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Morphological parameters and components of the productivity of corn second safra in the function of doses of agricultural gypsum

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Abstract. Subsoil acidity has been considered one of the main causes of limitation to agricultural productivity, because it restricts root growth and the absorption of water and nutrients by crops. The agricultural gypsum stands out for its benefits as a conditioner, reduces the saturation of aluminum and increases the levels of calcium and sulfur in subsurface, allowing the development of roots in deeper layers. The objective was to evaluate the ideal gypsum dose for the increment of vegetative characteristics and the components of maize crop productivity in the second crop season in Sinop, MT. A randomized block design (DBC) with five doses of agricultural gypsum (0, 1.0, 2.0, 3.0 and 4.0 t ha⁻¹). In the conditions under which the study was carried out, it can be concluded that the application of the agricultural gypsum impaired the vegetative growth and the development of the second maize crop cultivated in soils corrected and under high rainfall intensity. The application of gypsum in soils with Mg levels considered low reduces corn growth. The addition of agricultural gypsum doses did not influence the number of grain rows, number of grains per row and the mass of one thousand grains, due to the conditions of the study with the limiting content of Mg in the soil (0-20 cm layer) and with high volumes of rainfall in northern MT during the development of second crop maize.

Keywords: Zea mays L. Growth of second crop maize season. Yield components. Vegetative development.

Introduction

In Mato Grosso estate with the anticipation of sowing and the use of early soybean varieties, it allowed the subsequent cultivation, in this case maize, more time in the rainy period. In Mato Grosso estate, "second crop" maize had an average yield of 5.296 kg ha⁻¹, sown in an area of 3.531 million hectares, 90% of the state's maize crop (Conab, 2016).

Maize has been increasing productivity in recent years in Brazil, thanks to technological advances such as the development of hybrids and the adoption of modern management practices. Among these, it is worth mentioning the use of agricultural gypsum, which has a soil sub-surface conditioning effect, decreasing saturation by Al toxic and increasing the availability of nutrients, especially Ca and S (Caires et al., 2011). This causes the roots to have access to a greater volume of water and nutrients, providing greater productivity (Neis et al., 2010).

Subsoil acidity has been considered one of the main causes of limitation to agricultural productivity, because it restricts root growth and the

absorption of water and nutrients by crops. Agricultural gypsum or phosphogypsum is a byproduct of the phosphoric acid industry. In its basic chemical composition, agricultural gypsum contains calcium (17% to 20%), sulfur (14% to 17%) and residues of phosphorus (0.7% to 0.9% of P₂O₅), being excellent source of calcium and sulfur for plants (Dalla Nora et al., 2013).

The agricultural gypsum stands out for its benefits as a conditioner, reduces the saturation of aluminum and increases the levels of calcium and sulfur in subsurface (layer below 20 cm depth), allowing the development of roots in deeper layers. This causes the roots to have access to a greater volume of water and nutrients, providing greater productivity (Mongelo et al., 2008).

Some studies have revealed the beneficial effect of gypsum on annual crops. Zandona et al. (2015) describe that gypsum increases corn and soybean yield. Manetti et al. (2005) points out that gypsum may present some problems if applied in excess, such as the leaching of nutrients to subsurface, acting negatively on the efficiency of fertilization.

Studies carried out in Brazil still present controversial results regarding the use of gypsum, and few studies have been carried out in the state of Mato Grosso, especially in the northern region, the transition point of the Cerrado biome to the Amazon biome. In this context, the objective of this study was to evaluate the ideal gypsum dose for the increment of vegetative characteristics and the components of maize crop productivity in the second crop season in Sinop, MT.

Methods

The experiment was carried out in a commercial area, in the farm Ramada 2 located in the Sinop - MT, Brazil. The geographic location of the experimental area is at latitude 11°57'05" S, longitude 55° 23'51" W and altitude of 380m with flat topography (Garcia et al., 2013).

A randomized block design (DBC) with five doses of agricultural gypsum (0, 1.0, 2.0, 3.0 and 4.0 t ha⁻¹) and three replications. The area used by the experiment was 264 m², and each plot was represented by an area of 15.75 m² containing 7 rows of maize with 45cm spacing between the lines. The useful plot was composed of the four central lines (7.2 m²) of each plot and the border was half a meter of the useful area. The soil of the study site is classified as Yellow Latosol (Santos et al., 2013). Before soybean sowing, soil samples were collected in the 0 to 20 cm layer for the chemical analysis by the soil laboratory of the UFMT Campus Sinop. The results obtained with the analysis were: pH in CaCl₂ of 5.3, P content (Mehlich-1) of 12.98 mg dm⁻³, K content of 65 mg dm⁻³, Ca content of 36.1 mmol dm⁻³, Mg content 7.2 mmolc dm⁻³, organic matter content of 23.7 g cmolc dm⁻³ and 56% base saturation (V). Physical soil analysis revealed 349 g kg⁻¹ clay, 158 g kg⁻¹ silt and 493 g kg⁻¹ sand.

The corn sowing was performed on February 16, 2017 with the hybrid Dekalb 290 PRO3, with an early cycle, high stalk, good stalk quality, excellent rooting, above average grain weight and tolerant to the main diseases of the crop corn. Sowing was done in the no-tillage systalk (NTS), mechanized, with lines spaced 45 cm and with 2.8 seeds per meter. The area used was open area in 1998 and is permanently planted with the soybean / maize second harvest systalk, has a history of direct fertilization in no-tillage systalks and every three years the liming is performed according to the technical recommendations. The area used for the experiment corresponds to an area opened in 1998 and cultivated initially with maize and then with soybeans in the harvest and maize in the second harvest. From the year 2002 the area changed to the no-tillage systalk. For each soybean crop, 500 kg of fertilizers of different NPK formulations are placed on average in low-concentration nitrogen formulations. In terms of yields the average in the last three years was 60 bags ha⁻¹ for soybeans and 120 bags ha⁻¹ for corn. In the 2014/2015 harvest, maize cultivation was carried out with 40 kg of N ha⁻¹

1 using urea as source and 250 kg of the NPK formulation: 20-0-20 in V6. For weed control, 2 L ha⁻¹ of Atrazine and 1.5 L ha⁻¹ of Nicossulfuron were applied at 20 days after emergence. No chemical control of insects was required. A total of 0.5 L ha⁻¹ of fungicide containing Piraclostrobin 133g L⁻¹ and Epoxiconazole 50g L⁻¹ were applied in the 0.5 L ha⁻¹ dosage of 0.5 L ha⁻¹ with 0.5 L ha⁻¹ of mineral oil.

At the phenological stage of full flowering in R1, the morphological parameters were evaluated as the vegetative characteristics. For these variables, ten plants of the useful plot were sampled. The height of the plant, measured from the soil to the flag leaf, height of insertion of the main stalk, both determined with a measuring tape attached to a wooden support and the diameter of the stalk obtained with the aid of a pachymeter taking the measures in the middle of the first internode visible above the ground.

The harvest was carried out at the stage of physiological maturity, observed visually through the formation of the black layer and the loosening of the grains on the ear, at 142 days after sowing, on 07/07/2015. Ten representative ears of the plot were collected in the fifth line of each plot. The ears of each plot were identified and placed in plastic bags and then taken to the laboratory for evaluation. In the laboratory was determined: the number of rows of grains, number of grains per row and the mass of thousand grains. After the separation of the grain from the ear, using a manual thresher, three grain samples were obtained from each plot to determine the mass of one thousand grains, whose moisture was corrected to 130 g kg⁻¹ of water, the gravimetric method (BRASIL, 2009).

Corn grain yield was obtained by harvesting the ears of four central lines of each plot, respecting the half-meter border of the useful area. The ears were mechanically threshed and the production per plot was obtained by weighing in a precision scale. The yield of each plot was estimated by extrapolating the grain yield of the four plot lines for grain yield in kg ha⁻¹ after grain moisture adjusted to 130 g kg⁻¹ using the gravimetric method in the determination of humidity of each plot.

The data obtained were statistically analyzed using the F test ($p < 0.05$), and the means relative to the gypsum doses were submitted to polynomial regression using the SISVAR statistical program (Ferreira, 2011).

Results and discussion

With the application of gypsum doses there was a significant effect at the height of the ear insertion and stalk diameter, however, it did not influence significantly the height of the plants. Most of the maize productivity components, such as number of rows, number of grains per row and mass of one thousand grains, did not have a

significant effect, in other words there were no statistical differences between the doses of gypsum. Only for grain yield, there were significant differences between the doses of gypsum. (Table 1). Similar results were found by Castro et al. (2013) for which the application of agricultural gypsum in the presence or absence of limestone did not significantly influence the height, diameter of the colon and dry biomass of the area of maize plants.

Table 1. Summary of the analysis of variance of the morphological characteristics: plant height (PH), height of ear insertion (HEI) and stalk diameter (SD) of second crop corn, submitted to doses of agricultural gypsum. UFMT, Sinop - MT. 2015.

Source of variation:	Degrees of freedom:	Mean Square		
		PH (cm)	HEI (cm)	SD (mm)
Doses of Gypsum (t ha ⁻¹)	4	1,77	5,17**	7,11**
C.V(%)		3,70	3,88	3,77

** significant at the 1% probability level by the F test.

The application of the agricultural gypsum resulted in a reduction in the insertion height of the ears (Figure 1). It is noted that at every 1.0 t ha⁻¹ of gypsum there is a reduction of 2,726 cm at the

insertion height of the first ear. The corn stalk diameter had a behavior similar to that of the ear insertion height, with each application of 1.0 t ha⁻¹ of gypsum, with a reduction of 0.503 mm in stalk diameter (Figure 2). Comparing these results with those of Figure 1 it can be inferred that the doses of gypsum resulted in reduced growth and development of maize plants. Similar results were observed by Castro et al. (2013).

This fact demonstrates that the addition of gypsum may result in reduction in plant growth, but this fact should not be considered as damage to the crop, since when investing less in growth of the stalk, there will be surpluses that can be translocated to the grains, (Caíres et al., 2011). In addition, smaller plants are less susceptible to lodging and may accumulate more reserve of photo-assimilated compounds in the stalk, and may contribute to gains in productivity.

The diameter of the corn stalk exhibited a behavior similar to that of the ear insertion height, and for each application of 1.0 t ha⁻¹ gypsum there was a reduction of 0.503 mm in the stalk diameter (Figure 2). Comparing these results with those of Figure 1 it can be inferred that the doses of gypsum resulted in reduced growth and development of maize plants. Similar results were observed by Castro et al. (2013) and Caíres et al. (2004).

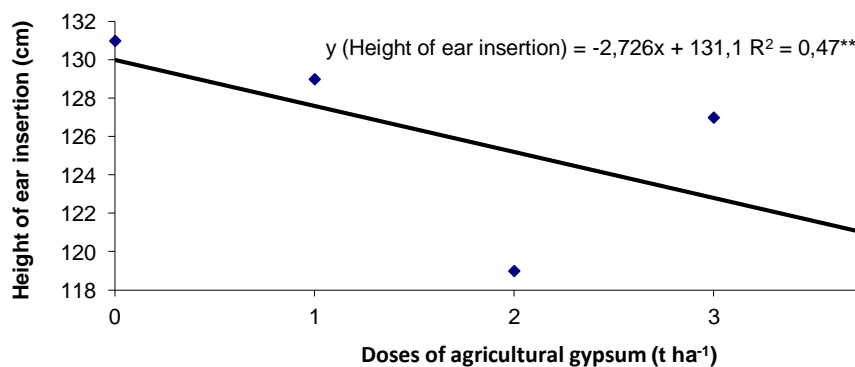


Figure 1. Height of ear insertion in second crop maize plants submitted to doses of agricultural gypsum. UFMT, Sinop, 2015.

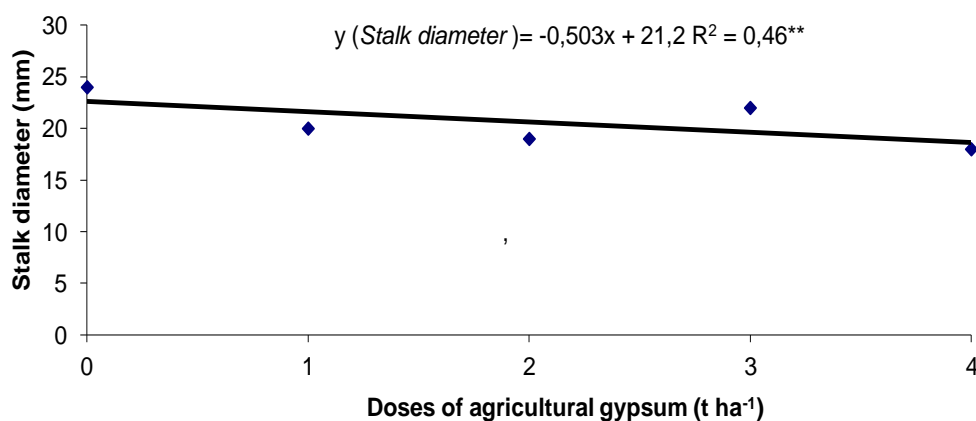


Figure 2. Corn stalk diameter of second crop corn plants submitted to doses of agricultural gypsum. UFMT, Sinop, 2015.

Another explanation for the reduction in ear height and diameter may be the dynamics of magnesium in soils that receive gypsum. In this context, Caires et al. (2003) observed a linear increase in the contents of exchangeable Ca, but according to the doses of gypsum applied, in the studied depths. In addition, the gypsum provided greater leaching of the Mg, which in turn reduced its availability. This effect of gypsum is commonly reported in studies, and this behavior supports one of the explanations pertinent to the effects already observed.

In the case of Mg deficiency, Ferreira (2012) states that maize plants with Mg deficiency present a decrease in their size, since Mg is a constituent of chlorophyll, being fundamental for the effective process of photosynthesis and, consequently, the activity cellular (Fancelli, 2010). In the case of maize, its efficient utilization between the V6 and V10 stages contributes to the increase of the reserve concentration in the stalk, which will be of great value for complementation of the grain filling in later stages.

It is important to note that, during the study, the rainfall intensity was very high in the experimental area, and may have negatively affected the growth of the plants, thus damaging the productivity. In the literature in general, few studies have shown negative effects of gypsum, being more common the occurrence of positive effects of the application of gypsum in the maize crop. The results observed in level of productivities contradict those reported by Zandoná et al. (2015), which verified an increase in maize grain yield with application of 2.0 t ha⁻¹ of agricultural gypsum, increasing the final yield by 9.3%.

According to Table 2, most of the productivity factors in the yield and productivity components, such as number of rows, number of grains per row and mass of one thousand grains were not altered by the doses of gypsum. It was verified a change only for grain yield with the application of gypsum doses. Caires et al. (1999) point out that, under conditions of regular rainfall

distribution, no responses to the application of gypsum.

Table 2. Summary of variance analysis of the components characteristics of corn yield: number of rows (NFG), number of grains per row (NGF), mass of one thousand grains (MMG) and grain yield (PROD) submitted to doses of agricultural gypsum. UFMT, Sinop - MT. 2015.

Source of variation:	Degrees of freedom:	Mean Square			
		NFG	NGF	MMG (g)	PROD (kg ha ⁻¹)
Doses of gypsum (t ha ⁻¹)	4	0,90	0,86	0,38	6,77**
C.V. (%)		4,70	7,28	5,98	11,04

** Significant at the 1% probability level by the F test.

It can be seen from Figure 3 that grain yield was influenced by the application of agricultural gypsum. According to the linear regression equation the doses of agricultural gypsum resulted in a reduction in grain yield with the increase of agricultural gypsum doses. On average, there were decreases of 390 kg ha⁻¹ in maize grain yield for every 1 ton of agricultural gypsum applied to the soil. This fact confirms that areas that had their fertility corrected over the years with successive applications of limestone and fertilizers tend to present smaller responses to the addition of agricultural gypsum described in the literature (Raj et al., 1998). These authors, working with different cultivars of tolerant and aluminum-sensitive maize, found that gypsum had a significant effect only on the aluminum-sensitive cultivar, that is, there was no effect for the aluminum tolerant cultivar. In this work the soil was corrected to reduce the presence of Al toxic, which probably reduced the need for gypsum which, under the conditions of the present study, can be represented by the soil corrected. Only the nutrient content Mg was below the level considered critical for the crops, being this limitation in the experiment for a higher crop productivity. This may explain the reduced productivity, since the Mg contents were

already low and the application of gypsum reduced the Mg contents even more.

The observed results contradict those reported by Zandoná et al. (2015), which verified an

increase in maize productivity with application of 2.0 t ha⁻¹ of agricultural gypsum, increasing grain yield by 9.3%.

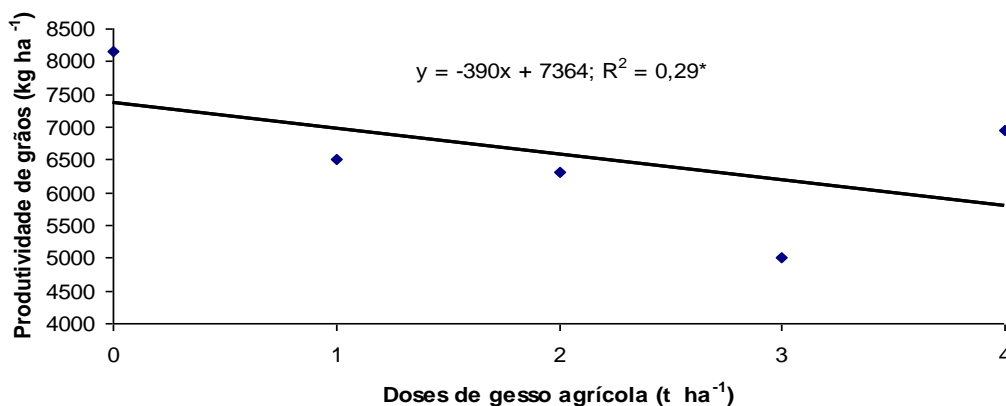


Figure 3. Productivity of grains corn crop submitted to doses of agricultural gypsum. UFMT, Sinop, 2015.

Studies such as those of Caires et al. (1999) point out that, under conditions of regular rainfall distribution, no response to the application of gypsum is normally observed. On the other hand, Caires et al. (2004) verified increases in maize grain production with the use of gypsum in no-tillage, which were attributed not only to the improvement of the chemical conditions of the subsoil but also to the increase of exchangeable Ca + 2 and S-SO₄-2 available in the superficial layers of the soil.

Caires et al. (2003) explain the increase in maize production with gypsum doses, only in the presence of acidity correction with dolomitic limestone, considering that the doses of gypsum, despite increasing the concentration of exchangeable Ca, provided a reduction in the Mg content exchangeable in the soil. It is known that gypsum reduces the Mg content in the most superficial layers of the soil after its application. Several factors can be attributed to the fall in maize productivity with the application of gypsum.

According to Fancelli (2010), the maize crop depends on the correction of soil acidity and sufficient quantities of the essential nutrients, such as calcium and magnesium, in order to demonstrate its maximum productive potential. Therefore, a possible reduction in grain yield in the present work may have been due to losses of Mg in the surface layers of a soil that had the limiting content of Mg (7.2 mmolc dm⁻³ of Mg in the 0-20 cm layer) and rainfall was very high in the experimental area, may have reduced plant growth and impaired grain yield.

In the literature there are few reports that have obtained negative effects of gypsum, being more common the occurrence of positive effects of the application of gypsum in the maize crop. The observed results contradict those reported by Zandoná et al. (2015), which verified an

increase in maize productivity with application of 2.0 t ha⁻¹ of agricultural gypsum, increasing grain yield by 9.3%.

With this, it is evident that great care is taken in the application of gypsum in order to improve the subsoil, observing several criteria, among which the Mg contents in the surface layer is near or below the critical level.

Conclusions

In the conditions under which the study was carried out, it can be concluded that the application of the agricultural gypsum impaired the vegetative growth and the development of the second maize crop cultivated in soils corrected and under high rainfall intensity.

The application of gypsum in soils with Mg levels considered low reduces corn growth. Maize productivity can be adversely affected when gypsum is used and Mg contents are not sufficient or are below sufficiency.

The addition of agricultural gypsum doses did not influence the number of grain rows, number of grains per row and the mass of one thousand grains, due to the conditions of the study with the limiting content of Mg in the soil (0-20 cm layer) and with high volumes of rainfall in northern MT during the development of second crop maize.

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