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Performance of irrigated green corn cultivars in different plant populations at sowing

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ABSTRACT
This study aimed to evaluate the yield of green corn hybrids grown under irrigation in different plant populations at sowing. The assay was carried out in the experimental area located in the city of Arapiraca, Alagoas State, Brazil, from November 2015 to January 2016. A randomized complete block design (RCBD) was used, in a 2 x 5 factorial scheme with four replicates. A double- and a single-cross hybrid (AG 1051 and BM 3061), which are suitable for green corn production, were cultivated in five spacings between plants at sowing (15.0, 17.5, 20.0, 22.5 and 25.0 cm). The characteristics photosynthetic rate (PR), ear length with rusk (HEL) and without husk (UEL), husked ear weight (HEW), unhusked ear weight (UEW), percentage of marketable ears (%ME) and weight of husk (HW) were evaluated. The double- and single-cross hybrids AG 1051 and BM 3061 showed green ears with commercial standard. The cultivar BM 3061 showed the best results for most of the characteristics related to the performance of green corn (PR, HEL, UEL, UEW, HEW, %ME). The spacing of 17.5 cm between plants at sowing was the most indicated for irrigated green corn cultivation.

Palavras-chave:
Zea mays
híbridos para milho-verde
densidades de plantas
produção de milho-verde

Desempenho de cultivares de milho verde irrigado em diferentes populações de plantas na semeadura

RESUMO
O trabalho objetivou avaliar a produtividade de híbridos de milho-verde sob irrigação cultivados em diferentes populações de plantas na semeadura. Foi conduzido na área experimental localizada no município de Arapiraca, AL, no período de novembro de 2015 a janeiro de 2016. O delineamento experimental utilizado foi em blocos casualizados, em esquema fatorial 2 x 5, com quatro repetições. Foram analisados dois híbridos, duplo e simples, indicados para milho verde (AG 1051 e BM 3061) e cinco espaçamentos entre plantas na semeadura (15,0; 17,5; 20,0; 22,5 e 25 cm). Foram avaliadas as características: taxa fotossintética (TF), comprimento de espigas com palha (CECP) e sem palha (CESP), peso de espigas com palhas (PECP) e sem palhas (PESP), porcentagem de espigar comerciais (%EC) e peso da palha (PP). Os híbridos duplo e simples, 1051 e BM 3061, apresentam espigas verdes com padrão comercial. A cultivar BM 3061 possui melhor desempenho para a maioria das características relacionadas ao desempenho da cultura (TF, CECP, CESP, PP, PECP, PESP, %EC). O espaçamento de 17,5 cm entre plantas na semeadura mostrou-se mais indicado para o cultivo do milho-verde irrigado.

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Introduction

Corn (*Zea mays* L.) has played an important socioeconomic role due to its agricultural aptitude and various applications in industries and animal feed (Oliveira Júnior et al., 2006). Besides being used for grains and silage, corn is commercialized in the beginning of the milky stage and in the beginning of the pasty stage of the grains for fresh consumption, in the form of ears, canned grains and its derivatives: 'pamonha', 'curau', juice, porridge, ice creams and cakes (Alves et al., 2004; Rodrigues et al., 2009).

Despite the importance, the producers cultivate green corn inadequately, without using hybrids indicated for this purpose and without the adequate plant population, or sowing density and, consequently, the final result reflects in the production of low-quality ears, decrease in the number of marketable ears per area and reduction of yield and profitability of the small rural producer (Almeida et al., 2000; Madalena et al., 2009; Vieira et al., 2010).

Like the choice of the correct hybrid, it is important to study the effect of sowing populations on the final quality of the ear. The companies indicate a spacing of 0.25 m, with plant populations at sowing ranging from 40 to 50 thousand plants ha^{-1}. The re-evaluation of recommendations of spacing and sowing densities for the corn crop through improvements for single or triple hybrids has become frequent, because the recommendation of specific populations can reach up to 100 thousand plants ha^{-1} (Brachtvogel et al., 2009; Assefa et al., 2012). However, it is necessary to evaluate if the reduction in sowing population affects the agronomic and physiological characteristics of green corn, especially the size of marketable ears.

Hence, this study aimed to evaluate the productive performance of corn hybrids indicated for green corn production at different spacings between plants at sowing.

Material and Methods

The study was carried out from November 2015 to January 2016 in an experimental area located in the municipality of Arapiraca, AL, Brazil, at the geographic coordinates of 9° 45' 58" S, 35° 38' 58" W and altitude of 264 m. Initially, the soil of the experimental area was collected and analyzed for interpretation, recommendation of correction and fertilization, taking as a reference the Agronomic Institute of Pernambuco. The experiment was conducted in soil classified as dystrophic Red Argisol (EMBRAPA, 2013). The results obtained with the chemical and physical analysis of the soil in this area (0-20 cm depth) were: pH in H_2O = 5.6; P = 11.0 mg dm^{-3}; K = 109 mg dm^{-3}; Ca = 14 $mmol_c$ dm^{-3}; Mg = 8 $mmol_c$ dm^{-3}; V% = 67.8; organic matter = 10.7 g kg^{-1}; Zn^{2+}= 2.8 mg dm^{-3}; Mn^{2+} = 39.7 mg dm^{-3}; Cu^{2+} = 0.7 mg dm^{-3}; Fe^{2+} = 66.2 mg dm^{-3}; and contents of sand, silt and clay of 82.6, 7.0 and 10.4%, respectively.

The experiment was set in randomized blocks in a 2 x 5 factorial scheme, with two hybrids recommended by the producers and companies for the production of green corn. Both cultivars are indicated for the consumption of green corn, AG 1051 and BM 3061. The five spacings between plants at sowing of green corn were: 15.0; 17.5; 20.0; 22.5 and 25.0 cm, equivalent to 83,333, 71,429, 62,500, 55,555 and 50,000 plants ha^{-1}, respectively.

The plots were composed of four 2.4-m-long rows, at spacing of 0.80 m between rows and plant population at sowing according to the respective treatment. Each plot varied from 32 to 53 plants, according to the plant population at sowing of each treatment. However, the two central rows were used as the evaluation area, considering 10 plants per plot as the material of study.

The soil of the experimental area was prepared through one plowing and two harrowings. Planting furrows with depth of 0.10 m were open. On the same day of sowing, basal fertilization was applied in the furrows, using 50 kg ha^{-1} of the NPK formulation (4-14-8), based on the soil analysis and recommendations of IPA (2008) for the Pernambuco state.

Sowing was manually performed on November 10, 2015, using two seeds per hole at 0.05 m above and 0.05 m beside the fertilizer. Eight days after sowing (DAS), thinning was performed, leaving only the most developed and vigorous plant per hole.

Top-dressing fertilization was manually performed in the furrows, 15 cm away from the plant rows and incorporated at depth of 5 cm, split into two applications: when plants achieved the phenological stage V5, at 21 DAS, and in the phenological stage V8, at 34 DAS, with the application of 50 kg ha^{-1} of nitrogen in the form of urea and 40 kg ha^{-1} of potassium as potassium sulfate, for each period.

Drip irrigation was adopted in the experiment, with water management based on crop evapotranspiration. Reference evapotranspiration was determined by the Penmann-Monteith method, while the crop coefficient (Kc) was determined according to the indications of Doorenbos & Kassam (1979) for the corn crop.

Weeds were controlled according to the needs of the crop, through manual weedings, while pest control was performed using an organophosphate chemical product, at the dose of 0.192 g ha^{-1} of Chlorpyrifos dissolved in 200 L, which was sprayed using a backpack sprayer and a personal protective equipment - PPE. Three applications were performed, at 20, 31 and 56 DAS.

Green corn ears were manually collected when they showed moisture content of about 70 to 80% at 72 and 74 DAS, which corresponded to approximately 20 and 25 days after female flowering or beginning of the milky stage and beginning of pasty stage of the grains.

The evaluated characteristics were: photosynthetic rate; ear length; husked and unhusked ear weight; percentage and yield of marketable ears.

The photosynthetic rate was measured at 55 DAS using an infrared gas analyzer (IRGA LI -6400XT Bioscience, Lincoln, NE, USA), in leaves still attached to the plants (non-destructive method), totaling two plants per plot, between 9 and 12 a.m., by sampling the first leaf opposite and below the ear. The results were expressed in μmol m^{-2} s^{-1}.

Husked and unhusked ear weights (g) were evaluated after harvest. The ears were transported to the laboratory and then weighed on a precision scale (Marte Científica AD3300), with two decimal places.

Husk weight (g) was determined by subtracting the husked ear weight from the unhusked ear weight.

Husked and unhusked ear lengths (cm) were measured using a 0.30-m-long ruler, considering the length from the base to the apex of the ear. Then, the husk was removed for the determination of husked ear length.

The percentage of marketable ears was estimated based on the ratio between the number of ears with length greater than 15 cm, those with length greater than 18 cm and diameter greater than 3 cm, and the total number of ears in the plot.

The data were subjected to analysis of variance using the statistical program Sisvar (Ferreira, 2011). The means were compared through regression analysis ($p < 0.05$) for the factor plant population at sowing and Scott-Knott test for the factor cultivar.

Results and Discussion

Table 1 shows the values of photosynthetic rate for the interaction between cultivar and plant populations considering the spacings between plants of 17.5 and 25.0 cm. The analyzed corn hybrids showed differences and the hybrid AG 1051 exhibited the highest results, 10.19% more at the spacing of 17.5 cm and 19.64% at spacing of 25 cm.

Different results were found by Gomes et al. (2011), who observed that the photosynthetic rates did not differ significantly as a function of the utilized plant spacings, obtained in the plant populations at sowing of 100,000, 71,428 and 55,555 plants ha^{-1}, 43.80, 51.52 and 50.40 µmol m^{-2} s^{-1} respectively, which are higher than those observed in the present study.

There are only a few studies correlating plant populations at sowing with the photosynthetic rate of the plant. However, the high photosynthetic rates are attributed to the high daytime temperatures (28-32 °C) (Durães, 2007). Regarding the reduction of photosynthetic rate, Cruz et al. (2009) claim that this fact occurs because of the water deficit, which affects plant metabolism and stomatal closure.

The results of the characteristics husked ear weight and husk weight for the factor hybrid can be viewed in Table 2.

Table 1. Photosynthetic rate (PR) for the interaction between cultivars and population densities of 71,429 and 50,000 plants in the irrigated cultivation of green corn

Hybrid	PR (μmol m^{-2} s^{-1})	
	Population spacings (cm)	
	17.5	25.0
AG 1051	34.75 aA	33.20 aA
BM 3061	31.21 bA	26.68 bB

Means followed by the same letters, lowercase in the column and uppercase in the row, belong to the same group, by the Scott-Knott test at 0.05 probability level

There was effect between hybrids and BM 3061 was the most productive, with mean ear weight of 329.35 g and husk weight of 127.83 g, superior to that of the hybrid AG 1051 (308.77 g ear^{-1} and 114.36 g $husk^{-1}$).

The hybrid BM 3061 has higher ear weight because of its husk cover, an important aspect to be considered in relation to green corn, because, besides preserving the ears, it favors the maintenance of grain moisture, which results in longer time of market (Albuquerque et al., 2008). In addition, it is a significant factor in the management of fall armyworm, because cultivars well covered by the husk are less damaged by this pest (Pereira Filho, 2002).

As to ear weight, Rocha (2008) observed different results, in which the hybrid BM 3061 showed lower weight (319 g) in comparison to AG 1051 (324 g). Pinho et al. (2008) also highlight that the cultivar AG 1051 exhibited the highest result for the conventional planting (420.15 g), 26.63% more in comparison to the cultivar VIVI (308.26 g).

For husk weight, Pinho et al. (2008) obtained a value of 146.01 g with the hybrid AG 1051, which differs from that of the present study, in which the highest result was obtained by the hybrid BM 3061 (127.83 g).

For unhusked ear length (UEL) and husked ear length (HEL) (Table 2), there were differences between the evaluated hybrids. The hybrid BM 3061 showed higher means, with values of 29.09 and 19.17 cm respectively. The hybrid AG 1051 exhibited values of 27.80 and 18.17 cm, for UEL and HEL, respectively.

Marketable ears with husk were considered as those with length greater than 25 cm and diameter greater than 5 cm, and for those without husk, length greater than 15 cm and diameter greater than 5 cm (Rocha, 2008). Hence, it is observed that the hybrids used in the present study fulfill these requirements, because they showed lengths greater than 15 cm for ears without husk and greater than 20 cm for ears with husk.

Albuquerque et al. (2008), evaluating the performance of 32 experimental hybrids and 4 commercial cultivars for the production of green corn, claim that, in order to consider ears without husk as marketable, they must have length and diameter greater than 15 and 3 cm.

Vieira et al. (2010) analyzed the aptitude of hybrids (Penta, 30P34, DKB 214 and SWB 551) and the effect of plant population (3.5; 5.0; 6.5; 8.0 and 9.5 plants m^{-2}) on the production of green corn and observed means of 30.22 cm for ear with husk for DKB 214. Rocha et al. (2011) obtained the highest means of ears without husk with the hybrids AG 1051, P3232, BM 3061 and AG 4051, and lengths of 17.7, 17.6, 17.2 and 17.2 cm, respectively.

Table 2. Unhusked ear weight (UEW), husked ear weight (HEW), husk weight (HW), unhusked ear length (UEL), husked ear length (HEL), and percentage of marketable ears (%ME) in the irrigated green corn cultivars

Hybrid	Evaluated characteristics					
	UEW	HEW	HW	UEL	HEL	%ME
		(g)		(cm)		
AG1051	308.77 b	194.41 a	114.36 b	27.80 b	18.17 b	63.50 b
BM3061	329.35 a	201.52 a	127.83 a	29.09 a	19.17 a	76.00 a
CV (%)	8.11	8.27	11.38	4.20	3.64	20.55

Means followed by the same letters in the columns do not differ by Scott-Knott test at 0.05 probability level

For the percentage of marketable ears (%ME), the cultivar BM 3061 showed the highest results (76%), surpassing the hybrid AG 1051 with percentage of 63.50% (Table 2).

Different results were observed by Moraes et al. (2010), they obtained the highest mean with the corn hybrid AG 4051 (80%) and the lowest one (69%) with AS 1592, and by Grigulo et al. (2011), who obtained 97.60 and 91.60% with the cultivars PL 6882 and AG 1051, respectively. Like the present study, Oliveira Júnior et al. (2006), obtained 74.79% of marketable ears with the genotype C43.

In relation to %ME, it is important to point out that, for the production of green corn, it is desirable to obtain high percentage of marketable ears, because this attribute is directly related to the commercialization of corn.

Figure 1 shows the regression equation for unhusked ear weight (UEW) (Figure 1A) and husked ear weight (HEW) (Figure 1B). The quadratic model was the one that best fitted to the data for both characteristics. The maximum unhusked ear weight was obtained at the spacing of 24.47 cm, with value of 353.6 g. The maximum husked ear weight was also obtained at the spacing of 24.63 cm, which led to 218.38 g per ear.

For husked ear weight, Rocha (2008) observed that the cultivars suffered reduction in ear weight when the plant population increased from 30 to 60 thousand plants, with decrease of 690 g, differing from the results found in the present study.

Plant population interferes with the performance of the corn crop when intended for the commercialization of green ears, because the higher the population density, the lower the length, reflecting in ears with low weights, since the denser cultivation favors competition between plants for incident solar radiation, nutrients and water, negatively acting on crop yield (Sangoi et al., 2000).

Figure 2 presents the regression equation for the values of husked ear length (HEL) (Figure 2A) and percentage of marketable ears (%ME) (Figure 2B) as a function of the different spacings between plants. The quadratic model fitted to the data of both characteristics. The maximum ear length of 19.35 cm was obtained for the spacing of 23.27 cm, while the maximum percentage of marketable ears (84.18%) was achieved at the spacing of 22.92 cm.

Different results for HEL were obtained by Barbosa (2011), who observed linear behavior for this characteristic, with decrease of 0.023 cm in ear length for every increase of a thousand plants, which was also observed by Marchão et al. (2005), who reported decrease of 0.057 for every increase of a thousand plants.

With the increase in plant population, there may be competition for water, light and nutrients and less photosynthesis, due to the effect of self-shading by the leaves of corn plants and, consequently, promote the shorter ear length,

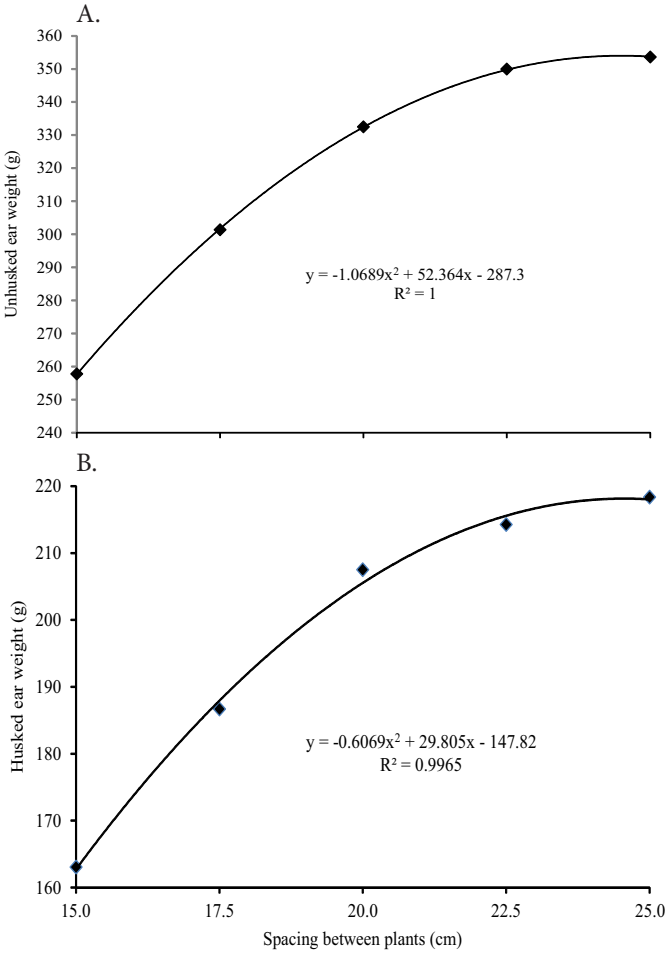

Figure 1. Unhusked ear weight (UEW) (A) and husked ear weight (HEW) (B) for the performance of irrigated green corn cultivars at different sowing densities

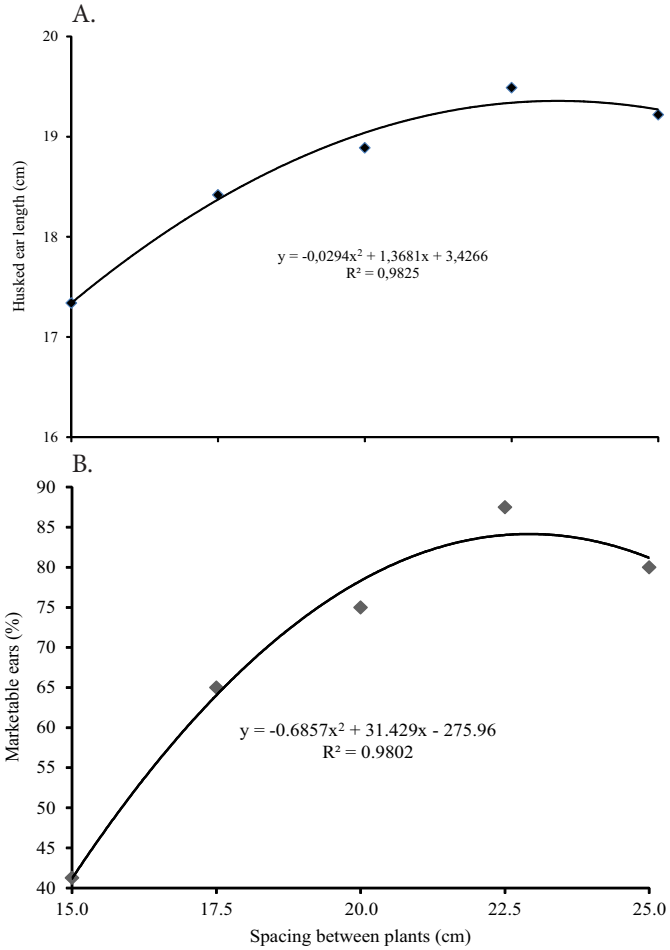

Figure 2. Husked ear length (HEL) (A) and percentage of marketable ears (%ME) (B) for the performance of irrigated green corn cultivars at different sowing densities

according to Argenta et al. (2001). An ideal plant population at sowing is the one that favors higher production of marketable ears and not the one that increments only the total production of ears (Paiva Júnior et al., 2001).

For the percentage of marketable ears, Vieira et al. (2010) obtained linear response as the plant population at sowing increased, with decrease of approximately 15.85% when the population varied from 3.5 to 9.5 plants m^{-1}.

It is notorious that the increase in plant population promotes satisfactory increments in yield; however, for green corn, without husk, this aspect produces a negative effect, because of the competition between plants (Taiz & Zeiger, 2002).

Conclusions

1. The hybrids AG 1051 and BM 3061 have green ears with length and diameter adequate for the commercial standard.

2. The hybrid BM 3061 showed the best results for most characteristics related to the performance of green corn production.

3. The spacing of 17.5 cm between plants at sowing proved to be the most indicated for irrigated green corn cultivation under the edaphoclimatic conditions of Arapiraca.

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