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PRODUCTION INDICATORS OF GREEN CORN CULTIVARS AT DIFFERENT POPULATION DENSITIES[1]

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ABSTRACT - Specific cultivars for production of green corn, more productive and adapted to the conditions of each region, combined with adequate population density, can increase the yield of the crop. This work aimed to identify, under different plant densities, the cultivars with agronomic characteristics for the production of green corn. The experiment was conducted from March to June 2018, in the experimental area of the Technical College of Teresina, at the Federal University of Piauí. The treatments were distributed in a randomized block design, in a factorial scheme, with three plant densities (40,000, 50,000 and 60,000 plants ha^{-1}) and two corn cultivars (AG 1051 and BRS 3046). The variables evaluated were the diameter and length of the commercial green ear, the yield, the percentage of commercial green ear and the length of the period between the emergence (VE) and the flowering stage (VT) of the cultivars in relation to the accumulated number of degree-days (ADD). In terms of cycle (period between VE and VT), the hybrid AG 1051 was later, with 47 days after emergence (DAE) and 823.23 ADD, than the BRS 3046 (44 DAE and 773.32 ADD); however, there was an acceleration of the period of vegetative development in the hybrids, which ranged from 43 (773.32 ADD) to 47 (828.23 ADD) days, respectively, so that there was male flowering. With the increase in densities, there was decrease in the values of production. The highest yield of commercial ears (15.45 Mg ha-1) was obtained at a density of 50,000 plants ha^{-1}.

Keywords: *Zea mays* L. Phenology. Degrees-days.

INDICADORES PRODUTIVOS DE CULTIVARES DE MILHO VERDE EM DIFERENTES DENSIDADES POPULACIONAIS

RESUMO - Cultivares específicas para produção de milho verde, mais produtivas e adaptadas às condições de cada região, aliada à adequada densidade populacional podem aumentar a produtividade da cultura. O objetivo deste trabalho foi, portanto, identificar, sob diferentes densidades de plantas, a cultivar com características agronômicas mais adequadas para produção de milho verde no município de Teresina, Piauí. O experimento foi conduzido no período de março a junho de 2018, na área experimental do Colégio Técnico de Teresina, da Universidade Federal do Piauí. Os tratamentos foram distribuídos em delineamento experimental de blocos casualizados, em esquema fatorial, com três densidades de plantas (40.000, 50.000 e 60.000 plantas ha^{-1}) e duas cultivares de milho (AG 1051 e BRS 3046). Foram avaliados o diâmetro e o comprimento da espiga verde comercial, a produtividade, a porcentagem de espigas verdes comerciais e a duração do período entre a emergência (VE) e o pendoamento (VT) das cultivares em relação à quantidade acumulada de graus-dias (GDA). Em termos de ciclo (período entre VE e VT), o híbrido AG 1051 foi mais tardio, com 47 dias após a emergência (DAE) e 823,23 GDA, que o BRS 3046 (44 DAE e 773,32 GDA), havendo, todavia, aceleração do período de desenvolvimento vegetativo nos dois híbridos, que variou de 43 DAE (773,32 GDA) a 47 DAE (828,23 GDA), respectivamente, para que houvesse o pendoamento. Com o incremento das densidades, houve um decréscimo nos valores das variáveis de produção. A maior produtividade de espigas comerciais (15,45 Mg ha^{-1}) foi obtida na densidade de 50.000 plantas ha^{-1}.

Palavras-chave: *Zea mays* L. Fenologia. Graus-dias.

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INTRODUCTION

Corn is one of the main crops produced and consumed in Brazil as well as in the world. In Brazil, the estimate of total corn production is over 4,709 kg ha^{-1} (CONAB, 2021). Its economic importance is characterized by the several forms of use in human and animal diets due to its production potential, chemical composition and nutritional value (ROCHA; FORNASIER FILHO; BARBOSA, 2011).

Although most of the corn production in the world is aimed at grain production (SOUSA, 2020), the cultivation of this species for green corn production has been increasing significantly, especially in the Northeast Region of Brazil, where cultivation occurs all year round, even under irrigation conditions (ROCHA; FORNASIER FILHO; BARBOSA, 2011; NASCIMENTO et al., 2017). However, this crop still has low yield in the region (CALDARELLI; BACCHI, 2012), and it is directly or indirectly influenced by several factors related to the plant and the environment.

Among the main factors, the climate, genetic potential of the cultivar, fertilizer management, soil fertility and planting density stand out (VALDERRAMA et al., 2011; DANTAS JUNIOR et al., 2016; MARENGO et al., 2016). According to Horbe (2014), plant arrangement is one of the factors that most affect corn yield because the crop produces one ear per plant and due to its high sensitivity to intraspecific competition. Therefore, changes in the planting arrangement can occur through alterations in the plant population from adjustments in the spacing between rows and/or between plants.

From the climatic factors, air temperature is one of the main limiting factors to the agronomic performance of corn (OLIVEIRA et al., 2016), influencing the plant cycle. Its phenological stages are determined by the number of daily heat hours, expressed in degree days (DD). When cultivars do not reach the required heat sums (accumulated degree days - ADD), there is an extension or reduction of the vegetative stage, compromising grain yield (ZUCARELI et al., 2010).

The use of specific cultivars for green corn production, productive and adapted to the conditions of each region, combined with adequate population density, can therefore be an important action to increase the yield of the crop. According to Fancelli (2015), the best use of solar radiation can be achieved by better spatial distribution of plants in the area, through suitable combinations between row spacing and the number of plants in the row. It is worth noting that, although the increasing density of corn plants can promote increase in yield, this potential is limited due to the low plasticity of leaf and monoecious reproductive structure, with competition of its inflorescences for photoassimilates (SANGOI et al., 2011).

Among the genetic materials traditionally adopted in local cultivation, the hybrid AG1051 has been widely used in family farming, standing out for its good yield results, both for silage and for green corn. It is the preferred by producers to obtain green ears, due to its uniformity of maturation and great acceptance by consumers, besides reaching a production from 335 to 550 25 kg bags and a population of 45 to 50 thousand plants per hectare (ARAÚJO et al., 2014; SEMENTES AGROCERES, 2014).

When evaluating the green corn yield of six cultivars at different planting densities, Rocha, Fornasier Filho and Barbosa (2011) observed that, although the hybrid AG 1051 responded positively to the density increment, it reached maximum yield in the treatment of 50,000 plants ha^{-1}, and this value decreased at the density of 60,000 plants ha^{-1}.

Another cultivar recommended for green corn production is BRS 3046, a triple hybrid, known as *Saboroso* (tasty), which can also be used for grain and silage production, in a population of 40,000 to 45,000 plants per hectare (EMBRAPA, 2018). Its yield, according to Carvalho et al. (2020), is influenced by the reduction of the spacing between rows, being more advantageous when this reduction is associated with higher planting densities (up to 80,000 plants ha^{-1}).

The aim of this work was to identify, under different plant densities, the cultivar with the most suitable agronomic characteristics for green corn production in the municipality of Teresina, Piauí, Brazil.

MATERIALS AND METHODS

This experiment was conducted from March to June 2018, in the experimental area of the Technical College of Teresina (CTT) of the Federal University of Piauí (UFPI), municipality of Teresina - PI, Brazil (05º05' 2" S; 42º48'42" W and 72 m altitude). The climate of the municipality, according to Köppen's climate classification, is Aw' (hot tropical sub-humid) with two defined seasons, dry season from June to November and rainy season from December to May (ANDRADE JÚNIOR et al., 2004). The rainfall is concentrated in the months from January to April, with an average annual precipitation of 1,393.2 mm, an average annual air temperature of 27.1 °C and an average annual relative humidity of 70% (INMET, 2009). During the research period, average weekly temperatures were recorded around 27.6 °C (minimum of 24.4 °C and maximum of 30.8 °C) and accumulated precipitation of 675.9 mm (Figure 1), by means of a meteorological station installed at the CTT/UFPI.

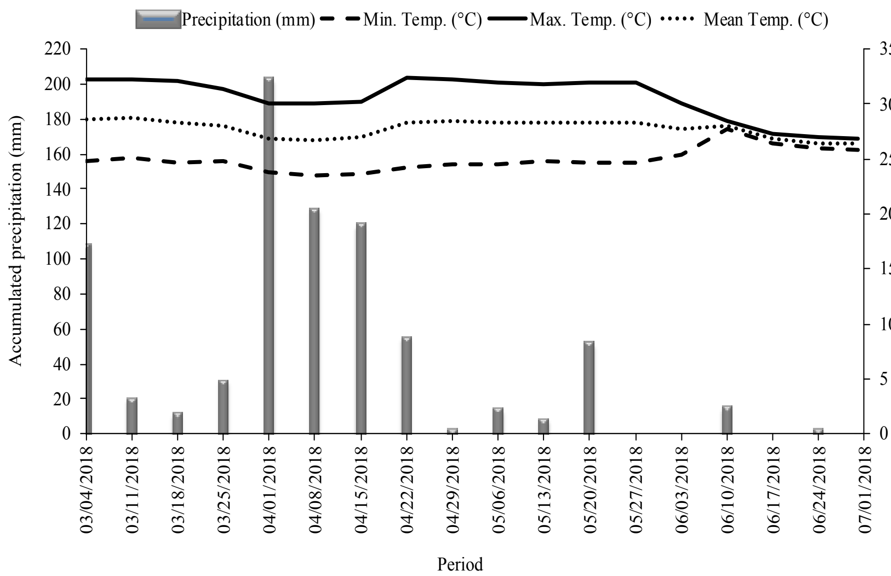

Figure 1. Accumulated precipitation and average weekly temperature corresponding to the period from March to June 2018.

In the soil of the experimental area, classified as Argissolo Vermelho-Amarelo (Ultisol) (EMBRAPA, 2013), with sandy texture and gently undulating relief, the following chemical characteristics were observed in the 0-20 cm layer: pH: 6.8; P: 17.0 mg dm^{-3}; K: 0.16 cmolc dm^{-3}; Ca: 2.0 cmolc dm^{-3}; Mg: 0.7 cmolc dm^{-3}; Al: 0 cmolc dm^{-3}; H+Al: 1.3 cmolc dm^{-3} and organic matter: 2.1%.

The treatments were distributed in a randomized block experimental design, in a 3 x 2 factorial scheme, with four repetitions, with three plant densities (40,000, 50,000 and 60,000 plants ha^{-1}) and two corn cultivars, a double hybrid (AG 1051) and a triple hybrid (BRS 3046). Each plot was made up of ten rows, five meters long each and spaced at 0.6 m apart. In order to obtain the data, the two central rows of each plot were considered as usable area, disregarding the last two plants at the beginning and end of each row.

The double hybrid AG 1051 has a semi-early cycle, high stature and planting flexibility in all regions of Brazil, both for silage, with high production of green mass and protein, and for green corn, due to its uniform maturation and great acceptance in the consumer market (SEMENTES AGROCERES, 2014). On the other hand, the triple hybrid BRS 3046 has a super-early cycle, with male flowering in 60.5 days, dented grains and large and well-stuffed spikes, and depending on weather conditions, with a harvest window of around five days (EMBRAPA, 2018).

Soil acidity correction was performed in March 2017, when the base saturation was raised to 65% by applying 2.0 t ha^{-1} of dolomitic limestone with 13% MgO, 38% CaO and relative total neutralizing power (RTNP) of 90%. At planting, manual fertilization with NPK was performed in the whole area, applying 20 kg ha^{-1} of nitrogen (N), 120 kg ha^{-1} of P_2O_5 and 60 kg ha^{-1} of K_2O in 15-cm-deep furrows. The sources used were ammonium sulfate (20% N), single superphosphate (18% P_2O_5) and potassium chloride (60% K_2O). Two manual fertilizers were applied as top-dressing, the first with 40 kg ha^{-1} of N and 60 kg ha^{-1} of K_2O, using ammonium sulfate and potassium chloride, respectively, when the plant had 4 to 5 true leaves, and the second, with 60 kg ha^{-1} of N, in the form of urea (45% N) at the stage of 8 to 10 fully developed leaves.

The soil preparation system adopted was conventional, through one plowing and two harrowing operations. The cultivars were sown by hand, with two corn seeds per hole, with distances between plants of 42, 33, and 28 cm, corresponding to the densities established in the treatments (40,000, 50,000, and 60,000 plants ha^{-1}, respectively). Thinning was performed 15 days after emergence (DAE), when the plants had two to three fully expanded leaves, leaving one plant per hole.

The crop was kept free of weeds by using the pre-emergent herbicide Primestra Gold, based on S-metolachlor (290 g L^{-1} active ingredient - a.i.) + atrazine (370 g L^{-1} a.i.), at a dose of 4.0 L ha^{-1}, applied immediately after corn sowing. In addition, manual weeding was performed, complementarily, between the rows, according to the emergence of some weeds in the area. The herbicide was applied using a CO_2-pressurized knapsack sprayer, with a spray volume equivalent to 400 L ha^{-1}.

Harvest was performed manually, approximately 64 days after planting, when 50% of the ears in the field reached the milky grain stage (R3), with approximately 70 to 80% moisture.

The following parameters were evaluated in all plants in the usable area of each plot: diameter of the middle portion of the commercial green ears with straw (DIAM, cm), with the aid of a caliper; length of the commercial green ear with straw (LENGTH, cm) determined from the base to the final end, by using a ruler graduated in millimeters; yield (YLD, Mg ha^{-1}) by means of the average weight of ears produced in each plot, extrapolating the result to the total yield of ears per treatment; and percentage of commercial green ears with straw (%CGE), by the ratio between the number of commercial ears and the total number of ears. Commercial ears were considered as those with size greater than 15 cm in length and diameter greater than three centimeters, with grains, free of damage from pests and diseases (ALBUQUERQUE; VON PINHO; SILVA, 2008).

The duration of the period between plant emergence (VE) and tasseling (VT) of the cultivars was also evaluated, regarding the accumulated degree-days (ADD), determining the male and female flowering (R1) when more than 50% of the plants in the usable area of each plot had the tassel releasing pollen and emergence of the style-stigma. To calculate the daily temperature sum, in degree days (ºC day), the following formula was used: $DD = \{(T + t)/2\} - 10$; where T = maximum temperature; t = minimum temperature and 10 = minimum basal temperature. The accumulated thermal sum (ºC day), from emergence to male and female flowering, was calculated using the equation: $ADD=\Sigma DD$, classifying the hybrids as super-early and early cycle. Maximum temperatures equal to or greater than 30 ºC were considered as 30 ºC, minimum temperatures equal to or lower than 10 ºC were considered as 10 ºC (EMBRAPA, 1993).

The data obtained were subjected to analysis of variance by the F test and the means were compared by Tukey test at 5% probability level, using the SISVAR program version 5.6 (FERREIRA, 2011).

RESULTS AND DISCUSSION

Phenological cycle

For the periods between VE-VT and VE-R1, based on DAE and ADD, there was no significant interaction ($p>0.05$) among treatments, but individual effects of cultivars and plant densities on these variables were observed (Table 1).

Regarding cultivars, it is observed that the ADD required for male and female flowering significantly varied among hybrids, regardless of plant densities (Table 2).

Table 1. Mean squares for male (VT) and female (R1) flowering variables, in days after emergence (DAE) and accumulated degree days (ADD) of corn cultivars subjected to different plant densities.

Sources of variation	VT		R1	
	DAE	ADD	DAE	ADD
Cultivars (C)	60.17**	20,239.14**	60.17**	20,224.62**
Densities (D)	7.17**	2,419.23**	2.54**	854.05**
C x D	1.17^{NS}	389.50^{NS}	0.54^{NS}	183.44^{NS}
Blocks	28.00**	9,394.43**	37.67**	12,592.55**
CV (%)[1]	2.20	2.20	1.10	1.10

[1]Coefficient of variation. *, ** and NS: significant ($p<0.05$ and $p<0.01$) and not significant, respectively.

Table 2. Male (VT) and female (R1) flowering, in days after emergence (DAE) and accumulated degree days (ADD), of corn cultivars.

Cultivars	VT		R1	
	DAE	ADD	DAE	ADD
AG 1051	46.92 a*	828.23 a	49.42 a	870.48 a
BRS 3046	43.75 b	773.32 b	46.25 b	822.18 b

*Means followed by the same letter in the column do not differ by Tukey's test at 5% probability level.

According to Table 2, it is also noted that there was an acceleration of the vegetative development period in both evaluated hybrids, ranging from 44 DAE (773.32 ADD) to 47 DAE (828.23 ADD) for VT to occur. The flowering of a super-early cultivar in the favorable period is around 60 DAE (FERREIRA; RESENDE, 2009; EMBRAPA, 2018). According to Zucareli et al. (2010), corn is a crop whose complete cycle is extremely variable, depending on the genotype and the environmental conditions that occur during its development stages, and the cycle is mainly influenced by temperature, as the corn plant needs to accumulate distinct amounts of caloric units required for each stage of growth and development, for each cultivar, and the phenological stages are determined by the number of daily heat hours (Figure 2). When these cultivars do not reach the required heat sums, the vegetative stage is prolonged or reduced, compromising yield in both situations.

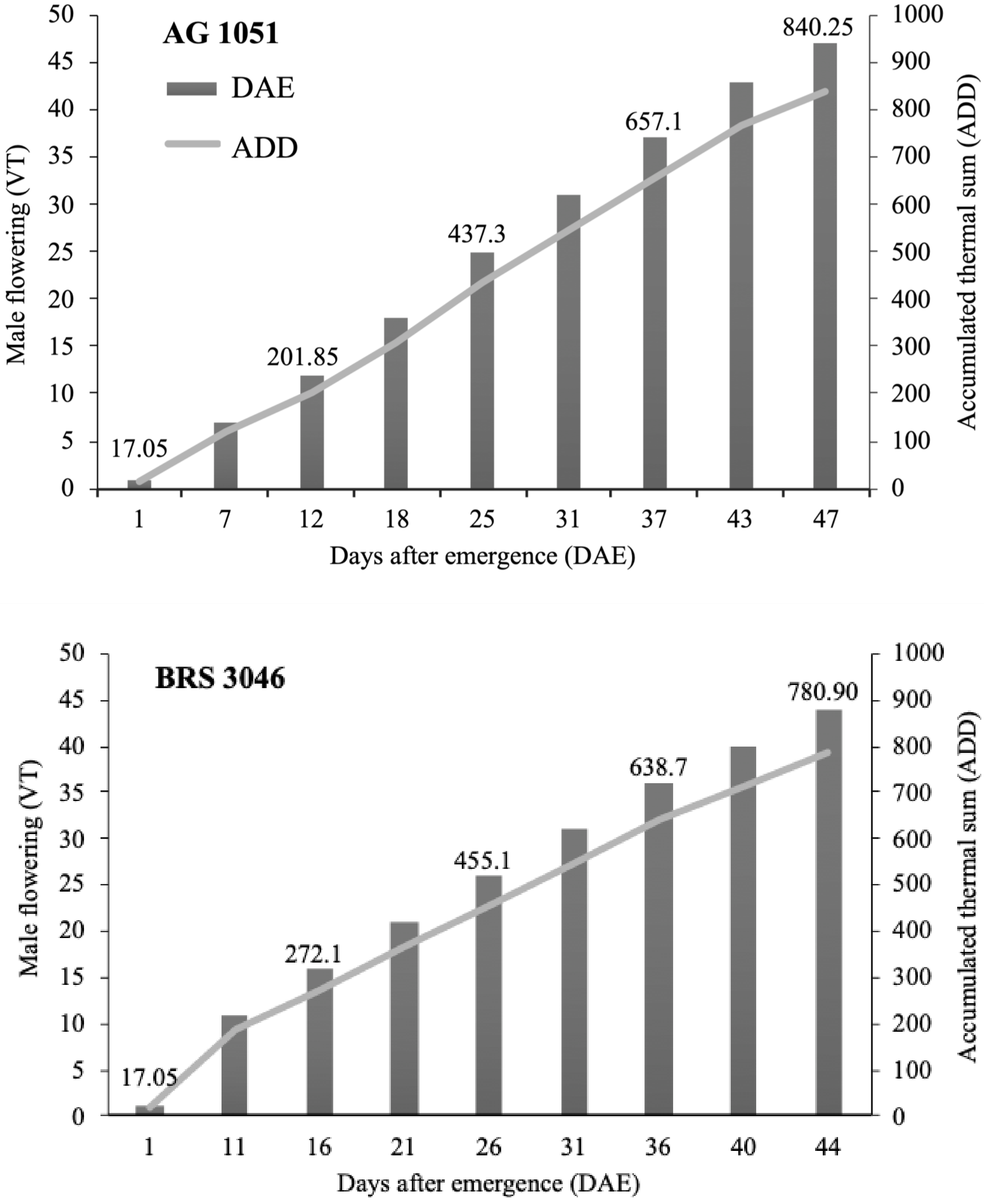

Figure 2. Accumulated degree days between the emergence (VE) and male flowering (VT) of the corn cultivars AG 1051 and BRS 3046.

It can also be observed that the hybrid AG 1051 was later (47 DAE and 838.98 ADD) than BRS 3046 (44 DAE and 780.90 ADD), in the period between VE and VT (Figure 2), as well as in the period between VE and R1. BRS 3046 can be classified as super-early based on the criteria presented by Cruz and Magalhães (2010), and according to them, corn cultivars are grouped according to the plant cycle as super-early, early and normal and, theoretically, have thermal requirements, in the phenological stage between VE and the beginning of pollination, lower than 830 ADD, from 830 to 890 ADD and higher than 890 ADD, respectively. However, considering data from crop seasons and information from corn seed companies themselves, these authors verified that the super-early cultivars had average heat requirements of 811 ADD, the early cultivars, 847 ADD, the semi-early cultivars, 898 ADD and the normal cultivars, 885 ADD.

For the plant densities, a difference was verified ($p<0.05$) only between the density of 40,000 plants ha^{-1} and the others (Table 3), which did not differ for the male flowering of corn. However, in female flowering there was a difference ($p<0.05$) between the density of 40,000 plants ha^{-1} and the density of 60,000 plants ha^{-1}, with cultivars showing later flowering cycles at the density of 60,000 plants ha^{-1}, both in VT and in R1, and the greatest variation in the amount of ADD required for VT and R1 of the hybrids was observed at the density of 50,000 plants ha^{-1}. According to Rocha, Fornasier Filho and Barbosa (2011), the duration between the VE and VT periods increases concomitantly with the increase in plant density, certainly due to competition between plants, resulting in a delay in the stages of development.

Table 3. Male (VT) and female (R1) flowering, in days after emergence (DAE) and accumulated degree days (ADD), as a function of corn plant densities.

Plant densities (plants ha^{-1})	VT		R1	
	DAE	ADD	DAE	ADD
40,000	44.25 b*	785.80 b	47.25 b	831.32 b
50,000	45.75 a	803.70 a	47.85 ab	849.30 ab
60,000	46.00 a	812.95 a	48.37 a	858.37 a

*Means followed by the same letter in the column do not differ by Tukey's test at 5% probability level.

3.2 Production potential

To the production characteristics (LENGTH, DIAM, YLD and %CGE), there was no significant interaction ($p>0.05$) between the factors cultivars and densities, and there were only individual effects ($p<0.01$) of plant densities for LENGTH, DIAM, YLD and %CGE, and of cultivars only for DIAM (Table 4).

Table 4. Mean squares for the variables length (LENGTH) and diameter (DIAM) of green ears, yield (YLD) and percentage of commercial green ears with straw (%CGE), of corn cultivars subjected to different plant densities.

Sources of variation	LENGTH	DIAM	YLD	%CGE
	------------ cm	------------	--- Mg ha^{-1} ---	---- % ----
Cultivars (C)	3.95^{NS}	0.28**	9,275,266.67^{NS}	5.34^{NS}
Densities (D)	11.04**	0.21**	40,051,266.67**	1,215.44**
C x D	1.27^{NS}	0.01^{NS}	2,403,216.67^{NS}	2.84^{NS}
Blocks	3.31^{NS}	0.02^{NS}	1,695,588.89^{NS}	4.69^{NS}
CV (%)[1]	3.28	1.63	11.38	4.36

[1]Coefficient of variation. *, ** and NS: significant ($p<0.05$ and $p<0.01$) and not significant, respectively.

The length of commercial ears of AG 1051 and BRS 3046 decreased with the increase of plant density to 60,000 plants ha^{-1} (Table 5). With this density, there was an average reduction of 1.8 cm in length compared to that observed at densities of 40,000 and 50,000 plants ha^{-1}, probably because it exceeded the appropriate plant population for these hybrids. Similar results were observed by Rocha, Fornasier Filho and Barbosa (2011) for the cultivar AG 1051, which stood out with ear length (27.44 cm) greater than those of the others tested (Cativerde 2 and SWB 551) at density of 40,000 plants ha^{-1}, with a reduction in ear length with the increase in plant densities of 50,000 and 60,000 plants ha^{-1}. These authors suggested that at higher densities there was a tendency to lower production of commercial standard ears, because each plant receives smaller amounts of nutrients, water and light, which may reduce cell metabolism, with a consequent decrease in length and diameter of ears.

Table 5. Length (LENGTH), diameter (DIAM), yield (YLD) and percentage of commercial green ears with straw (%CGE) of corn at different plant densities.

Plant densities (plants ha^{-1})	Production characteristics			
	LENGTH (cm)	DIAM (cm)	YLD (Mg ha^{-1})	%CGE
40,000	31.69 a*	6.09 a	12.61 b	94.25 a
50,000	30.72 a	6.04 a	15.45 a	91.08 a
60,000	29.35 b	5.79 b	11.04 b	71.49 b

*Means followed by the same letter in the column do not differ by Tukey's test at 5% probability level.

According to Pereira Filho et al. (2011), the increase in plant density also determines a reduction in the number of ears per plant and the size of the ear, which will directly affect the production of green corn regarding the commercial aspect. Similarly, Vieira et al. (2010) argue that the length of the ear with straw, at the time of commercialization, is one of the most important characteristics indicative of its commercial quality. The authors further assess that the length demonstrates ear development and the ability to supply photoassimilates for ear development and grain filling.

For ear diameter, the highest values were obtained by the cultivars at densities of 40,000 and 50,000 plants ha^{-1}, statistically similar to and higher than the results obtained with the density of 60,000 plants ha^{-1} (Table 6). The cultivar BRS 3046 (6.08 cm) achieved greater results than AG 1051 (5.86 cm). Rocha, Fornasier Filho and Barbosa (2011) and Araújo et al. (2016) obtained, for AG 1051, diameter of commercial ears with straw of 5.5 cm, highlighting that, in larger plant populations, there are decreases in plant metabolism and in the production of substances and plant tissues.

Table 6. Mean values of diameter of green ears of corn cultivars.

Cultivars	DIAM (cm)
AG 1051	5.86 b*
BRS 3046	6.08 a

*Means followed by the same letter in the column do not differ by Tukey's test at 5% probability level.

Regarding %CGE, the highest values were observed at densities of 40,000 and 50,000 plants ha^{-1} (Table 5), with a reduction in the percentage of commercial ears with the increase in plant density to 60,000 plants ha^{-1}. These results are in agreement with those obtained by Carvalho (2017). According to Pereira Filho et al. (2011), the sowing density for green corn cannot be high, remaining at the level of 40 to 55 thousand plants per hectare at most, depending on the specification of the company that has produced the seed.

The planting following lower planting densities aims to obtain a higher percentage of commercial green corn ears, which, according to Albuquerque, Von Pinho and Silva (2008), is highly desirable for the production of green corn and to obtain high weight of ears, since the commercialization is done based on these attributes. For these authors, commercial ears are considered those that are at least 15 cm long and three centimeters in diameter.

Regarding the yield of commercial ears, it is observed that there was no difference ($p>0.05$) between the hybrids evaluated. However, there was a difference between planting densities, with the highest yield (15.45 Mg ha^{-1}) obtained in the treatment with 50,000 plants ha^{-1} (Table 5). Rocha et al. (2016) obtained a similar result, stating that the plant density of 50,000 plants ha^{-1} is the most suitable for green corn and that, with the increase of density to 60,000 plants ha^{-1}, there was a reduction in the yield of commercial ears. Vieira et al. (2010) also observed that increasing density negatively influenced corn yield.

The grain yield of a corn plantation increases, therefore, with the increase in plant density until it reaches the excellent density, which is determined by the cultivar and by external conditions, resulting from local soil and climate conditions and cultivation management. According to Oliveira et al. (2016), in addition to thermal accumulation, the sowing season is fundamental for obtaining satisfactory agronomic yields.

CONCLUSIONS

The density of 50,000 plants ha^{-1} promotes higher yield of commercial green ears (15.45 Mg ha^{-1}).

The hybrid BRS 3046, of super-early male flowering, is the most indicated for green corn production in the city of Teresina, PI, under the edaphoclimatic conditions of the research.

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REFERENCES

ALBUQUERQUE, C. J. B.; VON PINHO, R. G.; SILVA, R. Produtividade de híbridos de milho verde experimentais e comerciais. **Bioscience Journal**, 24: 69-76, 2008.

ANDRADE JÚNIOR, A. S. et al. Zoneamento de risco climático para a cultura do milho no Estado do Maranhão. **Revista Brasileira de Agrometeorologia**, 12: 369-377, 2004.

ARAÚJO, K. K. S. et al. Diferentes embalagens na qualidade pós-colheita de milho verde 'AG 1051'. **Revista Agrotecnologia**, 5: 129-142, 2014.

ARAÚJO, L. S. et al. Desempenho agronômico de híbridos de milho na região sudeste de Goiás. **Revista Agro@mbiente On-line,** 10: 334-341, 2016.

CALDARELLI, C. E.; BACCHI, M. R. P. Fatores de influência no preço do milho no Brasil. **Revista Nova Economia**, 22: 141-164, 2012.

CARVALHO, L. R. X. **Densidade de plantas e espaçamento entre fileiras na produção de milho verde.** 2017. 25 f. Trabalho de conclusão de curso (Graduação em Engenharia Agronômica) - Universidade Federal do Piauí, Teresina, 2017.

CARVALHO, M. W. L. et al. Spatial arrangement of maize plants aiming to maximize grain yield in the hybrid BRS-3046. **Australian Journal of Crop Science**, 14: 1662-1669, 2020.

CONAB - Companhia Nacional de Abastecimento. **Acompanhamento da Safra Brasileira – Grãos**. Monitoramento agrícola - Safra 2020/21, v. 8. n. 10. Brasília, DF: CONAB, 2021. 110 p.

CRUZ, J. C.; MAGALHÃES, P. C. Cultivares superprecoces surpreendem produtores. **Campo e Negócios**, s/v.: 20-22, 2010. Disponível em: <https://www.infoteca.cnptia.embrapa.br/bitstream/doc/854950/1/Cultivaressuperprecoces.pdf>. Acesso em: 05 dez. 2018.

DANTAS JUNIOR, E. E. et al. Lâminas de irrigação localizada e adubação potássica na produção de milho verde, em condições semiáridas. **Revista Espacios**, 37: 26-26, 2016.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. **Recomendações técnicas para o cultivo do milho**. Brasília, DF: EMBRAPA-SPI, 1993. 204 p.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. **Sistema Brasileiro de Classificação de Solos**. 3. Ed. Brasília, DF: Embrapa, 2013. 353 p.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. **Híbrido BRS 3046 amplia mercado do milho verde.** 2018. Disponível em:<https://www.embrapa.br/busca-de-noticias/-/noticia/31597511/hibrido-brs-3046-amplia-mercado-do-milho-verde>. Acesso em: 5 dez. 2018.

FANCELLI, A. L. Cultivo racional e sustentável requer maior conhecimento sobre a planta do milho. **Revista Visão Agrícola**, 13: 20-23, 2015.

FERREIRA, L. F.; RESENDE, J. S. **A cultura do milho**. 2009. Disponível em: <http://www.emater.mg.gov.br/site_emater/Serv_Prod/Livraria/Cultura>. Acesso em: 6 dez. 2018.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, 35: 1039-1042, 2011.

HORBE, T. A. N. Semeadura precisa na cultura do milho. **Projeto aquarius**. 2014. Disponível em: <http://w3.ufsm.br/projetoaquarius/index.php/pt/linhas-de-pesquisa/semeadura-precisa-na-cultura-do-milho>. Acesso em: 7 dez. 2018.

INMET - Instituto Nacional de Meteorologia. **Agrometeorologia dos cultivos:** o fator meteorológico na produção agrícola. Brasília, DF: INMET, 2009. 530 p. Disponível em: <http://www.inmet.gov.br/portal/css/content/home/publicacoes/agrometeorologia_dos_cultivos.pdf>. Acesso em: 10 nov. 2018.

MARENGO, J. A. et al. Drought in Northeast Brazil - past, present and future. **Theoretical and Applied Climatology**, 20: 1-12, 2016.

NASCIMENTO, F. N. et al. Desempenho da

produtividade de espigas de milho verde sob diferentes regimes hídricos. **Revista Brasileira de Milho e Sorgo**, 16: 94-108, 2017.

OLIVEIRA, G. S. et al. Acúmulo térmico e produtividade do milho em quatro épocas de semeadura**.** In: CONGRESSO ESTADUAL DE INICIAÇÃO CIENTÍFICA E TECNOLÓGICA, 5., 2016, Iporá. **Anais...** Iporá: Instituto Federal Goiano, 2016. Disponível em: <https://even3.azureedge.net/anais/33791.pdf>. Acesso em: 20 nov. 2018.

PEREIRA FILHO, I. A. et al. **Milho verde**. 2011. Disponível em: <http://www.agencia.cnptia.embrapa.br/gestor/milho/arvore/CONT000fy779fnk02wx5ok0pvo4k3c1v9rbg.html>. Acesso em 4 nov. 2018.

ROCHA, D. R.; FORNASIER FILHO, D.; BARBOSA, J. C. Efeitos da densidade de plantas no rendimento comercial de espigas verdes de cultivares de milho**. Horticultura Brasileira**, 29: 392-397, 2011.

ROCHA, L. J. F. N. et al. Produção de espigas, silagem e grãos de milho em função da densidade de semeadura. **Enciclopédia Biosfera, Centro Científico Conhecer**, 13: 1054, 2016.

SANGOI, L. et al. Perfilhamento, área foliar e produtividade do milho sob diferentes arranjos espaciais. **Pesquisa Agropecuária Brasileira**, 46: 609-616, 2011.

SEMENTES AGROCERES. **Guia de híbridos**. [s.l], 2014 Disponível em: <http://www.sementesagroceres.com.br/pages/ManuaisTecnicos.aspx>. Acesso em: 3 mar. 2017.

SOUSA, V. F. A cultura do milho-verde e sua importância socioeconômica. In: SOUSA, V. F.; ZONTA, J. B. (Eds.). **Cultivo do milho-verde irrigado na Baixada Maranhense**. São Luís: Embrapa Cocais, 2020. cap. 1. p. 15-19. (Documentos / Embrapa Cocais, 6; Documentos / Embrapa Meio-Norte, 264).

VALDERRAMA, M. et al. Fontes e doses de NPK em milho irrigado sob plantio direto. **Pesquisa Agropecuária Tropical**, 41: 254-263, 2011.

VIEIRA, M. A. et al. Cultivares de milho e população de plantas que afetam a produtividade de espigas verdes. **Acta Scientiarum. Agronomy**, 32: 81-86, 2010.

ZUCARELI, C. et al. Acúmulo de graus dias, ciclo e produtividade de cultivares de milho de segunda safra para a região de Londrina-PR. In: CONGRESSO NACIONAL DE MILHO E SORGO, 28., 2010, Goiânia. **Anais...** Goiânia: ABMS, 2010. p. 87-89.