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Effect of Biostimulants in Late Seeding of Genotypes of *Zea mays* L.

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Authors' contributions

This work was carried out in collaboration among all authors. Authors LLF and IRC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RLFP, HZB, MSF and ABC managed the analyses of the study. Authors CRSC and AIAP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Seed treatment has as its main feature the prevention of pest entry in cultivated areas, besides being of great importance in the development of vigorous and healthy plants. The objective of this work was to evaluate the performance of corn genotypes with biostimulant in seed treatment under water stress environment. The experimental design was randomized blocks in a 3x3 factorial scheme, corresponding to three corn genotypes (P3707, P30S31 and P30F35) and three seed treatments with the biostimulants (ConrSeeds, Stimulate and Água). The experiment was carried out at Luiz Eduardo de Oliveira Sales Experimental Farm, located in the municipality of Mineiros, Goiás,

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from March 2018 to August 2018. Plant height, stem diameter, ear insertion height, number of rows per ear, number of grains per row, number of grains per ear and yield were evaluated. The obtained 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, testing univariate and multivariate analyzes. Analysis of variance revealed significance only for the main genotype effect. Seed treatments did not improve yield components of corn genotypes. The genotypes differed, where the variables number of rows per ear, number of grains per row and number of grains per ear directly influenced the grain yield.

Keywords: Corn; grains; plant protection; seed treatment.

1. INTRODUCTION

Fluctuations in final yield in maize crops in the main producing regions of Brazil are associated with water availability, most of the times being low, considering a water stress, especially in the critical period of the crop at the beginning of grain filling [1]. Thus, it is considered that maize production is limited by stress conditions common in tropical regions, including factors such as acid and dry soils, and the amount of water available annually. This allows strategies to be established to obtain economically viable yields and more efficient use of water [2].

In the region of Mineiros, Goiás, Brazil, corn is usually grown at the beginning of the rain season, in October, which characterizes the cultivation of summer corn, or even sowed after the soybean, in January, being denominated second crop corn. The late cultivation of this poaceae can cause low yields due to lack of water. However, climatic conditions sometimes fluctuate year after year, making it necessary to develop production systems with low availability of water resources.

Crop stresses such as inadequate and dry temperatures can significantly reduce crop yields and restrict planting in regions where commercially important species can be grown. Temperature has a great influence on speed, germination percentage and emergence, affecting the biochemical reactions that determine the germination process. In each type of seeds of species and or cultivar there is a temperature range, in which germination and ideal emergence occur. This, if the moisture supply is adequate and other stresses are minimal according to Vaz-de-Melo et al. [3].

According to Ferreira et al. [4] corn is considered one of the most technological crops, often technological innovations are increased, among them the treatment of seed in the production system, but one should pay attention to the real gains from the incorporation of these products to seeds, which are the main input of modern agriculture, because they are responsible for all the genetic and productive potential that guarantee a good harvest and consequently an expected income.

The use of macro nutrients, micronutrients and defensives in seed treatment provides the plant with early fertilization, as well as providing a defense system, which enables greater potential at the beginning of crop development. The control of pests and early diseases that attack seeds is carried out from the beginning of its cycle with the use of pesticides in seed treatment, which is a widely used and efficient practice [5].

Seed treatment has as its main feature the prevention of pest entry in cultivated areas, besides being of great importance in the development of vigorous and healthy plants. This practice consists in the initial protection of the seed, from the initial contact with the soil until the beginning of its growth, that is, the protection occurs before, during and after germination, causing seeds that could be attacked by diseases, pests or even climatic interference, can grow stronger, have a higher and more uniform germination content and have better rooting all of these characteristics turn to good productivity. Given the above, the objective of this study was to evaluate the performance of corn genotypes with biostimulant in seed treatment under water stress environment.

2. MATERIALS AND METHODS

The study was conducted at the Luiz Eduardo de Oliveira Sales Experimental Farm, in the municipality of Mineiros-GO, located between the geographic coordinates of 17°34'10" South latitude and 52°33'04" West longitude, with an average altitude of 760 m. Rainfall occurs mainly in spring and summer, between October and

March. However, during the experimental conduction period, approximately 200 mm of rainfall was accounted for, since this crop needs 400-700 mm per cycle, which characterized the environment of low water availability.The average temperature is 22.7°C, the average annual rainfall is 1695 mm occurring mostly in spring and summer. The experimental area is classified as Aw (hot dry) climate. The soil of the experimental area was classified NEOSSOLO Quartzarenic, with light texture, gently undulating to flat topography and good drainage [6]. Soil analysis in the 0-20 cm layer revealed: hydrogen potential 5.7; calcium 3, 0.8 magnesium, aluminum 0.2, hydrogen plus aluminum 2, cation exchange capacity 5.9, in $cmol_c\ dm^{-3}$; potassium 53, phosphorus 59, sulfur 1.7, boron 0.2, copper 1.4, iron 51, manganese 23, zinc 8.3, sodium 1.5, in mg dm^{-3}; clay 223, silt 50, sand 728, organic matter 20 and organic carbon 12, in grams dm^{-3}.

A randomized block design in factorial 3x3 corresponding to 3 corn genotypes (P3707, P30S31 and P30F35) was submitted to 3 seed treatments (CornSeeds, Stimulate and Água) in 4 replications, totaling 9 treatments and 36 experimental units. The experimental unit was composed of four rows of 4.0 m in length, spaced 0.5 m, totaling an area of 8 m^2 per experimental unit. The two central lines were evaluated as the useful area of each plot. The description of genotypes and seed treatments were stated in Table 1.

The tillage system was carried out with harrowing and plowing of the area. Seed treatment was carried out with a total volume of 900 ml 100 kg^{-1}. These were homogenized in a polyethylene bag. Sowing was done manually with seed distribution, reaching a population of 60.000 plants per hectare. Basic fertilization was performed using NPK mineral fertilizer. The corrections and fertilizations were in accordance with [7] where the applications of cover fertilization and nitrogen source were divided where urea was used in stage V5, V9 and V11 totaling a total of 120 points of N; Phosphorus was made 120 points based on MAP at V5 stage and potassium was used KCL with an amount of 90 points at V5 phenological stage.

The sowing took place on March 28, 2018, following the commercial farming models of the region. During the execution of the experiment the control of pests, diseases and weeds were performed whenever necessary, respecting the best practices and integrated pest management. For this purpose a single boom costal sprayer with a double fan type spray tip is used. The applications were carried out in the morning, with average ambient temperature of 25ºC, relative air humidity above 60% and average winds of 5 km h^{-1}.

Chemical applications were made with herbicides at stage V3 of corn, using Atrazine that is selective to genotypes. The insecticides used were from the presence of insects that were reported in the field, such as cartridge caterpillar and leafhoppers where they used connect and full engeneer. The applied fungicides were aproach prima and score flexi at stage V8 and pre-tassel.

The analyzed variables obeyed the homogeneity criterion, demonstrating the grain yield data at (13% humidity), besides the variables (DIC) stem diameter [8]; (AIE) height of ear insertion [9]; (ALT) plant height [8]; (NFE) row number per ear [8]; (NGF) number of grains per row [10]; (NGE) number of grains per ear [8] and (REN) yield [10].

Table 1. Main morphoagronomic characteristics of the evaluated corn genotypes and products used as seed treatment. Mineiros-GO, UNIFIMES, Brazil, 2019

Nomenclature of genotypes		Type [1]	Cycle [2]	Grains		
Technical	**Common**			**PMG[3]**	**Colour [4]**	**Texture [5]**
P3707VYH	P3707	HS	P	340	AM-AL	SMDENT
30S31VYH	P30S31	HS	P	305	AM-AL	SMDENT
30F35VYHR	P30F35	HS	P	310	AM-AL	SMDENT
Nomenclature of products		**Active Ing.**				**Dosage**
Technical	**Common**					**(ml or g 100 kg^{-1})**
CornSeed	COR	Algae Complex + Vegetable Polymers				600
Stimulate	STI	Cytokine + Gibberellin + Indolalcanoic Acid				600
Água	AGU	Distilled water H_2O				900

[1]HS-single hybrid; HSm modified simple hybrid; Dual-HD hybrid; HT-triple hybrid. [2]Cycle: SP-super early; Early P; SMP-semi-early. [3]PMG: weight of one thousand grains (g). [4]Color of Grain: AL-Orange; AM-yellow; LR-Orange. [5]Grain Texture: SMDENT-semidentate; SMDURO-semi-hard

The obtained 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 interaction between corn genotypes x seed treatment. When verifying the absence of interaction, they were broken down to the main effects by Tukey test at 5% probability. Subsequently, the variables were subjected to Pearson correlations in order to understand the tendency of association, and their significance was based on 5% probability by the t test. Following the path analysis was performed from the phenotypic correlation matrix, considering the REN as the dependent variable and DIC, AIE, ALT, NFE, NGF and NGE as explanatory. 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 genetic dissimilarity by the Mahalanobis algorithm, the residual matrix was weighted, the distance phylogenetic tree was constructed through the UPGMA cluster, and the biplot canonical variables method was used to visualize the general variability of the distances. Experiment and multivariate trends. The analyzes were performed in the interface Rbio and R [11], in addition to Software Genes [12].

3. RESULTS AND DISCUSSION

The analysis of variance revealed significance only for the main effect genotype (G) of the ear insertion height - EIA, row number per ear - NFE and grain number per ear - NGE (P> 0.01) variables. The averages for stem diameter - DIC (1.95 cm), plant height - ALT (1.68 m), number of grains per row - NGF (29.43 pcs) and REN yield (63.79 sc ha^{-1}) were expressed in the order (Table 2). The results corroborate with [13] when diagnosing that corn seeds produced by applying biological fertilizer and biostimulant do not increase the germination and vigor of corn seeds. Numerous factors influence this result, however, water deficiency causes greater changes in plant development and leaf area, and the latter determines the use of water by plants, water is a determining factor in corn production and its productivity potential is strongly inhibited. When exposed to water deficit [14]. For Wedge [15] the seed treatment with different types of insecticides and bioregulator dosages did not differ, but the rainfed production system obtained the best results for the agronomic evaluations number of grain row per ear and number of row grain, length of ear, yield and stem diameter.

Unfolding the main effect of the genotypes in the Tukey test at 5% probability in the AIE, NFE and NGE variables, it was observed that the P3707 genotype expressed the highest averages among these for all seed treatments analyzed (Table 3). Other genotypes had in some of the seed treatments a reduction in the analyzed averages, as explained by Schiavinatti et al. [16] when reporting that the water deficit can compromise both nutrient uptake, by stomatal closure that reduces water flow in plants, as well as by altering photosynthesis, thus compromising the energy production that would be used in plant metabolism to develop aspects such as plant height, ear height and leaf area. It is noteworthy that ears positioned in the first third may present complicating factors such as susceptibility to pathogens and difficulty in receiving photosimilates resulting in reduced size and weight grains, as well as ears positioned in the last third may predispose the plant to tipping.

Table 2. Summary of analysis of variance (Calculated QM and CV (%)) for stem diameter - DIC, ear insertion height - AIE, plant height - ALT, row number per ear - NFE, number of grains per row - NGF, number of grains per ear - NGE and yield REN. Mineiros-GO, UNIFIMES, Brazil, 2019

Fatores	Gl	DIC	AIE	ALT	NFE	NGF	NGE	REN
TS x G	4	0.202	0.001	0.007	1.854	9.402	3769.470	144.401
Treatment of seeds (TS)	2	0,273	0.003	0.006	0.895	1.090	863.439	413.446
Genotypes (G)	2	0.069	0.049**	0.021	10.145**	10.548	12451.855**	142.085
Blocks	3	0.345	0.035	0.102	1.932	11.377	5603.728	267.566
Residue	24	0.173	0.003	0.020	0.557	3.898	1355.181	149.906
Averages		1.95	0.83	1.68	14.46	29.43	425.96	63.79
CV (%)		21.31	7.03	8.50	5.17	6.71	8.64	19.19

*** significant at 1% probability by F test*

Table 3. Averages for ear insertion height - AIE, row number per ear - NFE and number of grains per ear - NGE of corn genotypes in different seed treatments under water stress. Miners, GO. UNIFIMES, Brazil, 2019

Genotype	-----------AIE-----------			-----------NFE-----------			-----------NGE-----------		
	------------------------------------ Seed Treatment ------------------------------------								
	COR	STI	AGU	COR	STI	AGU	COR	STI	AGU
P30S31	0.89 a	0.87 a	0.89 a	14.25 ab	14.62 a	14.75 a	411.0 ab	429.43 a	399.5 b
P30F35	0.74 b	0.77 a	0.77 b	13.25 b	13.25 a	13.0 b	380.5 b	442.5 a	383.0 b
P3707	0.82 ab	0.87 a	0.88 a	15.0 a	15.25 a	15.75 a	468.0 a	435.0 a	484.75 a

Averages followed by the same letter vertically do not differ from each other by Tukey's test at 5% probability

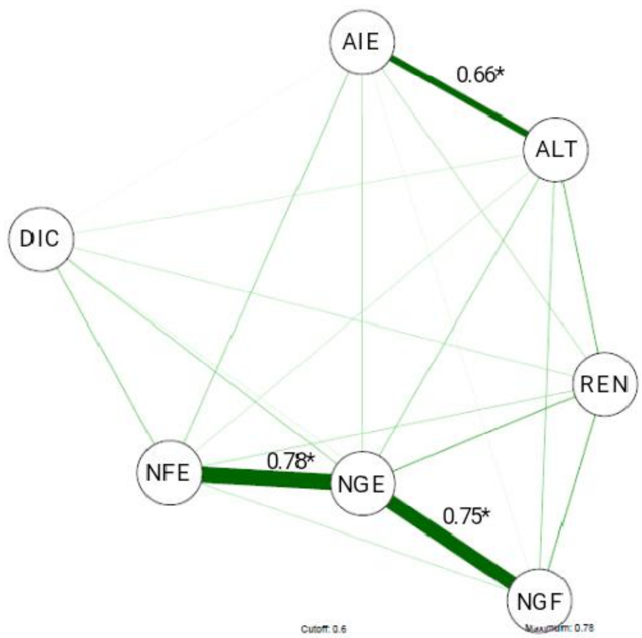

Fig. 1. Network of phenotypic correlations of corn genotype traits. Miners-GO, UNIFIMES, Brazil, 2019. Adult plant variables: stem diameter - DIC, ear insertion height - AIE, plant height - ALT, row number per ear - NFE, grain number per row - NGF, number of grains per ear - NGE and yield REN

Noting that high NFE and NGE averages may result in increased corn crop yield. For high yields in corn it is necessary to obtain high grains in the ear. For this, averages such as NFE above 15, NGF greater than 30, resulting in NGE beyond 450 grains enhance crop yield. The values obtained were below expectations, certainly due to the proposed water deficit. Several elements influence the response potential of the crop to seed treatment, such as the supply of other nutrients, soil profile depth with effective root presence, cultivation time, tillage system, crop rotation, solar radiation level. And soil organic matter content [17], as well as rainfall intensity and distribution.

Water deficiency is considered the major cause of reduced agricultural productivity in tropical climate. However, as there is variability in drought adaptation between species and within species, the behavior of different genetic materials in dry conditions should be evaluated for the recommendation of cultivation according to Quarry et al. [18]. Balbinot et al. [19] found that NGF was the yield component that presented the highest total correlation with yield when conducting an experiment on yield components in open pollinated grain yield of corn. Similar data were obtained by Farinelli et al. [20] and Amaral et al. [21]. For Vanin et al. [22], the determination of NFE and NGF is a very delicate and critical period because a good production of these two factors is necessary to obtain high REN.

The phenotypic correlation network of maize genotype characteristics showed positive correlations in pairs: NFExNGE, NGExNGF and AIExALT. This indicates that the behavior observed by NGE was analogous to NFE and NGF, as well as from AIE to ALT (Fig. 1). Positive correlations between pairs of variables indicate an increase in the averages of both parties, as well as savings in terms of field data taking. Costa et al. [23] observed that corn crop is affected in different ways by water deficit, such as changes in plant growth and leaf area expansion during vegetative and pollination stages; grain yield and shoot dry matter when water stress occurs in the reproductive stages of the crop cycle. The solution to this problem involves the right decision of the producer regarding the use of the right hybrid with greater drought resistance and technical assistance. It is necessary to follow agricultural zoning and to adopt practices such as crop rotation and sowing scheduling as risk reduction measures according to Bergamaschi et al. [1].

Table 4 shows the direct and indirect effects of primary components on grain REN. The coefficient of determination (R2) in the trail analysis model was greater than 0.99. Thus, the explanatory model adopted expressed the cause and effect relationship between secondary characters and grain REN. Direct and indirect effects were considered significant those with loads equal to or greater than 0.1. It was observed that directly and positively the variables NFE (0.21), NGF (0.38) and NGE (0.56) contributed to the REN, while DIC (-0.10) contributed negatively. Estimates of cause and effect on REN can be explained by plants with reduced IHD, and increased NFE, NGF and NGE enable high REN (Table 4).

Bergamaschi et al. [1] found that there may be yield reduction even in climatically favorable years, if the water deficit occurs in the critical period of corn development, that is, from pre-flowering to the beginning of grain filling. If the water deficit occurs in the critical period, the maximum productive capacity of the crop will not be reached, since the reproductive cycles are much faster than during the vegetative growth. For [16], corn grain yield is associated and influenced by soil N availability throughout the plant growth cycle. N exerts great importance on corn crop yield, since its lack can limit grain yield, due to the relevance of this element to plant metabolism.

For the vegetative stage it is of high importance to define the final productivity. Consequently, during this period, farmers should manage the crop as appropriately as possible, especially regarding nutrient availability and pest control. Inoculation in corn can stimulate the development of corn crop at its vegetative stage, increasing the chances of achieving a uniform plant stand, higher water stress resistance, higher resistance to sun pests and higher chlorophyll content in leaves in a final income gain, is what confirms the studies of PDD e al. [24].

Phylogenetic analysis indicated distinct positions in the G x TS interaction in two distinct groups formed by the AGU_P30S31 and the others in the following group. The variables with the highest load in their differentiation were reported in descending order: NGE, REN and NGF (Fig. 2).

Table 4. Estimates of direct and indirect effects of DIC, IEA, ALT, NFE, NGF and NGE secondary characters on REN of maize genotypes submitted to different seed treatments in water stress environment. Mineiros-GO, UNIFIMES, Brazil, 2019

Effect	Variable	DIC	AIE	ALT	NFE	NGF	NGE
Direct effect on	REN	-0.10	-0.01	0.06	0.21	0.38	0.56
Indirect effect via	DIC		-0.09	-0.09	-0.07	0.06	-0.03
Indirect effect via	AIE	-0.01		-0.01	-0.01	0.01	-0.01
Indirect effect via	ALT	0.05	0.05		0.05	-0.01	0.04
Indirect effect via	NFE	0.14	0.16	0.19		0.03	0.19
Indirect effect via	NGF	-0.23	-0.19	-0.08	0.05		0.20
Indirect effect via	NGE	0.18	0.26	0.39	0.51	0.30	
Total		0.03	0.18	0.46	0.75	0.77	0.96

Stem diameter - DIC, ear insertion height - IEA, plant height - ALT, row number per ear - NFE, grain number per row - NGF, grain number per ear - NGE and yield REN. Coefficient of determination R2: 0.99; K value used in the analysis: 0.01; effect of residual variable: 0.07; determinant of the correlation matrix between explanatory variables: 9.96E-08

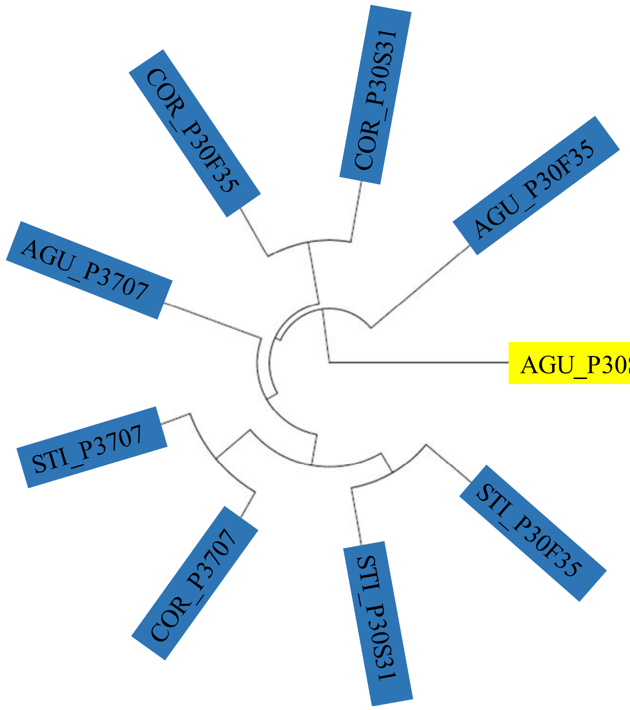

Fig. 2. Phylogenetic tree of interaction between seed treatments and corn genotypes. Miners-GO, UNIFIMES, Brazil, 2019

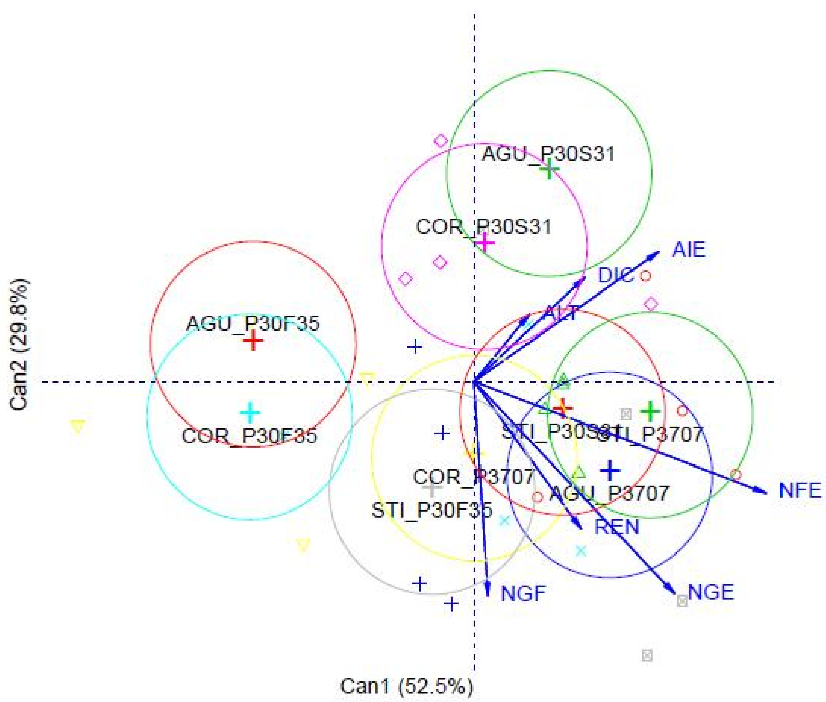

Fig. 3. Analysis of canonical variables of mean stem diameter - DIC, ear insertion height - EIA, plant height - ALT, row number per ear - NFE, number of grains per row - NGF, number of grains per ear - NGPE and yield REND, in corn genotypes submitted to seed treatments. Mineros-GO, UNIFIMES, Brazil, 2019

The analysis of canonical variables added in the first and second canonical pairs explainability of 82.31% of the experimental variation. Similar groups of variables were described (ALT, DIC and AIE) and (NGF, REN, NGE and NFE) in the first and fourth quadrants, respectively. Among these the variables with the highest contribution were: NFE, NGF and EIA, in this order. The genotype P30S31 with seed treatment AGU (AGU_P30S31) and COR (COR_P30S31) positively influenced the ALT, DIC and IEA variables. The other variables were more expressive in STI_P3707 and STI_P30S31 (Fig. 3). As shown in the studies by Ono et al. [25], the other yield components also help in defining grain yield. In addition, the components that are defined at the beginning of the cycle, such as stand, number of spikes per plant and number of rows of grains per spike are of great importance, as these may also be limiting factors for grain yield, even under the conditions improve in the final stages of the development cycle.

Seed treatments are complex that promote the hormonal balance of plants, favoring the expression of their genetic and productive potential, stimulating the development of productivity determinants, such as number of rows per ear, grains per ear, and root system according to Aguiar et al. [26]. As the TS, the results achieved with the application of micronutrients via seed treatment are also very variable, however, the increase in productivity and, consequently, the reduction of the cost of the crop has made the producers to use them, mainly for corn and soybean crops. No entanto é necessário a realização de novos ensaios para avaliar a produtividade dos híbridos sob efeito dos referidos tratamentos.

4. CONCLUSION

Seed treatments did not improve yield components of maize genotypes.

The genotypes differed, where the variables number of rows per ear, number of grains per row and number of grains per ear directly influenced the grain yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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