in coverage on the number of grains per ear.

The low increase observed in all variables analyzed in the 4th planting season with increasing N rates was due to thirteen days without rain at the beginning of flowering, a critical phase for corn in relation to soil water content, causing 15.1 mm water deficit in the soil, reducing N uptake by plants. Barbosa [25] reported that from 30 DAP increases N uptake to rates greater than 4.5 kg ha^{-1} day^{-1} between flowering and the beginning of grain formation, provided there is moisture in the soil.

The number of grains per ear (NGE) fitted the quadratic regression model for seasons 1, 2 and 3 with R2 of 99%, 88% and 99% respectively (Fig. 3). In E4, the best fit model was the linear regression model with an R^2 of 76%. The maximum observed NGE values in E1, E2, E3 and E4 were 675, 651, 658 and 673, respectively, obtained with the 225 kg N ha^{-1} dose, following the same order, the lowest observed values of MGE were 486, 407, 417 and 607, respectively, in the treatments in which they did not receive nitrogen fertilization. The maximum estimated values of number of grains per ear were 676; 662; 659 and 723 grains obtained with the doses of 176; 169; 240 and 287 kg ha^{-1} of N at times 1, 2, 3 and 4, respectively. The results corroborate with information contained in the literature, where some authors report that the number of grains per ear is highly responsive to nitrogen fertilization [26]. As nitrogen rates increased from 0 to 150 kg ha^{-1} of N, the number of grains per ear increased on average 35.5% for the four planting seasons.

Raasch et al. [23], in a study in the Alagoas Coastal Trays, observed that the highest number of grains per ear was 639 grains obtained with the 225 kg N ha^{-1} dose and the lowest NGE was 573 obtained with the control without nitrogen. [27], in a study with maize in the city of Rio largo, AL, obtained the maximum NGE of 615 grains, with the dose of 173 kg of N ha^{-1}.

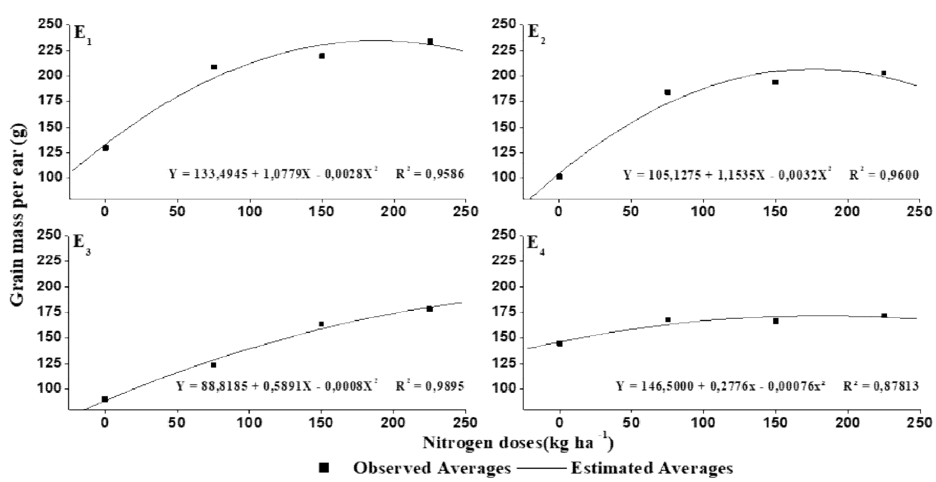

Fig. 2. Grain mass per ear (MGE), as a function of nitrogen rates, in four planting seasons (E1, E2, E3 and E4), in Rio Largo, AL, from May 28 to 30/10 2016

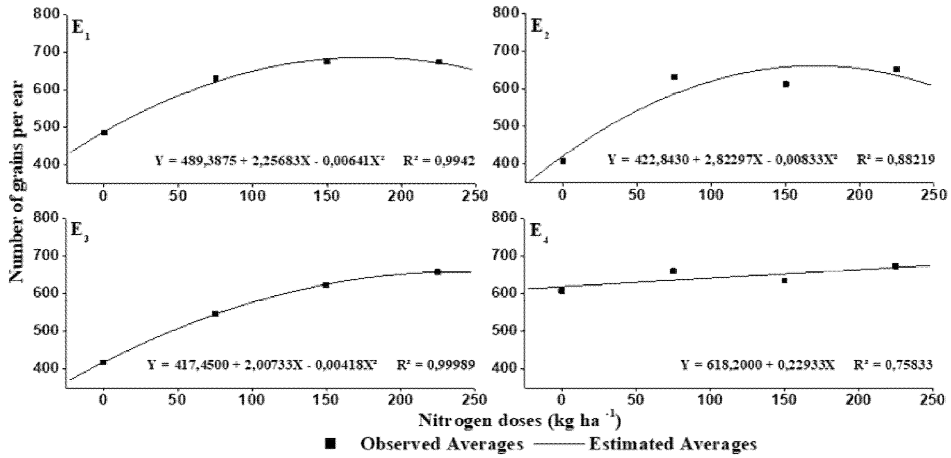

Fig. 3. Number of grains per ear as a function of nitrogen rates at different sowing times (E1, E2, E3 and E4) in Rio Largo, AL, from May 28 to October 30, 2016

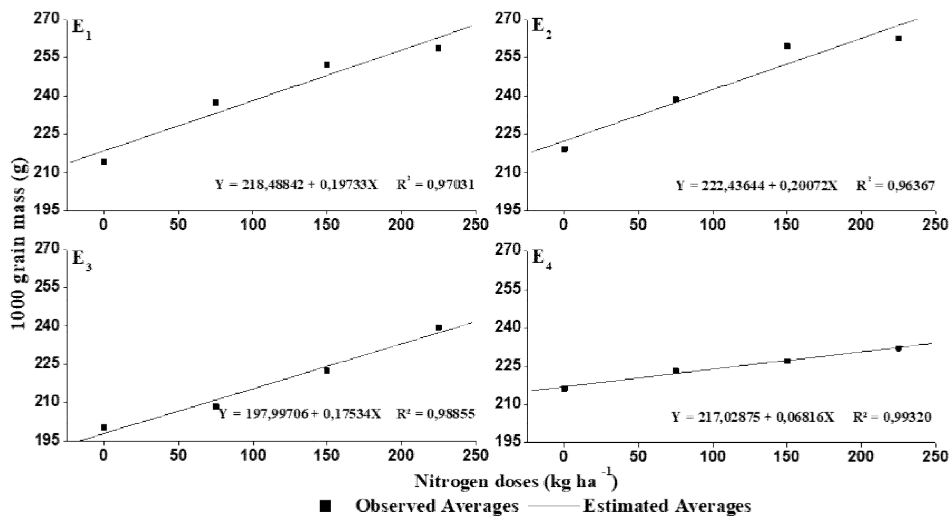

Fig. 4. Mass of 1,000 grains, as a function of nitrogen rates, at different sowing times (E1, E2, E3 and E4) in Rio Largo, AL, from May 28 to October 30, 2016

The results of the mass of 1,000 grains showed significant effects and fit the linear regression model, with R2 of 97%, 96%, 99% and 99% for the 1st, 2nd, 3rd and 4th planting season, respectively (Fig. 4). The highest values of 1,000 grains were obtained by applying 225 kg ha^{-1} of N, corresponding to 259; 262; 240 and 232 grams for E1, E2, E3 and E4, respectively. Veloso et al. [27] observed an increase of 14.5% in the mass of one thousand grains, evaluating increasing doses of N ranging from 0 to 170 kg ha^{-1}.

The 2nd degree polynomial equation showed significant adjustment for agricultural productivity, with R2 of 98%, 97%, 99% and 99% for the 1st, 2nd, 3rd and 4th sowing season, respectively. The maximum yield observed in E1, E2, E3 and E4 were 9.6; 9.4; 7.9; and 5.1 t ha^{-1}, obtained with the maximum applied dose. The estimated maximum yields were 9.6; 9.5; 8.1 and 7.1 t ha^{-1}, obtained at doses of 209; 186; 272 and 86 kg ha^{-1} of N respectively (Fig. 5).

In the 4th sowing season, it was the one that presented the lowest agricultural productivity, and this was because the crop was at the beginning of flowering (critical phase for maize), and during this period it went through thirteen days without rain, which reduced the absorption

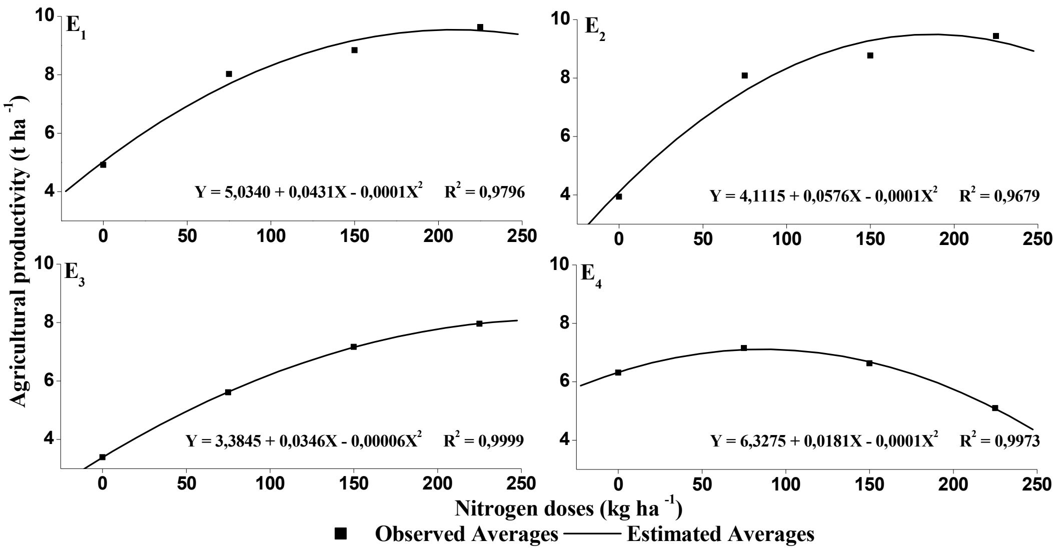

Fig. 5. Agricultural productivity as a function of nitrogen rates at different sowing times (E1, E2, E3 and E4) in Rio Largo, AL, from May 28 to October 30, 2016

of N in soil solution and by crop. And according to [28], the reduction in yield in plants subjected to water restriction is due to the low supply rate of ovarian assimilation, causing grain abortion. According to [29], the occurrence of water deficit in the flowering and grain filling phases is responsible for reducing the number and mass of grains per ear, which are determinant components of agricultural productivity.

Raasch et al. [23] obtained the maximum observed agricultural productivity of 9.0 t ha^{-1}, with the dose of 225 kg of N ha^{-1}, in contrast, the lowest observed agricultural productivity was 6.2 t ha^{-1}, with nitrogen free treatment. [30] verified the highest grain yield 8.9 t ha^{-1}, with application of 151 kg of N ha^{-1}. Veloso et al. [27], obtained higher grain yield of 8.0 t ha^{-1}, with the dose of 171 kg of N ha^{-1}. Lyra et al. [31], obtained higher grain yield 5.4 t ha^{-1}, with the dose of 200 kg of N ha^{-1}.

4. CONCLUSION

The highest values of grain mass per ear (235), number of grains per ear (675.0 grains), mass of 1,000 grains (559 g) are obtained from the second week of May until the first week of June with the fertilization of 225 kilograms of nitrogen per hectare.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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