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Corn yield components in function of the regulation of the seeder-fertilizer in a conventional planting system in amazon biome

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Abstract

The correct seeder-fertilizer adjustment is responsible for increasing the efficiency of corn cultivation's implementation process. This work aimed to evaluate transmission system regulation of seeder-fertilizer seed deposition unit in maize crop implantation in the Eastern Amazon. The experiment was carried out after the sowing process with a seeder-fertilizer for conventional planting with a mechanical seed distributor. The treatments resulted in five size combinations of driven gears (8, 10, 12, 15, 17) with the motor gear of size 7, which resulted in the respective corn sowing densities, 64.978, 62.311, 52.444, 44.977, 38.665 plants ha^{-1}. Each treatment consisted of a 200 m seeding strip divided into 20 plots per strip (treatment). The agronomic variables analyzed were: average Number of Days to Emergence (NDE), longitudinal distribution of plants in the standard (N), Fault (F) and Double (D) fields, Initial Plant population (IP), Final Plant population (FP), Stem Diameter (SD), Plant Height (PH), Number of Leaves (NL), Number of Ears (NE), Mass of one hundred grains (MG), Number of Grains per row (GR), Number of Ear rows (ER), Ear Length (EL), Ear Diameter (ED) and Productivity (P). Data were submitted to statistical analysis, correlation test and decision tree analysis. The decision tree showed which initial population was more important to classify the most relevant agronomic variables in corn planting. The initial stand of 62.442 plants ha^{-1} was the most suitable for corn in the Amazon region. There is potential to reach corn productivity of 5.14 to 5.33 t ha^{-1} when combined with a drive gear 12 and driven gear 7 seeder-fertilizer machine transmission system.

Keywords: Decision tree, Learning Machine, Agricultural Mechanization, Productivity.
Abbreviations: NDE_Average number of days to emergence, N_longitudinal distribution of plants in the standard, F_fault and double (D) field, IP_initial plant population, FP_final plant population, SD_stem diameter, ED_ear diameter, PH_plant height, NL_number of leaves, NE_number of ears, MG_mass of one hundred grains, GR_number of grains per row, ER_number of ear rows, EL_ear length, P_productivity, WCS_water content in the soil, RP_mechanical resistance of the soil to penetration, DT_Decision Tree, CV_coefficient of variation.

Introduction

Considered the third-largest corn producer in the world, the Brazil cultivates an area of 18.440 million hectares, producing 100.558 million tons (CONAB, 2020). Northern region grain production of the country is fundamental in agribusiness, characterized as a new agricultural frontier in Amazon. In this region, corn began to gain prominence in the last three agricultural years with a 10% increase in the sown area, totaling 3 thousand tons produced in the 2019/2020 harvest (CONAB, 2020).

Agricultural development applied in the eastern Amazon is agricultural models imported from Brazil's southeastern and central regions. Therefore, in many cases, they are not suitable for the implantation of the corn crop in the north region, given the local soil and climate variations. In addition, conservation techniques are not widespread, configuring another problem in the production process in conditions mechanized preparation intensive (Almeida and Vieira, 2019), which is associated with the natural characteristics of soils that can cause their compaction (Santos et al., 2016).

Soil compaction influences the relationships between air, water, and soil temperature, interfering with plant development and corn productivity (Labegalini et al., 2016). Corn productivity can be affected by weather conditions during sowing, seed distribution, and plant spatial arrangement (Cortez et al., 2020). These characteristics are essential for productive efficiency, as they are decisive for the final stand of the plants in the field. Thus, sowing is regarded as one of the crucial steps in the production system, as the mechanized set is responsible for uniformly distributing seeds in the field (Cortez et al., 2019). Therefore, it is essential to correctly adjust the seeder-fertilizer and adapt the tractor to local conditions to the edaphoclimatic requirements of the region (Macedo et al., 2016).

Seeders' performance and sowing quality are demonstrated in the literature to increase corn productivity (Mello et al., 2007).

This relevance promotes the development of studies on the precision and density of pre-seeding dosing mechanisms established by the culture (Dias et al., 2014). Researching seed distribution mechanisms under technical, operational and environmental conditions is essential for increasing a crop's productivity (Storck et al., 2015).

Studies on dosing mechanisms in the northern region of Brazil are still poorly explored. Faced with this gap, the evaluation of agricultural machines as seeders-fertilizers and seed population adequacy to the local soil and climate conditions are essential. In this sense, this research aimed to evaluate the combinations of motor and driven gears of the seeder-fertilizer transmission system. We are seeking to determine the best combination for corn sowing in the Western Amazon region.

Results

Statistical analysis

Statistical analysis results for the agronomic variables and soil attributes are shown in Table 2. According to the coefficient of variation (CV) classification (Gomes and Garcia, 2002) the variables analyzed in each treatment, the data showed average variability. Except for the longitudinal distribution of the variables of double plants (D), number of ears (NE), and soil mechanical resistance to penetration (PR), which obtained values greater than 30% and P (26.70%) (Table 2). The highest PR variation coefficients are demonstrated in the soil layers of 0-0.10 and 0.10-0.20m with 82.26 and 46.09%, respectively. From the information obtained in the analysis of variance, there was no difference between the treatments evaluated for the mean values of PR and soil water content (WCS). The results referring to the average indicated PR between 0.11 and 1.32 MPa in all soil layers and WCS around 20%.

Treatments influenced the agronomic characteristics of the evaluated plants, except for the longitudinal distribution of plant fault (F) and the number of leaves (NL) (Table 2). The five combinations of driven gears and motor gear provided a higher percentage of standard spacing and fewer faulty spacings in seeding lines in all treatments. Longitudinal distribution variables of plants presented higher rates of a N distribution with values between 56.35% and 72.21% and double spacings presence from 17% to 27.61%, while the faulty spacing was 15% in all treatments. In the comparison between treatments, T3 showed a higher percentage of N distribution (72.21%) and lower D (17.89%), as well as higher final plant population FP (62.442 plants ha^{-1}), and T2 showed a lower percentage of N spacings (56.35%) and higher D (27.61) and as well as T3, presented the highest final plant population (59,554 plants ha^{-1}) to the other treatments.

According to the increase in the variables plant height (PH) and FP in treatments T2 and T3, productivity tended to increase. Evidencing the effect of these variables on crop productivity, productivity in these treatments was 5.14 and 5.33 t ha^{-1}, respectively. The mean weight of MG was 38 mg ha^{-1} in T2 and 28 mg ha^{-1} in T3.

The variables plant height (PH), stem diameter (SD), ear length (EL), number of ears (NE) and hundred-grain mass (MG) were influenced by treatments. The treatments that maintained the average population adjustment of plants between 60.000 and 69.000 plants per hectare at the beginning and end of planting, expressed by the variables IP and FP, showed higher productivity when compared to the other treatments. This shows factors interference related to corn sowing, plants' final stand, and the link with final crop productivity.

Correlation analysis

The correlation analysis carried out the main attributes identification of the culture associated with the productive efficiency response in the field (Table 4). Variables with a correlation above 0.40 were classified as strong.

Analyzing the Average number of days to emergence (NDE) characteristics, a favorable effect was observed only for PH and MG but of low magnitude (r=0.22), and the longitudinal distribution variables of plants N, F and D had a high negative correlation (r>40). For these primary variables related to plant distribution, no direct and indirect effects of secondary variables of high correlation with crop productivity were observed, indicating that these variables are not the main components of variations between treatments.

Among the productive variables, there was a positive correlation between EL and ED with GR, resulting in r= 0.42 and 0.66, respectively. The NE presented a strong performance on the MG (r=0.94), which showed a low correlation with P (r=0.29). From this, it can be inferred that the NE is efficient in promoting gains by the correlated responses, even with the favorable indirect effect on the grain mass. In turn, P suffered a strong effect only of IP and FP with the respective correlation values of 0.58 and 0.68, which also have a high positive correlation (r=0.89).

Significant negative correlations were demonstrated in the SD analysis with the plant population in the PI (-0.50) and low in the field with P (-0.21). In general, according to these values, it is noted that factors related to stand density are directly related to ear yield variables, so IP exerts an effect, albeit low on MG (r=0.22) and in EL (r=0.35), which is positively associated with ED (r=0.35) and P (r=0.15).

Decision tree analysis

The classification performed with the decision tree algorithm presented a high performance of the model (Table 3), represented by the Roc curve (AUC =0.77) because it showed a value close to 1 and an accuracy (CA) of 0.578. Precision and Recall metrics were 0.57 and 0.578n, respectively.

The F1 score was 0.57, which can be interpreted as a weighted average of accuracy and recall. An F1 score reaches its best value at 1 and worst score at 0. The relative contribution of accuracy and recovery to the F1 score is the same. Each decision node present in the decision tree (DT) (Figure 1) represents the "most informative" variable among those not yet used in the path from the tree root.

The T2 treatment IP was the predictive attribute that divided the classes with the highest weight (≤ 53332), subdividing the total set of variables in the 100 evaluated plots with a weight value of 22.2% (20/90). Subsequently subdivided into two subgroups, T5 (IP) with 41.7%, 20/48 and T3 (NE) with 47.6%, 20/42. In smaller subgroups, we observed T3 (P) 87.0%, 20/23 and T2 (F) 84.2%, 16/19. The T5 IP generated a subtree (> 44443.3) with two branches, being the D spacing of the T4 treatment (47.2%) and the T1 ED (58.3%), which gave rise to another subgroup each.

Discussion

The spatial distribution of plants identified by the variables N, F and D showed differences in corn seeds' longitudinal distribution in the sowing line as a function of the treatments. Adjustments with the motor and moved gears of the seed deposition mechanism provided different percentages of N and D in the percentage and failure treatments between 9 and

Table 1. Chemical characteristics the soil in the experimental area.

Layers of soil (m)	0-0.2	0.2-0.4
pH (H2O)	5.6	5.6
N (%)	0.15	0.06
Organic matter (g/kg)	15.31	17.30
P (mg / dm^{-3})	2	1
k (mg / dm^{-3})	35	18
Na (mg / dm^{-3})	2	2
Ca (cmolc dm^{-3})	5.84	3.79
Ca + Mg (cmolc dm^{-3})	7.22	4.50
Al (cmolc dm^{-3})	0.14	0.06
H + Al (cmolc dm^{-3})	1.65	1.49

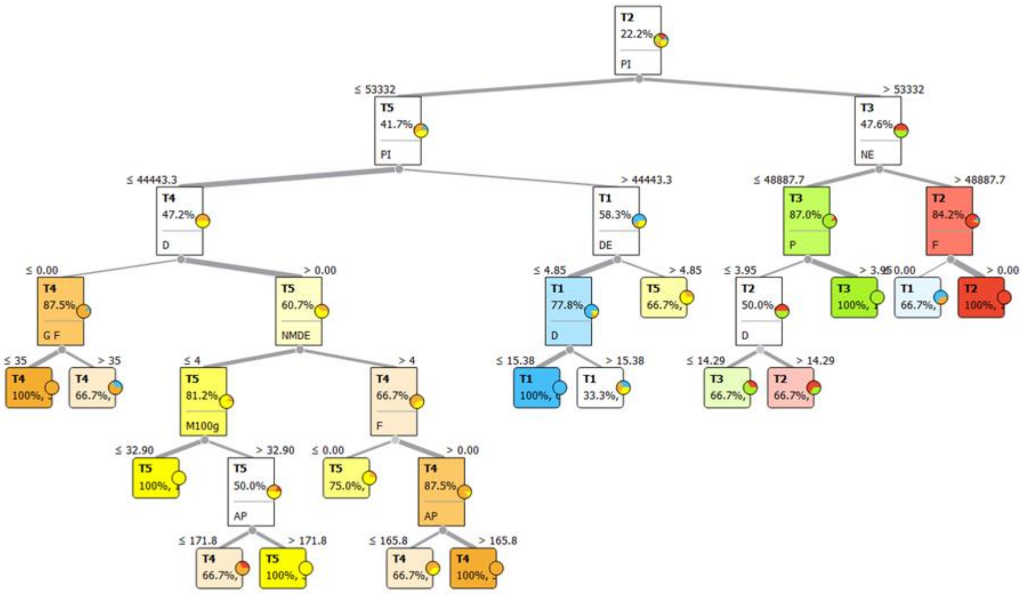

Figure 1. Decision tree of agronomic variables. T2:

Table 2. Summary of the values of the analysis of variance.

Factores	T1	T2	T3	T4	T5	Value F	DMS	CV
IP plants ha^{-1}	54665 b	69331 c	68887 c	41110 a	38887 a	63.58**	71.91	14.98
FP plants ha^{-1}	48665 b	59554 c	62442 c	39332 a	34666 a	33.33**	82.82	19.24
N (%)	68.17 a b	56.35 a	72.21 b	71.44 b	62.24 a b	24.02**	13.39	23.07
F (%)	15.61 a	16.35 a	9.9 a	14.31 a	11.47 a	1.29 ^{NS}	80.26	9.55
D (%)	16.25 a b	27.61 c	17.89 a b	17.25 a	26.29 b c	5.44**	10.27	57.11
SD (cm)	2.30 b c	2.11 a b	2.06 a	2.35 c	2.31 b c	6.38**	0.21	10.46
PH (cm)	143.89 a	173.01 b	170.69 b	166.87 b	165.82 b	7.76**	16.44	11.39
EL (cm)	17 a b c	17 a b	17 a	18.7 c	18.5 b c	6.26**	1.13	7.21
ED (cm)	4,55 a	4,61a b	4.61 a b	4.65 a b	4.78 b	2.66*	0.2	4.87
NL	11.4 a	12.6 a	11.85 a	12.15 a	12.20 a	1.71 ^{NS}	0.85	7.86
NE ha^{-1}	47109 c d	47776 c d	14888 a	38221 b c	33.554 b	32.467**	11.65	32.87
NDE	5 a b	4 a	5 a b	5 b	4 a	3.99**	0.45	11.17
MG (mg ha^{-1})	35.13 b c	38.14 c	28.47 a	33.75 b	32.34 b	19.67**	3.16	10.71
GR	31 a b	31 a	30 a	33 b	32 a b	2.98**	2.28	8.25
ER	15 a	15 a b	16 a b	15 a b	16 b	3.59*	0.92	6.86
P (t ha^{-1})	4.67 b c	5.14 b c	5.33 c	4.10 a b	3.48 a	7.85**	1.07	26.78
RP1 (Mpa)	0.13 a	0.26 b	0.22 a b	0.13 a	0.11 a	4.77**	0.12	82.26
RP2 (Mpa)	1.17 a	1.15 a	1.32 a	0.89 a	1.04 a	1.93 ^{NS}	0.46	46,09
WCS (%)	19.85 a	19.99 a	19.79 a	21.05 a	21.31 a	3.16 ^{NS}	0.26	8.88

*Averages followed by the same lowercase letters on the line do not differ, by Tukey's test, CV: coefficient of variation (%). ** significant (P <0.01). * significant (P <0.05). NS: not significant.

Table 3. Decision tree model values.

Model	AUC	CA	F1	Precision	Recall
AD	0.773	0.578	0.572	0.571	0.578

AUC: Roc Curve; CA: accuracy; F1: score

Table 4. Result of Pearson correlation analysis.

	PI	N	F	D	SD	PH	NL	NE	FF	NDE	MG	GR	ER	EL	ED	P
PI	1															
N	0.03	1.00														
F	-0.24	-0.62	1.00													
D	0.17	-0.74	-0.07	1.00												
SD	-0.50	-0.12	0.20	-0.02	1.00											
PH	0.05	0.04	-0.11	0.04	0.04	1.00										
NL	0.07	0.04	-0.11	0.05	0.15	-0.07	1.00									
NE	0.21	-0.19	0.02	0.23	-0.01	-0.13	0.26	1.00								
FF	0.89	0.07	-0.24	0.12	-0.48	0.07	0.09	0.20	1.00							
NDE	-0.08	0.07	0.05	-0.12	0.01	-0.22	0.01	0.22	-0.07	1.00						
MG	0.22	-0.11	-0.03	0.17	-0.05	-0.10	0.27	0.94	0.22	0.22	1.00					
GR	-0.25	0.01	0.13	-0.13	0.18	-0.06	0.13	0.09	-0.18	0.17	0.17	1.00				
ER	-0.10	-0.11	0.06	0.09	-0.05	0.11	-0.08	-0.07	-0.03	-0.13	-0.03	0.03	1.00			
EL	-0.35	-0.18	0.13	0.11	0.29	-0.05	0.19	0.17	-0.25	0.12	0.22	0.66	0.07	1.00		
ED	-0.18	0.05	0.02	-0.08	0.00	-0.03	0.08	-0.01	-0.13	-0.05	0.08	0.42	0.37	0.35	1.00	
P	0.58	-0.04	-0.07	0.10	-0.21	-0.07	0.20	0.24	0.65	0.02	0.29	0.22	-0.08	0.11	0.15	1.00

16%. In a study on corn sowing in the region of Minas Gerais, Weirich Neto et al. (2015) counted percentages between 2 to 8% of faulty spacings due to seeder-fertilizer machine-related factors.

The percentage of double spaces between plants was higher in T2 and T3 presented a higher rate of standard plant distribution about T2 with a difference of 16 %. Both resulted in similar PF, characterizing the treatments with the largest population to treatments T1, T4 and T5. Double spaces result in the sowing line up to 28% and single between 56 % and 72 %, resulting in essential conditions for final plant stand establishment. Sangoi et al. (2012) found that corn grain yield decreases proportionally to the increase in irregularity in plant distribution in the sowing line. Number increase moved gear teeth provides increased speed of the seed rotor, which can lead to filling, faster in the tube of the mechanism and distribution of seeds with different spacing between treatments.

The best productivity was found in the treatments T2 and T3, showing that the spatial arrangement of plants, around 60.000 plants ha^{-1} in PI and PF, positively influenced productivity. Sangoi et al. (2012) and Vian et al. (2016) highlight that the corn crop is highly dependent on the plant population to achieve high grain yields since this plant has a low recovery capacity and higher grain yield. Density recommendations for favorable management, climate and soil conditions range between 65.000 and 80.000 plants ha^{-1} (Sangoi et al., 2019). Still, densities such as these are expected to have grain yield prospects higher than 10 t ha^{-1} (Strieder et al., 2008), but the value reached in this study is 5.33 t ha^{-1}. Stork et al. (2015) showed average productivity of 11.361 t ha^{-1} after sowing approximately 62.500 seeds ha^{-1}. This indicates that sowing in different soil and climate conditions influences crop productivity and can represent a considerable drop in productivity.

Decision tree analysis

Classification by decision tree presented satisfactory treatment discrimination results and analyzed variables (Figure 1). According to Nogara Neto et al. (2011), the decision trees method is an exploratory method of statistical analysis that has greater flexibility and does not consider many of the restrictive principles considered by traditional statistics. According to Kodati and Vivekanandam (2018), the parameter Precision (Table 3) intuitively is the classifier's ability not to label as positive a negative sample, in which the best value is 1 and the worst value is 0. The parameter recall consists of the average probability of complete recovery. The classifier intuitively can find all positive samples in which the best value is 1 and the worst value is 0.

After analyzing decision tree values, it is possible to observe a high accuracy tendency to evaluate the agronomic variables of sowing and development of corn plants. It is indicating that few variables have been analyzed and misestimated. This analysis showed that using a time series of phenological metrics of corn plants makes it possible to verify which variables and treatments had the highest weight.

The highest accuracy values influencing corn plants were obtained through the series of agronomic variables of corn sowing together with the decision tree model. The IP variable of treatments T2 and T5 was an important factor, while in T3, where there was higher productivity, NE was a weight factor on productivity. Among the plant characteristics, only PH had greater relevance. In the T5, where there was lower crop yield, the plant's effective response was affected by factors IP, D, NDE, MG and PH. Thus, the combination of the T5 gear was not adequate to obtain satisfactory plant characteristics and high grain yield.

Motor combinations and moved gears of the t2 and t3 seed distribution system provided a distribution of plants in the sowing line with low F and D and high N. With this, a good PI and NE were obtained to give higher yields in corn planting. However, complementary studies are needed to optimize corn sowing to get higher results in corn crops under edaphoclimatic conditions in the Amazon region.

Materials and methods

Study site

The study was carried out in Technological Center for Support to Family Agriculture (CETAF) experimental area. The location was in the municipality of Parauapebas, in the southeastern region of Pará, integrating the Eastern Amazon, with a geographical location of 49 ° 51'19" W latitude, 06 ° 12'58" S longitude and altitude of 197 m. According to the Köppen classification, the region has an AW-type, rainy tropical climate, with concentrated rains in the summer and dry season in the winter, which may vary for Aw' presenting summer and autumn rains of 756.6 mm. The maximum precipitation occurred in January, the period after sowing during the experiment period. The soil in the experimental area was classified as a typical red dystrophic Argisol, with the following chemical characteristics in Table 1.

The mechanical devices and data acquisition

The mechanical seeder-fertilizer used was the Jumil-2040 G2 brand for conventional planting, pantographic coupling frame, mechanical seed distributor (horizontal honeycomb doser), fertilizer and seed of 39 liters each and with five lines spaced at 0.75 m. This equipment was pulled by a Massey Ferguson MF-275, 4x2 tractor, 75 CV power, and 7.50-16 tire, operating in 4th gear reduced to 1700 RPM.

The double hybrid corn BR 205, category S1, minimum purity of 98% and minimum germination of 85%, was used. Mineral fertilization in the sowing furrow was carried out with the application of 133 kg ha^{-1} of commercial formulation 9 (N); 25 (P2O5); 15 (K2O). Nitrogen fertilization was made to cover the entire area 35 days after emergence with 66.5 kg N ha^{-1} (urea). Four days after sowing, a pre-emergent herbicide was applied to eliminate weeds in a total area by spraying the herbicide atrazine and glyphosate (4 kg ai ha^{-1}). In addition, during the reproductive stage of corn, mechanical control of plans invasives (Ipomea sp.) was happened.

The experiment was installed in a continuous strip design in five treatments consisting of five driven combination gears 8, 10, 12, 15 and 17 with motor 7 of the seed depositor unit, which resulted in five sowing densities of corn (64.978, 62.311, 52.444, 44.977, 38.665 plants ha^{-1}), respectively. Each treatment (strip) contained five 200 m sowing lines, divided into 20 plots of 10 m each, totaling 100 sample units to carry out the evaluations. Corn was harvested 129 days after sowing in manual operation.

Agronomic characteristics

The agronomic variables analyzed were: average Number of Days to Emergence (NDE), longitudinal distribution of plants in the standard (N), Fault (F) and Double (D) fields, Initial Plant population (IP), Final Plant population (FP), Stem Diameter (SD), Plant Height (PH), Number of Leaves (NL), Number of Ears (NE), Mass of one hundred grains (MG), Number of Grains per row (GR), Number of Ear rows (ER), Ear Length (EL), Ear Diameter (ED) and Productivity (P).

Seeds' longitudinal distribution was evaluated with a tape measuring the spacing between plants in a range of 3 meters on the central line of each plot. The N, F and D spacing were analyzed according to a proposal from the Brazilian Association of Technical Standards (ABNT, 1989) and used by Dias et al. (2009). The average number of days for emergence (NDE) of the seedlings was counted through the daily count, considering any part of the seedlings visible on the soil, until stabilization, in three linear meters on the central line of each treatment. Initial population (IP) was considered the number of seedlings that emerged on the last day of the evaluation of the average number of days for emergence after stabilization. The final population (FP) was obtained on the day of harvest at the exact location as the average number of days for an emergency. The values were converted into plants per hectare.

For each repetition, the first five plants were selected in the central line and measured from the ground level to the point of insertion of the flag leaf to obtain the plant height (PH). The stem diameter (SD) was obtained using a digital caliper with 0.1 mm precision, measuring 8 cm above ground level. The number of ears/ha (NE) was counted on the central line at three meters from each repetition. The values found were estimated for 1 hectare, thus obtaining the number of ears per hectare.

The ears were harvested at the sampling location (NE) and weighed with and without straw on a precision scale. A representative sample of five was taken to dimension its length and diameter using a digital caliper. After that, the number of ear rows (ER) and the number of grains per row (GR) were counted. Mass (MG) was obtained starting at one hundred grains of corn were measured in triplicate of each plot sampling and weighed on a precision scale. The obtained data were transformed to 13% humidity and productivity (P) of the culture obtained according to the method proposed by Reetz (1987).

Soil resistance to penetration

After harvesting, the soil's physical properties were determined by systematic sampling of water content in the soil (WCS) and mechanical resistance of the soil to penetration (RP). A regular mesh (15 x 20m) formed by a sampling point in each portion of the five treatments makes 100 sample points. The collections of RP readings evaluated the soil resistance imposed by conventional tillage systems and soil moisture conditions regarding crop productivity.

The penetrometer with electronic data recording, PenetroLOG - PLG 1020 from Falker, was used. The RP was measured every 0.05 m to 0.20 m, and the pressure value was associated with soil compaction in the layer, forming the soil compaction profile (Reinert et al., 2007). An average measurements value at depths of 0.0-0.1 m (RP1) and 0.1-0.20 m (RP2) was used to represent the plot individually. For data conversion in KPa to MPa, the value measured was multiplied by the constant 0.098. The water content in the soil determination, undisturbed soil samples were collected, which were weighed on a precision scale after collection and, subsequently, remained in a forced air circulation oven at 150°. The examples were considered daily until they reached the constant weight and then applied the moisture quantification method on a gravimetric basis (Teixeira, 2017).

Statistical analyses

The data were submitted to distribution normality by the Shapiro-Wilk test, verifying that most of the variables had a normal distribution. After meeting the basic assumptions, the analysis of variance was performed and the Tukey test was applied at a 5% probability to compare the treatment means using the SISVAR statistical software (Ferreira, 2019). The variables were submitted to Pearson's correlation analysis and complementary analysis for pattern recognition using the decision tree classification algorithm using the Orange Canvas software, version 3.26 (Demsar et al., 2013). The application of Decision Tree classification algorithms was evaluated using the cross-validation method and five metrics: Accuracy, Roc Curve (AUC), Precision, Recall and F1. We sought to interpret the decision tree and describe a scenario capable of explaining the influence of sowing factors on the characteristics of corn plants.

Conclusions

According to the decision tree, the initial population was more important for classifying the most relevant agronomic variables in corn planting. The initial plant stands of 62.442 plants ha^{-1} was the most suitable for the corn crop in the Amazon region. There is a potential to reach maize productivity from 5.14 to 5.33 t ha^{-1} when combined driving gear 12 and driven 7 from the transmission system of the seeder-fertilizer machine.

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