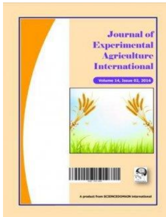

Journal of Experimental Agriculture International

30(2): 1-9, 2019; Article no.JEAI.46521
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Biometric Characteristics and Productivity of Potiguar Corn Cultivar in Different Row Spacing and Fertilizations

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2019/46521
Editor(s):
(1) Dr. Nazimah Maqbool, Professor, Department of Botany, University of Agriculture, Pakistan.
Reviewers:
(1) Addam Kiari Saidou, Institut National de la Recherche Agronomique du Niger (INRAN), Niger.
(2) Jin Seop Bak, Kyonggi University, South Korea.
(3) Nyong Princely Awazi, University of Dschang, Cameroon.
Complete Peer review History: http://www.sdiarticle3.com/review-history/46521

Original Research Article

Received 11 October 2018
Accepted 08 January 2019
Published 24 January 2019

ABSTRACT

Aims: To evaluate the biometric characteristics of production and productivity of Potiguar corn cultivar, which is recommended to the state of Rio Grande do Norte, Brazil, in different types of fertilizations and row spacing on irrigated system.
Study Design: It was adopted a randomized block design at 3 x 2 factorial experiment with four replications, the treatments consisted of three fertilizations (OF - Organic Fertilization; OMF – Organomineral Fertilization and MF - Mineral Fertilization) and two row spacing (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.

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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 biometric parameters of production: ear length, number of grain lines per ear and mass of 1000 grains were not significantly influenced by the factors fertilizations and row spacing. The mineral fertilization associated with the spacing of 80 cm between rows provided greater results in the biometric components ear diameter, mass of ear with husk, mass of ear without husk and mass of grains per ear.

Conclusion: Some of the biometric parameters evaluated were significantly influenced by the factors fertilizations and row spacing. The types of fertilizations studied, regardless of row spacing, did not significantly interfere in the productivity of the Potiguar corn cultivar.

Keywords: Zea mays L.; management practices; bovine manure; semiarid region.

1. INTRODUCTION

In the Brazilian Northeast, corn is one of the most important crops, mainly for the production of green corn and grains, which is one of the main sources of daily energy for human and animal food. In relation to cropped area in the region, the total corn crop in 2017/18 was 2.668 million hectares with an average productivity of 2,554.0 kg ha^{-1}. In spite of the low productivity, compared to the national average of 4,890.0 kg ha^{-1}, in the state of Rio Grande do Norte, the planted area in 2017/18 was 40,900.0 hectares with average productivity of 473.0 kg ha^{-1} [1].

The prices of chemical fertilizers, notably derived from petroleum, generate great evasion of financial resources of rural property. Therefore, alternative sources of fertilization, mainly organic, have aroused interest, as have producers as well as researchers in recent years [2]. Animal manure is the main material fertilizer used to improve soil fertility in the northeastern semi-arid region, but the amount of manure available on the properties is generally insufficient to meet the crop demand [3].

The use of manure is a widely adopted solution for the supply of nutrients, such as N, P and K in the soils of the semi-arid region [4], in this context [5] studied, in Gurupi, Tocantins, Brazil, the production of corn simple hybrid DAS655 with different levels of bovine manure (0, 10, 20, 20, 30, 40, 50 and 60 t ha^{-1}), obtained a greater ear length (15.96 cm), greater ear diameter (47.94 mm) and a higher value of 15.44 grains lines per ear, respectively in the treatments with 20, 40 and 60 t ha^{-1} of the evaluated organic material. As for mineral fertilization, [6] evaluated the effects of different sources and doses of Nitrogen (0, 50, 100, 150 kg ha^{-1}) on the development and productivity of sweet corn, and obtained values number of grains per ear ranged from 477.6 to 531.15 and mean values of ear insertion height ranging from 106 to 114 cm, according to the doses of N.

The manipulation of the spatial arrangement of plants by the alteration in spacing and plant density in the rows has been pointed out as one of the most important management practices to maximize corn productivity by optimizing the use of production factors such as water, light and nutrients [7]. The grain productivity of a plant population can be increased by maximizing its photosynthetic efficiency, which can be obtained by improving the interception of the photosynthetically active radiation by the canopy [8]. Some results of [9] show that the Potiguar corn variety has a genetic potential for productivity of 7,000.0 kg ha^{-1} and an average productivity of 5,240.0 kg ha^{-1}. These are average values, referring to the 28 tests installed in the period 2006 to 2007, in the Brazilian Northeast, without irrigation system.

Considering the dependence of corn on mineral, organic or organomineral fertilization, the aim was to evaluate the biometric characteristics of production and productivity of the Potiguar corn variety, recommended for the western region of Rio Grande do Norte, Brazil, according to different types of fertilizations and row spacing in an irrigated crop system.

2. MATERIALS 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°C, annual rainfall very irregular, averaging 673.9 mm and relative humidity 68.9% [10].

The soil of the experimental area was labeled according to the Brazilian soil classification as ARGISSOLO VERMELHO-AMARELO eutrophic latossólico of texture franco-arenosa [11], belonging predominantly to the Ultisol Order by U.S. Soil Taxonomy [12]. 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 physical attributes were 82% sand, 4% silt, 12% clay, soil density of 1.53 g cm^{-3}, particle density of 2.64 g cm^{-3} and porosity of 42.05%. 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, composed of three types of fertilizers, (OF - Organic Fertilization; OMF - Organomineral Fertilization and MF - Mineral Fertilization) and two row spacing E1 (80 cm) and E2 (50 cm), with four repetitions, totaling 24 experimental units of 4 x 30 m each. The organic fertilization (OF) was performed as minimum recommendation of [13], 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 the 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 according to [14], nitrogen in the form of urea with 50% N were applied at 15 kg ha^{-1} at foundation and 60 kg ha^{-1} at coverage. Phosphate fertilization was 80 kg ha^{-1} P_2O_5, as Monoammonium Phosphate (MAP) with 52% P_20_5 and potassium fertilization of 50 kg ha^{-1} K_2O from potassium chloride with 60% K_2O, both at foundation.

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 row spacing, 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 line also spaced 12 m. The spray had 250 kPa working pressure of 12 m range, flow rate of 528 L h^{-1} and height jet of 2.5 m. With the meteorological station installed near the experiment was determined and applied to the amount of water necessary for each stage of crop. 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.

For the evaluation of the production components 10 ears were collected, at random, from the two central lines of the plot, to obtain the ear length (EL) and ear diameter (ED), both without husk, number of grains lines per ear (NGLE), number of grains per ear (NGE), mass of grains per ear (MGE), mass of ear with husk (MEWH), mass of ear without husk (MENP) and mass of 1000 grains (M1000G). The productivity (P) was obtained by weighing the grain harvested in the area of the experimental plot, threshed mechanically, also summing up the mass of grains 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 [15].

3. RESULTS AND DISCUSSION

When analyzing the data presented in Table 1, it was verified that the variable ear length (EL) and number of grains lines per ear (NGLE) were not significantly affected by the evaluated factors. On the other hand, the variables ear diameter (ED) and number of grains per ear (NGE) were significantly influenced as a function of the interaction between fertilizations and row spacing factors (F x RS). Carmo et al. [6] found statistical difference for the ear length variable according to different doses and sources of N corroborating with the results of [5]. Stacciarini et al. [16] evaluated the influence of row spacing variation and planting density of corn crop, with two row spacing, 45 and 90 cm, and three population densities, 60,000, 75,000 and 90,000 plants per hectare, the hybrid used was the Pioneer 30K75, in Araporã, Minas Gerais, and obtained values of ear length ranging from 16.57 to 18.22 cm, as a function of row spacing and population densities.

Nummer Filho I and Hentschke CW [17] 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. Mata et al. [5] obtained lower mean value (44.75 mm) of ear diameter for 0 t ha^{-1} of applied bovine manure and higher average value when using organic fertilization for 40 t ha^{-1} of bovine manure, but for mineral fertilization was obtained 45.55 mm.

Santos et al. [18] obtained lower results for mean values of ear diameter without using green fertilization and without application of nitrogen in coverage, values of 44.00 and 44.70 mm, respectively. When using green fertilizer predecessors and nitrogen fertilization in coverage, the results were higher ranging between 45.30 and 47.80 mm for

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

Sources of variation	EL (cm)	ED (mm)	NGLE	NGE
Fertilizations (F)				
Organic (OF)	15.04 a	42.43 ab	13.70 a	439.22 a
Organomineral (OMF)	14.85 a	41.20 b	14.42 a	423.05 a
Mineral (MF)	15.54 a	43.22 a	13.62 a	437.40 a
Row spacing (RS)				
E1 (80 cm)	15.28 a	42.91 a	14.38 a	447.80 a
E2 (50 cm)	15.01 a	41.66 b	13.45 a	418.65 b
Values of F				
Fertilizations (F)	2.69^{ns}	6.57 *	0.76^{ns}	0.92^{ns}
Row Spacing (RS)	1.13^{ns}	7.50 **	2.55^{ns}	7.54 **
F x RS	1.86^{ns}	10.49 **	1.71^{ns}	4.31 *
Average	15.14	42.28	13.91	433.22
CV (%)	12.81	8.39	32.50	18.98

*Ear length (EL), ear diameter (ED), number of grains lines per ear (NGLE) and number of grains per ear (NGE). 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* ear diameter. Larger values were verified by [19] who evaluated the development of 30F80Y and 30K75Y YeldGard corn cultivars, and the conventional hybrids 30F80 and 30K75, with a population of 66,667 ha^{-1} plants and 90 cm row spacing, in the city of Santa Tereza do Oeste, Paraná. The research found average values of number of grains lines per ear that varied from 13.1 to 13.8. They also determined average values of number of grains per ear that varied from 463.0 to 481.0 depending on the corn variety.

From the splitting of interaction, the factor row spacing in each type of fertilization, the superiority of the mineral fertilization is verified in relation to the other fertilizations, which do not differ in the ear diameter of the plants spaced 80 cm between rows (Table 2). When comparing the values of 45.30 mm (MF) with 42.15 mm and 41.27 mm, it is observed that, although modest, the supremacy was 7.5% and 9.8%, respectively, on organic and the organomineral fertilizations. It was also verified that the plants of the row spacing 50 cm did not differ between the types of fertilizations.

Fertilizations types did not differ in the number of grains per ear at 80 cm (E1) row spacing, but the organic fertilization in plants spaced 50 cm (E2) between rows exceeded the organomineral fertilization plants by more than 13% (Table 2). In the evaluation of fertilizations in the two row spacing, it can be observed that, for the number of grains per ear, organic fertilization and mineral fertilization did not differ between plants spaced between 80 and 50 cm between rows. Concerning the organomineral fertilization with 50% of each type of fertilization, it is observed superiority of 14.8% of the plants in the row spacing of 80 cm in relation to the plants of 50cm between rows.

Santos et al. [18] found superior results for mean values of NGE with the predecessor green fertilizer called feijão-de-porco equal to 506.91 grains per ear. For the other green fertilizers, the NGE result was lower, ranging from 326.45 to 464.20, according to the fertilizer. [20] evaluated the effect of winter cover and soil mechanical decompaction on the performance of soybean and corn under no-tillage system. They used the hybrids D 766, in 2005/2006, and the hybrids P 3069, in 2006/2007, in row spacing of 45 and 90 cm, in the city of Eldorado do Sul, Rio Grande do Sul. Under these conditions, the authors obtained results with an average value of 270 grains per ear. [6] found higher mean values of NGE ranging from 477.6 to 531.15, according to the doses of N.

According to Table 3, the interaction between fertilizer types and row spacing had significant effects on mass of grains per ear, mass of ear with husk and mass of ear without husk, but the mass of 1000 grains and productivity was not influenced by any of the sources of variation studied. The average value of 130.06 g of M1000G is low compared to the variation of 313.0 to 324.0 g of M1000G obtained by [21] when evaluating different row spacing in corn crop, not verifying significant differences for this variable. In addition, [20] obtained results of mean values higher than 304 g of M1000G, but did not verify significant differences between the means as a function of the predecessor crop.

Productivity, as well as M1000G, was also not affected by any source of variation and the average value of 1492.13 kg ha^{-1} in the plants developed in the two row spacing studied was significantly lower than the range of 7109.0 to 7750.0 kg ha^{-1} of cultivar of corn denominated Impact, fertilized with N and K [22] in Alvorada do Sul, Paraná. It is also lower than the 4132.8 kg ha^{-1} harvested by [23] corn cultivar BR-206 fertilized with N, P and K in Quixadá, Ceará. However, a variable that has a great relation with productivity, the number of grains per ear, changed with significance as a function of the evaluated factors, which with the organic fertilization and the row spacing of 50 cm there was an increase in the number of grains per ear.

Table 2. Splitting of interaction between the factors fertilizations and row spacing

Fertilizations	ED (mm)		NGE	
	E1	E2	E1	E2
Organic (OF)	42.15 Ba	42.72 Aa	432.20 Aa	446.25 Aa
Organomineral (OMF)	41.27 Ba	41.13 Aa	452.25 Aa	393.85 Bb
Mineral (MF)	45.30 Aa	41.12 Ab	458.95 Aa	415.85 ABb

Ear diameter (ED) and number of grains per ear (NGE). Means followed by the same letter, uppercase in column and lowercase in row, do not differ by Tukey test at 5% probability

Table 3. Mean and the F values of biometric components and productivity that resulted from the analysis of variance

Sources of variation	MGE (g)	MEWH (g)	MENH (g)	M1000G (g)	P (kg ha^{-1})
Fertilizations (F)					
Organic (OF)	97.94 ab	147.12 ab	124.99 ab	126.98 a	1.578.56 a
Organomineral (OMF)	90.89 b	137.91 b	118.18 b	131.51 a	1.456.32 a
Mineral (MF)	108.74 a	161.46 a	138.09 a	131.70 a	1.441.52 a
Row spacing (RS)					
E1 (80 cm)	107.94 a	161.29 a	137.88 a	130.99 a	1.473.45 a
E2 (50 cm)	90.44 b	136. 37 b	116.29 b	129.14 a	1.510.81 a
Values of F					
Fertilizations (F)	7.39 **	7.07 **	6.61 **	0.58 ^{ns}	1.54 ^{ns}
Row Spacing (RS)	21.00 **	23.38 **	22.58 **	0.21 ^{ns}	0.28 ^{ns}
F x RS	7.97 **	9.89 **	9.32 **	0.86 ^{ns}	0.88 ^{ns}
Average	99.19	148.83	127.08	130.06	1.492.13
CV (%)	29.82	26.82	27.69	7.59	11.47

*Mass of grains per ear (MGE), mass of ear with husk (MEWH), mass of ear without husk (MENH), 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*

Santos et al. [24] obtained a lower mean of mass of grains per ear 112.87 g relative to the hybrids GNZ2728 and AG1051, mass of 111.04g for the cultivar BR2020 and 103.86 g corresponding to the cultivar BRS Caatingueiro. Values lower, comparatively, also for the varieties BR5037 Cruzeta, BR5011 Sertanejo and AL Bandeirantes, equivalent to 78.61, 83.74 and 89.47 g of mass of grains per ear, respectively. [25] evaluating the productive behavior of corn varieties and hybrids in the cities of Lagoa Seca and Puxinanã, Paraíba, aiming to identify the most promising ones, obtained mass of grains per ear ranging from 124.57 to 106.98 g and the lowest value was produced by the cultivar BRS Caatingueiro. [26] studying the effect of fertilization with bovine manure and chicken bed for the mass of grains per ear in Lagoa Seca, Paraíba, recorded a mean of 115.82g for the BRS Caatingueiro cultivar.

Santos et al. [27] after studying the behavior of corn varieties and hybrids in the swamp paraibano microregion, in the municipality of Lagoa Seca, found that the hybrid BRS2020, in the variable mass of grains per ear (188.45 g), was statistically better than the Jabatão variety (103.27 g), but did not differ from the other genotypes, with a general average of 143.30 g, obtaining values higher than those observed in Table 3, with an average of 99.19 g.

According to [28] smaller row spacings promote some potential advantages, among them can be cited the increase of productivity, due to a more equidistant distribution of plants in the area, increasing the efficiency of use of sunlight, water and nutrients and better plant control. Opposite results were verified by several authors who showed that the increase in row spacing resulted in a lower mass of ear with husk and mass of ear without husk, resulting in lower productivity [29,21].

According to [30] the increment of the grains yield with the reduction of the row spacing is attributed to the greater efficiency in the interception of radiation and to the decrease of competition between the plants in the row by light, water and nutrients, due to its distribution more equidistant from plants. Other factors can also be cited as the type of hybrid, plant population, climatic characteristics of the region and the level of soil fertility [31].

Analyzing the Splitting of interaction (Table 4), the factor row spacing on each type of fertilization, it is verified that for the row spacing of 80 cm there was a significant difference of the means in the different types of fertilizations with greater production of mass of grains per ear (MGE) 128.26 g using mineral fertilization. As for the row spacing of 50 cm there was no significant difference between the means according to the type of fertilization. As for the effects of fertilization on each row spacing, it was verified that for organic and organomineral fertilization, MGE values did not differ among them when compared to the spacing evaluated. However, for the mineral fertilization, the means differed according to the row spacing, being the spacing of 80 cm between rows which provided higher values of mass of grains per ear in this type of fertilization.

Table 4. Splitting of interaction between the factors fertilizations and row spacing

Fertilizations	MGE (g)	
	E1	E2
Organic (OF)	101.93 Ba	93.95 Aa
Organomineral (OMF)	93.64 Ba	88.14 Aa
Mineral (MF)	128.26 Aa	89.23 Ab

Mass of grains per ear (MGE). Means followed by the same letter, uppercase in column and lowercase in row, do not differ by Tukey test at 5% probability

Table 5. Splitting of interaction between the factors fertilizations and row spacing

Fertilizations	MEWH (g)		MENH (g)	
	E1	E2	E1	E2
Organic (OF)	150.63 Ba	143.62 Aa	129.32 Ba	120.66 Aa
Organomineral (OMF)	143.15 Ba	132.67 Aa	121.57 Ba	114.78 Aa
Mineral (MF)	190.10 Aa	132.82 Ab	162.75 Aa	113.42 Ab

Mass of ear with husk (MEWH) and mass of ear without husk (MENH). Means followed by the same letter, uppercase in column and lowercase in row, do not differ by Tukey test at 5% probability

Analyzing the Table 5, which has the splitting of interaction, in the factor row spacing according to each type of fertilization, it is verified that for the row spacing of 80 cm there was a significant difference of the means in the different types of fertilizations with greater mass of ear with husk (MEWH) and mass of ear without husk (MENH) of 190.10 and 162.75 g, respectively, using mineral fertilization. As for the row spacing of 50 cm, there was no significant difference between the means according to the type of fertilization. Analyzing the behavior of the fertilizations, in relation to both row spacing, it is verified that for the organic and organomineral fertilizations, the values of MEWH and MENH did not differ among themselves when compared the row spacing evaluated. As for mineral fertilization, the means differed according to the row spacing, being the row spacing of 80 cm which provided higher values with this type of fertilization. Therefore, in the mineral fertilization the highest values of MEWH and MENH were obtained with the row spacing of 80 cm, resulting in values of 190.10 and 162.75 g, respectively.

4. CONCLUSION

The variables: ear length, number of grains lines per ear and mass of 1000 grains were not significantly influenced by fertilizations and row spacing factors. The mineral fertilization associated with the row spacing of 80 cm was more efficient to the variables: ear diameter, mass of ear with husk, mass of ear without husk and mass of grains per ear. The types of fertilizations studied, regardless of row spacing, did not significantly interfere in the productivity of the Potiguar corn cultivar.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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