Corn (*Zea mais* L.) sowing quality in the province of Corrientes, Argentina

Calidad de siembra de maíz (*Zea mais* L.) en la provincia de Corrientes Argentina

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Abstract

In three departments of the Corrientes province, the performance of 6 seeders was evaluated during corn sowing at three different speeds for each machine. A randomized complete block design was used with nested treatments arrangement. A seeder factor (6 types), a speed factor (3 levels) and three blocks determined a total of 54 experimental units. As for the speed factor, the first level corresponds to speed 2 (Sp 2) which the operator regularly uses. The second level and the third level correspond to a lower speed (Sp 1) and a higher speed (Sp 3) respectively which were used for this study. The equidistance between seeds and sowing depth were analysed as the response variable. Conclusions: 1) Four of the six seeders studied at three chosen speeds showed no differences regarding seed deposition. This was observed considering significant differences between sowing depth and seed spacing in a given line. 2) The two methodologies used to evaluate sowing efficiency, *i.e.* the coefficient of variation (CV) and the ISO 7256-1 standard, showed differences in evaluation. The second technique was more accurate since no differences between treatments were found with the CV. 3) According to these results, it is possible to conclude that the corn sowing quality in the Corrientes province is acceptable at the sowing speeds used by the contractors.

Keywords
density • spatial distribution • depth

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Resumen

En tres departamentos de la provincia de Corrientes, se evaluaron el desempeño de 6 sembradoras durante la siembra de maíz a tres distintas velocidades para cada máquina. El diseño experimental fue en bloques completos aleatorizados con arreglo anidados de tratamientos, siendo un factor sembradora (6 tipos) y otro factor velocidad (3 niveles) y tres bloques lo que determinó un total de 54 unidades experimentales. Se analizaron como variable respuesta, la equidistancia entre semillas y la profundidad de siembra. Conclusiones: 1) La mayoría de las sembradoras estudiadas a tres velocidades, no mostraron diferencias en la calidad de deposición de la semilla expresado como diferencias significativas entre la profundidad de siembra y el distanciamiento entre las mismas dentro de la línea. 2) Las dos metodologías utilizadas para evaluar la eficiencia de siembra (coeficiente de variación (CV) y norma ISO 7256-1) mostraron diferencias de evaluación, siendo más exigente esta segunda técnica ya que con el (CV) no se encontraron diferencias entre tratamientos. 3) De acuerdo con los resultados encontrados es posible concluir que la calidad de siembra de maíz en la provincia de Corrientes es aceptable a las velocidades de siembra utilizadas por los contratistas.

Palabras claves
densidad • distribución espacial • profundidad

Introduction

In Argentina, corn cultivation along with wheat and soybean cultivations, are the main agricultural activities. As for corn cultivation, it is estimated that the area for the 2017/18 campaign will reach 5.4 million hectares and the production will be 41 million t. This shows an increase over the previous campaign 2016/17 which recorded 5.1 million hectares with a production of 39 million t (2).

It is interesting to mention that this crop has a very important impact on regional economies since it influences balanced feed for different animal species. High-Quality corn grains stand out as a basic feed in the demanding poultry production. Likewise, high-quality corn grains and whole corn plants are also used as a basic feed in cattle production. This type of industry has a high economic impact on the NEA (Northeast Argentina), which boosts corn cultivation development by minimizing freight costs due to regional demands (1, 8).

Sowing quality is one of the key factors in producing high corn yields. The corn crop is the most affected by sowing mistakes given its physiological and structural characteristics in comparison with other crops, Vélez *et al.* (2015) coinciding with the investigations of Delgado Martinez *et al.* (2015). An adequate sowing operation is observed when there is a minimal difference between the number of plants that could be obtained and the number of plants that emerged. Besides, there is a uniform separation between plants and there is a minimum elapsed time for plant population emergence (14, 19).

Seed dosing and seed distribution are the two most important functions performed by a seeder. The first function, that is to say seed dosing, seeks an exact and uniform seed delivery, without causing damage to it (15). The second function, that is to say seed distribution, consists of placing the seed in the soil according to a determined disposition, maintaining the equidistance and the sowing depth (9). The seeder soil-engaging components are responsible for carrying out the seed distribution (10).

The sowing quality effect on yields has been quantified by some authors. Although the bibliography does not present a uniform criterion on its impact, Olmos y Menéndez (2005) reported yield losses of up to 147 kg ha^{-1} for each centimeter of standard deviation (SD) found for densities of 71.000 plants ha^{-1}. Nevertheless, Olmos *et al.* (2005) found no effect of non-uniformity on yield for densities of 58.000 plants ha^{-1}. Hidalgo and Alvarez (2012) mentioned decreases of 60 kg ha^{-1} for every 2.5 cm increase in SD, coinciding with Nielsen (2004) who also found yield decreases with the increase in SD. However, Valentinuz *et al.* (2077b) mention that the non-uniformity distribution variable and yield are not associated.

These differences in results can be explained by the different behaviour of hybrids in situations of competition or use of resources in different environmental situations (20). The methodology used to evaluate sowing may also be one of the factors that hinder sowing quality determination. In fact, D' Amico (2012) mentions that the use of descriptive statistics such as the SD is a worse indicator for sowing quality and its influence on yield than the ISO 7256-1 methodology based on faults proportions. D' Amico (2012) also indicates that corn crop yield is affected by density variations caused by sowing seeds distribution faults.

Recent studies indicate that deep corn sowing increases both crop yield and plant density in comparison with conventional sowing. These increases are attributed to the fact that the thermal amplitude is lower at a greater depth, favouring root growth increase and nutrients and water absorption, among other variables (5). Coinciding with these studies, Bragachini *et al.* (2012) indicate that a difference of 1.370 kg was achieved at a depth of 6 centimeters and with a speed of 6 km/h with respect to other plantations. In addition, indicated that yield quality was mainly due to planting depth than to the spatial distribution of the plants. This suggests the need for greater control of this variable in future seeder designs. Studies conducted by Manso *et al.* (2012) reached similar conclusions when working on a mollisol soil under a direct seeding system.

It is interesting to know about the corn sowing efficiency level in the Corrientes province which has the smallest sown area. In fact, the province had only 10.000 sown hectares in the campaign 2016/17 (23). Thus, it will be possible to determine if this variable is likely to be an important factor in yield determination.

Objective

This work aims to quantify the corn sowing efficiency level employing two methods: the coefficient of variation and the ISO 7256 standard in the Corrientes province.

Hypothesis

Hypothesis 1: Changes in sowing speed do not affect the seeds' spatial variability, *i.e.* the distance between seeds and the depth in the furrow of seeds.

Hypothesis 2: The sowing quality determined by spatial variability measurements using the methodology based on the ISO 7256-1:1984 standard.

Materials and methods

In the Mercedes, Santo Tomé and Sauce departments located in the Corrientes province, the main sowing equipment was identified. This was done in order to carry out a directed sampling that would represent the sown area in that province. In this way, six equipments responsible for more than 60% of the province's total sowing were identified.

A randomized complete block design with nested treatments arrangement was proposed (16). A seeder factor (6 types), a speed factor (3 levels) and three blocks determined a total of 54 experimental units. The equidistance between seeds and sowing depth was analyzed as a response variable.

Sampling was carried out under the commercial operating conditions of the sowing equipment, *i.e.* without making any modifications or adjustments to the machine. The working speed at which the operator was sowing at that time was identified as Sp 2. Three repetitions were made counting the number of seeds in 5 linear meters. The intended sowing density was of 3 seeds per linear metre so that, in theory, 15 seeds should be counted in the 5 linear metres. In order to have more information, the sampling was repeated at two more speeds: a lower Sp 1 and a higher Sp 3 which were also used in the sowings, according to the information provided by the operators. Thus, a total of 135 seeds was observed (table 1).

Table 1. Sowing speeds in km h^{-1}.

Tabla 1. Velocidades de siembra en km h^{-1}.

Speeds	Seeders					
	1	2	3	4	5	6
Speed 1	8.5	7.3	7.5	7.2	5.5	5.7
Speed 2	9.5	8.4	8.0	8.0	6.7	6.4
Speed 3	10.6	9.2	9.6	9.0	7.5	7.7

Plants density per hectare was 54.800, taking into account these last considerations as well as the distance of 0.52 m between furrows and the 5% decrease in germinating power, mechanical damage, flora, and fauna.

Two methods were used to quantify seeding efficiency: the statistically-based method using the average distance, its standard deviation and it's coefficient of variation. The mean X is calculated as follows:

$$X = \frac{\sum_{i=1}^{N} xi}{N}$$

where:

xi = the distance between two consecutive plants or seeds (i and i+1) within the same sowing row

N = the total number of measurements. The mean distance will be directly influenced by the proportion of faults and/or multiple.

The standard deviation (σ) of the spacing is determined from the following equation:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} (xi - X)^2}{N-1}}$$

where:

xi = the distance between two consecutive plants or seeds within the same sowing row

X = the mean distance

N = the total number of measurements.

If the spacing were uniform, the standard deviation would be zero.

Finally, the coefficient of variation will estimate the relative dispersion of the sample determined from the following equation:

$$CV(\%) = \frac{\sigma * 100}{X}$$

where:
σ = the standard deviation
X = the mean distance.

The method based on the ISO 7256-1:1984 standard (21) uses the concept of theoretical space defined by the manufacturer according to the chosen density. This may generally differ in a very small magnitude from the theoretical space for the same density. This occurs because the mechanical elements of regulation are mostly discontinuous in their regulation. In this way, multiple index, failure index and power quality index are defined. The multiple index (M) is the percentage of spacing that is less than or equal to half the theoretical space. This is calculated from the following equation:

$$M(\%) = \frac{n_1 * 100}{N}$$

where:
n1 = the number of seed spacing measurements in the interval [0; 0.5 theoretical space value]
N = the total number of measurements made

The failure index (F) is the percentage of spacing that is greater than 1.5 times the theoretical space. This is calculated by means of the following equation:

$$F(\%) = \frac{n_2 * 100}{N}$$

where:
n_2 = the number of seed spacing measurements in the interval [1.5 theoretical space value; ∞]
N = the total number of measurements made.

Finally, the power quality index (A) is the difference between 100% and the F and M indices.

A (%) = 100% - M (%) - F (%)

A random evaluation was carried out on sowing depth at the three speeds under study for each machine. Six data per speed were determined with three repetitions, counting 18 values of seed depth per sowing machine for a total of 108 data.

In order to describe the sampled equipment, these were grouped according to their metering system. Thus, the horizontal and inclined plate mechanical equipment and pneumatic vertical plate equipment using negative pressure (vacuum) stood out.

Seeder 1 (S1)

This seed drill has a horizontal plate seed meter and a toothed star-shaped ejector, but it does not have a seeding monitor sensor. It was manufactured in 2012 and it is in good condition. 12 furrows at 52 cm. Seeder soil-engaging components: Turbo coulter blade, double disk furrow opener, depth-limiting wheel mounted on the furrow opener, seed firming wheel, notched covering disc.

Seeder 2 (S2)

This seed drill has a horizontal plate seed meter with seeding sensors mounted on the drop tubes. It was manufactured in 2014 and it is in good condition. 18 furrows at 52 cm. Seeder soil-engaging components: Turbo coulter blade, double disk furrow opener, depth-limiting wheel mounted on the furrow opener, seed firming wheel, notched covering disc.

Seeder 3 (S3)

This seed drill has a horizontal plate seed meter with seeding sensors mounted on the drop tubes. It was manufactured in 2011 and it is in good condition. 14 furrows at 52 cm. Seeder soil-engaging components: Turbo coulter blade, double disk furrow opener, depth-limiting wheel mounted on the furrow opener, seed firming wheel, notched covering disc.

Seeder 4 (S4)

This seed drill has a pneumatic vertical plate seed meter using a negative pressure (suction) powered by 2 turbines with a seeding monitor. It was manufactured in 2013 and it is in good condition. 18 furrows at 52 cm. Seeder soil-engaging components: Turbo coulter blade, double disk furrow opener, depth-limiting wheel mounted on the furrow opener, seed firming wheel, smooth covering disc.

Seeder 5 (S5)

This seed drill has an inclined plate seed meter and a star-shaped ejector. It also has a seeding monitor and sensors mounted on the drop tubes. It was manufactured in 2010 and it is in regular condition. 18 furrows at 52 cm. Seeder soil-engaging components: Turbo coulter blade, double disk furrow opener, depth-limiting wheel mounted on the furrow opener, seed firming slide, notched covering disc. Some soil-engaging components present a certain amount of wear.

Seeder 6 (S6)

This seed drill has an inclined plate seed meter and a star-shaped ejector. It also has a seeding monitor and sensors mounted on the drop tubes. It was manufactured in 2010 and it is in regular condition. 18 furrows at 52 cm. Seeder soil-engaging components: Turbo coulter blade, slightly worn double disk furrow opener whose bearing also presents a certain amount of wear, depth-limiting wheel mounted on the furrow opener, seed firming slide, notched covering disc whose blades are worn.

Results and discussions

Equidistance between seeds

Considering the expected theoretical density of 3 seeds per linear metre with a distance of 33.33 cm between them, the statistical analysis shows a different behaviour in the seed drills evaluated. No statistical differences between speeds were determined in the Seeder 1 which has a horizontal plate seed meter and which is in good condition. Given this fact, it would be possible to work at the highest speed (10.6 km h^{-1}), increasing the seeder operating capacity. However, not only the equidistance between seeds must be taken into consideration when analysing this determination, but also a set of variables and situations. The account should be taken, for example, of the fact that coulter blades can remove soil from the furrow excessively at high sowing speeds. This leads to a reduction in the furrow moisture, making it difficult to cover it later. The statistical analysis showed differences between speeds for the Seeder 2 which has a horizontal plate seed meter and which is in very good condition. The mean equidistance for speed 1 (9.5 km h^{-1}) is the closest to the theoretical requirement. The Seeder 3 which has a horizontal plate seed meter and which is in good condition showed similar behaviour. In the S3 analysis, statistical differences between speeds were observed. Besides, the average value of equidistance for speed 1 of 7.3 km h^{-1} was the closest value to the intended spacing according to the sowing density proposed. As a matter of fact, the speed 1 of 7.3 km h^{-1} is the closest speed to 6 km h^{-1}, considered to be the most suitable speed to achieve seeding efficiency. The Seeder 4 which has a pneumatic vertical plate seed meter using negative pressure (suction) and which is in very good condition showed similar behaviour to the S1 behaviour. In the analysis of the S4, no statistical differences between speeds were observed. This would increase the seeder working capacity by operating at the highest speed (9 km h^{-1}). The observations described for S1 are also valid for this case. An interesting behaviour was observed in the Seeder 5 which has an inclined plate seed meter and which is in regular condition. The statistical analysis showed differences between speeds. In addition, the ideal mean value of equidistance was observed when working at the highest speed of 7.5 km h^{-1}, in spite of the regular condition of certain seeder constituent components. As for this seeder and the study conditions, the results suggest that it is advisable to work at the highest speed, favouring the seeder operative capacity. From a statistical point of view, there are significant differences between speeds in the Seeder 6 which has an inclined plate seed meter and which is in regular condition. The closest values to the theoretical equidistance were observed when working at a lower speed of 5.7 km h^{-1}. The regular condition of certain seeder constituent components and a higher fall height due to the use of inclined plate seed meters could have possibly influenced the results (table 2).

Table 2. Equidistance results averages in centimetres, at different speeds for each seeder under study.

Tabla 2. Promedios de resultados de equidistancia en centímetros, a diferentes velocidades para cada sembradora en estudio.

	Seeders					
	S1	**S2**	**S3**	**S4**	**S5**	**S6**
Speed 1	34.84 a	34.04 b	33.39 a	34.40 a	38.93 b	32.23 a
Speed 2	33.80 a	35.05 b	31.81 a	34.11 a	35.64 ab	31.78 a
Speed 3	35.30 a	30.74 a	37.95 b	34.93 a	34.40 a	34.98 b
MC error	**25.91**	**31.29**	**42.11**	**16.57**	**70.71**	**36.43**

References: MC (Mean coefficient) / Referencia: MC (Coeficiente medio)

Means with a common letter (the same letter) are not significantly different ($p > 0.05$). Analysis by column.

Medias con una letra común no son significativamente diferentes (p > 0,05). Análisis por columna.

When analysing each machine performance, it can be observed that the Seeder 4 was the best at performing. In the three speeds used, there was little difference with the intended equidistance between seeds in relation to the proposed density.

This was observed considering the method based on statistics using the mean distance, its standard deviation and its coefficient of variation. It should be noted that the S1 also demonstrated proper operation (table 3and figure 1). These results vary from the statements of Olmos y Menéndez (2005) explaining that for every 2.5 cm increase in the standard deviation (SD), there is a decrease of 60 kg ha^{-1}. If this were the case, all seeders would be inefficient in sowing.

Table 3. Statistical method of quantification of equidistance between seeds.

Tabla 3. Método estadístico de cuantificación de equidistancia entre semillas.

	Seeder 1			Seeder 2			Seeder 3		
	Sp 1	Sp 2	Sp 3	Sp 1	Sp 2	Sp 3	Sp 1	Sp 2	Sp 3
Mean	34.84	33.80	35.30	34.04	35.05	30.74	33.39	31.81	37.95
Standard D.	5.18	4.70	5.43	5.48	5.43	4.34	6.78	5.73	5.99
CV	14.82	13.91	15.42	16.11	15.41	14.13	19.89	18.01	15.74
	Seeder 4			**Seeder 5**			**Seeder 6**		
	Sp 1	**Sp 2**	**Sp 3**	**Sp 1**	**Sp 2**	**Sp 3**	**Sp 1**	**Sp 2**	**Sp 3**
Mean	34.40	34.11	34.93	38.93	35.64	34.40	32.23	31.78	34.98
Standard D.	4.03	4.10	3.97	4.55	6.58	9.92	7.63	5.77	11.10
CV	11.70	12.02	11.38	14.11	18.78	30.21	20.44	16.33	31.67

References: Sp 1 (Speed 1); Sp 2 (Speed 2); Sp 3 (Speed 3); Standard D. (Standard deviation); CV (Coefficient of variation).

Referencias: Sp 1 (Velocidad 1); Sp 2 (Velocidad 2); Sp 3 (Velocidad 3); Standard D. (Desvío estándar); CV (Coeficiente de variación).

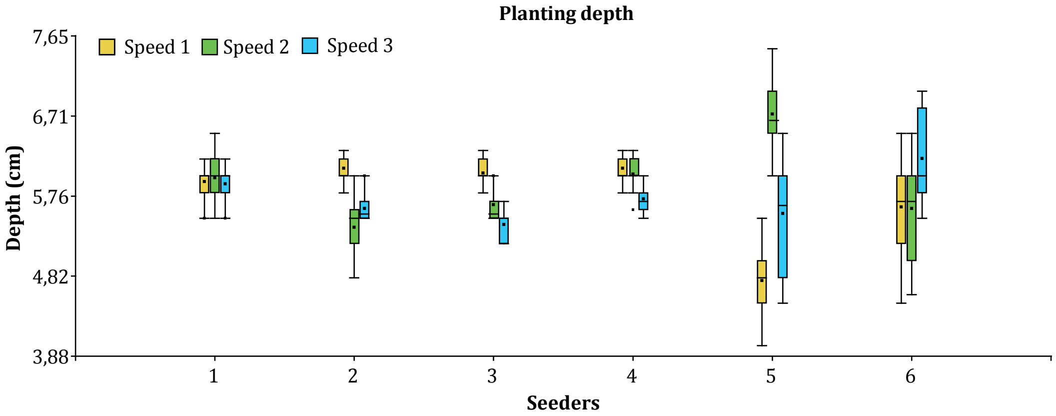

Figure 1. Seeders performance based on equidistance between seeds and speeds.

Figura 1. Rendimiento de las sembradoras basado en la equidistancia entre las semillas y las velocidades.

On the other hand, Valentinuz (2007a) state that no effect of non-uniformity on yield with densities of 58.000 plants ha^{-1} was found. Therefore, it can be deduced that the result would be the same with a density of 54.800 plants ha^{-1}.

When considering the method based on the ISO 7256-1:1984 standard to determine the multiple index (M), no distance equal to or less than half the theoretical spacing (16.67 cm) was observed in any of the cases under study. On the contrary, values higher than 1.5 times the theoretical distance (50.00 cm) were found in the S3 which has a horizontal plate seed meter. Values higher than 1.5 times the theoretical distance (50.00 cm) were also found in the S5 and S6 which have an inclined plate seed meter. Failure indices of 2.17 were determined at the speed 1 of 7.5 km h^{-1} in the S3, while no failures were recorded at the two higher speeds (Sp 2 and Sp 3). This would indicate that this result is possibly due to a measurement error. Failure indices of 2.27 and 8.51 were obtained for speeds 2 and 3 respectively (6.7 and 7.5 km h^{-1}) in the S5. On the other hand, the failure index was 9.09 for speed 3 (7.7 km h^{-1}) in S6. According to these results, only these seeders are inefficient in seeding (table 4).

Two factors could have influenced the working capacity of these last two machines, causing failures in sowing. On one hand, the first factor would be the regular condition of certain constituent components.

On the other hand, the second factor would be the inclined plate seed meters which lead to a greater height of seed exit. This increases the possibility of seed rebound in the drop tube, altering the equidistance.

Sowing depth

The intended theoretical depth was 6 cm. Statistical analysis showed differences between speeds for each seeder. There were no statistical differences in depth values at different speeds in the S1. According to these results, it would be advisable to work at the highest speed (10.6 km h^{-1}) to increase the seeder operational capacity. Moreover, there were no statistical differences between speeds in the analysis of equidistance between seeds. This seeder performance differs from the statements made by several authors (4, 22). They point out that, on one hand, the machine is more likely to jump at a seeding speed greater than 6 km h^{-1}. Consequently, these jumps lead to a deficient plantation as soil-engaging components are not able to maintain regular soil unevenness necessary to achieve uniform sowing density.

Table 4. Failure index values at three speeds for each seeder.

Tabla 4. Valores de índice de fallos en tres velocidades para cada sembradora.

	Seeder 3			Seeder 5			Seeder 6		
Speeds	**Meas.**	**Total N° of Meas.**	**Failure Index**	**Meas.**	**Total N° of Meas.**	**Failure Index**	**Meas.**	**Total N° of Meas.**	**Failure Index**
Speed 1	1	46	2.17						
Speed 2				1	44	2.27			
Speed 3				4	47	8.51	4	44	9.09

Reference: Meas. (Measurement). / Referencia: Meas. (Medición).

On the other hand, each soil-engaging component must dose, transport, deliver, firm and cover 8.16 seeds per second. This happens if corn is sown at a higher speed, for example, 7 km h^{-1}, using a density of 80 thousand seeds per hectare and with a separation of 52.5 cm between furrows.

These observations emphasize how important is to carry out a careful operation which must not only be fast but also precise. In addition, it is also important to take into account the importance of the working speed impact on yields. Even so, considering these results, working at the highest speed would allow a considerable increase in the seeder operating capacity without affecting the two variables under study: distance between seeds and depth. The behaviour of the S2 and the S3 was very similar as statistical differences between speeds were determined in both machines. At speed 1 of 7.3 h^{-1} and 7.5 km h^{-1} for the S2 and the S3 respectively, the mean was closer to the intended theoretical depth. The statistical analysis also showed differences between speeds in the S4. The closest values to the intended depth were observed at the two lowest speeds (7.2 and 8 km h^{-1}); while the values were lower at 9 km h^{-1}. However, a difference of 0.27 cm is considered negligible to negatively affect seeding efficiency. The performance of the last two seeders was practically similar as the statistical analysis showed differences between speeds. Closer values to the theoretical depth were obtained when working at the second speed for both machines (5.56 and 6.21 km h^{-1} for the S5 and the S6 respectively). At speed 3 of 7.5 km h^{-1} for the S5 and 7.7 km h^{-1} for the S6, the sowing depth was shallower. The regular condition of certain constituent components could have possibly influenced the results (table 5).

As for sowing depth, the seeder 4 (S4) was the best at performing, observing the lowest SD values. This was considered according to the method based on the use of the mean distance (M), the standard deviation (SD) and the coefficient of variation (CV). The S1 also showed a proper behaviour (table 6 and figure 2, page 121). A similar situation was observed in the analysis of the equidistance between seeds.

Table 5. Sowing depth values in three speeds for each seed drill.

Tabla 5. Valores de profundidad de siembra en tres velocidades para cada sembradora.

	Seeders					
	S1	**S2**	**S3**	**S4**	**S5**	**S6**
Speed 1	5.93 a	6.09 c	6.03 c	6.09 b	6.73 c	5.63 a
Speed 2	5.98 a	5.39 a	5.66 b	6.02 b	5.56 b	6.21 b
Speed 3	5.91 a	5.62 b	5.43 a	5.73 a	4.77 a	5.62 a
MC Error	**0.04**	**0.05**	**0.03**	**0.02**	**0.27**	**0.35**

Means with a common letter (the same letter) are not significantly different ($p > 0.05$). Analysis by column.

Medias con una letra común no son significativamente diferentes (p > 0,05). Análisis por columna.

Table 6. Statistical method of sowing depth quantification in three speeds for each seeder under study.

Tabla 6. Método estadístico de cuantificación de la profundidad de siembra en tres velocidades para cada sembradora en estudio.

	Seeder 1			Seeder 2			Seeder 3		
	Sp 1	**Sp 2**	**Sp 3**	**Sp 1**	**Sp 2**	**Sp 3**	**Sp 1**	**Sp 2**	**Sp 3**
Mean	5.93	5.98	5.91	6.09	5.39	5.62	6.03	5.66	5.43
Standard D.	0.17	0.17	0.21	0.14	0.23	0.14	0.17	0.21	0.17
CV	2.81	2.90	3.64	2.30	4.37	2.47	2.84	3.70	3.22
	Seeder 4			**Seeder 5**			**Seeder 6**		
	Sp 1	**Sp 2**	**Sp 3**	**Sp 1**	**Sp 2**	**Sp 3**	**Sp 1**	**Sp 2**	**Sp 3**
Mean	6.09	6.02	5.73	6.73	5.56	4.77	5.63	6.21	5.62
Standard D.	0.14	0.19	0.13	0.41	0.67	0.46	0.63	0.60	0.57
CV	2.30	3.14	2.19	6.15	12.03	9.62	11.21	9.71	10.14

References: Sp 1 (Speed 1), Sp 2 (speed 2), Sp 3 (speed 3), Standard D. (Standard deviation); CV (Coefficient of variation).

Referencias: Sp 1 (Velocidad 1); Sp 2 (Velocidad 2); Sp 3 (Velocidad 3); Standard D. (Desvío estándar); CV (Coeficiente de variación).

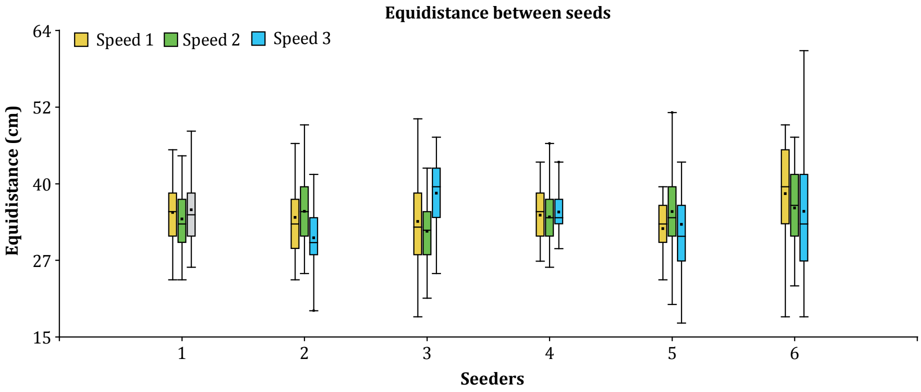

Figure 2. Seeders performance depending on sowing depth at different speeds.

Figura 2. Rendimiento de las sembradoras dependiendo de la profundidad de siembra a diferentes velocidades.

The soil compaction degree mainly in the tractor and seeder tracks is another possible factor that may have influenced the results, coinciding with Botta *et al.* (2018) and Hidalgo *et al.* (2020) studies.

Conclusions

Four of the six seeders studied at three chosen speeds showed no differences regarding seed deposition. This was observed considering significant differences between sowing depth and seed spacing in a given line. The S5 and the S6 showed faults at the two highest speeds, while the S3 showed faults only at the lowest speed, considered as a measurement error.

The two methodologies used to evaluate sowing efficiency, *i.e.* the coefficient of variation (CV) and the ISO 7256-1 standard, showed differences in evaluation. The second technique was more accurate since no differences between treatments were found with the CV.

According to these results, it is possible to conclude that the corn sowing quality in the Corrientes province is acceptable at the sowing speeds used by the contractors.

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