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Agronomic characteristics of corn in function of the application of K, S and Mo by foliar via with and without plaster in red Latosol

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The study aimed to verify the response of the application of foliar fertilizers based on potash, sulfur and molybdenum, with and without plaster in the soil, on the agronomic traits of corn crop. The experimental design was a randomized block in a factorial 5 x 2 with four replications. The sources of variation showed no significant effect. These results indicate that the plaster efficiency in the agronomic characteristics can be possibly found with more reaction time of this conditioner into the soil, this justifies the non-significant effect of plaster on this cycle. The application of foliar fertilizers provided no significant increase in any of the variables, with no nutrients, probably due to availability and sufficient quantity in the soil where the study was conducted.

Keywords: Yield, calcium sulphate dyhidrate, *Zea mays*.

INTRODUCTION

Among the cereals grown in Brazil, corn (Zea mays L.) is the most significant, with an expectation of 83 million tons of grain produced in an area of approximately 15 million hectares, referring to two seasons, summer and winter. For its physiological characteristics, the corn crop has high yield potential, having already been obtained a productivity of more than 16,000 kg ha^{-1}. However, Brazilian productivity is very low, about 5469 kg ha^{-1}, demonstrating that the different corn production systems should be greatly improved to achieve the productivity and potential of this culture (conab, 2016).

The application of conditioners as the agricultural plaster in the soil, can improve the chemical characteristics, favoring the development of the roots in depth, contributing to the correction of calcium deficiency, neutralization of Al^{3+} toxic and supply of S, in the deeper layers, decisive factors for crop productivity. As a result, and with the greatest amount of roots underground, there is a better use of water and nutrients by plants especially in water deficit periods (Zandoná et al., 2015).

Foliar fertilization is among the several ways to provide nutrients for plants, and when well managed it can be an

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effective alternative for the solution of specific problems and/or to complement a rational fertilization (Faquin, 2005), but there is in the literature a certain shortage related to application of fertilizers based on K, S and Mo by foliar application in corn.

According to Büll and Cantarella (1993), potassium has a great impact on crop quality influencing positively on the individual grain weight and number of grains per ear; however there is little publication and research material in Brazil on the implementation of this element by foliar via, stressing the need for further study. Karlen et al. (1998) concluded in their work that S is accumulated throughout the crop cycle, and almost all S accumulated by the ear and peduncle is absorbed by the plant during the stage of reproductive development. According to Rezende et al. (2009), more expressive works with the application of S through the leaves can be seen in soy with increase in grain yield of up to 32% compared to the control.

According to Teixeira (2006), the application of molybdenum in corn crop provides no additions to plant growth or grain yield. However, Ferreira et al. (2001) and Silva et al. (2011) obtained increases of corn productivity with different doses of molybdenum fertilization, occurring variation between years and it can be influenced probably by the variation of rainfall and by other environmental factors such as temperature and light.

The application of plaster in the soil and mineral sources by foliar via on corn leads to improvements in the nutritional conditions of the plants and consequently favors the expression of genetic potential of corn, expressed in agronomic characteristics.

In this context, the aim of this study is to evaluate the agronomic characteristics of maize depending on the application or not of the plaster in the soil and foliar fertilizers on corn, based on potash (K), sulfur (S) and molybdenum (Mo).

MATERIALS AND METHODS

The experiment was conducted under field conditions in Toledo - Paraná - Brazil, situated (24°32'30") of South latitude and (53°54'32") West longitude, with an altitude of approximately 386 m of the sea level. The soil of the experimental area was classified as eutrophic Red Latosol (eRL) and by chemical analysis the following values was observed:

to layer of 0-0,20 m: Ca= 4.19 $cmol_c$ dm^{-3}; Mg= 0.99 $cmol_c$ dm^{-3}; K= 0.12 $cmol_c$ dm^{-3}; Al = 0.35 $cmol_c$ dm^{-3}, H + Al = 5.88 $cmol_c$ dm^{-3}, SB= 5.30 $cmol_c$ dm^{-3}; CTC= 11.18 $cmol_c$ dm^{-3}; MO = 27.34 g dm^{-3}, V = 47.41%; Al = 6.19%; P = 4.11 mg dm^{-3}; CaCl pH = 4 62 mg dm^{-3}; Cu = 16.50 $cmol_c$ dm^{-3}; Zn = 4.00 $cmol_c$ dm^{-3}; Mn = 121.00 $cmol_c$ dm^{-3}; Fe = 27,50 $cmol_c$ dm^{-3} to layer. 0,21-0,40 cm: Ca = 4.92 $cmol_c$ dm^{-3}; Mg = 1.44 $cmol_c$ dm^{-3}; K = 0.06 $cmol_c$ dm^{-3}; Al = 0.05 $cmol_c$ dm^{-3}, H + Al = 4 30 $cmol_c$ dm^{-3}, SB = 6.42 $cmol_c$ dm^{-3}; CTC = 10.72 $cmol_c$ dm^{-3}; OM = 13.67 g dm^{-3}, V = 59.89%; Al = 0.77% ; P = 3.67 mg dm^{-3}, pH CaCl = 5.10 mg dm^{-3}; Cu = 16,90 $cmol_c$ dm^{-3}; Zn = 2.50 $cmol_c$ dm^{-3}; Mn = 57.00 $cmol_c$ dm^{-3}; Fe = 34.40 $cmol_c$ dm^{-3}.

During the experiment conduction period, the study collected weather information, as presented in Figure 1, being the minimum temperature of 20°C and maximum 34°C. The experimental design was in randomized blocks (R.B.D.) with four replications, in a factorial 5 x 2. The study evaluated foliar fertilizers and a witness along with the application or not of agricultural plaster, totaling 40 experimental plots.

The foliar fertilizers were applied in their commercial doses, recommended by the manufacturers, with and without the presence of plaster, defining the treatments as it follows:

For the treatments in which it was added agricultural plaster in superficial application in the soil, the treatments were: T_1- treatment with product 0-0-50+S (2 kg ha^{-1}) with plaster (1065 kg ha^{-1}); T_2-treatment with L-S product (2.5 L ha^{-1}) with plaster (1065 kg ha^{-1}); T3-treatment with Potamol-Plus (0.4 L ha^{-1}) with plaster (1065 kg ha^{-1}); T4 treatment with Ammonium Molybdate (0.030 kg ha^{-1}) with plaster (1065 kg ha^{-1}); T_5-Witness with plaster (1065 kg ha^{-1}). With regard to the treatments in which plaster was not added, the treatments were: T_1-treatment with product 0-0-50 + S (2 kg ha^{-1}) without plaster (0 kg ha^{-1}); T_2-treatment with L-S product (2.5 L ha^{-1}) without plaster (0 kg ha^{-1}); T_3-treatment with Potamol-Plus (0.4 L ha^{-1}) without plaster (0 kg ha^{-1}); T_4 treatment with Ammonium Molybdate (0.030 kg ha^{-1}) without plaster (0 kg ha^{-1}); T_5-control without plaster (0 kg ha^{-1}).

The total area of the experiment was 675 m^2, composed of four blocks with 10 treatments each. Each experimental parcel was composed of six planting lines with 5 m length and spacing between lines of 0.45 m, totaling 13.5 m^2 per parcel and its useful area was of 3.6 m^2.

As for the seeding, using the P30F53YH corn material, it was made on October 11, 2013 (agricultural year 2013/2014) using a tractor and seeder with 9 lines of planting and spacing of 0.45 m, set to distribute 3.3 seeds per meter, totaling 73,332 h^{-1} of corn seed and for the basis fertilization it was used 400 kg ha^{-1} of fertilizer formulated 06-30-22 (N-P-K), equally distributed the seeds and the fertilizer for all parcels.

Seven days after the planting, the demarcation of the main plots was carried out along with the application of dolomitic lime on the soil surface based on the chemical analysis of soil and under recommended criteria of 2000 kg ha^{-1}. Limestone was applied to the total area of the experiment. The agricultural plaster was applied on the 19 October, 2013 (8 DAP). Its application was on the soil surface at a dose of 1065 kg ha^{-1}, applying it only in the experimental plots relevant to their use.

The coverage fertilization was carried out according to Embrapa (2008), based on the results of the soil analysis and expected productivity for corn destined to grain production. The fertilizer used was ammonium sulphate composed of 21% of nitrogen and 24% of Sulphur, and the applications were divided into two times. The first application was held on October 30 (12 DAE) when the corn plants showed four expanded leaves (V_4 stage) in the dosage of 70 kg ha^{-1} of N and 80 kg ha^{-1} of S. The second application occurred on October 27, 2013 (40 DAE) when the corn plants showed eight expanded leaves (V_8 stage) at a dose of 70 kg ha^{-1} of N and 80 kg ha^{-1} of S.

The application of foliar fertilizers occurred on 25 November, 2013 (138 DAE) (V_7 stage) when the corn plants showed seven expanded leaves. The products were applied on this stage in their commercial doses following the manufacturer's recommendation. The application was terrestrial with costal spray with capacity for 20 L, properly calibrated, showing a flow of 200 L ha^{-1}.

For the final population, the manual counting on 18 February 2014 (133 DAE) of all plants in the useful area represented by the agronomic characteristics, in all experimental plots was carried out. The harvest of the plots was carried out manually, and the ears were placed in plastic bags properly identified, and subsequently it was made the threshing with the aid of a stationary manual threshing.

All the plants of the useful area of the portion of each treatment

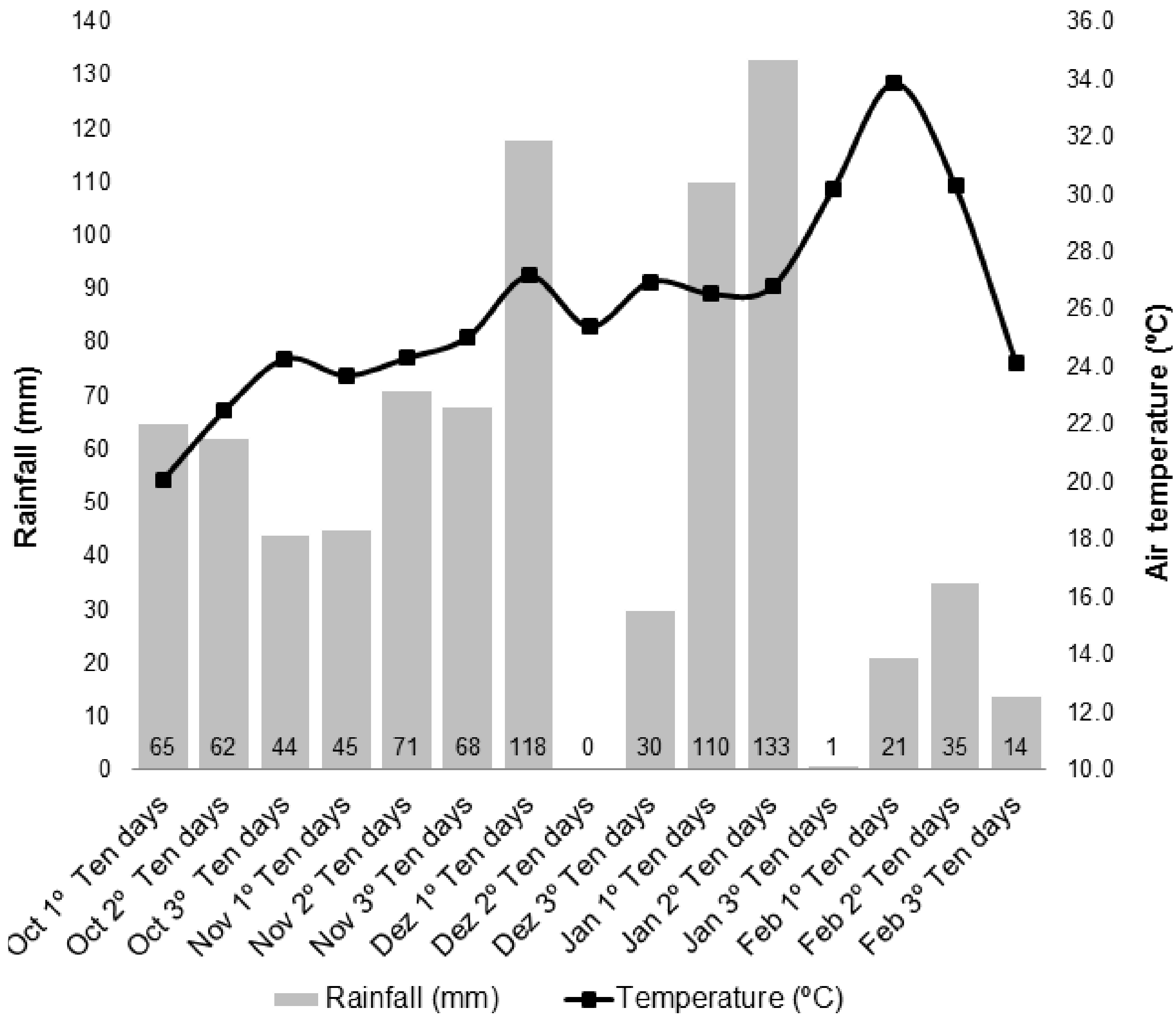

Figure 1. Ten-day cumulative rainfall data in millimeters (mm) and average temperature in degrees Celsius (°C) for the conduction period of the experiment.

and repetition were counted, and thus it was obtained the number of plants in each experimental area. They have been converted by simple rule of three to 10.000 m² thus obtaining the final population of plants per hectare. The stem diameter (STE) was measured at random, within the useful area of each treatment and repetition, the stem of ten plants in full female flowering (visible style-stigma). This measurement was carried out using a caliper (mm) in the first half expanded internode, getting the average basal diameter of the stem portion. The plant height was also made at random, using 10 plants within the useful area of each treatment and repetition, measuring from the plant lap to the curvature of the flag leaf in full female flowering (visible style-stigma), using a tape measure in cm and obtaining the average height of the plants.

After the harvest, the study sampled all the ears inside the useful area of the plot of each treatment and repetition, thus obtaining the average number of rows of grains per ear (RGE). The number of grains of all rows (GPR) of the ears in the useful area of the portion of each treatment and repetition was also counted, thus obtaining the average number of grains per row of each parcel ear.

The number of grains of all ears in the useful area of the portion of each treatment and repetition was counted, thus obtaining the average number of grains per ear (AGE). The mass of 1000 grains (MAM) was evaluated according to the Rules for Seed Analysis (Brazil, 2009). Eight repetitions of 100 seeds per plot were used. The samples were identified and weighed in a precision balance, and then placed to dry in a greenhouse at 105°C for 24 h. With the samples being withdrawn, they were weighed again and made subsequent conversion of grain moisture to 14% (wet basis). To obtain the mass of 1000 grains, a mass transformation of 800 grains to 1000 grains as simple rule of three was carried out.

The mass of the ear (MAE) was defined from the data of mass of 1,000 grains (MAM), and the average number of grains per ear (AGE) as simple rule of three. The productivity calculation in kilograms per hectare (PKH) was based on the analysis of population (POP), on the average number of grains per ear (AGE) and on the 1000 grain mass (MAM), expressing the results in productivity in kilograms per hectare (PKH). Data were tabulated and submitted to analysis of variance by F test at 5% probability of error. When the F test indicated differences between treatments, the averages were compared by Tukey test at 5% error probability

Table 1. Summary of the analyses of variance with the medium squares (M.S.) of the variables population (POP), stem diameter (SD), plants height (PH), number of grains row per ear (NRE), number of grains per row (NGR), average number of grains per ear (AGE), mass of 1000 grains (MAM), mass of the ear (MAE) and productivity kg per hectare (PKH).

Variation sources	LD	Medium square		
		POP	STE	PH
Block	3	0.2694187^{ns}	0.8888867^{ns}	0.9500556^{ns}
Plaster (with and without)	1	1736111.0^{ns}	0.5760000^{ns}	0.9712103^{ns}
Foliar Fertilization	4	4147377.0^{ns}	0.5349000^{ns}	0.1566608^{ns}
Plaster x Foliar Fertilization	4	0.1089892^{ns}	0.5508850^{ns}	0.9891615^{ns}
Residue	27	7508859.0^{ns}	0.2771570^{ns}	0.8539767^{ns}
Total	39	-	-	-
CV (%)	-	4.1668	2.3015	1.1219

Variation sources	LD	Medium square		
		NRE	GPR	AGE
Block	3	0.3166159^{ns}	28.39233^{ns}	10525.40^{ns}
Plaster (with and without)	1	0.3939477**	2.605517^{ns}	2264.419^{ns}
Foliar Fertilization	4	0.1581997*	4.662933^{ns}	1500.706^{ns}
Plaster x Foliar Fertilization	4	0.2216681^{ns}	2.280914^{ns}	720.8473^{ns}
Residue	27	0.5866546^{ns}	3.369881^{ns}	1046.463^{ns}
Total	39	-	-	-
CV (%)	-	1.5514	5.3073	5.9865

Variation sources	LD	Medium Square		
		MAM	MAE	PKH
Block	3	155.6890^{ns}	1937.924^{ns}	3666012.0^{ns}
Plaster (with and without)	1	0.5574966^{ns}	298.4334^{ns}	763854.5^{ns}
Foliar Fertilization	4	127.1457^{ns}	298.1885^{ns}	1599380.0^{ns}
Plaster x Foliar Fertilization	4	66.23129^{ns}	121.2257^{ns}	563945.8^{ns}
Residue	27	61.05655^{ns}	154.1975^{ns}	685258.5^{ns}
Total	39	-	-	-
CV (%)	-	2.1658	6.3659	6.4659

*Significant (P ≤ 0,05) by F test; ** significant (P ≤ 0,01) by F test; ns: non-significant.

(Table 1). The statistical program used was Sistema De Análises Estatísticas e Genéticas – SAEG (SAEG, 2007).

RESULTS AND DISCUSSION

The weather conditions in this experiment, shown in Figure 1, demonstrate satisfactory effect for the development of the crop with well-distributed rainfall (473 mm) and average minimum temperature of 20 to 27°C since germination to the phenological stage V12. Nonetheless, the drought faced in the 2nd and 3rd ten days of December (days 10 to 27), during which the corn was in growth stage R1 (silking and pollination), can be directly related to the lack of results of this work. According to Cruz et al (2008), the lack of water in this period causes poor pollination and low graining tang, that once under drought, both the "hair" and the grains tend to dissection. Water stress was extended for R2 stages which may have caused deficiency in dry matter accumulation, and R3 which although has been less critical than in the previous phase, can affect production.

According to Fancelli and Dourado-Neto (2000), the process of transpiration and evapotranspiration are responsible for the movement of water and nutrients absorbed by corn. Thus, in the absence of water, nutrient assimilation process can be affected by decreasing the accumulation of dry matter. In the 1st and 2nd periods of ten days of January, due to rainfall occurrence, the crop can continue the process of maturation, however, facing again a water deficit in the 3rd ten days of January and 1st ten days of February, along with the rise in temperature, causing an early death of plants.

Table 1 shows the results of analysis of variance with the mean squares of the set of the agronomic characteristics analyzed both in the field and in the

Table 2. Number of rows of grains per ear of corn P30F53YH in function of the foliar application in the 2013/2014 harvest, in Toledo-PR.

Foliar fertilization	Number of rows
0-0-50+S with plaster	15.7a
L-S with plaster	15.5a
Potamol-Plus with plaster	15.6a
Ammonium molybdate with plaster	15.7a
Witness with plaster	15.4a
Average	15.6
CV (%)	1.6
DMS	0.5

Lowercase letters above do not differ statistically among each other by Tukey test at 5% probability.

laboratory, based on the F significance test. The coefficients of variation (CV%) were of low magnitude, below 7%, which indicates high accuracy and demonstrates credibility in the conduction of the experimental procedures.

Analysis of variance showed that there was no significant effect on the F test in the following variables: POP, STE, PH, GPR, AGE, MAM, MAE and PKH. For the NRE variable, there was significant effect in F test ($P \leq 0.05$) in the source of foliar fertilizer variation requiring the application of Tukey's test for multiple comparison between the averages (Table 2).

When the averages were compared by Tukey test, it was concluded that there was no significant effect between foliar fertilizer treatments and NRE variable. Analyzing Plaster environments (presence or absence), it is concluded that there was no significant difference between any of the variables. Conte et al. (2013) in a similar experiment to evaluate the plaster in the development of corn grown in a Yellow Red Latosol dystrophic with plaster application 30 days prior to planting in dosages of 1000, 2000, 4000, 6000, 8000 kg ha^{-1}, obtained the same results, in other words, plaster did not significantly influenced the height and stem diameter of corn plants. This same author assessed in another experiment the plaster reaction time, applying the 75, 60, 45, 30, 15 and 0 days before planting, at a dose of 3300 kg ha^{-1}, the variables plant height and stem diameter had no significant difference, showing that even with a longer reaction time, plaster application did not lead to positive results.

According to Oliveira et al. (2007), in an experiment with plaster in the same day of seeding, the mass of 100 grains of corn had no significant difference, however, productivity increased significantly. This can be associated with an increased number of grains per ear, because as the weight of 100 grains was the same, there was a greater average in grain crop with the plaster applied, expressing this results in productivity. More promising resultson the efficiency of plaster on agronomical characteristics can be more expressive with more reaction time of this conditioner in the soil, since according to Caires et al. (2003), the effect of plaster can last for several years, justifying no significant effect of plaster application at planting time.

For the purposes of foliar fertilizers based on Mo, K and S and their impacts on the agronomic characters of all treatments, they had no effect. Similar results were also obtained by Ferreira et al. (2001), for the number of plants per plot, number of ears per plant and plant height with the application of Mo. The final stand and grain yield were not significantly affected by the application of molybdenum doses, as well as the 1000 seeds and productivity. Better results were obtained by Araújo et al. (1996), with an increase of 14.3% in production with application of 90 g ha^{-1} of Mo, and by Coelho (1997), with an increase of 39.5% in production, using a dose of 50 g ha^{-1} of Mo.

With regard to the application of potassium, the variables did not obtain positive results before their application, probably due to the large amount of K from the NPK formulation (06-30-22 to 400 kg ha^{-1}) which was added to the soil, made based on the chemical analysis of the soil and applied the formulation at the time of sowing.

As for the response to foliar application of S, the components of the production, and also Mo and K, they did not obtain significant responses. This nutrient can be supplemented to the culture in order to complete the N need of corn in the form of ammonium sulfate, (N 21%) and (S 24%) twice, stage (V4) and stage (V8) totaling 160 kg ha^{-1} of S, a factor that may be crucial to the insignificant response to the application of the element S by foliar via.

Considering the application of foliar fertilizers, the study did not obtained significant results in any of the variables with any of the nutrients, probably due to sufficient acquisition of these, by the crop, through the ground, concluding that the a correct fertilization at sowing and supplement the soil in peaks of need, are sufficient for the result of productivity.

Bearing in mind the application of agricultural plaster at the time of sowing, the plaster also had no effect on the assessed agronomic variables, probably due to the short response time of this conditioner in the soil, suggesting more visible results over the years.

Conclusion

Based on study carried out in the period of the experiment, it was not observed significant effect with increase in the agronomical characters of the corn crop in function of the plaster. With regard to the foliar fertilizer, there was no significant difference on the agronomical variables assessed in function of its application by foliar via.

Conflict of interests

The authors have not declared any conflict of interest.

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