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Influence of seeding speed and spacing between corn crop lines in the Amazon

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Abstract

The sowing stage in the crop implantation process is directly related to its productivity due to factors such as adequacy of the speed of operation of the seeder-fertilizer and the spacing between lines adopted according to each region of Brazil. Thus, the objective of the study was to evaluate the agronomic characteristics of corn in relation to the spacing between rows and speeds of operation of the seeder-fertilizer in the sowing process in the eastern Amazon region. The experiment was carried out in the experimental area of the Technological Center for Support of Family Farming, located in the municipality of Parauapebas, in the southeastern region of Pará. The experimental design used was in continuous bands (subdivided into five plots) of four treatments, resulting in the factorial arrangement 2 x 2, consisting of two operating speeds (5.5 and 6.5 km h^{-1}) and two spacings between rows of the seeder-fertilizer (0.75 and 0.55 m), totaling 20 experimental plots to evaluate the crop. The evaluations carried out after sowing were: SD (seed depth), TS (total seeds), IP (initial population), PH (plant height), EH (ear height), SD (stem diameter), FP (final population) and SI (survival index). The use of spacing between lines of 0.75 m promoted an increase in stem diameter (2.10 cm), plant height (2.29 cm) and seed depth (4.97 cm). It was found that the increase in operating speed (6.5 km h-1) and the use of 0.55 m line spacing provides an increase in the final plant population (60,000 plants ha^{-1}).

Keywords: germination; mechanized seeding; mechanical seed distributor; seeder-fertilizer; *Zea mays* L.
Abbreviations: CV%_coefficient of variation; EH_corn ear height; FP_final population; HP_horsepower; IP_initial population; MSD_minimum significant difference; NPP_nitrogen, phosphorus and potassium; PH_plant height; S_sulfur; Zn_zinc; SD_seed depth; SD_stem diameter; SI_survival index; TS_total seeds.

Introduction

Corn is one of the main cereals produced in the world and the most cultivated in Brazil due to the technological efficiency of management and cultural treatments adopted in the field, ranging from the stage of implantation to the harvest (Farinelli et al., 2012). Among the factors responsible for impacting grain productivity, there is the mechanized sowing operation. At this stage of the process, the tractor-seeder-fertilizer set is responsible for depositing the seed in the field, being directly related to the uniformity of seed distribution and the development of plants (Cortez et al., 2019). The sowing factors that influence corn production are the sowing speed (Reynaldo et al., 2016), the population arrangement, manipulated through changes in plant density, the spacing between rows and the distribution of plants in the row (Farinelli et al., 2012).
Raises in speed are used to increase the operational capacity of mechanized assemblies (Dias et al., 2014) due to the decrease in the time available for sowing (Mello et al., 2007), which contributes decisively to the longitudinal distribution and mechanical damage of seeds (Silva and Gamero, 2010), compromising seedling germination and emergence.
Inadequate plant spacing also plays an important role in crop productivity, as it is directly related to the efficient use of light, water and nutrients by the plants, which translates into the development and formation of the planting canopy (Hörbe et al., 2016; Piao et al., 2016; Sangoi et al., 2012). The line spacing adopted for the corn crop varies according to each brazilian region in which it is produced, due to the genetic materials of the cultivars that adapt to the intrinsic climatic conditions of each location (Francisco et al., 2017).
According to Sangoi et al. (2011), the new cultivars available on the market are highly sensitive to variations in plant spacing, uniformity and longitudinal distribution, making it necessary to study the implantation of the crop in the field, especially in the edaphoclimatic conditions of the Amazon region. Thus, the objective of the study was to evaluate the agronomic characteristics of corn in relation to the spacing between lines and speeds of operation of the seeder-fertilizer in the sowing process in the Eastern Amazon.

Results and discussion

The variables TS, IP, FP, SI and SD presented a coefficient of variation (CV) between 20 and 30%, while the variables SD, PH and EH obtained values below 10% (Table 2). According to Gomes and Garcia (2002), the CV indicates the uniformity of the evaluated parameters and are classified as medium (10% <CV ≤ 20%), high (20% <CV ≤ 30%) and very high (CV> 30%). In a study on the sowing speed in the implantation of corn, Bottega et al. (2014) found a low uniformity in the parameters related to the distribution of seeds in the soil, due to the variation of seed dimensions, the height of fall and the speed of fall in the seed tube in sowing machines.

Spacing between the lines

From the results obtained, it was found that the spacing between lines influenced the variables, except for the SI and EH as well as Farinelli et al. (2012) that did not obtain a significant response with the application of line spacing for the variable EH. Gilo et al. (2011) and Takasu et al. (2014), observed significant results for the insertion of the ear for the spacing between lines.

The smallest spacing between lines resulted in the highest TS, IP and FP values with the units of 75.454, 68.636 and 56,363 plants ha^{-1}, respectively (Table 2). While, the values of the variables SD (seed depth), SDI (steam diameter) were higher as the spacing between lines increased, with the values of 4.97, 2.10 cm respectively and Ph of 2.29 m. Farinelli et al. (2012) evaluated the spacing between lines of 0.40, 0.60 and 0.80 m for the corn crop in the southeast region of Brazil, and did not obtain a significant response for the variables SD and EH, checking only the PH with the highest values in the spacing of 0.60 m (2.12 m) and 0.80 m (2.17 m). In the Cerrado biome, Gilo et al. (2011) evaluating the spacing of 0.45 and 0.90 m, found that the SD had an average value of 1.90 cm in the smallest spacing and 1.92 cm in the largest with average plant height of 1.82 m. Kappes et al. (2011) studying the spacing between lines of 0.45 and 0.90 m, observed that the smaller spacing promoted greater SD (2.01 cm).

In the Northeast region, Porto et al. (2011), who evaluated the performance of corn in the spacing between lines of 0.40, 0.60, 0.80 and 1.0 m, found that the increase in spacing between lines promoted increases in the height of ear insertion, reaching up to 1.16 m in 1.0 m spacing. The same authors also found an increase of 0.49 m in the height of insertion of the ear for an increase of 0.1 m in spacing, provided by the interspecific competition of plants. According to Carvalho et al. (2015) the height of plants is directly related to the establishment of crops in the field, and that the lower height of ear insertion contributes to the better balance of the plant, minimizing stem breakage, especially in higher population densities. Corn has a natural tendency to promote higher plant height in situations of high population densities, due to the combined effect of intraspecific competition for light, with a consequent stimulation of apical dominance (Gross et al., 2006; Argenta et al., 2001), since the lower oxidation of auxins stimulates cell elongation and, thus, the internodes of the stem grow longer, increasing the plant's height (Sangoi et al., 2002).

Displacement speed

From the results obtained for the displacement speed of the seeder-fertilizer, there was a significant effect on the variables TS, IP and SD, in which the speed of 5.5 km.h^{-1} promoted a higher average of TS (66.727 seeds ha^{-1}), IP (60.454 plants ha^{-1}) and SD (2.04 cm) with average plant height of 2.22 m. Kopper et al. (2017), studying four sowing speeds (5, 7, 9 and 11 km h^{-1}), found that for the agronomic characteristics of the corn crop, the speed influenced only the height of insertion of the first ear and grain yield . Silva et al. (2000), in a study of speeds of 3, 6, 9 and 11.2 km h^{-1} in the spacing between lines of 0.90 m using the seed metering mechanism of the horizontal perforated disc type, found that the TS was influenced by speeds from 9 km h^{-1} on reducing the number of plants per linear meter with increasing sowing speed.

The efficiency of the dosing mechanisms is reduced by increasing the speed, since the time to fill the cells of the seed disk is reduced, causing distribution failures (Silva et al., 2000; Bottega et al., 2018). Regardless of the machine and dosing disc used, increasing the speed of operation reduces the number of seeds distributed per unit area (Silva et al., 2000). Bottega et al. (2018) tested three speeds (4, 6 and 8 km h^{-1}) of displacement of the mechanized set and two seed metering systems (pneumatic and horizontal perforated disc) and observed that the increase in displacement speed in the sowing of corn interfered in the precision and distribution of plants, in which the adequate distribution of plants was obtained at speeds 4 and 6 km h^{-1}, using the pneumatic seed doser.

Trogello et al. (2014) studying the spacing between lines of 0.80 m and operating speeds of 4.5 and 7 km h^{-1}, obtained an initial plant population of 71.871 and 70.234 plants ha^{-1}, respectively. The same authors found a relationship between the PH at the operating speed of 4.5 and 7 km h^{-1} at 35 days after sowing, in which the plants had the higher height of 46.85 cm at the speed of 4.5 km h^{-1}, attributing the result to the initial plant population of 71.871 plants ha^{-1}, 2.3% higher than that obtained at the speed of 7 km h^{-1}.

The IP variable showed a significant difference only between the spacing and speed factors, so, the speed of 5.5 km h^{-1} resulted in a higher IP compared to the speed of 6.5 km h^{-1}. Possibly, the increase in the speed of the sowing operation provided greater distance between the seeds, resulting in less amount of seed per linear meter. Storck et al. (2015) found that the machine's travel speed of 7 km h^{-1} determined a greater average of the distance between the plants, reducing the number of plants in the correct spacing between seeds. Boligon et al. (2013) obtained different results in the initial and final population of corn plants, not being influenced by the travel speeds 3.0, 4.5 and 7 km h^{-1}.

Interaction between spacing and speed

From the results of Figure 1, there was an interaction between the spacing and sowing speed for the variable FP, in which the increase in the displacement speed of the tractor-seeder set associated with the lower spacing between rows promoted a greater final plant population, which is an important agronomic characteristic in planting because it is directly related to final productivity. Boligon et al. (2013), studying the influence of sowing speed, did not observe significant differences for the final plant population. Silva et al. (2000) and Kopper et al. (2017) found that there was a reduction in the plant population with the increase in travel speed. With the increase in the displacement speed, the rotation speed of the dosing discs proportionally increases, which reduces the time available to fill the holes with seeds, which determines the quality of seed distribution in the furrow and consequently the final plant population (Silva and Gamero, 2010). It is evident that the increase in sowing speed

Table 1. Chemical characteristics of the soil used in the experiment.

Depth	pH	N	MO	P	K	Na	Ca	Ca + Mg	Al	H + Al
m	H_2O	%	g /kg	----------- Mg/dm³ -----------				-----------Cmol/dm³-----------		
0 - 0.10	5.6	0.13	13.24	2	148	2	4.77	6.07	0.07	1.65
0.10 - 0.20	5.6	0.14	11.51	1	117	4	4.83	6.22	0.06	2.15

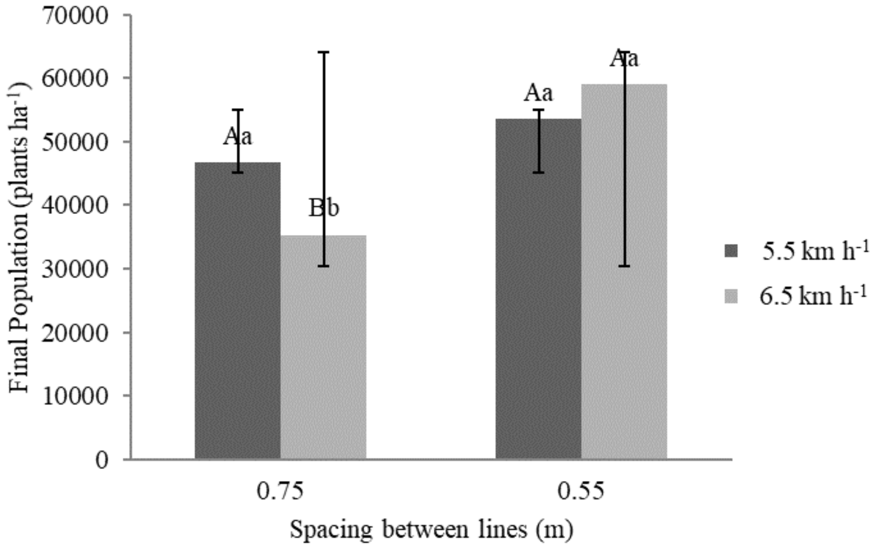

Fig 1. Interaction between sowing speed and spacing for the final population of maize plants.

Table 2. Statistical analysis results of total seeds per area (TS) in seeds ha^{-1}, initial population (IP) and final population (FP) in plants per ha^{-1}, survival index (SI) ear diameter (ED), ear length (EL), plant height (PH), ear height (EH) and stem diameter (SD).

Variables	ST	IP	FP	SI	SD	DP	PH	EH
Spacing (E)				%	------ cm ------		------ m ------	
0.75m	51.333 a	44.333 a	40.999 a	80.53 a	4.97 a	2.10 a	2.29 a	1.34 a
0.55m	75.454 b	68.636 b	56.363 b	76.03 a	4.16 b	1.87 b	2.18 b	1.35 a
Speed (V)								
5.5 Km^{-1}	66.727 a	60.454 a	50.151 a	76.90 a	4.56 a	2.04 a	2.25 a	1.36 a
6.5 Km^{-1}	60.060 b	52.515 b	47.242 a	79.65 a	4.57 a	1.94 b	2.22 a	1.32 a
F value								
E	49.1**	44.92**	20.30**	0.95^{ns}	15.4**	30.5**	14.91**	0.72^{ns}
V	5.24*	3.43*	0.74^{ns}	0.95^{ns}	0.00^{ns}	6.64*	0.71^{ns}	1.62^{ns}
E x V	0.95^{ns}	3.43^{ns}	6.06*	0.39^{ns}	0.97^{ns}	3.51^{ns}	2.60^{ns}	2.66^{ns}
DMS	6.94	7.21	6.83	9.27	0.41	0.08	0.05	0.05
CV (%)	27.46	25.39	31.32	26.45	20.3	9.42	5.94	8.66

* Averages followed by the same lower case letters in the column do not differ, according to the Tukey test, CV: coefficient of variation (%). ** significant (P <0.01). * significant (P <0.05). ns: not significant.

contributed to the deposition of the seed in the furrow without compromising the final plant population. As the spacing between lines increased, the author noticed that there was a tendency to increase plant height and stem diameter and despite the tendency to increase plant size, there were no problems related to the lodging or breaking of plants in the area, which leads to greater efficiency in mechanical harvesting and consequently in the final productivity of the corn crop.

Materials and methods

Experimental Site and Management

The experiment was carried out from October to March 2014/2015, in the experimental area located in the municipality of Parauapebas, in the southeastern region of Pará, the area's soil was classified as a Dystrophic Red Latosol (Santos et al., 2018), with a geographical location of 49 °51'19"W latitude, 06°12'58"S longitude and altitude of 197m. According to the Köppen classification, the municipality of Parauapebas, Pará, has an AW type climate, that is, a tropical rainy season, with concentrated rains in the summer, and a dry season in the winter, which may vary for Aw, with summer and autumn rains of 756.6 mm. During the experiment period, maximum precipitation occurred in December, sowing time, with 246.2 mm.month^{-1} and March with 226, 4 mm month^{-1}. The history of use in previous years consisted of bean

cultivation and two consecutive corn cultivations under conventional planting. The experimental period covered the 2014/2015 corn cultivation, so the mechanized sowing occurred on October 23 and 24, 2014 using the hybrid Bio Z 236, with a minimum germination level of 85% and minimum purity of 98%. The fertilizer used at the time of sowing was NPP: 9-2-15 + 4% S + 0.4% Zn, at a dose of 72.5 kg ha^{-1}.

The initial soil preparation was carried out using a 4x2 tractor, with a power of 75 hp, with a 7.50-16 tire and the attached Baldan harrow with 14 discs. The first soil preparation took place to incorporate the rest of the previous crop. The second, at the end of August, was carried out for the incorporation of limestone. Subsequently, in October a new harrowing was carried out using the light grid with 22 discs, with the purpose of isolating the area. The mechanical seeder-fertilizer used for conventional planting contained five lines of the brand 2040 Jumil G2, with pantographic coupling frame, rear wheel drive system, double parallel fertilizer disk, double parallel seed disk, with furrow coverers, rear compacting wheel with rubber band, distributor of mechanical seeds with perforated horizontal disc system, fertilizer deposit and seed with a capacity of 39 liters in each. During the experiment, weed control was not carried out.

Experimental design and management

The experiment was installed in a continuous strip design in four treatments, resulting from the 2x2 factorial arrangement that consisted of two displacement speeds of the mechanized set (5.5 and 6.5 km h^{-1}) and two spacings between sowing lines (0.75 and 0.55 m). Each treatment (strip) contained five sowing lines of 100 m, which were divided into five plots of 20 m each, totaling 20 plots in the entire area to carry out the evaluations.

Vetegal characteristics

The variables analyzed were plant height (PH), height of the first ear (EH), stem diameter (SDI), initial population (IP), final population (FP) and survival index (SI), total seeds per area (TS) and seed depth (SD). To evaluate the SD and TS variables, only the first meter of each plot was used, right after the sowing process, where the soil was carefully dug in the central sowing lines in the treatments, up to the place where the seeds were, to measure the depth with the aid of a graduated ruler and quantify the number of seeds. The IP and FP were determined respectively, five days after sowing and in the final data collection, with the help of a measuring tape. An initial meter of the five lines was measured, counting the number of plants and extrapolating the value of plants per ha^{-1}. After 75 days of sowing, upon reaching the plant's physiological maturity, the plants were measured with the aid of a measuring tape, to reach the PH, EH and SD values.

Measuring the survival rate

The SD was measured above the third internode with the aid of a digital caliper. To determine the SI, the average proportion of plants that reached maturity was calculated in relation to the initial average plant population, represented by equation 1.

In which:

(Eq.1)

$$SI = \frac{FP}{IPl} x100$$

SI: Survival Index (%);

FP: Final Plant Population (plants.ha^{-1});

IP: Initial Plant Population (plants.ha^{-1}).

Statistical analyses

The experimental data was subjected to the Shapiro-Wilk and Levene tests at 1% probability, to verify residual normality and homoscedasticity. After meeting the basic assumptions, the analysis of variance was performed and the Tukey test was applied, at 5% probability, to compare the treatment means, using the SISVAR statistical software (Ferreira, 2019).

Conclusion

The use of the mechanized set with greater distance between sowing lines (0.75 m) resulted in an adequate seed depth for the establishment of the crop and favorable agronomic characteristics of plants, such as the increases in stem diameter and height of the plants.

The combination of the speed of 6.5 km h^{-1} with the line spacing of 0.55 m promotes the largest final plant population (60.000 plants ha-1) in the edaphoclimatic conditions of the eastern Amazon.

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