Original Research Article

Performance of Corn Cultivars in Different Row Spacing and Types of Fertilizations

ABSTRACT

Aims: This study aimed to evaluate the productivity and production components of two cultivars of corn for different types of fertilization and row spacings on irrigated farming system.
Study design: It was adopted a randomized block design at 3 x 2 x 2 factorial experiment with four replications, the treatments consisted of three fertilization (OF - Organic Fertilization; OMF – Organomineral Fertilization and MF - Mineral Fertilization), two cultivars of corn (Bras 3010 and Potiguar) and two row spacings (80 cm and 50 cm).
Place and Duration of Study: The experiment was carried out from June to October 2013, at Fazenda Experimental Rafael Fernandes, in the community of Alagoinha, belonging to the Federal Rural University of Semi-Arido (UFERSA), lying 20 km from the city of Mossoró, Rio Grande do Norte, Brazil.
Methodology: The organic fertilization (OF) was performed as minimum recommendation corresponding to 10 t ha^{-1} of bovine manure. The organomineral fertilization (OMF) was made by applying 50% of the recommended amount of manure recommended in organic fertilization (OF), 5 t ha^{-1}, and 50% of the recommendation of mineral fertilizer (MF). The mineral fertilization (MF) was performed based on the parameters observed in the soil analysis and recommendation for the corn crop in the region due to an expected maximum productivity.
Results: The study showed that the mineral fertilization (MF) provided an increase in the productivity components of both evaluated, the hybrid variety Bras 3010 and Potiguar. The OMF did not show significant differences regarding the MF in production components of corn cultivars evaluated.
Conclusion: Components of production and productivity of corn cultivars were incremented when using the spacing of 80 cm between rows. The variety Potiguar corn had higher grain productivity compared with the Bras 3010 hybrid when used the organic fertilization.

Keywords: Zea mays L.; organic fertilizer; spatial arrangement; production.

1. INTRODUCTION

Aspects such as nutritional quality, ease of adaptation and applicability, make the corn crop, an important world cereal. The United States, China and Brazil are among the largest producers of this cereal with 371.0, 259.1 and 82.0 million tons in the 2017/18 harvest respectively, representing 66.16% of world production [1]. World demand for food, feed and fuel is increasing continuously. The corn is frequently used to meet these three uses. This multipurpose characteristic grain led to a dramatic increase in cereal production demand during the last decade [2].

Among the crops grown in Brazil, the main cereal is corn (*Zea mays L.*) highlighting the volume of production and the socio-economic importance. It is estimated that in the 2017/18 harvest were grown 16.63 million hectares of this culture, in which they were produced 81.35 million tons of grain in the country [3]. Corn also is configured as one of the important crops in the state of Rio Grande do Norte, being cultivated in all 167 counties of this state, culture is mainly explored by small farmers.

The corn productivity is dependent on the technological level and the interaction between genetic factors, environmental and crop management [4]. It is considered that soil fertility is one of the main factors responsible for the low productivity of areas intended to produce corn grains. This is due not only to low levels of nutrients present in the soil, but also to the inappropriate use of liming and fertilization [5]. Several studies have shown the positive effect of mineral fertilizer in the biometric characteristics of corn, such as the number of grains per ear, mass of ear with and without husk as well as in the productivity [6,7,8].

In order to increase the efficiency in the use of fertilizers in agricultural systems while maintaining the ecological balance, interest in the use of biofertilizers or organic fertilizers has recently increased, associated with the use of mineral fertilizers. [9] found out that continuous use of organomineral fertilizer over the years significantly increase grain production. A practice commonly adopted to increase production is the use of manure as an organic fertilizer for the supply of Nitrogen and Phosphorus in soils [10]. Little or no research are available in the combined use of organic and mineral fertilizers. [11] reported that the integrated use of organic compost and mineral fertilizer did not significantly increase productivity of corn crop in an Ultisols. The productive potential of corn crop can be exploited by the judicious implementation of technical aspects such as the choice of cultivar best suited to growing conditions, spacing and proper management.

Research works have been developed trying to evaluate and validate new corn cultivars under different soil and climatic conditions in different regions [12,13]. [14] in studies in the Northeast Nebraska, reported that reducing the spacing between the crop rows can favor an increase in grain production, because smaller spacing in the row result in a distribution more equidistant between plants, increasing the leaf area, trapping solar radiation and shading the soil, leading to a reduction in water loss by evaporation, resulting in a higher photosynthetic capacity and consequently in a higher grain yield.

In Guarapuava, Brazil, [15] did not obtain difference in the ear lengths when compared spacings of 40 and 80 cm in a population of 50,000 plants ha^{-1}. [16] evaluating the performance of three corn hybrids, AS 1570, AS 1565 and AS 1575, at three locations in western Paraná, Brazil, did not observe significant changing in the number of grains per ear, in three different spacing between rows (45, 68 and 90 cm). [17] found that row spacing did not affect the number of grain lines per ear, evaluating five corn hybrids early and super early maturing, when the row spacing was reduced from 90 to 45 cm.

With the growing need for an increase of the agricultural productivity in Brazil, it becomes paramount the scientific advancement in the supply studies of nutritional deficiencies and management deficiencies in corn, acting increasingly as relevant factor for science and agriculture. In this scenario, the aim of this work was to evaluate the production components and the productivity of two corn cultivars in function of different types of fertilization and row spacing on irrigated farming system in the western of Rio Grande do Norte state.

2. MATERIAL AND METHODS

The experiment was carried out from June to October 2013, at Fazenda Experimental Rafael Fernandes, in the community of Alagoinha, belonging to the Universidade Federal Rural do Semi-Árido (UFERSA). Located at Latitude 5°03'37" S Longitude 37º23'50" W, with an average altitude of 72 meters and slope between 0 and 2%, lying 20 km from the city of Mossoró, Brazil. The city of Mossoró is in the Rio Grande do Norte state Northwest region. According to W. Koeppen climate classification, the climate is BSwh' type, dry climate, very hot and rainy season in the summer lingering for fall, with an average annual temperature of 27,4^{o}C, annual rainfall very irregular, averaging 673.9 mm and relative humidity 68.9% [18].

The soil of the experimental area was labeled according to the brazilian soil classification as ARGISSOLO VERMELHO-AMARELO eutrófico latossólico de textura franco-arenosa [19], belonging predominantly to the Ultisol Order by U.S. Soil Taxonomy [20]. The chemical analysis of the soil, carried out before trial installation at 0-20 cm depth, showed the following results: pH 4.8; 0.14 g kg^{-1} N; 4.19 g kg^{-1} of organic matter; 8.1 mg dm^{-3} P; 40.1 mg dm^{-3} K; 7.6 mg dm^{-3} Na; 0.52 cmolc dm^{-3} Ca; 0.44 cmolc dm^{-3} Mg and 0.15 cmolc dm^{-3} Al. The area had small shrub native vegetation by the year 2010, which was subsequently removed, in 2011 was barred, scarified and cultivated with bean in conventional farming system. In 2012 the area was set aside. The soil was plough, level and lime to increase the pH requirement of 5.5 to 6.5 for corn production. It was distributed 2.5 t ha^{-1} of limestone, with 12% MgO, applied 60 days before sowing and distributed at a depth of 0-10 cm. The irrigation was twice a week made for the same period to assist the product reaction with the soil mineral particles.

The experimental design was randomized blocks in factorial 3 x 2 x 2, composed of three types of fertilizers, (OF - Organic Fertilization; OMF – Organomineral Fertilization and MF - Mineral Fertilization), two row spacings, E1 (80 cm) and E2 (50 cm), and two cultivars of corn, hybrid Bras 3010 and the cultivar Potiguar, with four repetitions, totaling 48 experimental units of 4 x 30 m each. The organic fertilization (OF) was performed as minimum recommendation of [21], corresponding to 10 t ha^{-1} of bovine manure. The material was collected in the cattle sector from the Federal Rural University of Semi-Árido, which material was chemically analyzed and obtained the following characteristics: pH 7.7; 10.22 g kg^{-1} N; 34.68 g kg^{-1} of organic matter; 806.7 mg dm^{-3} P; 5178.5 mg dm^{-3} K; 1887.4 mg dm^{-3} Na; 9.6 cmolc dm^{-3} Ca; 8.3 cmolc dm^{-3} Mg and 0.44 cmolc dm^{-3} Al. The organomineral fertilization (OMF) was made by applying 50% of the recommended amount of manure recommended in organic fertilization (OF), 5 t ha^{-1}, and 50% of the recommendation of mineral fertilizer (MF). The mineral fertilization (MF) was performed based on the parameters observed in the soil analysis and recommendation for the corn crop in the region due to an expected maximum productivity, 15 kg ha^{-1} of Nitrogen, being applied in the foundation, and 60 kg ha^{-1} in coverage fertilization. It was applied to 80 kg of phosphorus and 50 kg ha^{-1} of potassium in the foundation. Before sowing operation, the seeds were treated with imidacloprid insecticide active principle and thiodicarb at a dose of 0.35 L ha^{-1}.

With emerging percentage values and purity of each batch of seeds used in the experiment, the seeder was set to distribute 4.18 and 3.46 seeds per meter spacing for 80 and 50 cm, respectively. The expected values were 69,200 and 52,250 seeds per hectare for a desired population of 50,000 plants per hectare. In the experiment was used a precision seeder, Marchesan brand T2SI model chassis 2,800 mm, weight 656 kg and required power of 60 HP operating at an average speed of about 5 km h^{-1}, adjusted to 80 and 50 cm between rows, respectively. The irrigation water available at the Experimental Farm came from a well at Sandstone aquifer, characterized by presenting approximate depth of 1000 m, with good quality electrical conductivity (ECw) of 0.58 dS m^{-1} and pH 7.5. The irrigation system used was by spraying, powered by a three-phase hydraulic pump Thebe brand, with capacity of 7.5 hp and maximum flow of 38 m^3 h^{-1}, consisting of 9 sidelines spaced 12 m, with 8 sprinklers brand agropolo NY 25, each row also spaced 12 m. The spray had 25 mca working pressure of 12 m range, flow rate of 528 L h^{-1} and height 2.5 m jet. With the meteorological station installed near the experiment was determined and applied to the amount of water necessary for each stage of culture. Irrigation was always done at night because the best application efficiency, lower drift caused by wind and consequently a better water use by the crop.

To evaluate the production components were collected 10 ears, at random, from two central lines of the plot, targeting the following determinations: mass of ear with and without husk, ear length, ear diameter and mass of 1000 grains. The grain productivity was obtained by weighing the grain harvested in the area of the experimental plot, threshed mechanically, also summing up the grain mass of the collected ears, correcting the moisture to 13%, being held adjustment for kg ha^{-1}. The data were submitted to analysis of variance by F test at 5% probability. Then the averages were compared by Tukey test at 5% probability. In the statistical analysis was used the software SISVAR 5.0 [22].

3. RESULTS AND DISCUSSION

Data from the mass of ear with husk (MEWH), mass of ear without husk (MENP), ear length (EL) ear diameter (ED), mass of 1000 grains (M1000G) and productivity (P) obtained in the experiment, as well as F values, are presented in Table 1. Analyzing the data presented, it was found that the variables: mass of ear with and without husk and ear diameter showed significant interaction for factors, cultivar and row spacing (F x C x RS), respectively.

Table 1. Mean and the F values of productivity and production components that resulted from the analysis of variance

Sources of variation	MEWH (g)	MENH (g)	EL (cm)	ED (mm)	M1000G (g)	P (kg ha^{-1})
Fertilizations (F)						
Organic (OF)	125.28 b	107.78 b	15.00 b	39.73 b	127.01 a	1255.79 a
Organomineral (OMF)	137.23 a	118.33 a	15.32 ab	40.31 ab	128.04 a	1435.58 a
Mineral (MF)	141.32 a	122.55 a	15.69 a	40.75 a	127.00 a	1415.83 a
Cultivars (C)						
Bras 3010	119.69 b	105.04 b	15.56 a	38.06 b	124.63 b	1245.99 b
Potiguar	149.53 a	127.41 a	15.10 b	42.47 a	130.07 a	1492.14 a
Row spacing (RS)						
E1 (80 cm)	147.42 a	127.30 a	15.51 a	41.03 a	128.54 a	1379.31 a
E2 (50 cm)	121.80 b	105.13 b	15.16 b	39.49 b	126.15 a	1358.82 a
Values of F						
Fertilizations (F)	7.66 **	7.75 **	5.18 **	3.40 *	0.07 ^{ns}	1.31 ^{ns}
Cultivars (C)	73.68 **	50.23 **	6.67 *	187.55 **	4.17 *	6.10 *
Row Spacing (RS)	54.28 **	49.33 **	3.95 *	22.86 **	0.80 ^{ns}	0.04 ^{ns}
F x C	12.29 **	10.91 **	4.73 **	5.92 **	1.13 ^{ns}	4.02 *

F x RS	5.96^{**}	4.94^{**}	1.28^{ns}	6.31^{**}	0.08^{ns}	0.01^{ns}
C x RS	0.04^{ns}	0.00^{ns}	0.91^{ns}	0.05^{ns}	0.04^{ns}	0.34^{ns}
F x C x RS	5.15^{**}	5.41^{**}	1.20^{ns}	3.88^{*}	1.34^{ns}	0.45^{ns}
Average	134.60	116.22	15.33	40.26	127.35	1369.06
CV (%)	28.29	29.75	12.66	8.77	7.24	25.21

*Mass of ear with husk (MEWH), mass of ear without husk (MENP), ear length (EL) ear diameter (ED), mass of 1000 grains (M1000G) and productivity (P). Means followed by the same letter do not differ by Tukey test at 5% probability. *P < 0.05; **P < 0.01; ^{ns}Not significant; C.V.: Coefficient of variation.*

Fertilization, cultivars and evaluated spacings had significant effect on the ear diameter (ED). The mineral fertilization increased the ear diameter, followed by organomineral fertilization, differing significantly from organic fertilization. The ear length and the productivity showed significant interaction of factors fertilization and cultivar (F x C). [23] state that the proportionate differences in the components of corn yield, including the thousand grain weight, is more due to population density than exclusively to spacing.

The splitting of significant triple interaction between fertilization, cultivars and spacings for the mass of ear with husk are shown in Figure 1. It was found that the hybrid Bras 3010 showed greater mass of ear with husk when used organomineral fertilization, use spacing of 80 cm between rows, not differing significantly from the mineral fertilizer. The combination of organic fertilization with mineral fertilizer is presented as a viable alternative to the increased mass of ear with husk, it reduces at 50% of costs, as the acquisition of mineral fertilizers, providing soil improvements in physical, chemical and biological terms. Since the spacing of 50 cm between rows promoted a decrease in the mass of ear with husk in the hybrid Bras 3010 with the use of organic fertilizer, and this may have been due more competition for light, because there was a fast closure of the corn plants in this spacing, as well as the time of decomposition of the organic matter in the soil may have been less, causing a slow nutrient availability.

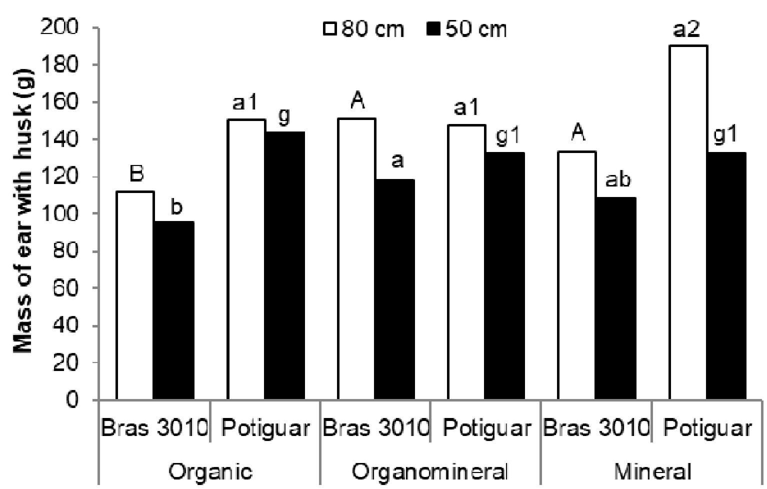

Fig. 1. Mass of ear with husk of corn cultivars (Bras 3010 and Potiguar) submitted to organic, organomineral and mineral fertilizations in the row spacings of 80 and 50 cm

Means followed by the same letters, uppercase and lowercase to Bras 3010 in each type of fertilization in both row spacings, respectively, Greek letters (α) and (ɣ) followed by the same numbering for Potiguar in both row spacings, do not differ by Tukey test at 5% probability.

[16] states that in tight spacing there is an increase in the production of components and consequently, increased grain yield, due to a more equidistant distribution of plants in the area, increasing the efficiency of utilization of sunlight, water and nutrients, improving weed control because of the faster closure of the spaces available, reducing erosion, improving the quality of seeding through the slower speed of rotation of the seed distribution systems, maximizing the use of seeders. The variety of Potiguar corn had a higher mass of ear with husk in relation to hybrid Bras 3010, especially when fertilized in mineral form in the spacing of 80 cm between rows (190.10 g). These results corroborate those of [24], who evaluated two spacings (90 and 45 cm) in corn, found greater results of mass of ear with husk in higher assessed spacing. The spacing of 50 cm between rows did not significantly alter the mass of ear with husk for Potiguar variety of corn in the evaluated fertilizations.

The mass of ear without husk followed the tendency of the mass of ear with husk. The fertilization significantly alters the mass of ear without husk. The hybrid Bras 3010 showed higher mass of ear without husk when fertilized in mineral form, no significant interference of organomineral fertilization, differing only treatment with organic fertilization. The spacing of 80 cm between rows positively influenced the mass of ear without husk in Bras 3010 corn, especially with mineral and organomineral fertilization, promoting higher values in the mass of ear without husk as shown in Figure 2. The spacing of 50 cm between rows significantly changed the mass of ear without husk in the hybrid tested, with higher values with organomineral and mineral fertilization, respectively.

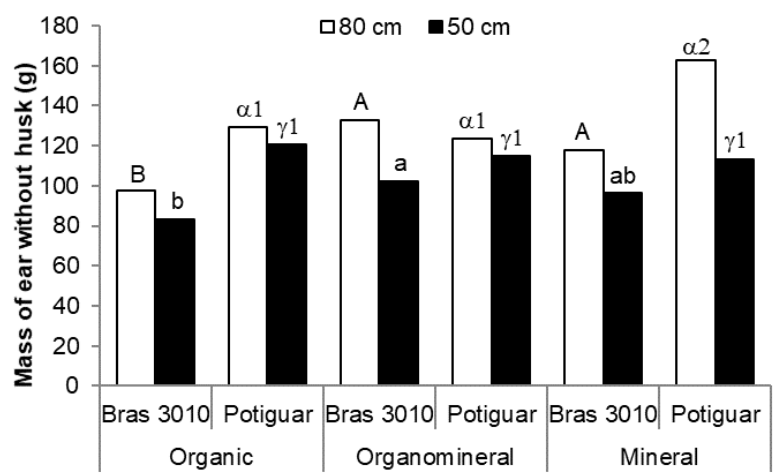

Fig. 2. Mass of ear without husk of corn cultivars (Bras 3010 and Potiguar) submitted to organic, organomineral and mineral fertilizations in the row spacings of 80 and 50 cm

Means followed by the same letters, uppercase and lowercase to Bras 3010 in each type of fertilization in both row spacings, respectively, Greek letters (α) and (ɣ) followed by the same numbering for Potiguar in both row spacings, do not differ by Tukey test at 5% probability.

The splitting of significant triple interaction between fertilization, cultivars and spacing to the ear diameter is shown in Figure 3. The row spacing of 80 cm combined with organomineral fertilization significantly affected the ear diameter of hybrid Brasmilho 3010 evaluated, presenting a larger ear diameter. The results differ from those obtained by [25], which did not find significance in the ear diameters at different spacings. They could only observe a decreasing trend in the ear diameter with increased spacing, which claim to be associated with increased intra-specific population and competition. The spacing between rows of 50 cm did not cause significant changes in the ear diameter of Bras 3010 when subjected to the three types of evaluated fertilizations. According to [26] the ear diameter reflects the productive capacity of the plants, the largest diameter favors the formation of a larger amount of grains. The author found that the manure doses responsible for the best effect in diameter were 20, 40, 50 and 60 t ha^{-1}. Studying different corn hybrid under organic fertilization, [27] found the largest 44 mm ear diameter.

The spacing of 80 cm between rows also significantly affected the ear diameter of Potiguar corn, obtaining the highest values when fertilized with mineral fertilization. No significant difference was observed from the variable when fertilized with organic and organomineral fertilization. The increase in the ear diameter with the use of mineral fertilization corroborate with [28], who stated that nutrients present in mineral fertilizers play an important role in the growth and development of crops. The ear diameter of Potiguar variety was not significantly altered by fertilizations evaluated using spacing of 50 cm between rows. [29] claim that the equidistant distribution of corn plants in the field improves the components production, including the ear diameter. Affirming also that the equidistant distribution between plants favors the closing of the leading, improving the interception of solar radiation and the rate of growth of corn plants in the early stages, exactly as happen with the stem diameter.

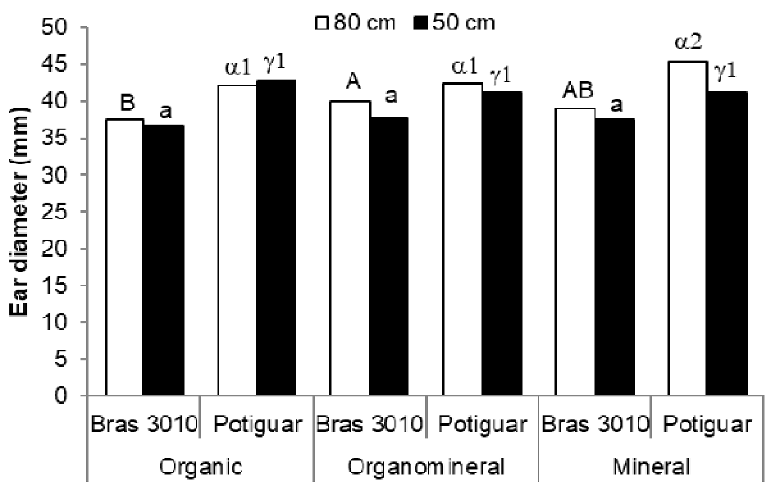

Fig. 3. Ear diameter of corn cultivars (Bras 3010 and Potiguar) submitted to organic, organomineral and mineral fertilizations in the row spacings of 80 and 50 cm

Means followed by the same letters, uppercase and lowercase to Bras 3010 in each type of fertilization in both row spacings, respectively, Greek letters (α) and (ɣ) followed by the same numbering for Potiguar in both row spacings, do not differ by Tukey test at 5% probability.

The splitting of significant interaction between fertilization x cultivar (F x C) for the variables ear length and productivity are shown in Table 2. For variable ear length it is observed that the mineral fertilization provided higher average values, followed by organomineral, 15.69 cm and 15.32 cm, respectively, differing significantly only from organic fertilization results.

This variable was changed significantly by the evaluated spacings where the spacing of 80 cm between rows promoted higher values.

Table 2. Splitting of interaction between the factors fertilizations and cultivars

Fertilizations	EL (cm)		P (kg ha^{-1})	
	Bras 3010	**Potiguar**	**Bras 3010**	**Potiguar**
Organic (OF)	14.94 Ba	15.05 ABa	933.04 Bb	1578.55 Aa
Organomineral (OMF)	15.92 Aa	14.72 Bb	1414.81 Aa	1456.34 Aa
Mineral (MF)	15.84 Aa	15.54 Aa	1390.13 Aa	1441.53 Aa

Ear length (EL) and productivity (P). Means followed by the same letter, uppercase in column and lowercase in row, do not differ by Tukey test at 5% probability.

These results corroborate with [30], who found significant change in the ear length subjected to organic fertilization, starting at a dose of 20 t ha^{-1} of manure, compared to mineral fertilization. For spacings between lines, the results differ from those obtained by [31], that when assessing three varieties of corn (Arapuim, BR 106 and AL Bandeirante) and four row spacings (40, 60, 80 and 100 cm), found that there were no significant differences in the ear lengths, just checking out differences between varieties. [15] also did not obtain differences in ear length when compared to the spacing 40 to 80 cm in a population of 50,000 plants h^{-1}. Corroborating with those obtained by [32], reported that 90 cm row spacing gave greater ear length compared to 45 cm plant space, claiming that a largest spacing between rows can provide higher incidence of light on the canopy and the competition of plants by incident solar radiation, for nutrients and water, determines the formation of the ear, especially in a dense crop, which may result in a deficit of carbon and nitrogen supply to the plants.

It was found that the fertilization significantly influenced the ear length of the hybrid corn Bras 3010. The organomineral and mineral fertilizations did not differ significantly from each other, differing only from organic fertilization results. The organomineral fertilization provided higher ear length (15.92 cm), followed by mineral fertilization (15.84 cm). The ear length of Potiguar cultivar did not have significant difference when compared mineral and organic fertilizations, but there was when used organomineral fertilization. The mineral fertilization provided an increase in the ear length (15.54 cm), followed by organic fertilization (15.05 cm). [33] had higher average values of ear length ranging between 18.61 and 19.51 cm, according to the doses of Nitrogen. Corroborating the results [34], determined that higher values of ear length ranging from 16.57 to 18.22 cm, depending on the row spacing and population densities. [26] obtained higher values (15.96 cm) of ear length with 20 t ha^{-1} of manure applied and lower average values when used organic fertilization (0, 10, 30, 40, 50 and 60 t ha^{-1}) and mineral ranging between 14.03 and 15.12 cm for ear length, according to fertilization.

Fertilization exerted significant interference in the productivity of Bras 3010 hybrid. The organomineral fertilization increased grain productivity of assessed hybrid (1414.81 kg ha^{-1}), followed by mineral fertilization (1390.13 kg ha^{-1}), differing significantly from results of organic fertilization (933.04 kg ha^{-1}). The productivity of the Potiguar variety was not affected significantly by any types of evaluated fertilization. Observing increased productivity when fertilized only organically (1578.5 kg ha^{-1}). Although these results are lower than those of [21], they are positive, with a view of reducing costs with mineral fertilizers, proving positive response from the Potiguar variety of corn with organic fertilization, becoming a strategy for improving the quality of soil and, consequently, increase productivity. There was a significant change between the hybrid Bras 3010 and the Potiguar variety of corn in relation to productivity. There was a significant decrease in productivity of the hybrid Bras 3010 (933.04

cm) when fertilized organically with no significant reductions between this hybrid and the Potiguar variety with the use of organomineral and mineral fertilizations.

4. CONCLUSION

The mineral fertilization provided an increase in the components of production of the hybrid Bras 3010 and variety Potiguar. The organomineral fertilization showed no significant differences from the mineral fertilization in the production components of evaluated corn. The components of production and productivity of corn cultivars were incremented when using the spacing of 80 cm between rows. The variety Potiguar corn had higher grain productivity compared with the Bras 3010 hybrid when used the organic fertilization.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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