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COMPARISON OF THREE-LED AND FOUR-LED SEED SENSOR TECHNOLOGIES FOR MONITORING CORN, SOYBEANS, AND SORGHUM SOWING

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ABSTRACT: Large Brazilian farms currently are reliant upon seed sensor technologies to monitor seed populations during planting and optimize crop yields. Thus, the present study aimed to evaluate the performance of two different seed sensor technologies containing three and four light emitting diodes (LEDs), respectively. An experiment was performed using randomized blocks with four replications in a 2 × 3 factorial. Three tractor displacement speeds of 4.0, 8.0, and 12.0 km/h were used when evaluating each of the two sensor types. Corn, soybean, and sorghum seeds were sown individually to determine differences in sensor accuracy by seed type. A pneumatic seeder was used with the sensors affixed in the seed delivery tube. The three-LED seed sensor exhibited higher accuracies than the four-LED seed sensor. The highest accuracies were observed for the corn crop, with relatively lower accuracies observed for the soybean and sorghum crops.

KEYWORDS: seeder, agricultural technology, Zea mays, Glycine max, Sorghum bicolor.

COMPARAÇÃO DE SENSORES DE SEMENTES COM TRÊS E QUATRO LEDS NO MONITORAMENTO DA SEMEADURA DE MILHO, SOJA E SORGO

RESUMO. Em grandes propriedades brasileiras já é uma realidade o monitoramento da semeadura, otimizando a produtividade final. Desta forma, o presente estudo teve por objetivo avaliar o desempenho de duas tecnologias de sensores de sementes, sendo uma com três, e outra com quatro diodos emissores de luz (LEDs), respectivamente. O experimento foi conduzido em blocos ao acaso, com quatro repetições, em esquema fatorial 2 × 3. O desempenho dos sensores de sementes de três e quatro LEDs foi avaliado em três velocidades de deslocamento do trator, sendo 4, 8 e 12 km h^{-1}. Sementes de milho, soja e sorgo foram semeadas, individualmente, para determinar se houve diferença na acurácia dos sensores devido ao tamanho das sementes. Foi utilizada uma semeadora pneumática, onde foram fixados os sensores nos tubos condutores de sementes. O sensor de sementes de 3 LEDs apresentou eficiência superior ao de 4 LEDs. A maior acurácia foi observada para a cultura do milho, sendo relativamente inferior o desempenho para as culturas de soja e sorgo.

PALAVRAS-CHAVES: Semeadora, tecnologia agrícola, Zea mays, Glycine max, Sorghum bicolor.

1 INTRODUCTION

Seed sowing optimization is directly related to agricultural productivity, providing the procedures adopted during seed deposition are directly linked to the final product. Uniformity in the longitudinal distribution of seeds directly contributes to healthy plant growth and improved crop productivity (SANTOS et al., 2011).

In the agricultural sector, onboard technology (i.e., sensors embedded in agricultural management equipment) supports accounting in the sowing stage by providing data collection and management, automatic operation control, and global positioning mapping (BRAULIO; CAIMI, 2008). Agricultural operations that do not have a structured performance measurement system are more vulnerable to changes in the external environment (PELOIA; MILAN, 2010).

Of all techniques used in precision agriculture, the variable rate technology for fertilizer application has seen the greatest commercial success and ascension in use (COLAÇO; ROSA; MOLIN, 2014). However, other technologies such as seed sensors are becoming essential to ensure proper sowing.

New technologies have already demonstrated final crop productivity improvements, however, these productivity gains must be considered with deployment costs (MOLIN et al., 2010). The production cost constitutes 20–40% of the overall agricultural equipment cost, representing a strategic opportunity for new technology developers (ROSA; MILAN, 2015).

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Existing seed sensor technologies available for monitoring sowing operations primarily rely upon high-cost LEDs. The reduction of even a single LED in each seed sensor represents a significant savings in the final production cost of this technology.

SANTOS et al. (2011) reported that even with existing technologies to analyze data obtained under field conditions, agricultural operations still face many scientific challenges. To be successful, the agricultural sector, like any other industry, must adjust revenues and costs to ensure business profitability. This study aimed to assess whether comparable sowing accuracies could be achieved using a lower cost

2 MATERIALS AND METHODS

This experiment was carried out in 2013 by researchers at São Paulo State University's College of Agronomy located in Botucatu – São Paulo (22°51' S and 48°26' W, average altitude of 770 m). A tractor-seeder combination was used in the experiment. The tractor (New Holland TS 110) had 4 × 2 front wheel assistance and a rated engine power of 80.5 kW (109.5 hp). The precision seeder (Exacta 2980 PD) had a, pneumatic seed deposition system capable of concurrently sowing seven rows spaced 0.45 m apart.

The precision seeder was equipped with a monitoring system (AUTEQ MPA 2500). The number of seeds deposited was recorded by a sensor located within each seed delivery tube. Sensors with three LEDs were used in rows three, five, and seven; sensors with four LEDs were used in rows two, four, and six. The first row (row one) was excluded from this experiment.

The experiment was conducted in 4 × 20 m plots comprising six rows. The soil in each plot was flat and firm. The accuracy of the two seed sensors (with three and four LEDs, respectively) was evaluated at three tractor displacement speeds of 4.0, 8.0, and 12.0 km/h. The experiment was carried out in randomized blocks with four replications in a 2 × 3 factorial. Corn, soybean and sorghum seeds were sown individually to determine differences in sensor accuracy by seed type. The data obtained from each experimental plot were evaluated using analysis of variance methods. Treatment effects were assessed using F test and Tukey comparison of means test at a 5% probability level.

The true seed population was collected in plastic bags fastened to the ends of the six seed delivery tubes. The collected seeds were subsequently counted manually. The number of seeds registered by each of the six sensors was compared to the true number of seeds determined manually.

To support comparisons among the data, the data were normalized as a percentage using the following equation: % Accuracy = (Sensor Data / True Data) * 100

3 RESULTS AND DISCUSSION

No significant factor interactions were observed for the corn seeds (Table 1), suggesting no significant difference between the three-LED and four-Led seed sensors in sowing accuracy.

Table 1 - *Comparison of means and analysis of variance (ANOVA) for the accuracy of the sensors in relation to the displacement speeds. (Comparação de médias e análise de variância (ANOVA) para a precisão dos sensores em relação às velocidades de deslocamento)*

Corn seeds		
Displacement speeds (km/h)	Three-LED seed sensor	Four-LED seed sensor
4.0	99.87	99.77
8.0	99.71	99.44
12.0	99.47	99.43

ANOVA					
F (LEDs)	F (Speeds)	Interaction	LSD (Speeds)	LSD (LEDs)	C.V. (%)
$0.45^{n.s.}$	$1.20^{n.s.}$	$0.11^{n.s.}$	0.58	0.4	0.85

Tukey test at 5% probability was used. n.s. not significant ($p \geq 0.05$). LSD Least significant difference. C.V. Coefficient of variation in %.

Regardless of the tractor displacement speeds, the three-LED seed sensor performed well for corn seeds because of their flattened shape and larger size. The use of variable rate seeding technologies remains limited in Brazil because of their high associated costs (MACHADO et al., 2015). Lower cost sensor technologies may help to reduce overall costs.

As opposed to the findings for corn seeds, significant sensor or tractor displacement speed interactions were observed for the soybean (Table 2) and sorghum (Table 3) seeds.

Table 2 - *Interaction of factors and analysis of variance (ANOVA) for the accuracy of the sensors in relation to the displacement speeds. (Interação de fatores e análise de variância (ANOVA) para a precisão dos sensores em relação às velocidades de deslocamento)*

Soybean seeds		
Displacement speeds (km/h)	Three-LED seed sensor	Four-LED seed sensor
4.0	98.72^{aA}	84.05^{bB}
8.0	97.54^{aA}	91.34^{aB}
12.0	96.04^{aA}	86.64^{bB}

ANOVA					
F (LED's)	F (Speeds)	Interaction	LSD (Speeds)	LSD (LEDs)	C.V. (%)
113.8^{**}	4.69^{*}	6.82^{**}	3.27	3.93	4.34

Tukey test at 5% probability was used. The means followed by the same superscript letter do not differ. Uppercase and lowercase for lines for columns. ** Significant at the 1% of probability ($p < 0.01$). * Significant at the 5% of probability ($p < 0.05$). LSD Least significant difference. C.V. Coefficient of variation in %

Table 3 - *Interaction of factors and analysis of variance (ANOVA) for the accuracy of the sensors in relation to the displacement speeds. (Interaction of factors and analysis of variance (ANOVA) for the accuracy of the sensors in relation to the displacement speeds).*

Sorghum seeds		
Displacement speeds (km/h)	Three-LED seed sensor	Four-LED seed sensor
4.0	64.49^{aB}	64.57^{aA}
8.0	71.35^{abA}	60.95^{aB}
12.0	75.09^{aA}	53.33^{bB}

ANOVA					
F (LED's)	F (Speeds)	Interaction	LSD (Speeds)	LSD (LEDs)	C.V. (%)
36.3^{**}	$0.45^{n.s.}$	12.6^{**}	6.14	7.37	11.6

Tukey test at 5% probability was used. The means followed by the same superscript letter do not differ. Uppercase and lowercase for lines for columns. ** Significant at the 1% of probability ($p < 0.01$). * Significant at the 5% of probability ($p < 0.05$). LSD Least significant difference. C.V. Coefficient of variation in %

According to the Intelligence Center in Soybean (2013), soybean seeds can be classified as slick, oval, globose, or elliptical. The three-LED seed sensor offering higher accuracy attributable to a greater angle range was better suited to this seed type. The lower observed accuracy for the four-LED seed sensor may be attributable to tractor displacement speeds. Jasper et al. (2011) reported that higher tractor displacement speeds (12.0 km/h) when sowing soybeans results in lower seed distribution uniformity.

Sorghum seeds are small (the smallest seed considered in this study), winged, flat, and rough (SILVA et al., 2006). Consistent with the soybean findings, the three-LED seed sensor was better suited to this seed type, although its observed sowing accuracy (approximately 75%) was, relatively low compared to other seed types, particularly corn seeds. This difference in accuracy may be attributable to differences in seed densities; sorghum has a higher seed density than corn. Contrary to this study's findings, Rodrigues et al. (2011) concluded that plant populations decreased as tractor displacement speeds sowing increased. In this study, sensor accuracies for sorghum seed sowing increased as tractor displacement speeds increased.

Prior studies have observed that increased tractor displacement speeds, decreased the rate of acceptable spacing between plants, decreased effective field capacity, and increased planting depth errors (PINHEIRO NETO et al., 2008; GARCIA et al., 2011).

Soybeans and sorghum had the largest numbers of seeds during the monitoring period, reducing precision in the four-LED seed sensor results. The hypothesis of this study was that a three-LED seed sensor could perform with comparable accuracy under different tractor displacement speeds.

4 CONCLUSIONS

Based on the findings of this study, the less costly three-LED seed sensor can effectively replace the four-LED seed sensor, resulting in higher accuracies in seed identification and placement.

Seed sensor accuracy was highest for corn seeds, which may lead to greater sowing precision. For soybean and sorghum seeds, lower seed sensor accuracies suggest a need for further research regarding sensor performance and possible technology enhancement.

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