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Trail Analysis with and without Inoculation of *Azospirillum brasilense* in the Corn Crop in GURUPI-TO

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Abstract *– This study aimed to evaluate the analysis of trails with and without inoculation of the corn crop in the municipality of Gurupi-TO. The experimental design used was randomized blocks. It used 20 treatments, in a factorial scheme 2x10. The treatments consisted of 10 maize cultivars. The agronomic characteristics evaluated were Number of grains per row (NGPF), Number of rows on the cob (NFE), Plant height (AP), Height of the ear (AE), Humidity (UMID), and grain yield in kg ha^{-1} (PRODG). Trail analysis was performed through the Gene computer program. Highlighting that the Number of Rows in the Spike, Plant Height, and Humidity showed statistically higher productivity results.*

I. INTRODUCTION

The corn (*Zea mays* L.) has been standing out by having good productivity results and becoming the largest crop in recent decades, thus reaching the mark of 1 billion tons the expressive value that abandons rice and wheat. The corn stands out for its versatility because we see it with several applications of more than 3500 of this cereal. In addition to the relevance in the aspect of food safety, in human food and, mainly, animals, it is possible to produce with corn a multitude of products, such as fuels, beverages, polymers, etc. [1].

In Brazil, corn is the second most economically important crop, second only to soybeans. The states with the highest cereal production are Mato Grosso, Paraná and Mato Grosso do Sul [2]. Forecasts production of 116.7 million tons for the 2021/22 crop in the face of an expected increase in 28% productivity of crops.

Although many of the typical foods in Brazil are made from corn, only a small fraction of the corn produced is destined for human consumption its largest portion is destined for animal feed, grains are rich in energy, carbohydrates, proteins, vitamins, minerals, and fibers [3].

Second Pinheiro et al. (2021) [4] by highlighting that the corn crop has very instigating study characteristics, as it provides the basis for future advances. Corn has been gaining space in the national territory, in the same way as all other traditional crops, which used less developed technology, seeking land not yet agricultural, as well as the natural fertility of soils. The evaluation of properties of physical attributes is an alternative to improve the quality of the performance of large-scale corn yields because from these characteristics one can aim at productivity.

Being these factors of interest, path analysis consists of the study of the direct and indirect effects of explanatory variables on a basic variable, whose estimates are obtained through regression equations, in which the variables are previously standardized. Although the correlation is an intrinsic characteristic of two variables, in the given experimental condition, its decomposition is dependent on the set of variables studied, which are usually evaluated by the researcher through the previous knowledge of its importance and possible interrelationships expressed in the "trail diagrams" [5].

The search is the need to find alternative sources to reduce cost, in addition to helping the plant have productivity, the bacterium promoting plant growth (BPCP) is a biological alternative that acts to increase various activities such as nitrate reductase, solubilization of phosphate, and acting as a biological pathogen control agent. The ability of this bacterium to biologically fix nitrogen [6].

Gender *Azospirillum* has been standing out in several studies with great results [7]. Or *Azospirillum brasilense* promotes plant growth through the production of plant hormones and by providing other nutrients such as phosphorus [8].

Studies on *Azospirillum brasilense* in corn crop [9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20]. However, in the state of Tocantins, there are few studies of trail analysis associated with *Azospirillum brasilense*.

Thus, because of the above, this work aims to evaluate trail analysis with and without inoculation of *Azospirillum brasilense* in the corn crop in Gurupi-TO.

II. MATERIAL AND METHODS

The Trials were conducted at the Federal University of Tocantins (UFT) Gurupi (11°44' latitude S, 49°05' longitude W, and altitude of 280 Meters) in the crop 2019/20. The region presents the climate classified as Aw, a tropical region, with a moderate water deficiency, the region has average annual temperatures of 33°C in periods of drought and averages of 26°C in the rainy seasons [21], with annual rainfall around 1804 mm, rainy summer, and dry winters, according to the classification of Köppen [22].

Starting the soil preparation, the first activity was the case in which two tons of ha^{-1} dolomitic limestone Filler, which was incorporated into the soil utilizing plowing and grading operations in the surface layer, soon after the swelling in the area, then the fertilizers were applied and sowing performed manually, the doses of correctives and fertilizers followed, 5ª Approach [23], according to the characteristics obtained in the chemical and physical analysis of the soil, expressed in Table 1.

Table 1. Chemical and textual attributes in the layer 0-20 cm to the site of the experiment. Gurupi – TO, 2020, the agricultural year 2019/20.1

pH[1]	M.O.	P[2]	K[2]	K[2]	Ca[3]	Mg[3]	Al[3]	H+Al[3]	SB	CTC	V
	dag.kg^{-1}	mg dm^{-3}	----------cmolc.dm^{-3}----------								%
5.2	1.7	2.2	30	0.08	1.2	0.7	0.0	2.50	1.98	4.48	44
	Clay (g kg^{-1})				Silt (g kg^{-1})				Sand (g kg^{-1})		
	275				50				675		

(1): CaCl2 0.01 mol L-1; (2): Extractor Mehlich: (3) KCL 1mol; M.O.: Organic matter.

The recommendation for basic fertilization was 500 kg ha^{-1} of the Formulated 5-25-15 and for fertilization coverage 150 kg ha^{-1} from urea (43% from N), fractional in two applications, in the V_4 (Fourth expanded sheet) and V_6 (Sixth expanded sheet).

An experimental design was used in randomized blocks, with 3 replications, in a factorial scheme 2 x 10, Totaling 20 Treatments. The first factor consisted of the use of seeds treated in the management of with and without *Azospirillum brasilense*. In the treatment with *Azospirillum brasilense,* a ratio of 100 ml of the inoculum to 50 kg of seed was used and homogenized in a plastic bag. The second factor refers to the ten commercial maize cultivars, which are listed below (Table 2) with their respective agronomic characteristics.

Table 2. Agronomic characteristics of the ten maize cultivars used in the experiment.

Trade name	Genetic basis	Transgenics	Cycle	Technological level	Purpose of use
AG8088 PRO2	HS	PRO2	P	A	G/MV/ SPI
M 274	HS	C	P	B/M	G/SPI
ANHEMBI	PPA	C	P	B/M	G/SPI
AG 1051	HD	C	SMP	M/A	G/MV/ SPI
BR 2022	HD	C	P	B/M	G/SPI
BR 205	HD	C	P	B/M	G/SPI
BM 3051	HS	C	P	M/A	MV/SPI
CATIVERDE	PPA	C	SMP	M	G/MV/ SPI
PR27D28	HD	C	SP	B/M	G/SPI
BRS 3046	HT	C	SMP	M/A	G/MV/ SPI

HS: simple hybrid, HD: double hybrid, HT: triple hybrid, PPA: open pollination populations, G: grain, MV: corn green, SPI: whole plant silage; C: conventional; PRO2: technology VT PRO 2™; P: precocious; SMP: semi-precocious; SP: Super-precocious; A: high; M: medium and B: low. The adapted of Cruz et al. (2015) [24], Pereira Filho and Borghi (2016) [25], Pereira Filho and Borghi (2020) [26].

The experimental unit consisted of two rows of 3.0 m in length, adopting spacing of 1 m between rows with an experimental area of 6 m^2. In each linear meter, 5 seeds obtained the finals population of 50.000 Plants ha^{-1}. The entire experimental area was used for the evaluation.

In pre-sowing, seeds with fungicide and insecticide (active ingredient Piraclostrobina, Tiofanato Metílico and Fipronil). For cartridge Caterpillar control (*Spodoptera frugiperda*), Caterpillar elasmo (*Elasmopalpus lignosellus*), and Caterpillar-threaded (*Agrotis ipsilon*) throughout the crop cycle, insecticides were used: Deltamethrin (200 mL ha^{-1}); Clorpirifós (1 L ha^{-1}); Lambda-Cialotrina + Chlorantraniliprole (150 mL ha^{-1}). For control of the Green-bellied Bedbug (*Dichelops furcatus*), Cigarrinha-do-milho (*Dalbulus maidis*) and fly white (*Bemisia argentifolii*) used: Tiametoxam + Lambda-Cialotrina (180 mL ha^{-1}), Imidacloprid + Bifenthrin (400 mL ha^{-1}) and Acetamiprid + Alfa-Cypermethrin (250 mL ha^{-1}) [27].

The management for the control of weeds, pests, and diseases was carried out according to the technical recommendations found in the literature for corn crops [28].

The harvest was performed when the plants reached the ideal physiological stage (R6) of grain production. The ears were harvested in the two central lines that make up the useful area and the characteristics, grain yield in kg ha^{-1} (PRODG), and the explanatory: Number of grains per row (NGPF), Number of rows on the cob (NFE), Plant height (AP), Height of the ear (AE), Humidity (UMID) [29].

After the data were obtained and tabled, Pearson's correlation coefficients were estimated between the characters. Correlations with values of $r \geq 0.6$ or $r \leq -0.6$, from the methodology proposed by Dancey et al. (2018) [30], where r above 0.6 is considered moderate to strong. Then, trail analysis was performed, and correlations were unfolded in direct and indirect effects of the variables (independent variables) on the productivity of straw-without ears (PESP) [31].

The analyses were performed using the Computational Genes program, 2007 [32].

III. RESULTS AND DISCUSSION

In the analysis of variance (Table 3), one can observe the representative effects obtained by the variation of the bacterium *Azospirillum,* through the management with and without application of *Azospirillum brasilense*, we observed that there was a significant difference in the following characteristics of NGPF, PRODG with *Azospirillum* or without *Azospirillum,* already note that in the characteristics NFE, AP significant values were obtained only with*Azospirillum* and the AE only features in the following feature AE.

Table 3. Summary of variance analysis of the grain number per row characteristic 3(NGPF), Number of rows on the cob (NFE), Plant height (AP), Height of the ear (AE), Humidity (DE), and grain yield in kg ha^{-1} (PRODG), relating to 10 maize genotypes.

Source of variation	GL	Medium Squares											
		NGPF		NFE		AP		AE		UMID		PRODG	
		C/A	S/A	C/A	S/A	C/A	S/A	C/A	S/A	C/A	S/A	C/A	S/A
Block	2	3.7	15.8	0.2	0.2	43.2	16.6	171	37.6	28.9	9.1	941135.0	283724.6
Cultivate	9	61.9*	49.4*	4.3*	2.8^{ns}	578.3*	233.1^{ns}	626	208.4^{ns}	4.9^{ns}	13.4^{ns}	6260931.8*	484970.0*
Residue	18	11.5	11.4	1.6	1.6	92.57	272.9	246	219	15.5	17.8	826231.6	1354864.4

Average	35	34	15.8	15.5	192	193	88	94	29.9	29.9	7167	6766
CV (%)	9.82	9.94	7.94	8.25	5.01	8.54	17.84	15.67	13.18	14.12	12.68	17.20

$^{ns; *}$ significant at 5% probability by the F test. GL – Degree of freedom. C/A – With *Azospirillum.* S/A – Without *Azospirillum.*

The coefficients of variation (CV) observed that the coefficient values below 10% in the following characteristics NGPG, NFE, and AP. The coefficient of variation below 10% is considered low which indicates good accuracy, already the values are as it is 10 until 20% you mean average like literature [33].

The Coefficients of Determination reveal that we have a strong relationship with Productivity and other variables indirect in the estimates (Table 4). With *Azospirillum* (0.9752) and without *Azospirillum (*0.7809) being a positive point demonstrating that these variables have a significant contribution to corn yield. Residual Variable Effect with *Azospirillum* (0.1576) and without *Azospirillum (*0.4681) is considered low.

Table 4. Estimates of the direct and indirect effects involving the main variable, grain yield in4 kg ha^{-1} (PRODG), and the explanatory: Number of grains per row (NGPF), Number of rows on the cob (NFE), Plant height (AP), Height of the spike (AE), Humidity (DE), 10 maize genotypes.

Characters	Association Effects	With *Azospirillum*	Without *Azospirillum*
		Estimate	
NGPF	Direct effect on PRODG	0.0240	0.9664
	Indirect effect via NFE	-0.0954	-0.0094
	Indirect effect via AP	0.1573	0.1392
	Indirect effect via AE	0.0194	-0.3501
	Indirect effect via UMID	0.5054	0.1023
	Full	0.6106	0.8484
NFE	Direct effect on PRODG	0.2018	-0.0510
	Indirect effect via NGPF	-0.0113	0.1774
	Indirect effect via AP	-0.1582	0.0128
	Indirect effect via AE	-0.0246	-0.0754
	Indirect effect via UMID	-0.2540	-0.0251
	Full	-0.2464	0.0387
AP	Direct effect on PRODG	0.4235	0.3112
	Indirect effect via NGPF	0.0089	0.4322
	Indirect effect via NFE	-0.0754	-0.0021
	Indirect effect via AE	0.0899	-0.3544
	Indirect effect via UMID	0.2651	0.1267
	Full	0.7119	0.5137
AE	Direct effect on PRODG	0.1159	-0.4349
	Indirect effect via NGPF	0.0040	0.7780
	Indirect effect via NFE	-0.0429	-0.0088
	Indirect effect via AP	0.3284	0.2536
	Indirect effect via UMID	0.3138	0.1319
	Full	0.7192	0.7197
UMID	Direct effect on PRODG	0.7183	0.1840
	Indirect effect via NGPF	0.0169	0.5372
	Indirect effect via NFE	-0.0714	0.0070
	Indirect effect via AP	0.1563	0.2144
	Indirect effect via AE	0.0506	-0.3118
	Full	0.8707	0.6308
Coefficient of determination (R^2)		0.9752	0.7809
Effect of residual variable		0.1576	0.4681

Mundim et al. (2013) [34], report that the value of the coefficient of determination reflects how much, as a percentage, of the variation of the main variable, is explained by those used in the trial analysis.

In (Table 4) the NGEF in conditions with *Azospirillum* (C/A) and without *Azospirillum* (S/A) showed a direct effect on the PRODG (0.0240 C/A) and (0.9664 S/A) and indirect routes estimates AP from (0.1573 C/A) and (0.1392 S/A) and UMID (0.5054 C/A) and (0.1023 S/A) also AE (0.0194 C/A), however, it had indirect effects on the variables in NFE from (-0.0954 C/A) and (– 0.0094 S/A), also in AE from (-0.3501 S/A), having negative effects on the effect of PROD. Guimarães et al. (2021) [11], point out that the treatments that have been used by the *Azospirillum*, or NGEF hears a greater contribution to the productivity effect compared to treatment without the use of inoculant.

In the estimates(C/A) that show the relationship NFE that has via positive direct effect PRODG (0.2018), with this the negative indirect effects via NGPF (-0.0113), AP (-0.1582), AE (-0.2046) and UMID (-0.2540). With a total in the feature NFE direct and indirect means has a negative value (-0.2464). In the estimate (S/A) the relationship NFE note that it came back with negative NFE between the direct effect route PRODG (-0.0510), indirect via AE (-0.0754) and UMID (-0.0251), and indirect positive via NGPF (0.1774) and AE (0.0128). Guimarães et al. (2021) [11] highlight that the inoculated plant has a better vegetative development which causes a greater nitrogen reserve which justifies this result.

Carvalho et al. (2018) [35], Faria et al. (2021) [36], and Oliveira et al. (2021) [37] report that high values of correlations and right effect reveal direct, the cause-effect association between the attributes used in the analysis.

In relation to the AP, there were direct effects on the PRODG (0.4235 C/A) and (0.3112 S/A) and indirect via NGPF (0.0089 C/A) and (0.4322 S/A), UMID (0.2651 C/A) and (0.1267 S/A) and AE (0.0889 C/A), and negative indirect effect via NFE (-0.0754 C/A) and (-0.0021 S/A), AE (-0.3544 S/A).

The variable AE with *Azospirillum* positive direct effect on the PRODG (0.1159), indirect via NGPF (0.0040), AP (0.3284), and UMID (0.3138), and negative via NFE (-0.0429). The variable AE without *Azospirillum* there is a negative direct effect on the PRODG (-0.4349) and an indirect positive via NFG (0.7780), AP (0.2536), and UMID (0.1319), however, it had a negative indirect effect on NFE (-0.0088). Santos et al. (2018) [38], observed in 16 maize genotypes that, although AE has no relation to productivity, the ear should be inserted into the middle part of the plant, possibly avoiding bedridden and plant breaking.

The UMID provided a positive direct effect on the PRODG (0.7183 C/A) and (0.1840 S/A), and indirect positive via NGPF (0.0169 C/A) and (0.5372 S/A) and AP (0.1563 C/A) and (0.2144 S/A), AE (0.0506 C/A) and NFE (0.0070 S/A), in the meantime it had a negative indirect effect via NFE (-0.0714 C/A) and AE (-0.3118 S/A).

Guimarães et al. (2021) [11] highlight that the use of inoculation proved agronomically efficient in the corn crop, being close to the values presented in this work where the comparative treatment is used by the *Azospirillum*, the variable NFE, NGEF, AP, and AE productivity effect was obtained values close to or higher than fertilization only with nitrogen application the treatment of inoculant use in conjunction with the initial application, which is based on the effect of the indirect variables addressed.

In the general context, the effects of the developments, through the analysis of the correlation coefficients of NGPF, AP, AE, and UMID past NFE (C/A), were positive with high significance. But the effect of NFE (S/A) which had a positive direct effect with PRODG was negative and was explained by the negative variables of indirect effect.

IV. CONCLUSION

The variables Number of grains per row, Number of rows on the cob, Plant height, Spike height, Humidity, and a positive direct effect are closed by comparing the two estimates with and without *Azospirillum brasilense*.

Highlighting the number of rows in the ear, Plant Height and Humidity presented statistically higher productivity results being more indicated for indirect selection for productivity handling *corn with Azospirillum brasilense* in the Southern Region of Tocantins.

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