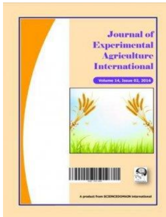

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Effect of the Sowing Speed on the Distribution Regularity of Maize Seeds

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Authors' contributions

This work was carried out in collaboration among all authors. Authors WN, ARBS and DSP designed the study and wrote the protocol. Authors WN, OHSR and MFA carried out the experiment. Authors WN, ARBS and DSP performed the statistical analysis and wrote the first draft of the manuscript. Authors ARBS, PSXP and ECC managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This work aimed to evaluate the influence of the sowing speed on the regularity of longitudinal distribution of maize seeds through a pneumatic metering seeder. The experimentation of 4 sowing speeds (4, 6, 8 and 10 km h-1) was performed in randomized blocks design with four replicates. The parameters evaluated were the mean distance between plants, coefficient of variation of the distance between plants, percentage of acceptable, flawed and double spacings, precision index, plant stand, initial population, mean seed deposition depth, and coefficient of variation of the seed

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deposition depth. The increase in the operating speed linearly reduced the percentage of acceptable spacings, plant stand, initial population, and mean seed deposition depth. Conversely, it linearly increased the values of mean distance between plants, coefficient of variation of the distance between plants, percentage of double and flawed spacings, precision index, and coefficient of variation of the deposition depth. Therefore, the increase in the displacement speed of the tractor-seeder set reduced the regularity of the longitudinal distribution of the plants, as well as the sowing quality.

Keywords: Percentage of acceptable spacing; distance between plants; double spacing; flawed spacing; depth seeding.

1. INTRODUCTION

Maize (*Zea mays* L.) is a worldwide-cultivated crop, widely used for human consumption and employed in animal feeding. In 2018, the planted area in Brazil was equivalent to 17 million hectares, with production expectation of 91.7 million tons [1]. However, for the crop to express its productive potential during the cycle, sowing must be carried out correctly [2].

To obtain uniform plant stands, the metering mechanism must be appropriately regulated. Among the several types of seed metering devices, there are those of mechanical and pneumatic distribution. According to Rabbit [3], pneumatic seeders can work efficiently within the speed range of 6 to 8 km h^{-1} what, on average, represents 40% more speed when compared to the flat disk mechanical seeder.

In seeders with a mechanical distribution system, the different displacement speeds influence seed field uniformity, increasing the occurrence of flawed and double spacings and reducing the acceptable spacings for maize [4].

Furthermore, irregularities in seed distribution might occasion a decrease in the final population [5]. By studying the maize crop, it was verified that the increase in the sowing speed resulted in a lower percentage of normal spacings and lower grain yield for the simple hybrid [6].

Generally, the regulation of the metering mechanisms and the adequate displacement speed are related to the obtaining of greater distribution regularity, and the seed metering is considered one of the main functions to be performed by every seeder.

Therefore, this work aimed to evaluate the influence of the sowing speed in the regularity of longitudinal distribution of maize seeds using a pneumatic metering seeder.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in the Nadin Farm, located at 12°49’24” S latitude, 56°11’48” W longitude, and an average elevation of 390 m, in the district of Groslândia (Lucas do Rio Verde), Mato Grosso state, Brazil. The soil of the experimental area was classified as dystrophic Red-Yellow Latosol, cultivated in a soybean-maize succession system for nearly 20 years.

The soil presented high fertility, with adequate pH ($CaCl_2$) value (5.4), and high contents of phosphorus (P) and potassium (K) (31.5 and 98 mg dm^{-3}, respectively), adequate values of calcium (Ca), magnesium (Mg), organic matter (O.M.), Cation Exchange Capacity (CTC), and base saturation (V%), and low aluminium satuaration (m%) level. The physical characteristics of the soil in the experimental area were: 27.3% sand, 15.6% silt, and 57.1% clay.

The four treatments consisted of different operating speeds of the tractor-seeder set, namely 4, 6, 8 and 10 km h^{-1}. The experimental plots had dimensions of 9.9 m x 50 m (495 m^2). For the evaluations, usable areas of 24 m^2 were considered (9 lines of 6 m spaced 0,45m).

The experimental area was sowed on January 9, 2019, right after the soybean harvest in the area. A John Deere CCS 2122 seeder (2016’s model) was employed, with 22 rows spaced 0.45 m with a VacuMeter^{TM} pneumatic seed metering system, model ProMax40 of 40 holes (Fig. 1). The adopted vacuum pressure was 10 psi in the larger turbine and 9 psi in the two smaller ones. The traction tractor employed was a New Holland T7 245, with 238 hp (242 cv) of engine power, 4x2 FWD (auxiliary front wheel drive) and GPS for aid in the operation. The adjustments adopted in the seeder were performed to provide a plant stand of 62 thousand plants per hectare, thus distributing 2.8 seeds per meter of row.

The fertilizer broadcast spreader employed was the Jan Lancer 12000, pulled by a New Holland T6.110 tractor, with 110 hp (112 cv) of engine power, 4x2 TDA (auxiliary front wheel drive) and GPS for aid in the operation. The sprayer employed for the application of the defensives was a self-propelled Jacto 2500 Plus sprayer, with a 2500-liter tank and 28-meter boom with 56 nozzles spaced 50 cm.

The employed maize hybrid was the MG652 PW, classified in the RC2 sieve, with minimal germination of 80% and purity of 99%, preferably recommended for the first plantings in high-fertility areas. This material possessed the Power Core and Power Core Ultra biotechnologies, presenting four insecticidal proteins destined to the control of the main maize caterpillars. Its population recommendation for the second crop is from 60 to 62 thousand plants per hectare, according to the region and the sowing season. By adopting a 0.45 m spacing, the adequate plant stand corresponded to 2.78 plants per meter of row. The maize seeds were treated with the CropStar® insecticide (Imidacloprid + Thiodicarb) and the Vitavax Thiram 200 SC fungicide (Carboxine+Tiram) in the doses of 240 ml/ha and 100 ml/ha, respectively. The employed fertilizer was the 20-00-20 (N-P-K), in the dose of 330 kg ha^{-1}, performed in two applications, in VE and V3, both performed through broadcast spreading.

In the weeding of the area before planting, the Glyphosate active ingredient herbicide was employed (Roundup WG, 720 g kg^{-1}), in the dose of 1.25 kg ha^{-1}, along with the Atrazina Nortox 500 SC herbicide (Atrazine 500 g L^{-1}) in the dose of 3 liters ha^{-1}. For the control of the stinkbug, the following insecticides were employed: Acefato Nortox (Acephate 750 g L^{-1}) in the dose of 1 kg ha^{-1} and 2 applications of Engeo (Cypermethrin 220 g L^{-1} Tiamethoxam 110 g L^{-1}) in the dose of 0.3 liters ha^{-1}.

2.2 Data Collection

The distance between plants was measured with the aid of a measuring tape, in 9 rows of 6 meters, located in the usable areas of each plot. Through these measurements, the percentages of the acceptable, double and flawed spacings were obtained, along with the mean distance between plants.

The coefficient of variation of the distance between plants was calculated ratio of the standard deviation of the distances between plants over the mean of the distance between plants. The higher was this value, the higher was the difference between the distances between plants.

The percentage of acceptable spacings was calculated by considering all spacings between plants, of 0.5 and 1.5 (50% error) times the mean spacing and 0.8 and 1.2 (20% error) times the mean spacing (MS). The obtained values that were outside this range were considered as flawed (above 1.5 times the MS) or double (under 0.5 times the MS) [7].

The precision index was determined by dividing the standard deviation of the normal spacing between plants by the reference distance – which each plant should possess for presenting the ideal plant stand – multiplying this value by 100.

The initial plant stand and the initial population were determined by the amount of plants found in each usable area, 7 days after sowing, by performing the proportion for the size of the usable area (24 m2).

The sowing depth was evaluated seven days after sowing through the measuring of the plant mesocotyl length, performed close to the soil surface until is lower extremity. In each usable area, the depth of ten plants was randomly evaluated, thus obtaining the mean depth.

2.3 Data Analysis

The depth coefficient of variation was calculated by dividing the standard deviation of the depths by the mean of the depths, and the value was expressed in percentage. The higher this value was, the higher was the difference between depths.

The experimental design was a randomized block, with four replications. Treatments consisted of different displacement speeds (4,6, 8 and 10 km h^{-1}). The data on parameters evaluated were subjected to regression analysis using the SISVAR statistical software [8].

3. RESULTS AND DISCUSSION

The effect of the treatments was assessed for all the variables considered. There was an increasing linear effect for the mean distance between plants, coefficient of variation of the spacings, percentage of double and flawed spacings and the coefficient of variation of the seed deposition depth. For the percentage of acceptable spacings, plant stand, initial population and mean deposition depth, there was a decreasing linear effect.

Regarding the longitudinal distribution, the increase in the operating speed from 4 to 10 km h^{-1} provided an increase of 8.62% in the mean distance between plants that represented an addition of 3.10 cm (Fig. 2A). Conversely, there was a reduction of the percentage of acceptable spacings. Therefore, the increase in speed decreased the distribution regularity of the plants in the crop (Fig. 2C). This may be confirmed by the increase in the coefficient of variation and in the percentage of double and flawed spacings, suggesting a quality loss at sowing (Fig. 2B and D).

Similarly, for all speeds and densities tested, there was a reduction in the percentage of acceptable spacing and an increase in the number of failures, with an increase in the working speed for corn [9,10].

In order to obtain more uniform sowings, the double and flawed spacings should be null or close to zero, with low coefficient of variation, and distance between plants with mean value next to the regulating distance (35.8 cm); however, several factors related to both the machine and soil, contribute to the occurrence of irregularities.

For the mean distance between plants, coefficient of variation, percentage of normal, double and flawed spacing and precision index, there was an effect of the treatment, suggesting that the displacement speed of the tractor-seeder set influenced the precision and the quality of the sowing. The coefficient of determination for the cited variables was high, with values above 0.88. With regard to the precision index, an increase of 7.84% was observed. This variable is the ratio between the standard deviation of the normal spacings and the reference spacing. Therefore, higher indexes represent more dispersion in the spacings and, consequently, less irregularity. Consequently, the increase in the operating speed decreased the precision with which the seeds were deposited in the soil.

Studying plant distribution in the crop, some authors [11,12,13,14,15], found that the speed increase resulted in reduction of the sowing regularity. It was further confirmed that the lowest displacement speeds provided a lower coefficient of variation in seed distribution [11,16,17].

High displacement speeds resulted in an irregular filling of the alveoli, causing a reduction in the uniformity of seed deposition in the soil, what might be one of the factors that increase the percentage of flawed spacings and reduce the acceptable ones [18].

Studying beans, Silveira et al. [19] observed that very small distance between plants can cause greater competition between them and reduce the yield per plant and per area. In contrast, greater distances between plants may mean reduction in yield per area since more empty spaces were left, giving to the weeds a chance to arise.

By comparing these values with the limits established for the percentage of acceptable spacings, it can be said that the values found in this research were within the desired range (> 90% of acceptable spacings), except for the speed of 10 km h^{-1}, in which the value found was 85.55% of acceptable spacings, that is, below the established limit [3].

Fig. 1. Frontal, lateral and posterior views of the tractor-sowing system, used in sowing of corn

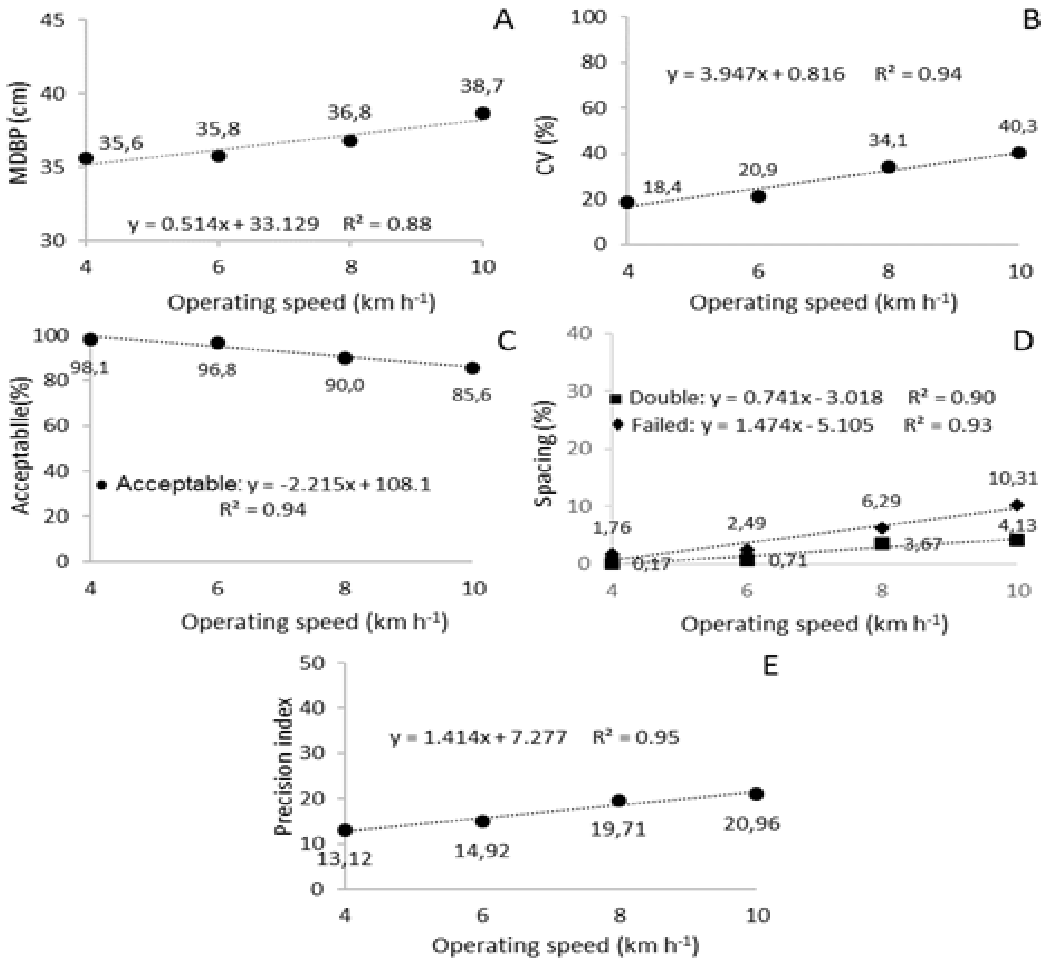

Fig. 2. Mean distance between plants (ADBP) (A), coefficient of variation (CV) of the distance between plants (B), percentage of acceptable spacings (C), percentage of flawed and double spacings (D) and precision index (E) after sowing in different displacement speeds of the seeder with vacuum distribution system

According to Kings and Alonço [20], for speeds over 7.5 km h^{-1} for the longitudinal distribution of seeds, both for the pneumatic and for the mechanical metering system of horizontal perforated plate, variation errors might occur due to the trajectory of the seed, from the liberation by the meter until reaching the soil, due to rolling and/or ricocheting of the seed in contact with the conductor tube and with the soil.

As to the plant stand and initial plant population, by comparing the treatments of 4 and 10 km h^{-1}, there was a reduction of 0.2 plant m^{-1} and 4527 plants ha^{-1}, respectively. A factor that contributed to the decrease in the plant stand and initial plant population was the gradual increase in the percentage of flawed spacings as a consequence of the increase in the displacement speed of the tractor-seeder set. Therefore, the higher is the number of flaws at sowing, the lower is the initial plant population (Fig. 3A and B).

The flaws might be related to the non-filling of the disc alveolus or to the higher incidence of broken or damaged seeds. When in the presence of a high speed, due to the increase in the speed of the seed metering disk, mechanical shocks and abrasion might occur. Reason [21] affirms that the percentage of broken or damaged seeds increased by 13% when compared to the sowing speeds of 4 and 8 km h^{-1}, thus decreasing the initial population and the plant stand.

Studying corn, different answers can be found in the literature; for Silva et al. [22] and Santos [23] a decrease in the plant stand occurs according to the increase in the operating speed. However, no effect of the speed on the initial and final plant stand was observed [14,24,25].

The seed metering regularity can present a maximum variation of 7% around the mean [3]. In this research, only the speed of 10 km h^{-1} trespasses 7% compared to the other three (lower) displacement speeds whose initial populations had a regular level. In their work, Silva et al. [22], also obtained variations lower than 7% in plant population for their treatments with different speeds.

By observing this criterion established by the authors, it can be said that only the speed of 10 km h^{-1} exceeded the limit (7%) when all treatments are compared for the initial population. Casão Júnior et al. [26] observed variations in plant population inferior to 7% for the different evaluated speeds.

Regarding the sowing depth, it was found that the rate of depth reduction in relation to the unitary increase in the speed (1 km h^{-1}) was 0.16 cm, with the coefficient of variation of the seed depth equivalent to 12.9 and 33.2% for the speeds of 4 and 10 km h^{-1}, respectively. Consequently, in the faster sowings, the seeds were laid nearer to the soil surface (Fig. 4A and B).

A lower sowing depth in higher speeds can be caused by the fluctuation of the seeder, so that the groove opening process is performed with low efficiency. In this case, there may be a higher occurrence of exposed seeds and, therefore, a lower plant stand. Similar results were found by Madaloz [27], in which in higher sowing speeds there was lower uniformity in the seed deposition depth.

Besides the fluctuation in the seeder for the higher operating speeds, this lack of regularity might occur due to irregularities in the terrain, compact soils in some areas and also due to the straw of the previously cultivated crop. When evaluating the displacements at 7, 8 and 9 km h^{-1}, Amado et al. [16] concluded that with the increase in the operating speed, a lower seed deposition depth occurred, resulting in a lower plantlet emergence index.

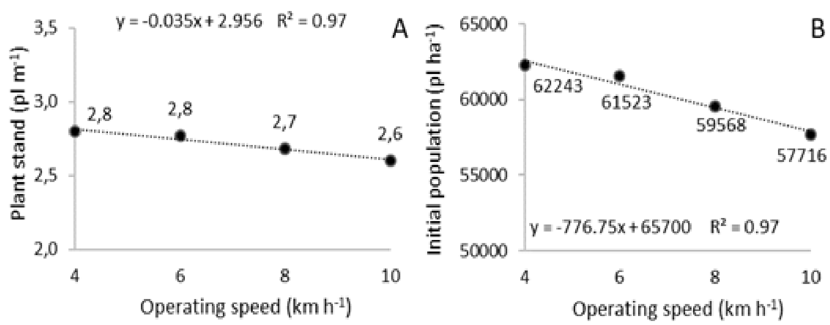

Fig. 3. Plant stand (A) and initial plant population (B) after sowing in different displacement speeds of the seeder with vacuum distribution system

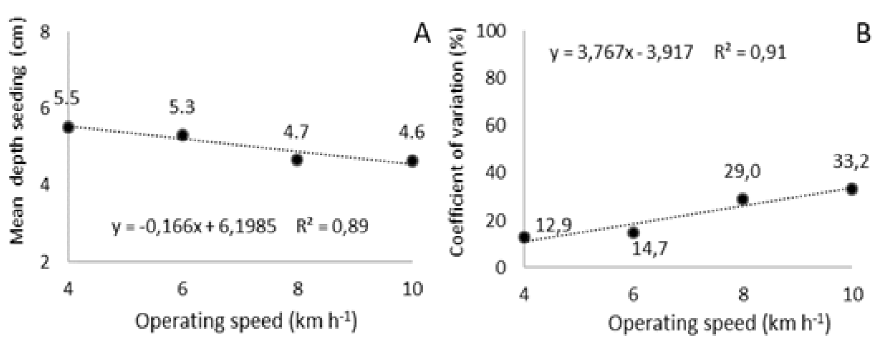

Fig. 4. Seed deposition depth (A) and coefficient of variation (%) of the seed deposition depth (B) according to the sowing speed

In general, the increase in speed led to a reduction in the seed distribution quality in the field, resulting in a decreasing in the final population up to 5,000 plants per hectare. Considering the limit established by Coelho [28], which suggests that pneumatic seeders should provide uniform spacing between seeds (within the lines) above 90%, the speed should not exceed 8.0 km h^{-1}, a speed at which the percentage of acceptable spaces was 90%.

In practical terms, uniform crops generate greater inter and intraspecific competition, reducing efficiency in the exploitation of soil and natural resources. In this study, we observed an increase in mean spacing between plants and all the coefficients of variation. Mello [10] affirms that, higher speeds may cause a reduction in final productivity.

4. CONCLUSION

The displacement speed of the tractor-seeder set interfered positively with mean distance between plants; coefficient of variation of the distance between plants; percentage of acceptable, flawed and double spacings; precision index; plant stand; initial population; mean seed deposition depth and coefficient of variation of the seed deposition depth. The increase in the displacement speed interfered negatively with the distribution regularity of maize seeds when utilizing a seeder with the pneumatic metering system. There was also a reduction in plant population as well as a decrease in the sowing depth with the increase of the displacement speed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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