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Cause and Effect Estimates on Corn Yield as a Function of Tractor Planting Speed

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this work was to explain the cause and effect estimates on corn yield as a function of planting speed. The study was conducted from January 21 to June 15, 2019, at Fazenda Invernadinha, rural area of the municipality of Mineiros, GO, Brazil. The experimental design consisted of randomized blocks, corresponding to five tractor planting velocities (4, 6, 8, 10 and 12 km h^{-1}), in 4 replicates, where each plot consisted of 8 300 m long lines spaced at each 0.9 m, for a population of 60.000 plants ha^{-1}. Sowing was carried out in no-till system after soybean harvest. A John Deere tractor and planter assembly were used, models 7715 (182 hp horsepower) and 2115 CCS Vacumeter (8 rows of 0.9 m respectively) with 30-hole 30 mm seed discs. Data were submitted to the assumptions of the statistical model, verifying the normality and homogeneity of the residual variances, as well as the additivity of the model. The analyzes were performed in the Rbio R

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interface, besides the Genes Software. It was concluded that the plant population is the variable that most influences the cause and effect estimates on corn yield. For high corn yields it is recommended that the tractor planting speed be adjusted to 6 km h^{-1}.

Keywords: Sowing; planting; plant population; Zea mays.

1. INTRODUCTION

Brazil stands out as one of the largest corn producers (*Zea mays*) in the world, being surpassed only by the United States and China [1]. Corn is a cereal that, in addition to being used for human consumption, can also be used for the manufacture of animal feed as well as an energy source [2]. Aided by the good weather performance and the larger area allocation for corn, it contributes to a record harvest, which should reach almost 100 million tons, representing a 23.9% increase over last season [3]. This crop in the Southwest region of Goias is mainly worked in the second crop.

CurYIEtly, the presence of modern equipment in rural properties is common. However, only the presence of these do not guarantee the success of the crop, which depends on a variation of details. Several factors, such as area choice, soil amendments and conditioning, nutritional management, integrated pest management, crop genetics, climate factors, can influence crop yield as well as crop quality.

The planting window for corn in the second cropping period in Brazil, coupled with the unstable rainfall indices, has required producers to be more agile in the sowing process to ensure a good crop development. Adopting high planting speeds can cause serious problems, the most impacting being reduced productivity. Corn is a crop that requires attention to sowing quality, since the potential of the crop is closely linked with this activity.

The high planting speed does not guarantee seed deposit in the proper place, resulting in planting failures, double plants, diffeYIEt depths and uneven plant emergence. Linear variation between seeds can increase the coefficient of variation of plantability, leading to a decrease in yield. According to Lamana [4], corn is a grass that does not have the ability to till to compensate for the lack of plants in the population, such as wheat and oats that belong to the same botanical group, which makes the act of precission, quality sowing important.

It is crucial that at the time of planting all variables associated with soil condition are assessed and recognized d, to facilitate the choice of the optimum speed in the sowing operation since it may vary depending on the type of mulch, soil moisture, topography and logistics adopted in the field. There are a few studies dealing with this subject, Fawcett, et al. [5], Jasim, et al. [6] and Machado, et al. [7], however, there is some controversy in the literature when seeking practical recommendation to the producer.

Justification for this research stands from the problem of having constant working-speed variations during seeding process. These constant speed changes are often necessary and dependant on the soil type, soil moisture, soil cover and even the equipment used. Although today's equipment has a great seed distribution technology leading producers to believes that an increase of the work-speed results in higher performance efficacy. Currently, this fact is not generally accepted among the producers in the Southwest region of Goias.

However, the quality of sowing is not influenced only by the equipment technology but with a number of other factors that must be considered, especially the work speed, where the equipment will make the cut, groove opening, time-effective seed deposition and coverage to insure maintaining quality and better operational efficiency. Therefore, the objective of this study was to explain the cause and effect estimates on corn yield as a function of planting speed.

2. MATERIALS AND METHODS

The study was conducted from January 21 to June 15, 2019, at the Invernadinha Farm, rural area of the municipality of Mineiros, GO, Brazil. Geographically it is at 17º24'51.10"S and 52º26'29.02"W, and approximately 930 m altitude. The average air temperature of 23.5ºC and precipitation of 756 mm prevailed during the study period. The experimental area is classified as Aw (hot dry) climate [8]. The experimental design consisted of randomized blocks, corresponding to five planting speeds (4, 6, 8, 10 and 12 km h^{-1}), in 4 replications, totaling 20 experimental units, where each unit consisted of 8 rows of 300 m in length with row sapcing of 0.9 m, for a population of 60,000 plants ha^{-1}.

Before planting, the soybean crop was desiccated for harvest, thus eliminating any type of weeds present in the field. At soil preparation before planting, 350 kg ha^{-1} of fertilizer 23-03-12 was applied at the phenological stage V2 - V3, covered urea (46-0-0) was applead at a rate of 100 kg^{-1}. The hybrid used was the Morgan MG 580 PW RC3 sieve. The seeds were conditioned to “On Farm” treatment using: Standak Top (fipronil + piraclostrobin + thiophanate-methyl), Sombrero (imidaclioprido), Azos (Azospirillum brasilense), Maxim XL (Fludioxonil + Metalaxyl-M), Cruiser (Thiamethoxam) and Quality (*Trichoderma asperellum*), at rates recommended by the manufacturers.

Sowing was carried out on January 21, 2019 in a no-till system after soybean harvest. A John Deere tractor and planter assembly was used, whose models 7715 (182 hp horsepower) and 2115 CCS VacuMeter (15 spacing lines 0.45 m) respectively, with 30 - hole 30 mm seed discs. The sprayer used for proper crop treatments was a John Deere model 4730 with 30 m of bars. Pest and disease management was conducted following the good agronomic practices guidelines prescribed by the property management standards.

At the time of planting, the previously established set adjustments (seed disc, population, seed depth, vacuum, pressure of the cutting discs and covering wheels) were maintained, according to the beginning of planting in the field, where the only change was the speed of planting in each plot. The speed was controlled on the tractor monitor, varying according to the protocol established for each plot during the planning phase of this study.

Data collection began at the stage V4, where plant spacing of 30 sequential plants in the 8 central lines of each plot were measured, so that the information obtained was representative of each treatment. From these data the final plant population (POP) was established. At harvest on June 15, 2019, 10 ears of 10 sequential plants were taken to establish the planting density (DEN), row number per ear (NRE), number of grains per row (NGR) number, grain per ear (NGE), one thousand grain weight (TGW) and yield (YIE). We also harvested the useful plot, discarding the edges, with a John Deere STS 9670 harvester coupled to a plot compatible platform (8 rows of 0.9 m), doing the proper weighing and grain moisture discount according to the local warehouse.

Data was submitted to the assumptions of the statistical model, verifying the normality and homogeneity of the residual variances, as well as the additivity of the model. Afterwards, the analysis of variance was performed in order to identify the main effects of planting speed on corn variables. Subsequently, the variables were subjected to linear correlation in order to understand the tendency of association, and their significance was based on 5% probability by the t test. In sequence, the path analysis was performed from the phenotypic correlation matrix, considering the YIE as the dependent variable and DEN, NRE, NGR, NGE, TGW and POP as explanatory variables. Identifying the presence of high multicollinearity among the data, the path analysis was performed under multicollinearity, with subsequent adjustment of the k factor to the diagonal elements of the correlation matrix. After that, the genetic dissimilarity was performed by the Mahalanobis algorithm, where the biplot canonical variables method was used, allowing the visualization of the general variability of the experiment and the multivariate tYIEds. The analyzes were performed in Rbio R interface [9], in addition to Software Genes [10].

3. RESULTS AND DISCUSSION

The summary analysis of variance with the mean square QM and significance by the F test revealed significant diffeYIEces in the final plant population (POP) and YIE yield variables (Table 1). Corroborating this with Delafosse [11], who reports that the speed in the sowing operation is one of the parameters that most influences the performance of sowing machines, and the longitudinal distribution of seeds in the sowing furrow is affected by the displacement speed, which, for example. In turn influences the YIE of the crop. This confronts with Machado, et al. [7], who state that the increase in the speed of displacement of the seeders influenced the reduction of plant number, increase of faulty and multiple spacing, but not influencing the corn YIE. The other variables showed no significant diffeYIEces when varying the work speed at sowing (Table 1).

According to Fig. 1 (A and B), the values for POP (A) and YIE (B) showed quadratic behavior as a function of planting speed. The POP presented the largest number of plants per linear meter corresponding to 5.22 pl m^{-1} at a speed of 5.45 km h^{-1}, with a plant spacing of 19.16 cm (Fig. 1A). The maximum YIE was obtained at the speed of 5.77 km h^{-1}, reaching an average of 166.71 bags ha^{-1} (Fig. 1B).

According to Cruz et al. [12], the ideal population density of seed distribution by a sower is mainly affected by planting speed. However, YIE will only be affected by planting speed if it reduces the number of plants per area [13]. Garcia et al. [14] verified a linear reduction in soybean YIE with increasing sowing speed. Chaves [15], in his work, relating diffeYIEt planting systems with speeds from 4 to 8 km h^{-1}, using a pneumatic seeder, demonstrated reduced productivity as the speed increased. As studied by Kopper et al. [16], the increase in sowing speed reduces plant height and grain yield.

The correlation network applied to the characteristics of the hybrid MG 580PW at the diffeYIEt planting speeds indicated the positive correlation between the pairs: NGE x DEN, NGE x TGW, DEN x TGW, NGE x NGR and POP x YIE. Negative correlation was observed in POP x TGW, POP x DEN, NRE x NGR and NRE x NGE (Fig. 2). Pearson's linear correlation coefficient measures the stYIEgth and direction of the correlation (positive or negative) between two random characters X and Y [17]. The correlation network shows the degree of matching that the variables can present to each other, saving time in data collection, as well as explaining the oscillations of the averages, since the variables have interdependencies.

Estimates of the direct and indirect effects of explanatory variables on YIE were based on the causal scheme of the trail analysis, revealing that POP (1.22) was the character that most influenced YIE, followed by NGE (0.50), NRE (0.38), NGR (0.21) and DEN (0.18) (Fig. 3). As described by Follmann et al. [18], in the trail analysis the grain YIE has been used as the main character due to several explanatory characters. The coefficient of determination equivalent to ≅98% indicates that the explanatory variables fully determined the variation of the basic variable. For Fawcett et al. [5] Planting a very high corn population can result in increased sterility and therefore lower yields.

In the principal component analysis, the first two axes explained 83.36% of the total variation present in the covariance matrix, with the first major component accounting for 56% and the second major component accounting for 27% of the total variation. The ordering of the characters as a criterion of importance in the joint analysis was NGE, YIE and NRE (Fig. 4). According to the report by Machado, et al. [7] canonical variables are used in studies of geneticdissimilarity, with the purpose of identifying similar paYIEts in two- or three-dimensional scatter plots. However, the statistical tool can also be used efficiently in studies involving other phytotechnical themes such as plantability potential and final field performance. In this study, it was possible to verify that NGE and NGR, as well as POP and YIE showed similarities of each other, with high expressions at operating speeds of 8 and 6 km h^{-1}, respectively (Fig. 4). Jasim, et al. [6] showed optimization in 9.53 identifying that above this there was a reduction in field efficiency, leaf area, and corn YIE.

Table 1. Summary of analysis of variance (calculated QM and CV (%)) for row planting density (DEN), row number per spike (NRE), number of grains per row (NGR), number of grains per spike (NGE), one thousand grain weight (TGW), final plant population (POP) and yield (YIE). Mineiros-GO, UNIFIMES, Brazil, 2019

FV	GL	DEN	NRE	NGR	NGE	TGW	POP	YIE
Planting speed	4	0.46^{ns}	0.02^{ns}	1.04^{ns}	188.56^{ns}	8.47^{ns}	0.04^{**}	16.95^{**}
Blocks	3	0.65	0.21	0.32	238.61	41.04	0.01	0.77
Residue	12	1.00	0.25	1.11	496.64	24.16	0.01	1.89
CV	-	4.90	3.02	3.22	4.06	1.44	1.67	0.83
Average	-	20.42	16.77	32.71	548.54	340.96	5.15	165.56

*^{ns} not significant at 5% probability by F test; **significant at 1% probability by F test; PV: source of variation; GL: degree of freedom*

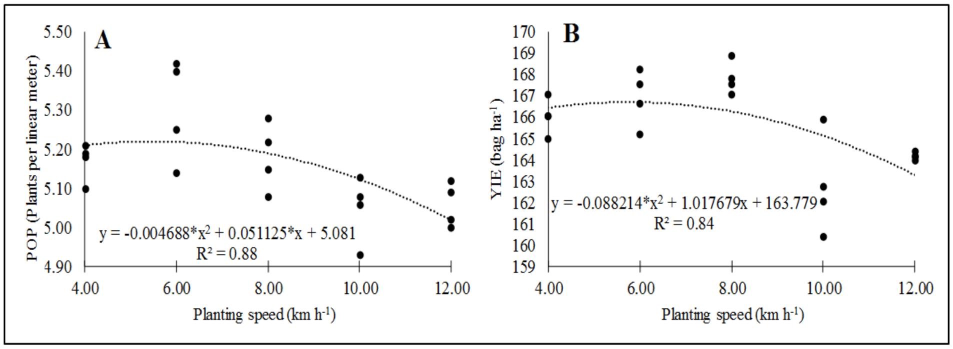

Fig. 1. Values for POP (A) plant population and YIE (B) yield of corn crop, as a function of planting speed. Miners-GO, UNIFIMES, Brazil, 2019

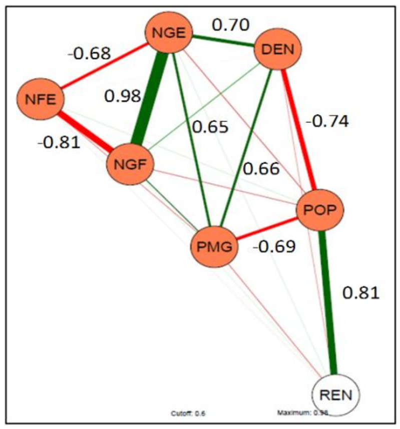

Fig. 2. Linear correlation network for corn characters as a function of planting speed, based on significance by t-test at 5% probability. Miners-GO, UNIFIMES, Brazil, 2019

Variables: For row planting density (DEN), row number per spike (NRE), number of grains per row (NGR), number of grains per spike (NGE), one thousand grain weight (TGW), final population of (POP) and yield (YIE)

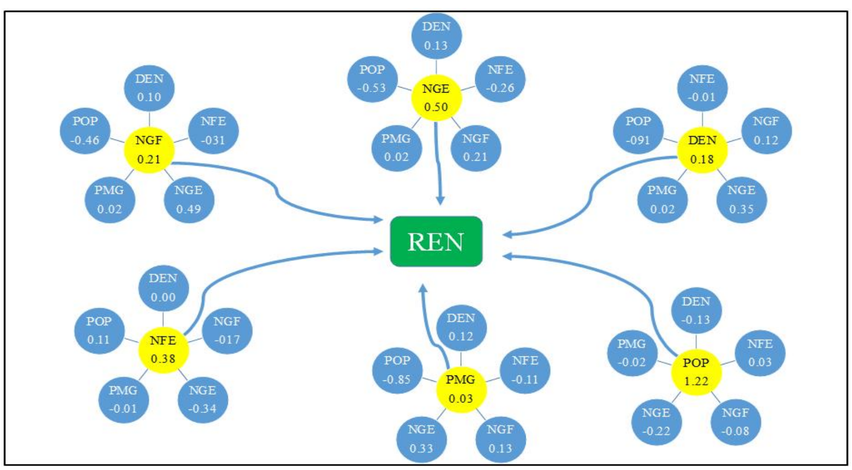

Fig. 3. Estimates of direct and indirect effects on trajectory analysis of explanatory traits row planting density (DEN), row number per ear (NRE), number of grains per row (NGR), number of grains per ear (NGE), weight of one thousand grains (TGW), final plant population (POP) on YIE yield in corn crop as a function of planting speed. Miners-GO, UNIFIMES, Brazil, 2019

Coefficient of determination: 0.97824; K value used in the analysis: 0.01063; Effect of residual variable: 0.1475; determinant of the correlation matrix between explanatory variables: 8.04E-05

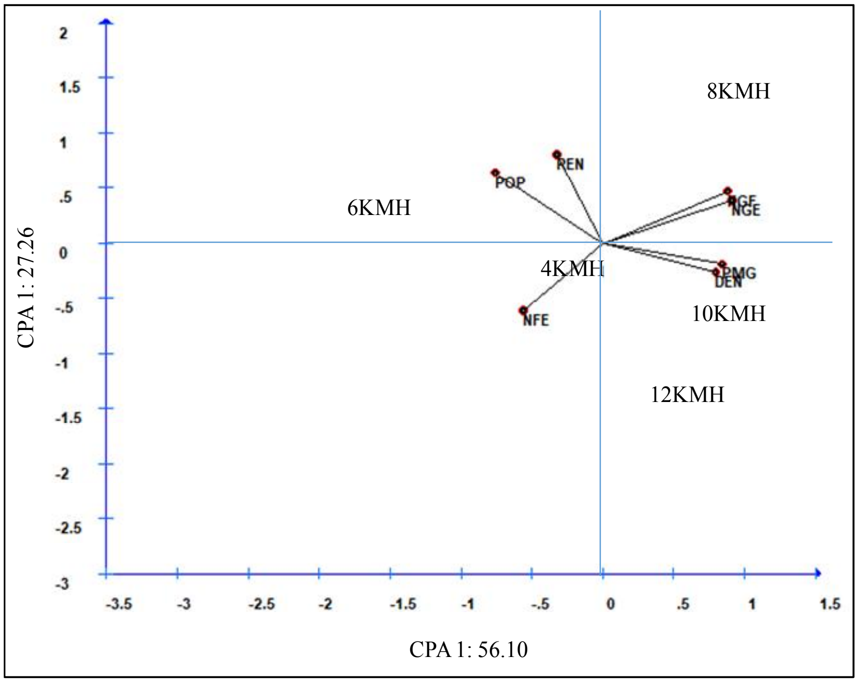

Fig. 4. Principal component analysis of characters of corn hybrids as a function of planting speed. Miners-GO, UNIFIMES, Brazil, 2019

Variables: For row planting density (DEN), row number per spike (NRE), number of grains per row (NGR), number of grains per spike (NGE), one thousand grain weight (TGW), final population of (POP) and yield (YIE)

The sowing speed presented variance of POP in the planting line, as well as in the corn YIE. Regression analysis describes that the speed of approximately 6 km h^{-1} is the most efficient for YIE elevation. Similar to the work of Nantes and Carvalho [19], where the sowing speed of 6.7 km h^{-1} provided the highest grain yield. Vasconcellos, et al. [20], also concluded that the increase of sowing speed negatively influences the emergence and yield of wheat, where the highest yield is obtained when using the speed of 6 km h^{-1}.

The correlation network described the positive and negative interaction between the variables, highlighting the NGE by the magnitude and expansion of influence with the NGR, NRE and DEN. Among the estimates of direct effects on YIE, only TGW did not influence. Also, in convention with regression analysis, the main components reinforce that the highest YIE was obtained at the planting speed of 6 km h^{-1}.

4. CONCLUSION

Plant population is the variable that most influences cause and effect estimates on corn yield.

For high yields of corn crop (YIE ≥ 160 bags ha^{-1}) in the studied environment, it is recommended that the planting speed be adjusted to 6 km h^{-1}.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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