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Maize Sowing Speeds and Seed-Metering Mechanisms

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Abstract

The intensifying use of machines in agriculture to increase operational capacity requires investments in more powerful and automated machines capable of working at higher speeds to meet the demands of agricultural activities. The objective of this study was to evaluate the sowing quality of a second crop maize using a pneumatic sowing machine equipped with two seed-metering devices at different displacement speeds. The statistical design was a randomized block design arranged in 6 × 2 factorial, with 4 replications, totaling 48 experimental plots. Where it was tested two seed-metering mechanisms from different manufacturers denominated A and B, and 6 displacement speeds of approximately 2.0; 4.7; 6.5; 9.1; 10.3 and 12.3 km h^{-1}. The seed-metering mechanisms were compared by mean test while displacement speeds were compared by regression plots. The initial and final plant populations, seed depth, seedling longitudinal distribution (normal, faulty and double spacing) and grain yield were also evaluated. Displacement speed and seed-metering devices showed significant interaction only for the percentages of normal, faulty, and double spacings. The initial and final population presented an isolated effect for both the seed-metering devices and velocities. The seed depth showed an isolated velocity effect. The grain yield showed a significant isolated effect from the analyzed seed-metering devices. The seed-metering device B operating at lower speeds had better performance in the sowing process.

Keywords: longitudinal distribution, agricultural machinery, plant population, regression

1. Introduction

Maize world production is about 1.1 billion tons while the United States ranks first, with 369 million tons, followed by China and Brazil, with 218 and 80 million tons, respectively (USDA, 2016). In Brazil, the yield was distributed in 15.7 million hectares in the 2015/2016 harvest (CONAB, 2016). Maize is currently the basic input for poultry and swine farming, two extremely competitive markets internationally and great revenue generators for Brazil (Caldarelli & Bacchi, 2012).

Second-crop maize cultivation has increased significantly in recent years since it is important for the national economy and crop rotation to maintain soil-straw in the no-tillage system. As a result, agricultural mechanization has intensified, requiring new investments in machines with greater power and automation to meet the demands of the agricultural activities (Jasper et al., 2013).

The demand for increasing operational capacity requires higher speeds when performing the agricultural activities and more efficient seeders-fertilizers and machinery, in general, to reduce operational costs and improve the quality of the sowing process (Santos et al., 2016).

The precision pneumatics seeders are widely used due to their advantages over mechanical seeders, such as better working quality, more accurate seed-metering rate with lower seed damage rates, better control and adjustment, and a broader applicability (Zahn et al., 2010).

The pneumatic seed metering mechanisms are responsible for capturing and ejecting the seeds uniformly, operating with variable seed size without damaging the seeds (which harms germination), should be robust and use established and proven technology (St Jack et al., 2013; Narang et al., 2015). Therefore, in addition to construction parameters, other factors influence seed distribution into the soil, such as the distance between the seed-metering mechanism and the soil, and the rotation direction of the disk since it can delay the seed arrival on the soil.

Maize needs to be planted with extreme care and accuracy to achieve the best possible germination, emergence, and productivity (Singh et al., 2016). During the mechanized sowing, several factors interfere with the establishment of the plant stand and crop productivity, and the machine operation speed in the field is one of them. This parameter can influence the skidding of the wheels; field capacity; speed of the seed-metering mechanism; distance and depth of seeds; occurrence of doubles, and mechanical damage (Garcia et al., 2011).

Seeders-fertilizers are indispensable tools for successful producers that seek high productivity. There are several metering systems in the national market that differ regarding operation quality, being necessary to determine their construction characteristics and the working speed employed during sowing.

The seed-metering mechanism is the main component of a seeder, and its performance affects greatly crop yield. Therfore, the objective of this study was to evaluate the maize sowing using a pneumatic seeder-fertilizer to test two seed-metering mechanisms A and B operating at different displacement speeds.

2. Method

2.1 Description of the Experimental Area

The experiment was conducted in the Teaching Farm Research and Extension (TFRE) of Unesp, in Jaboticabal, São Paulo. The farm is located in the 21°14′54″S and 48°16′51″W coordinates, at 568 m average altitude and 4% average slope. The climate is classified as Aw (subtropical), according to Köppen adapted by Alvares et al. (2013). The soil in the area is typical Eutroferric Red Latosol, with moderate, clayey texture and smooth undulating relief, according to EMBRAPA classification (2013).

2.2 Experimental Design

The statistical design was a randomized block design arranged in 6 × 2 factorial with 4 replicates, totaling 48 experimental plots. Where it was tested to test two seed-metering systems of different manufacturers denominated A and B, and 6 displacement velocities, approximately (V1 = 2.0, V2 = 4.7, V3 = 6.5, V4 = 9.1, V5 = 10.3 and V6 = 12.3 km h^{-1}). The displacement speeds were selected according to the gears reached by the tractor-seeder assembly seeking to evaluate three velocities above and three below the usual average sowing speed. The 11 x 10 m plots were used to evaluate themechanized set while 5 m of the two central rows (4.5 m^2) of the plot was used for the seed-metering mechanism.

2.3 Climate Characteristics

Total precipitation during the evaluated period (January to May 2015) was 567.2 mm. The mean maximum temperature was 28.84 °C, ranging from 25.92 to 30.54 °C and the mean minimum temperature was 19.02 °C, ranging from 15.54 to 23.06 °C. The mean relative humidity was 80.38%, varying between 70.54 and 87.76%. These data were provided by the meteorological station of the São Paulo State University (UNESP), School of Agricultural and Veterinarian Sciences, Jaboticabal.

2.4 Used Machines

The Massey Ferguson tractor model MF 7370, with 125 kW (170 hp) power at 2000 rpm was used to draw a seeder prototype Jumil 3070 pneumatic Exacta Air, consisting of four seeding units with different seed metering mechanisms, resulting in four 0.90 m-spaced rows distributing 4 seeds per meter.

This prototype seeder was equipped with a 17 inches smooth cutting disc, groove opening mechanism and grout-type fertilizer deposition, 14 inches mismatched double discs for dosing and seed deposition, respectively, and twin-wheeled V shape compactor wheels.

The seed-metering mechanism consisted of 28-hole disks. The seed-metering device A and the seed disks were made from a polymer called polyacetal, which was adapted to a seeder unit attached to the chassis of the prototype seederto perform the tests, rotating clockwise. On the other hand, seed-metering mechanism B had aluminum distributors and plastic discs, chassis for heavier seeders, and unlike the other equipment, the disk rotated counterclockwise.

2.5 Sampling Procedures

The parameters evaluated were:

Initial and final plant population: determined by countingthe number of plants inside the experimental plot area.

Sowing depth: determined after plant emergence was observed about 10 days later. The soil was dug using a pocketknife until the seed was found, and a graduated rulerwas used to measure the height between the soil level and the seed. Five plants were collected per plot to determine average seed depth. The seederwas set to 5 cm deep sowing.

Longitudinal distribution between seedlings in the sowing row: evaluated by counting the number of seedlings, adapted from Kurachi et al. (1989). The spacings were determined using a graduated ruler and classified by determining the percentages of spaces in the following classes: “double” spacings (D), less than 0.5 times the expected average spacing; “acceptable” (A), 0.5 to 1.5 times the expected average spacing, and “faulty” (F) greater than 1.5 times the expected average spacing. The expected average spacing was about 0.23 m between plants.

Yield: calculated by harvesting the ears of the experimental area (4.5 m^2) of each plot using a mechanical harvester. The grains were separated, weighed and the values corrected for 13% moisture, and extrapolated to kg ha^{-1}.

2.6 Statistics Analysis

Normality of the data was checked by the Anderson Darling test. After that, the results were submitted to the analysis of variance by the F-test ($p < 0.05$) and, when significant, the means were compared by Tukey test at 5% probability. The results were submitted to regression analysis to verify the behavior of the characteristics according to the sowing speeds using the AgroEstat software (Barbosa & Maldonado, 2014).

3. Results

Sowing speed and seed metering devices showed significant interaction only for the percentages of normal, faulty and double spacings. The initial and final population had an isolated effect for both, metering devices and speed. Seed depth was affected only by the displacement velocity while grain yield was affected by the seed-metering mechaninsm only (Table 1).

Table 1. Maize initial and final population; seed depth; normal, faulty and double spacings, and crop productivity for the displacement velocities and the two seed-metering devices analyzed

Treatment	Population		Depth	Spacings			Yield
	Initial	Final		Normal	Faulty	Double	
	------- plants ha^{-1} ------		--- cm ---	-------------------- % --------------------			-- kg ha^{-1} --
Seed-metering (D)							
A	42361 b	40139 b	3.63 a	41.26 b	36.57 a	22.09 a	7112 b
B	43657 a	41222 a	3.54 a	64.92 a	28.13 b	6.92 b	7667 a
DMS (5%)	749	1062	0.28	3.26	2.32	2.07	496.28
Displacement speeds (km h^{-1})							
2	44000	42944	3.91	58.85	26.96	14.19	7524
4.7	44417	43167	3.53	57.19	28.98	13.83	7654
6.5	44944	43528	4.09	56.27	29.32	14.41	7444
9.1	42833	40611	3.35	52.18	35.26	12.5	7331
10.3	42500	41583	3.5	50.94	33.36	15.71	7570
12.3	39361	32250	3.17	43.12	40.25	16.4	6816
DMS (5%)	1928	2735	0.71	8.39	5.97	5.32	1277
Seed-metering (D)	12.40**	4.30*	0.44^{ns}	217.83**	54.72**	222.96**	5.19^{*}
Velocity (V)	19.98**	44.65**	4.34**	8.57**	12.46**	1.25^{ns}	1.02^{ns}
D × V	1.72^{ns}	0.84^{ns}	0.59^{ns}	13.08**	10.47**	4.96**	0.44^{ns}
CV (%)	2.97	4.45	13.1	10.46	12.21	24.25	11.43

Note. Means followed by the same letters in the column do no differ by Tukey at 5%. ^{ns} Non-significant. * and **Significant by F test, at 5 and 1%, respectively.

The seed-metering device B yielded the highest plant mean values per hectare as shown by the comparison between the initial and final plant population (Table 1).

Regression graphs were plotted for the variables that presented an isolated velocity effect to explain better the results. The initial plant population data fitted a quadratic polynomial regression model best, with coefficient of determination (R^2) of 0.96. The 6 km h^{-1} velocity yielded the highest initial population of plants with approximately 12% more plants compared to the highest sowing speed of 12.3 km h^{-1} (Figure 1).

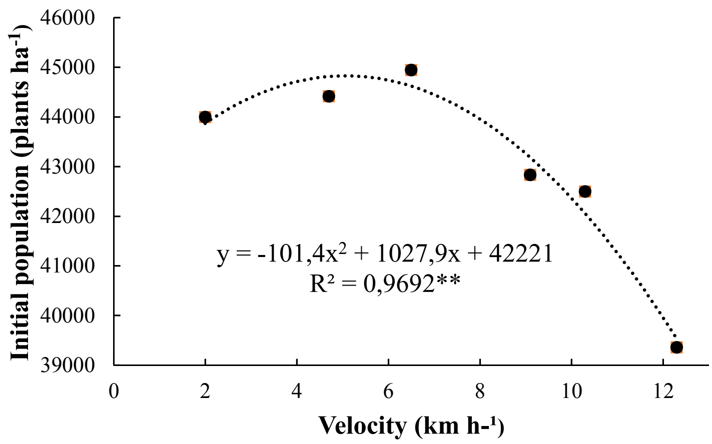

Figure 1. Initial population versus different displacement velocities

The final population of plants is greatly influenced by the environmental and soil conditions, representing the plant survival rate in relation to the initial population. The quadratic polynomial regression model was the best fit for this variable, with about 0.87 of R^2 (Figure 2).

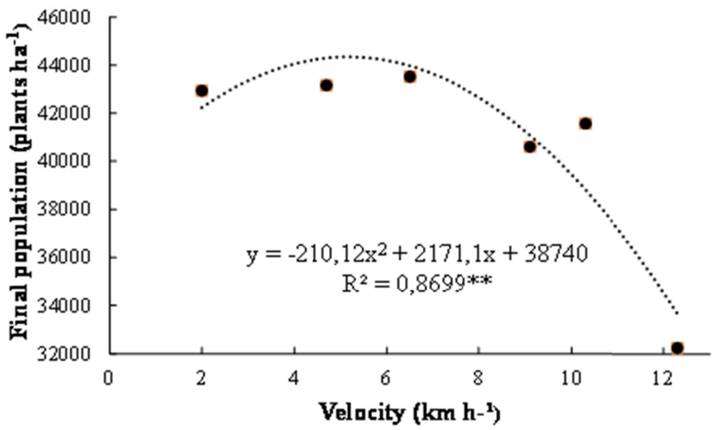

Figure 2. Final population versus different displacement velocities

The final population of plants was on average 2 to 3% smaller for sowing velocities V1, V2 and V5, about 5% smaller for the velocities V3 and V4, while V6 had the lowest plant survival rate since the initial population decreased 18%.

The seed depth results fitted the linear regression model with a significant isolated effect of the velocity (Figure 3), and V6 had the lowest averages. However, theseed sowing system had a pantographic system to adjust depth according to soil imperfections, it was evident that increasing speed affected seed depth.

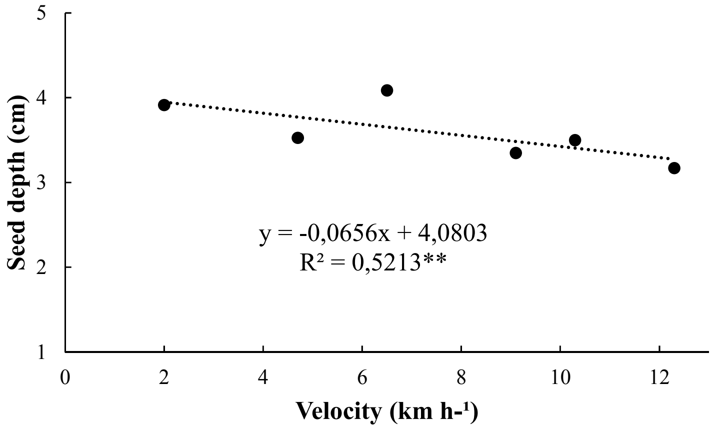

Figure 3. Seed depth versus different displacement velocities

The changing velocity did not affect the percentage of normal spacings, about 42% on average, for the seed-metering device A. Mean while, seed-metering B data fitted a quadratic regression model (R^2 = 0.97), with approximately 82% normal spacings for lower displacement speed, about 49% higher than the values obtained for the higher velocity (Figure 4).

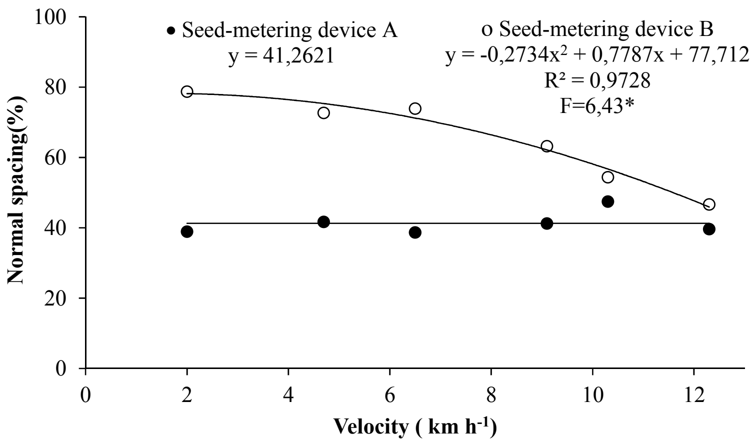

Figure 4. Normal spacing for seed-metering devices A and B versus different displacement velocities

Despite significant interaction for faulty spacings, seed-metering A, that behaved similarly regarding normal spacings. The seed-metering A had approximately 37% faulty spacings on average (Figure 5).

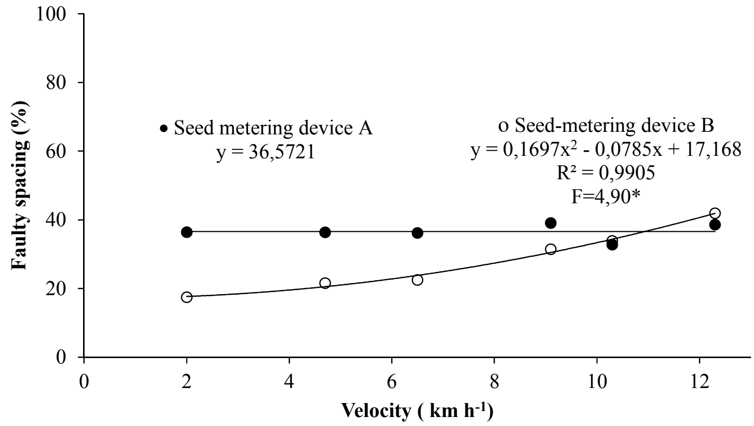

Figure 5. Faulty spacing for seed-metering devices A and B versus different displacement velocities

The results of the seed-metering device B fitted the quadratic regression model, with R^2 of 0.99. It was verified a 42% increase of faulty spaces from the lowest to the highest speed evaluated (Figure 5).

For double spacings, a significant interaction was observed between velocities and seed-metering devices, and the data from A and B fitted the linear regression model, decreasing and increasing, respectively (Figure 6).

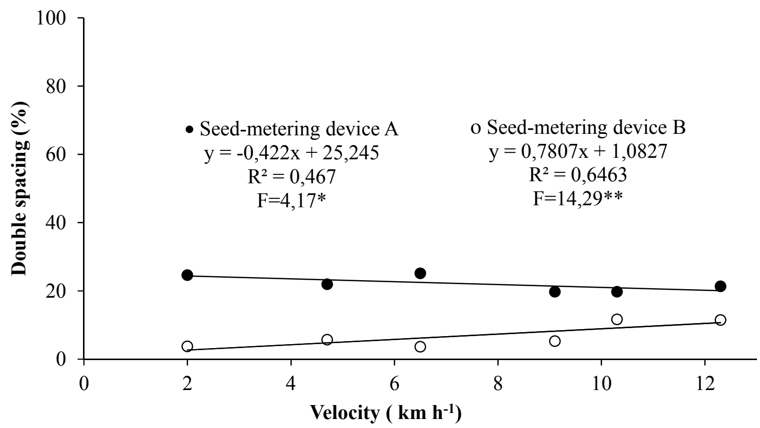

Figure 6. Double spacing for seed-metering devices A and B versus different displacement velocities

As the sowing speed increased in the seed-metering A, the percentage of double spacings decreased, contrary to B.

The comparison of the two seed-metering devices showed that double spacing percentages were much higher for A compared to B, which maybe explained by the construction characteristics and rotation direction of the discs.

Grain yield was significantly affected by the seed-metering devices; equipment B had the highest grain yield (7667 kg ha^{-1}), approximately 8% higher than A (Table 1). This difference may also be explained by the construction characteristics of the different equipment, and the rotation direction of the seed discs since high percentages of normal spacings reduced intraspecific competition among the seedlings.

4. Discussion

Pinheiro Neto et al. (2008) investigated the performance of seed-metering devices and verified that the pneumatic seeder had the best distance between plants and the closest to that agronomically recommended for plant population, thus demonstrating that an adequate plant population requires a suitable seed-metering mechanism.

Sowing speed depends on the field conditions but is usually equal to or less than 8 km h^{-1} (Khodei et al., 2015). The initial population of plants increased slightly from the lowest speed (2 km h^{-1}) to the intermediate speed of approximately 6 km h^{-1}; however, the initial population decreased considerably as the sowing speed increased.

Similar to the initial population behavior, the final plant population decreased markedly for speeds above 6 km h^{-1}. The seed-metering mechanism is a vital part of the seeder since it ensures that the desired final population of plants is reached (Mandala et al., 2013). The maize crop does not have the plasticity of other crops and, therefore, it is not able to compensate the absence of plants so that the plant stand and the production per plant are the components that determine the crop yield (Silva et al., 2016).

Trogelo et al. (2014) investigated the development of maize crop at different displacement speeds and reported that the best agronomic results were found for the lowest speed. These authors attributed this result to the greater difficulty of the sowing machine to distribute the seeds evenly, so the plants tend to become more competitive among themselves for light.

Corrêa Júnior et al. (2014) reported that seed depth was not affected by the displacement velocity while the obtained means showed that the seeds were deposited very close to the regulated depth.

Very wet or dry soils combined with high seeding depths may slow down the seed germination process. Therefore, it is recommended that corn seeds should be planted 5 cm deep for the best growth and development of the rooting system in the soil (Khodei et al., 2015).

The sowing depth is correlated with the soil morphological conditions, high depths and irregularities can damage the population of plants and their development. The deeper the seed deposition, the greater is the energy required for the emergence process, and possibly germination losses caused by low temperatures and low oxygen levels (Trogello et al., 2013).

The percentage of normal spacings was significantly affected by the velocities for the B seed-metering device. Unlikely, Dias et al. (2014) observed no significant differences on the percentage of acceptable, multiple and faulty spaces between maize seedlings for the investigated metering mechanisms and their interaction with velocity.

The appropriate population and uniformity of longitudinal distribution of maize plants in the row is important when aiming at high yield (Storck et al., 2015).

The higher percentages of normal spacings obtained for seed-metering B can be attributed to the anti-clockwise disk rotation, which ejects the seed to the conductive tube more appropriately, preventing friction between the seeds and the seed-conducting tube walls and faulty longitudinal distribution since the seeds reach the ground at the adequate moment and positioning. According to St Jack et al. (2013), the accuracy of the seed-metering device to individualize and eject the seeds depends on several parameters, especially the configuration of the disc orifice, the vacuum level, when applicable, and disk rotation during operation.

An important criterion when evaluating sowing performance is the uniformity of seed spacing since uniform seed distribution allowing maximum space for each plant reduces intra-specific competition and increases yield (Zahn et al., 2010).

Miller et al. (2012) planted corn with different sowing units at four displacement speeds and found no advantage at speeds below 8 km h^{-1}, while the speeds of 11.3 and 14.5 km h^{-1} influenced the spacing between plants.

The seed-metering devices had a good performance at 3.6 and 5.4 km h^{-1} speeds; however, performance dropped above 7.2 km h^{-1} (Yazgi & Degirmencioglu, 2014). Weirich Neto et al. (2012) investigated no-tiller sowing of maize with pneumatic and mechanical seed-metering device and concluded that the feeder type did not affect significantly seed longitudinal distribution in the groove.Viana et al. (2014) have also reported such problems and pointed out the inadequacies of maize sowing equipment.

Pinheiro Neto et al. (2008) did not observe a significant effect of the pneumatic seeder on either plant population or yield. The performance study of a seed-metering mechanism has a practical significance and reference value for improving device design and determining the best operation speed (Zhao et al., 2012). The establishment of a maize crop is extremely important since this crop does not compensate the plants with increased tillering or higher number of ears. Trogello et al. (2014) reported no significant differences in final crop yield between the 4.5 and 7.0 km h^{-1} speeds.

5. Conclusions

The seed-metering device B yielded better productivity components and performance regarding the longitudinal distribution of seedlings, thus demonstrating better construction characteristics compared to A. In addition, the rotation direction of the seed distribution disc influences seed distribution while counterclockwise direction provided the best results.

The lower velocity had the best percentages of normal spacings, indicating that the increasing velocity may lead to higher percentages of faulty and double spacings, compromising the sowing quality.

The seed-metering B operating at displacement speed V1, V2 and V3 yielded the highest plant populations and percentages of normal spacings while higher velocities influenced these parameters significantly and negatively.

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