

Yield parameters of two maize hybrids submitted to different spacing in Paraibano Semiarid, Brazil

Uriel Calisto Moura Pessoa¹, Anielson dos Santos Souza², Rafael Vítor da Silveira Muniz³, Alberto de Andrade Soares Filho⁴, Martiliana Mayani Freire⁵, Laís Barreto Franco⁶, Joaquim Vieira Lima Neto⁷

¹Master degree student in Department of Agricultural Engineering, Federal Rural University of Pernambuco-UFRPE, Dom Manuel de Medeiros Street – Dois Irmãos, Recife-PE, zip code 52171-900, Brazil

Abstract— One of the most important crop practices to obtain high grain and forage yields in maize is the correct management of the seeding density, because the plant stand can influence growth components, production and partitioning of photoassimilates. The objective of this study was to evaluate the growth and yield of corn cultivation at five spacings, using two hybrids. The experiment was installed at the experimental farm of the Federal University of Campina Grande, CCTA/UFCG, Campus de Pombal, located in the city of Santo Domingo—PB. The experimental design was a randomised complete block, in a factorial scheme, with the factors being five spacings and two hybrids, with four replications. The spacings were 0.15, 0.30, 0.45, 0.60 and 0.75 m between plants, and the two hybrids were 'AG-1051' and 'BR-106'. The following yield components were evaluated: ear weight with straw and without straw; weight of 1000 seeds, ear length and diameter, grain yield and mass of corn. The spacings of 0.30 and 0.45 m had the best results, corresponding to the population densities of 30,000 and 40,000 plants ha⁻¹, and the 'AG-1051' cultivar had the best performance, with an average yield of 13 t ha⁻¹, largely due to its better genetic load.

Keywords— Productivity, sowing densities, *Zea mays* (L).

I. INTRODUCTION

Corn (*Zea mays* L.) is a monocot the Poaceae family, native to Central America, and it is among the most cultivated cereals consumed in the world, due to production potential, chemical composition, nutritional value, multiplicity of applications and high adaptability, which facilitate cultivation beyond the broad market [12].

Among the various factors that may interfere with the productivity of the corn, seeding density and arrangement appear to be the main factors responsible for the low yield of corn in Brazil [13]. This is because the plant stand can affect the growth of the culture components due to increased competition in assimilate partitioning [2]. The ideal population to maximise the yield of corn grain ranges from 30 to 90 thousand ha⁻¹ plants, depending on the availability of water, soil fertility, sowing and spacing adopted among rows and among plants in the cultivation line in addition to cultivating characteristics, which are crucial to plan the density of plants [8].

According to [14], studies indicate that modern hybrids have had a reduction in spacing from 0.9 to 0.4–0.6 m, and an increase in the population of plants 60 to 75 ha⁻¹ plants.

[17] showed that plant populations between 60 and 80 thousand plants ha⁻¹ showed increases in productivity of approximately 12.5 to 13.6%, corresponding to spacing between plants in the row of 0.6 and 0.8 m. The use of higher plant densities in smaller spacing allows greater interception of photosynthetically active radiation, promoting higher grain yields per plant [15].

According [19] the management of plant density is one of the cultural practices that most interferes with the productivity of maize. This response is associated with the fact that maize does not have an efficient space compensation mechanism, since it tends little and has low prolificacy and limited expansion capacity. The effects of density are also reflected in genotype hybrids with smaller numbers of leaves that are upright, with lower biomass production, which reduces the interference of one plant with another [9].

Considering the importance of obtaining high yields and knowledge about the double spacing recommendations between rows of commercial hybrids, this work was to evaluate the influence of five spacings cultivation, growth and productivity of two hybrids of commercial corn.

II. METHODOLOGY

The experiment was conducted at the experimental farm Federal University of Campina Grande - CCTA/UFCG, Campus de Pombal, located in Santo Domingo, in the middle region of the Paraíba backwoods and de Sousa microregion, with an altitude of 190 m.

Soil preparation was done by cross harrowing five days before sowing, favouring the initial weed control as well as providing conditions for a good germination and root growth of commercial culture.

Before sowing, soil sampling data was collected at a depth of 0–0.20 m and sent to the Soil and Plant Nutrition Laboratory, LSNP, at the Centre for Science and Agrifood Technology at the Federal University of Campina Grande, to determine its physicochemical characteristics and preparation of fertiliser recommendations (Table 1 and 2).

Table 1. Physical attributes of soil.

Physical characteristics	Collection depth 0-0.20 m
Sand (g kg ⁻¹)	536.8
Silt (g kg ⁻¹)	332.4
Clay (g kg ⁻¹)	130.8
Apparent density (g cm ⁻³)	1.22
Real Density (g cm ⁻³)	2.56
Total Porosity%	52.3
textural classification	sandy loam

Particle size by decimetre (Boyucos); Bulk density by 100-mL beaker method and flask method for determination of true density. Laboratory Soil Science and Plant Nutrition of UAGRA/CCTA/UFCG.

Table 2. Chemical properties of soil.

chemical characteristics	Collection depth 0-20 cm
pH H ₂ O	5.47
N (g kg ⁻¹)	0.74
P (mg dm ⁻³)	8.29
K ⁺ (dm ⁻³ cmolc)	3.05
Na ⁺ (dm ⁻³ cmolc)	9.39
Ca ⁺⁺ (cmolc dm ⁻³)	1.88
Mg ⁺⁺ (cmolc dm ⁻³)	1.13
H ⁺ + Al ³⁺ (cmolc dm ⁻³)	0.1
MO (g kg ⁻¹)	12.79

Analysis carried out on Soil Science and Plant Nutrition Laboratory of UAGRA/CCTA/UFCG. P, K, Na extractor Mehlich 1; Al, Ca, Mg: 1 M KCl extractor L-1; H + Al: extractor calcium acetate 0.5 M L-1, pH 7.0. MO: wet digestion Walkley-Black.

The fertilisation was performed during the period of sowing, and 10, 60 and 20 kg ha⁻¹ of nitrogen, phosphorus

and potassium, respectively, were applied in the groove. After 30 days, 20 kg ha⁻¹ of nitrogen was applied to cover. The sources used were superphosphate, potassium chloride and urea fertilisers.

The seeding was performed manually in open grooves with the aid of spades; the spacing used was 0.8 m between the double rows and 0.30 m between the single rows. Each plot consisted of three double rows, with different plant densities in planting lines according to the treatments employed. Thinning was performed at the V3 stage, when the plants had three fully expanded leaves.

The treatments consisted of two corn hybrids ('AG-1051' and 'BR-106') and five approximate density values: 24, 30, 40, 60 and 121 thousand plants per hectare. These treatments were arranged in a randomised block in a 5 × 2 factorial design with four replications, totalling 40 experimental units with dimensions of 3.0 × 3.20 m (9.6 m²), which totals 384 m² plots, with 1 m between the rows. The calculation of the populations was performed from double spacing: 0.8 × 0.3 × 0.75 m, 0.8 × 0.3 × 0.6 m, 0.8 × 0.3 × 0.45 m, 0.8 × 0.3 × 0.3 m and 0.8 × 0.3 × 0.15 m (1).

$$D = \frac{10.000}{\left[\left(\frac{a}{2}\right) + \left(\frac{b}{2}\right)\right] \times c} \quad (1)$$

where:

D = estimated density (plants per hectare);

a = the spacing between the double rows (m);

b and c = the distance between the plants in rows (m).

The management of the weeds was conducted by means of chemical control associated with manual hoeing undertaken only as post-emergent application in the association of herbicides (Atrazine + Nicossulfurom) at a dosage of 1.5 to 5 L h⁻¹, respectively, which are recorded in the MAP (Ministry of Agriculture Livestock and Supply) and are selective for the corn crop.

Based on the water requirement of 800 mm culture during the cycle, irrigation was handled to provide a sheet of 6.7 mm/day/plot, since both hybrids have an average cycle of 120 days. The irrigation system was with 20 mm thick dripping tapes with self-compensating drippers, and the dripping tapes were coupled to spiders, which were arranged in 32 mm tubing, in a single line, in the experimental area.

Throughout the crop cycle data on precipitation and temperature were monitored. According to INMET (2017), one 206 mm rainfall during the experiment was observed as well as an average temperature of 28°C (Fig. 1).

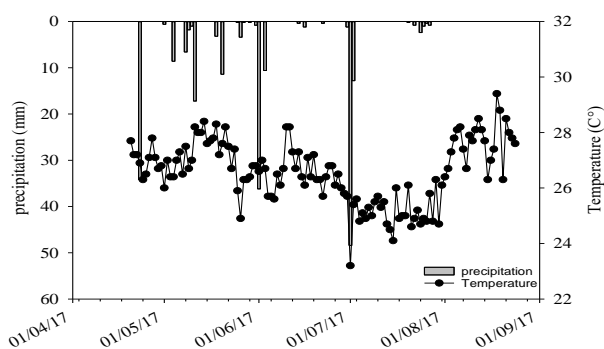


Fig.1: Meteorological parameters.

Source: INMET (National Institute of Meteorology).

Harvest was done manually at 127 OF before the physiological maturation stage R6, with the particular components of the production culture of ear weights with and without straw (kg ha⁻¹), number of grains per spike (kg ha⁻¹), diameter of shank (mm), ear length (cm), weight of 1000 seeds, seed yield (kg ha⁻¹) and cob weight.

Data were subjected to analysis of variance by F (p ≤ 0.05) test, when significant effect was verified the treatment means were unfolded, and regression analysis was applied to the density factor, and for the hybrid factor. All statistical procedures were performed using the computer program for statistical analysis SISVAR [7].

III. RESULTS

The interaction between hybrids and different spacing did not influence all variables (Table 3). Evaluating the effect of different spacings, we observed a significant effect on the straw with ear weights (PES/P), the ear weights without straw (PES SP) and numbers of grains per spike (N° GR ESP). For hybrid sources of variation, there was no significant effect for the studied variables, except for PES/P.

Table 3. Analysis of variance.

FV	G L	mean squares			
		C PES / P ¹	PES SP ²	No. GR ESP ³	D ⁴
Hybrid s (H)	1	731,496.9**	19879,55 ^{ns}	3064,25 ^{ns}	11,84 ⁿ s
Spacin g (E)	4	581,129.42 **	595033.97 **	14897.99* *	11,5 ^{ns}
H x E	4	64468,64 ^{ns}	78511.29 ^{ns}	3370,63 ^{ns}	1,5 ^{ns}
Block	3	69640,49 ^{ns}	27049.12 ^{ns}	1831,45 ^{ns}	2,89 ^{ns}
CV (%)	-	14.2	18.96	6.29	4.77

¹Ear weight with straw; ²Weight of the shank without straw; ³Number of grains per spike; ⁴The shank diameter. (*) (**) (ns), significant at p < 0.05 and p < 0.01

respectively probability and not significant by F test. Spacing: 0.15, 0.30, 0.45, 0.60 and 0.75 m. Cultivars: ‘AG-1051’ and ‘BR-106’.

The maximum observed values of the studied hybrids for the variables PES C/P, PES SP and N° GR ESP were 1.76, 1.46 and 0.533 Mg ha⁻¹, respectively, spaced 0.43, 0.47 and 0.48 m (Fig. 2A, 2B and 2C). The spacings above 0.45 m (0.60 and 0.75 m) did not promote significant increases for variables of these hybrids. The values of the straw with ear weight corroborate those obtained by [16] that when evaluating the hybrid ‘AG-1051’, aimed at producing corn, reached values of 14.39 Mg ha⁻¹.

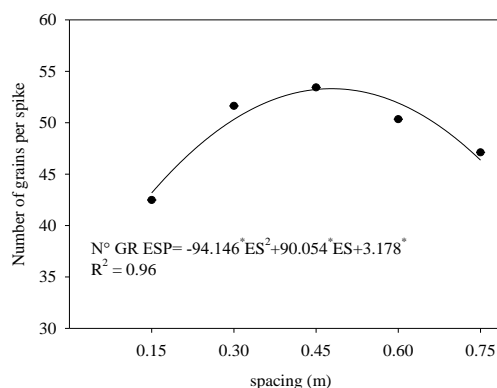
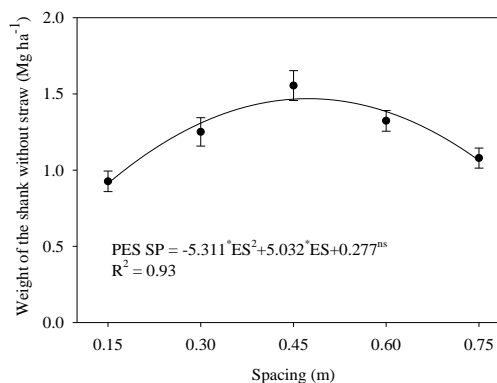
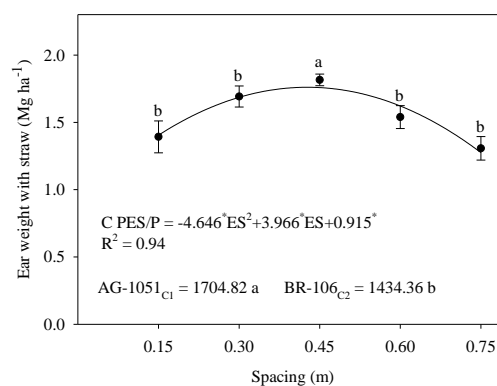


Fig.2. Straw ear weight (PES/P) without straw (PESP) and number of grains per ear (ESP GR°C), due to different spacing and two hybrids.

The interaction between hybrids and spacing influence ($p < 0.01$) the weight of 1000 seeds (P 1000). The length of the spike (C), grain yield (PG) and mass cob (MSAB) were affected ($p < 0.01$) by treatment alone (Table 4). Based on these results, we can infer that the seeding density was not a determining factor for there to be changes in the variables P 1000.

Table 4. Analysis of variance for ear length, 1000 seeds weight, grain yield and corn mass.

FV	G L	Mean squares			
		C ¹	Q ² 1000	PG ³	MSAB ⁴
Hybrid (M)	1	16.05*	1686.75 ns	28358189.52 *	0.0013 ^{ns}
Spacing (e)	4	14.91*	2511.86 ns	14926884.48 *	0.013 ^{**}
HXE	4	0.79 ^{ns}	3382.24 *	12083927.09 ns	0.0065 ^{ns}
Block	3	0.21 ^{ns}	1495.72 ns	5251413.34 ^{ns}	0.0045 ^{ns}
CV (%)	-	5.58	8.96	21.69	20.55

ear length; 21000 seeds weight; 3grain yield; 4corn mass. (*) (**) (ns), significant at $p < 0.05$ and $p < 0.01$ respectively not significant probability and by test F. Spacing: 0.15, 0.30, 0.45, 0.60 and 0.75 m. Hybrids: 'AG-1051' and 'BR-106'.

The length of the spike (C) increased linearly at the rate of 5.680 cm for each meter (m) increment, considering all studied spacings (Fig. 3A), with a maximum of 15.768 cm in spacing of 0.75 m.

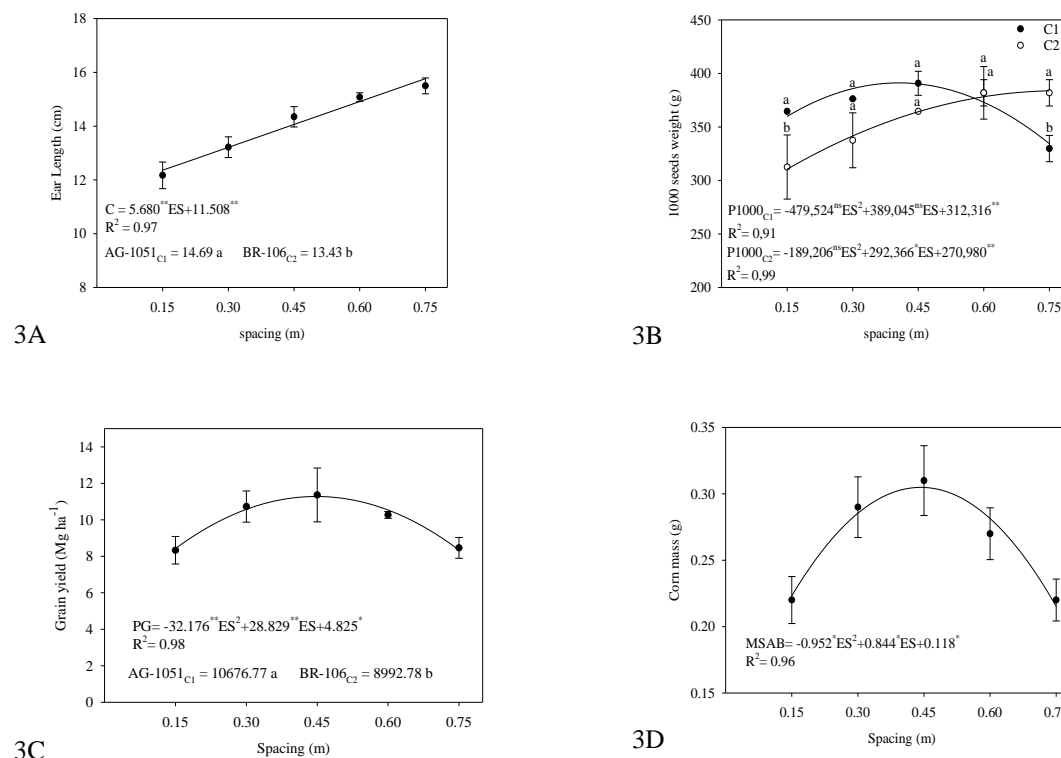


Fig.3: Spike length (C), Loss of 1000 seeds (P 1000), Grain yield (PG) and mass of the cob (MSAB) of the 'AG-1051' and 'BR-106' hybrids to 127 OF depending on the spacing.

The maximum values observed for the variable P1000 seeds was 391.23 g for the hybrid 'AG-1051', when the 0.41 m spacing was used and 383.92 g for the hybrid 'BR-

106', under the spacing of 0.77 m. Similar results were obtained by [1] evaluating the effect of spacing on growth and yield of corn, reaching higher 1000 grain weights in

largest spacing tested (0.90×0.30 m). Such results for the lowest population density of plants may be due to the greater availability of abiotic resources such as water, nutrients and solar radiation and thus greater efficiency of utilization of resources (Abubakar et al., 2019).

IV. DISCUSSION

[18] noted that dehusked ear weight and number of grains per spike showed higher average values when the corn was cultivated under larger spacings (0.83 and 1.00 m), assigning the highest weights to less competition for abiotic factors, such as water, sunlight and nutrients and hence the greater potential for expression of genetic potential. [6] to evaluate the performance of corn cultivars for the production of corn found significant differences among cultivars, for ear weight variables and dehusked ears, with an average of 253.12 and 190.29 g, respectively. on the importance of the work or suggest applications and extensions.

As the spacing is an alternative to increase the interception of solar radiation, as well as a better photosynthetic activity and proper allocation of assimilates, depending on other management factors such as irrigation, the plant can not only reduce the average ear weight values, but also other factors such as the number of grains per spike [18], [5].

[20], who studied the performance of corn hybrids in different spacings, had higher mean values for the variables of the shank length and number of grains per spike, as it increased the spacing between plants.

The delay in processing the lateral branches of spike early observed in cultures denser, can affect the final number of grains per spike and the morphological and physiological changes imposed on the female inflorescence before flowering, during fertilisation and early grain filling. The number of grains per spike at high densities can also be reduced by the abortion of newly fertilised eggs in the early part of grain filling, occurring more frequently in localised grains in the apex of the ear, which are the last to be fertilised [9].

[3], when evaluating the production potential of several hybrids in different spacings, observed that there was no significant difference for the weight of 1000 grains.

The maximum observed values of grain and cob weights in plots spaced at 0.45 m and 0.44 m, respectively, was 10.74 Mg ha^{-1} and 0.31 g. The results, possibly because there were larger gaps and therefore less plant population, potentiating the photosynthetic capacity of the plants, and the C4 metabolism that makes them highly efficient in converting light energy into chemical energy, allowing more significant yields and better utilisation of

the available radiant energy, as a result of the equidistant distribution of plants. [4] found that the grain yield was influenced by the double line spacing (0.20×0.70 m).

[11] studied different populations of plants (40, 53, 71, 84 and 97 thousand ha^{-1} plants) observed linear productivity, as the plant density increased, for some hybrids. The authors concluded that the increase in grain yield, with increase in plant density, depends on the hybrid being worked.

V. CONCLUSION

The combination of 0.8 m spacing between the double rows, and spacing of 0.45 m between plants in the row corresponding to a population of approximately 40.000 ha^{-1} plants showed promise for achieving high productivity. We analysed two different hybrids, and for most of the observed variables, the results obtained increased with increased spacing and decreased from 0.45 m spacing between plants.

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