Electric drive system for seed metering and its effects on the distribution and development of the corn crop

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ABSTRACT
The present study aimed to evaluate the efficiency of the electric transmission drive of the seed metering mechanism of a precision seeder, in relation to the mechanical drive, in the distribution of corn seeds, and its effects on the development of the crop. The experiment was carried out using precision agriculture techniques - geostatistics - in a plot of 4.19 ha managed under no-tillage system. The area was divided into a grid with 35 points for each treatment (electrical transmission of the seed metering mechanism and mechanical transmission of the seed metering mechanism). To carry out the experiment, a precision seeder consisting of 7 lines was used, configured with 0.45m line spacing, being: 4 consecutive lines by electrical transmission and 3 consecutive lines driven by mechanical transmission. The electrical transmission of the seed dosing mechanism provided, in relation to mechanical transmission, a lower coefficient of...
variation of the linear distribution of seeds, a lower spacing index with failure, a higher normal spacing index, and a smaller difference in seeding density. As a consequence, the electrical transmission of the seed metering mechanism increased the productivity of the corn crop by 1.33% (87.96 kg ha\(^{-1}\)) when compared to mechanical transmission.

**Keywords:** *Zea mays*, technology, horizontal disc, precision farming.

**RESUMO**

O presente estudo teve como objetivo avaliar a eficiência do acionamento por transmissão elétrica do mecanismo dosador de sementes de uma semeadora de precisão, em relação ao acionamento mecânico, na distribuição de sementes de milho, e seus efeitos no desenvolvimento da cultura. O experimento foi conduzido via técnicas de agricultura de precisão – geoestatística - em um talhão de 4,19 ha manejado sob sistema plantio direto. A área foi dividida em um grid com 35 pontos para cada tratamento (transmissão elétrica do mecanismo dosador de sementes e transmissão mecânica do mecanismo dosador de sementes). Para a realização do experimento utilizou-se uma semeadora de precisão composta por 7 linhas, configurada com espaçamento entre linhas de 0,45m, sendo: 4 linhas consecutivas por transmissão elétrica e 3 linhas consecutivas acionadas por transmissão mecânica. A transmissão elétrica do mecanismo dosador de sementes proporcionou, em relação à transmissão mecânica, menor coeficiente de variação de distribuição linear de sementes, menor índice de falhas, maior índice de aceitáveis e menor diferença entre densidade. Como consequência, a transmissão elétrica do mecanismo dosador de sementes incrementou em 1,33% (87,96 kg ha\(^{-1}\)) a produtividade da cultura do milho quando comparada à transmissão mecânica.

**Keywords:** *Zea mays*, tecnologia, disco horizontal, agricultura de precisão.

**1 INTRODUCTION**

Sowing is a fundamental process in the establishment of annual crops propagated through seeds, because at this moment one of the main yield components is defined: the number of plants per area (Santos et al., 2011; Dias et al., 2014; Cintra et al., 2020). In addition, sowing must provide an adequate longitudinal distribution of the seeds in the soil, keeping the seeds equidistant, in order to avoid spaces without plants or two plants growing together in the same space (Almeida et al., 2010; Arcoverde et al., 2017).

In some crops such as soybean (*Glycine max* (L.) Merr.) and wheat (*Triticum aestivum* L.), the higher shoot emission (Balbinot Junior et al., 2015; Büchling et al., 2017) and the higher tillering (Fioreze & Rodrigues, 2014; Fioreze et al., 2019), respectively, can mitigate the negative effects of irregular sowing. On the other hand, in crops with low plasticity morphologic, such as corn (*Zea mays* L.), the sowing process assumes even greater importance, since these plants have
a low capacity to compensate the productivity under conditions of irregular plants spacing (Mondo et al., 2012; Sangoi et al., 2012; Weirich Neto et al., 2015; Fernandes et al., 2019).

To distribute the seeds individually in regular spacing, precision seeders are used (Francetto et al., 2015; Ferreira et al., 2019; Correia et al., 2020). However, the efficiency of these seeders in the quality of sowing occurs, among other factors, mainly through the mechanisms of activation of the seed meters, which can be mechanical, hydraulic or electric (Damasceno et al., 2017).

Currently, the mechanical mechanisms of activation of the seed meters are the most used in agriculture around the world, but they have some problems, especially in situations of sowing in curves (Damasceno et al., 2017). In addition, the skidding of the seeder wheel and vibrations in the gear belts may impair the dosage of seeds in seeders that use the mechanical mechanisms of activation of the seed meters (Cay et al., 2018a). This system can be composed of a belt-gear, or a gearbox-card, or a union of the two. These systems need lubrication every 10 hours and the lack of lubrication results in the hardening of the belt system and consequently failure in the drive transmission of the seed meters.

In order to solve the problems of the mechanical mechanisms of activation of the seed meters, there is the electric system (Cay et al., 2018b). The characteristics of the electric system are: possibility of instantaneous changes in sowing density and curve compensation, since the seed distributors are activated individually in each row (Damasceno et al., 2017). However, there are few studies in the literature about this system.

The present study aimed to compare a electric drive system for seed metering with a mechanical drive system on the seeds distribution and corn crop development.

2 MATERIAL AND METHODS

The experiment was carried out in the crop season 2019-20 with corn crop in the experimental area of the “Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul – Campus Sertão” (28° 02' 53.56" S, 52° 16' 1.14" W and average altitude of 685 m), in the municipality of Sertão (south of Brazil).

The soil at the site is classified as Dystrophic Red Nitosol (Santos et al., 2018) or Udic Oxisol (Soil Survey Staff, 2010). The soil has been managed for more than 5 years by the no-tillage system. The area has a humid subtropical climate (Cfa) according to the Köppen climate
classification, with well-distributed rainfall throughout the year, an annual average of 1,803.1 mm and an average annual temperature of 17.7 °C (Ramos et al., 2009).

During the development of the corn crop there was a water deficit. Total rainfall from September 2019 to February 2020 was just 867.4 mm - a reduction of 450.2 mm compared to the same period in the crop season 2018-19 crop which was 1317.6 mm (Embrapa Trigo, 2020).

The study was conducted via geostatistics in an area of 4.19 ha. A sampling grid of 35 points was used in each treatment. The treatments were: electrical transmission of the seed metering mechanism (ELE) and mechanical transmission of the seed metering mechanism (MEC).

The precision seeder used was a Kuhn® PG700 (Figure 1A) equipped with horizontal seed plate, double disc for the sowing and furrow opener for the fertilizer. The fertilizer doser used was the helical distributor with longitudinal discharge through overflow (Fertisystem®). The tractor used was a New Holland® TL95E. The precision seeder was set with a row spacing of 0.45 m. Three consecutive lines with MEC and four consecutive lines with ELE were used.

Figure 1. A) Precision seeder used in the experiment. B) Electric drive system for seed metering. Illustration of a precision seeder with a mechanical drive system (C) and electric drive system (D) for seed metering.
The mechanical mechanism of activation of the seed meters used in the experiment consists of transmission of mechanical energy via the drive wheel of the seeder (Figure 1C). This energy is transmitted via the gear-belt system to an axle system located at the end of the main frame. After, the energy is transmitted through a cardan to a gear system. This gear system, through an axle, drives the crown and pinion of the horizontal disc.

For electrical mechanism of activation of the seed meters, electric motors (Figure 1B) were directly coupled to the horizontal disk drive crown. For this, the application control system Fertisystem® TXF MB and the controller Variable Rate Application (VRA) PRO were used (Figure 1D).

The corn crop was sown on September 25, 2019, according to the Agricultural Zoning Climate Risk. The hybrid Agroeste® 1596 PRO3 (early cycle) was used at a density of 3.5 seeds m⁻¹. The sowing speed was 4.5 km h⁻¹, controlled through the VRA controller.

The variables analyzed in the experiment were: coefficient of variation of the linear distribution of seeds, plantability indexes (normal spacing, double spacing, and spacing with failure), emergency speed index, difference in seeding density, plant height, ear insertion height and productivity. All were evaluated considering 3 linear meters at each point of the grid.

For the evaluation of plantability indexes (normal spacing, double spacing, and spacing with failure), the methodology of ABNT (1994) was used. The normal spacing index indicates that the space between the seeds is between 0.5 to 1.5x the reference spacing. The double spacing index indicates that the space between the seeds is below 0.5x the reference spacing. The spacing index with failure indicates that the space between the seeds greater than 1.5x the reference spacing.

The coefficient of variation of the linear distribution of seeds (CVD) was calculated based on the spacing between the seeds. Through the classification of the plantability index, the CVD was classified as excellent (90% to 100% of the seeds in the normal spacing index), good (75% to 90% of the seeds in the normal spacing index), regular (50% to 75% of the seeds in the normal spacing index) and unsatisfactory (below 50% of the seeds in the normal spacing index) (Tourino & Klingensteiner, 1983).

For estimate the emergency speed index (ESI), the number of seedlings emerged at 10 mm above the soil were counted daily. The count was made until the value did not change for
three consecutive days of analysis. Data were calculated using the formula proposed by Maguire (1962).

The difference in seeding density was obtained by the difference between the density regulated in the precision seeder by the final plant density at the end of emergence.

The coefficient of variation (CV) of the data of the variables analyzed were evaluated according to the methodology of Ogunkunle (1993). The CV between 0 to 15%, between 15 to 35% and greater than 35% indicates that the data have low variability, moderate variability and high variability, respectively.

To verify the existence of spatial dependence, the Spatial Dependency Index (SDI) was estimated. This index represents a percentage ratio of the amount of spatial dependence (Zimback, 2001), quantified by the semivariogram model. The SDI is classified as strong (SDI >75%), medium (25< SDI ≤ 75%) and low (SDI ≤ 25%). The SDI is calculated by the following formula, where C0 is the nugget effect and C0+C is the sill.

\[
SDI = \left( \frac{C_0}{C_0 + C_1} \right) \times 100
\]

The Degree of Spatial Dependence (DSD) was also calculated, evaluated by the adjustments of semivariogram models. The DSD was considered strong (semivariogram has a nugget effect less than or equal to 25% of the spatial dependence range), moderate (semivariogram has a nugget effect between 25 and 75% of the spatial dependence range) or weak (semivariogram has a nugget effect greater than 75% of the spatial dependence range) (Cambardella et al., 1994). The following equation was used, where \(y(h)\) is the semivariance as a function of the separation distance (h) between pairs of points; h = separation distance between pairs of points; \(N(h)\) = number of pairs of experimental points separated by a distance h.

\[
y(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(x_i) - Z(x_i + h)]^2
\]

For spatial delimitation of the area and location of the points of the sample grid, a GNSS brand Garmin® model Etrex 20 was used. The maps were processed by the software Campeiro
which was also used to assemble the grids, isoline maps and evaluation of geostatistical parameters.

In addition, the data obtained were submitted to analysis of variance and the means were compared by the Tukey test (p < 0.05) using the Sisvar 5.6® software.

### 3 RESULTS AND DISCUSSION

Considering all variables analyzed, statistical difference was observed only for the difference in seeding density (Table 1). For both the MEC and the ELE, the CVs of the data for the CVD variable were considered highly variable (Ogunkunle, 1993), above 35%, which will reflect on the greater heterogeneity of the spatial arrangement of the plant, being 37.42% in the ELE and 49.26% in the MEC. This greater irregularity of seed distribution in the MEC is confirmed by analyzing the kriging maps where it was observed that in the ELE only 10.98% of the area presented CVD above 33.25% (Figure 2A) while in the MEC 31.26 % of the area presented CVD above 33.25% (Figure 2E). It is possible to observe that the greatest variations in the MEC occurred at the edges of the area, mainly in the regions of terrain curve (Figure 2E), a problem that was greatly mitigated with the use of the ELE (Figure 2A).

Table 1. Statistical analysis of the coefficient of variation of the linear distribution of seeds (%), normal spacing index (%), spacing index with failure (%), emergency speed index (%), difference in seeding density (plants ha⁻¹), plant height (m), ear insertion height (m) and productivity (kg ha⁻¹) of the corn crop in the mechanical and electrical mechanisms of activation of the seed meters.

<table>
<thead>
<tr>
<th>System</th>
<th>M</th>
<th>Mn</th>
<th>Mx</th>
<th>Sk</th>
<th>S</th>
<th>K</th>
<th>CV</th>
</tr>
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<td>Coefficient of variation of the linear distribution of seeds (%)</td>
<td></td>
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</tr>
<tr>
<td>Mechanical</td>
<td>28.30 a</td>
<td>9.26</td>
<td>65.63</td>
<td>0.64</td>
<td>13.94</td>
<td>0.06</td>
<td>49.26</td>
</tr>
<tr>
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<td>11</td>
<td>46.64</td>
<td>0.71</td>
<td>8.83</td>
<td>0.19</td>
<td>37.42</td>
</tr>
<tr>
<td>Normal spacing index (%)</td>
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</tr>
<tr>
<td>Mechanical</td>
<td>81.12 a</td>
<td>33.33</td>
<td>100</td>
<td>-1.03</td>
<td>18.69</td>
<td>0.18</td>
<td>23.04</td>
</tr>
<tr>
<td>Electrical</td>
<td>87.26 a</td>
<td>42.60</td>
<td>100</td>
<td>-1.44</td>
<td>12.82</td>
<td>2.99</td>
<td>14.69</td>
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<tr>
<td>Spacing index with failure (%)</td>
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</tr>
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<td>Mechanical</td>
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<td>18.90</td>
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<td>101.67</td>
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<tr>
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<td>0</td>
<td>71.43</td>
<td>1.92</td>
<td>16.20</td>
<td>4.43</td>
<td>114.65</td>
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<tr>
<td>Emergency speed index (%)</td>
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<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>4.02 a</td>
<td>1.91</td>
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<td>0.31</td>
<td>1.23</td>
<td>-1.19</td>
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<tr>
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<td>1.73</td>
<td>5.38</td>
<td>-0.19</td>
<td>0.98</td>
<td>-0.83</td>
<td>25.46</td>
</tr>
<tr>
<td>Difference in seeding density (plants ha⁻¹)</td>
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</tr>
<tr>
<td>Mechanical</td>
<td>0.77 b</td>
<td>0.17</td>
<td>2.17</td>
<td>1.29</td>
<td>0.44</td>
<td>2.40</td>
<td>57.56</td>
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<tr>
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<td>0.51 a</td>
<td>0</td>
<td>1.5</td>
<td>0.79</td>
<td>0.36</td>
<td>0.26</td>
<td>69.22</td>
</tr>
<tr>
<td>Plant height (m)</td>
<td></td>
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</tr>
<tr>
<td>Mechanical</td>
<td>2.33 a</td>
<td>1.75</td>
<td>2.7</td>
<td>-0.67</td>
<td>0.22</td>
<td>0.89</td>
<td>9.26</td>
</tr>
<tr>
<td>Electrical</td>
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<td>1.8</td>
<td>2.6</td>
<td>-0.26</td>
<td>0.21</td>
<td>-0.60</td>
<td>9.19</td>
</tr>
<tr>
<td>Ear insertion height (m)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>1.30 a</td>
<td>1.02</td>
<td>1.65</td>
<td>0.36</td>
<td>0.14</td>
<td>-0.11</td>
<td>10.98</td>
</tr>
<tr>
<td></td>
<td>1.30 a</td>
<td>1.05</td>
<td>2.35</td>
<td>3.13</td>
<td>0.23</td>
<td>13.80</td>
<td>17.57</td>
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<tr>
<td><strong>Productivity (kg ha⁻¹)</strong></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>6616.42 a</td>
<td>1805.31</td>
<td>11617.05</td>
<td>0.09</td>
<td>2519.51</td>
<td>-0.62</td>
<td>38.08</td>
</tr>
<tr>
<td>Electrical</td>
<td>6704.38 a</td>
<td>1975.44</td>
<td>14644.31</td>
<td>886406</td>
<td>2607.94</td>
<td>1524194</td>
<td>38.90</td>
</tr>
</tbody>
</table>

* Different letters indicate significant difference among treatments (Tukey test; p < 0.05).

M – mean; Mn – median; Min – minimum; Mx – maximum; Sk – skewness; S – standard deviation; K – kurtosis; CV – coefficient of variation.

Figure 2. Kriging map of (A) coefficient of variation of the linear distribution of seeds, (B) spacing index with failure, (C) normal spacing index, and (D) difference in seeding density of the corn crop in the electrical mechanism of activation of the seed meters; (E) coefficient of variation of the linear distribution of seeds, (F) spacing index with failure, (G) normal spacing index, and (H) difference in seeding density of the corn crop in the mechanical mechanism of activation of the seed meters.
The spatial dependence range (A) represents the radius of a circle, within which the values are so similar to each other that they become correlated (Vieira, 1997). This is an important parameter in the study of the semivariogram, as it provides information on this spatial correlation explained by the model (SILVA et al., 2017). In the CVD (Table 2), the spatial dependence range (A) of the MEC was 200 and that of the ELE was 150. This occurs because of the greater variation between the seed spaces in the MEC, however, continuously throughout the area. The sill (C0+C) was 249.59% higher in the MEC (194.48) compared to the ELE (77.92). As the sill (C0+C) increases, so does the maximum value for stabilizing the variance of the data. Furthermore, there was a greater nugget effect (C0) in the MEC (0.81) compared to the ELE (0.46). This confirms the fact that there is greater variability of CVD in the MEC treatment.

Table 2. Geostatistical analysis of the coefficient of variation of the linear distribution of seeds (%), normal spacing index (%), spacing index with failure (%), emergency speed index (%), difference in seeding density (plants ha\(^{-1}\)), plant height (m), ear insertion height (m) and productivity (kg ha\(^{-1}\)) of the corn crop in the mechanical and electrical mechanisms of activation of the seed meters.

<table>
<thead>
<tr>
<th>System</th>
<th>SDI</th>
<th>C0</th>
<th>C0 + C</th>
<th>A</th>
<th>Mod.</th>
<th>R(^2)</th>
<th>MSE</th>
<th>DSD</th>
</tr>
</thead>
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<tr>
<td>Mechanical</td>
<td>61.35</td>
<td>75.16</td>
<td>194.48</td>
<td>200</td>
<td>Exp.</td>
<td>0.848</td>
<td>213.46</td>
<td>38.65</td>
</tr>
<tr>
<td>Eletrical</td>
<td>55.86</td>
<td>34.39</td>
<td>77.92</td>
<td>150</td>
<td>Sph.</td>
<td>0.901</td>
<td>85.34</td>
<td>44.14</td>
</tr>
<tr>
<td>Normal spacing index (%)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>47.36</td>
<td>141.57</td>
<td>268.93</td>
<td>100</td>
<td>Exp.</td>
<td>0.978</td>
<td>276.16</td>
<td>52.64</td>
</tr>
<tr>
<td>Eletrical</td>
<td>62.23</td>
<td>39.33</td>
<td>104.13</td>
<td>150</td>
<td>Exp.</td>
<td>0.992</td>
<td>106.56</td>
<td>37.77</td>
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<tr>
<td>Spacing index with failure (%)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>48.19</td>
<td>174.23</td>
<td>336.27</td>
<td>100</td>
<td>Exp.</td>
<td>0.618</td>
<td>345.96</td>
<td>52.11</td>
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<tr>
<td>Eletrical</td>
<td>41.96</td>
<td>143.76</td>
<td>247.68</td>
<td>50</td>
<td>Sph.</td>
<td>0.600</td>
<td>233.79</td>
<td>58.05</td>
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<tr>
<td>Emergency speed index (%)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>48.21</td>
<td>0.81</td>
<td>1.56</td>
<td>200</td>
<td>Sph.</td>
<td>0.938</td>
<td>0.90</td>
<td>58.86</td>
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<tr>
<td>Eletrical</td>
<td>52.64</td>
<td>0.46</td>
<td>0.97</td>
<td>100</td>
<td>Exp.</td>
<td>0.939</td>
<td>1.62</td>
<td>48.74</td>
</tr>
</tbody>
</table>

Difference in seeding density (plants ha\(^{-1}\))
Regarding the plantability indexes, there were no double spacing in the area, only normal spacing and spacing with failure. For both MEC and ELE, the CVs for the spacing index with failure were considered highly variable (Ogunkunle, 1993). About 86.16% of the MEC area had a spacing index with failure lower than 35.70% (Figure 2F), while in the ELE the representativeness of the area with a spacing index with failure lower than 35.70% was higher, about 94.03 % (Figure 2B).

Regarding the CVs of the normal spacing index, the ELE was classified as low variability and the MEC as moderate variability (Ogunkunle, 1993). In the ELE, 94.51% of the area had a normal spacing index greater than 69.0% (Figure 2C) against 81.38% of the area in the MEC (Figure 2G).

The spatial dependence range (A) was different in the evaluated plantability indexes. In the normal spacing index, ELE presented a value for the spatial dependence range (A) of 150 and the MEC a value of 100. As for the spacing index with failure, ELE presented a value of 50 and the MEC a value of 100 (Table 2). In addition, the nugget effect (C0) was higher in the MEC in the spacing index with failure, indicating greater variability at the point itself, with a higher sill (C0+C) in this point.

According to the classification of Tourino & Klingenstein (1983), 13.2% of the ELE area was classified as regular performance, 52.6% as good performance and 34.2% as excellent performance. No unsatisfactory performance was observed for the ELE. For the MEC, 2.5% of the area was classified as unsatisfactory performance, 27.5% as regular performance, 42.5% as good performance and 27.5% as excellent performance.

<table>
<thead>
<tr>
<th></th>
<th>Mechanical</th>
<th>Electrical</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Plant height (m)</td>
<td>Ear insertion height (m)</td>
<td>Productivity (kg ha⁻¹)</td>
<td></td>
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<tr>
<td></td>
<td>Mechanical</td>
<td>Electrical</td>
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<td>50</td>
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<td>127.44</td>
<td>Exp.</td>
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<tr>
<td></td>
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<td>40</td>
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<td>Exp.</td>
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SDI - spatial dependence index; C0 – nugget effect; C0+C – sill; A – spatial dependence range; Mod. - model; R² - coefficient of determination; MSE - mean squared error; DSD - degree of spatial dependence.
The irregular longitudinal distribution of plants reduces the efficiency in the use of available resources, such as water, nutrients and light (Sangoi et al., 2012). The accumulation of plants (double spacing) causes the development of larger individuals with reduced individual production and problems with rooting. On the other hand, spacing with failure lead to the establishment of plants of reduced size and with greater individual production, in addition to facilitating the development of weeds (Castela Júnior et al., 2014).

It is important to emphasize that the plantability index can be influenced by factors other than the drive systems for seed metering evaluated in the present study. For example, the occurrence of a rebound effect inside the seed conductor tube, which can change the trajectory and time of seed descent through the conductor tube, thus contributing to the irregular distribution of seeds (Carpes, 2014). The drive systems for seed metering as well as seed quality (germination and vigor) also influence the plantability index (Weirich Neto et al., 2015). Therefore, the distribution of seeds in the soil is dependent on a number of factors.

The smallest difference in seeding density observed in the ELE, proves the efficiency of this system in relation to the MEC, which presented a difference between density of 0.26 plants ha\(^{-1}\) greater than the ELE (Table 1). In both MEC and ELE, the CVs of the difference in seeding density variable were considered highly variable (Ogunkunle, 1993). About 91.17% of the ELE area showed a difference in seeding density less than 0.87 plants ha\(^{-1}\) (Figure 2D), while in the MEC about 72.07% of the area showed a difference in seeding density less than 0.87 plants ha\(^{-1}\) (Figure 2H), reinforcing the greater regularity of seed distribution in the electrical system. The nugget effect (C0) of the difference in seeding density variable was close to zero, demonstrating little variability at the point itself (Table 2).

There is a strong interdependence between the maps of difference in seeding density with those of CVD and normal spacing indexes and spacing indexes with failure. The lower the CVD, the lower spacing indexes with failure, the higher the normal spacing indexes and, therefore, the lower the difference in seeding density.

Cay et al. (2018b), evaluating the performance of an electric drive system for seed metering compared to the mechanical system, also in corn, reported that the electrical system provided spacing values between plants closer to the desired values.

The emergence speed index (ESI) did not differ between treatments, however it was 0.16% higher in the MEC compared to the ELE (Table 1). For both the MEC and the ELE the
CVs of the ESI were considered moderately variable (Ogunkunle, 1993). In the MEC, about 14.32% of the area had an emergency speed index greater than 5.05% (Figure 3E), while in the ELE only 4.77 had an emergency speed index greater than 5.05% (Figure 3A).

Figure 3. Kriging map of (A) emergency speed index, (B) plant height, (C) ear insertion height, and (D) productivity of the corn crop in the electrical mechanism of activation of the seed meters; (E) emergency speed index, (F) plant height, (G) ear insertion height, and (H) productivity of the corn crop in the mechanical mechanism of activation of the seed meters.
For both treatments evaluated, the ESI showed a nugget effect (C0) close to zero (Table 2). According to McBratney & Webster (1986), the nugget effect is an important parameter of the semivariogram, as it indicates an unexplained variability considering the sampling distance used. According to Farias & Albuquerque Junior (2003), the experiments are subject to many errors, and the reflection of these possible errors, in the variogram, is the presence of this nugget effect, thus, there was no variation in the point itself related to this parameter. The spatial dependence range (A) had greater variability in the MEC (200) compared to the ELE (100).

Despite the absence of statistical difference between treatments, a plant height 0.09 m higher was observed in MEC compared to ELE, therefore, a very subtle difference (Table 1). In both MEC and ELE, plant height CVs had a low variability (Ogunkunle, 1993). Analyzing the kriging maps, it can be observed that in the ELE only 4.54% of the area presented plant height between 2.47 and 2.71 m (Figure 3B), while in the MEC 18.38% of the area presented plant height between 2.47 and 2.71 m (Figure 3F).

The means of ear insertion height were the same between treatments (Table 1). However, analyzing the kriging maps, it can be observed that a greater representation of the area with ear insertion height greater than 1.34 m in the MEC (32.46%) (Figure 3G) when compared to the ELE (17.42%) (Figure 3C). This higher ear insertion height in the MEC is closely related to the higher plant height in this treatment (Figure 3F), as they are correlated variables. Regarding ear insertion height CVs, MEC data had a low variability and ELE data had a moderate variability, according to Ogunkunle (1993). As for the spatial dependence of the attributes (Table 2), the SDI was classified as medium spatial dependence (Zimback, 2001) and the DSD as moderate spatial dependence (Cambardella et al., 1994), since both the SDI and GDE values are between 25 and 75%, that is, the influence of the random component on the spatial variability of the data is moderate.
The ELE provided an increase of 1.33% (87.96 kg ha\(^{-1}\)) in corn productivity in relation to the MEC (Table 1). Observing the kriging maps, the ELE (Figure 3D) presented an area of 33.42%, considering a productivity between 7110 to 11510 kg ha\(^{-1}\), while the MEC presented an area of 28.87% (Figure 3H). Both treatments showed CVs with high variability (Ogunkunle, 1993). The semivariogram that best fitted to model the variability of corn productivity in the area was the exponential model, also used by Silva et al. (2003). The higher corn productivity verified in the ELE was due to the lower coefficient of variation of the linear distribution of seeds, allied to the lower spacing index with failure, the lower difference in seeding density, and the higher normal spacing index in compared to the MEC.

Under spacing with failure, the lack of plants in the corn crop negatively affects the number of ears per unit area, and therefore productivity (Kopper et al., 2017). Although there is a tendency for corn plants, under spacing with failure, to produce more grains per ear compared to plants in normal spacing, this compensation is not enough to maintain high productivity levels (Madalóz, 2018). Fernandes et al. (2019), concluded that the reduction in the normal spacing index drastically reduced the sowing uniformity and grain yield of the corn crop. Therefore, the regular distribution of plants (low coefficient of variation of the linear distribution of seeds, low spacing index with failure and high normal spacing index) is directly related to the increase in corn productivity.

Although the emergence speed index was higher in the MEC in relation to the ELE, this variable did not influence the productivity of the corn crop, reinforcing the study by Trogello et al. (2013) who, evaluating different vegetation cover managements and sowing speeds, also did not observe any influence of the emergence speed index on corn productivity. In the same way, the higher plant height observed in the MEC compared to the ELE, also did not influence corn productivity, since the difference in plant height between treatments was very small.

It can be seen, therefore, based on the data obtained, that the use of an electric drive system for seed metering is an alternative that can be used in agriculture due to the higher quality in the sowing process, corroborating with the study by Cay et al. (2018b).

4 CONCLUSIONS

The electrical mechanism of activation of the seed meters, in relation the mechanical system, caused in the corn crop a lower coefficient of variation of the linear distribution of seeds,
a lower spacing index with failure, a lower difference in seeding density, and a higher normal spacing index.

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REFERENCES


