Residual effect of agricultural gypsum and its forms of application in wheat cultivation in Paraguay

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Abstract

Agricultural gypsum is an amendment that makes chemical conditioning possible in the subsurface layer of soil. It helps to neutralize aluminum, facilitates the vertical mobility of nutrients, incorporates exchange bases in the subsoil and, in some cases, causes an increase in crop yields. The objective of the research was to evaluate the residual effect of agricultural gypsum and its forms of application on some productive parameters of wheat cultivation in an oxisol soil. The research was carried out in the experimental field of Agronomico S.A., located in the district of Hernandarias, Department of Alto Paraná, during the 2021 campaign. The experimental design used was Bifactorial with completely randomized block distribution with ten treatments and four repetitions. Different doses of agricultural gypsum consisting of 0, 1, 2, 4 $t.ha^{-1}$ and a control (without lime or gypsum) were used as factor A. For factor B there were two levels, surface application and incorporated application. The variables evaluated were grain yield, number of grains/spike, weight of a thousand seeds and hectoliter weight. The agricultural gypsum presented significant differences in grain yield and the number of grains/spike, however, both the weight of a thousand seeds and the hectoliter weight did not present significance. The forms of application did not present significant differences for any of the productive parameters.

Keywords: amendment, subsurface, aluminum.

Introduction

Wheat is considered one of the three most important grains for the world economy and global food security (Fornasieri, 2008). Paraguay went from being a net importer to an exporter of wheat, increasing the productivity and quality of the crop. With a cultivated area of 450 thousand hectares, the department of Alto Paraná occupies the largest area with 39%, Itapúa 31% and Caaguazú 15% (UNA, 2022).

The soils of the eastern region have medium to low levels of fertility with sulfur content below 10 mg.dm3 available in the soil (Hahn & Fioretto, 2017). In areas of low fertility and SOM (soil organic matter), sulfur is one of the nutrients that limits the productivity of grain crops (Fatecha et al., 2017). The successive harvest of grains of wheat, soybean and corn with which sulfur is exported leads to the deficiency of this ion in the soil.

Other causes are the limited application of sulfur fertilizers, high leaching to deeper layers due to its high mobility and lack of recycling by other crops (Watanabe, 2013).

Sulfur is a component of proteins and participates in the synthesis of amino acids such as cystine, cysteine and methionine (Broch et al., 2011). It is also a constituent of various organic compounds such as vitamins, coenzymes and phytohormones (Nazhar et al., 2011). The nutritional requirement of wheat is 5 kg.t-1 of total grain absorption and 2 kg.t-1 grain extraction (Ciampitti & García, 2007).

Agricultural gypsum is a by-product of the phosphoric acid industry. It mainly contains sulfur and calcium and, in small concentrations, phosphorus and fluorine (Caires et al., 2003). Agricultural gypsum is used as a chemical amendment in the subsurface horizons of the soil (Martínez, 2020). It reacts with Al3+ precipitating it to its less toxic forms and in addition to increasing the levels of Ca2+ and SO42- in the deepest layers of the soil (Neis et al., 2010). In addition, the sulfate ion of agricultural gypsum promotes the transport of bases such as Mg2+ and K+ from the superficial layers of the soil to the deeper ones (Caires et al., 2003).

In periods of water deficit, agricultural gypsum can be an alternative, because it increases root growth that allows water and nutrients to be absorbed. The increase in root length is due to Ca2+ due to its action in cell division and because it is immobile in the plant (Hawkesford et al., 2012).

On the other hand, the widespread recommendation and use of agricultural gypsum may unnecessarily increase the cost of production. And it can cause negative effects such as the leaching of exchangeable bases such as Mg2+ and K+ that causes loss of crop productivity (Fontoura et al., 2012).

In Brazil and Argentina, the effect of agricultural gypsum is reported by Caires et al. (2002), Rampim et al. (2011), Steinbach & Álvarez (2014) and Novaczyk (2021). However, in Paraguay, the works on agricultural gypsum in wheat are very scarce, only Watanable (2013), has a well-structured study. Therefore, more studies are needed to make better decisions on dose recommendations for this crop. In this way, the objective of this work was to evaluate the residual effect of agricultural gypsum and the forms of application on some productive parameters of wheat.

Materials and methods

The research was carried out in the experimental field of Agronomic S.A., located in the City of Hernandarias, Department of Alto Paraná, Eastern Region of Paraguay, whose geographic coordinates are latitude 25° 22¨ 00” south and longitude 55° 45¨. 00” west at an altitude of 232 meters above sea level.

The average precipitation during the experiment was 184.4 mm and the average temperature was 22.5 °C. The soil is classified as an Oxisol, it has a clay textural base, with a very acidic pH with a high content of Fe and Al oxide. The experimental period lasted 5 months, which corresponds to the months of May, June, July, August, September of the year 2021.

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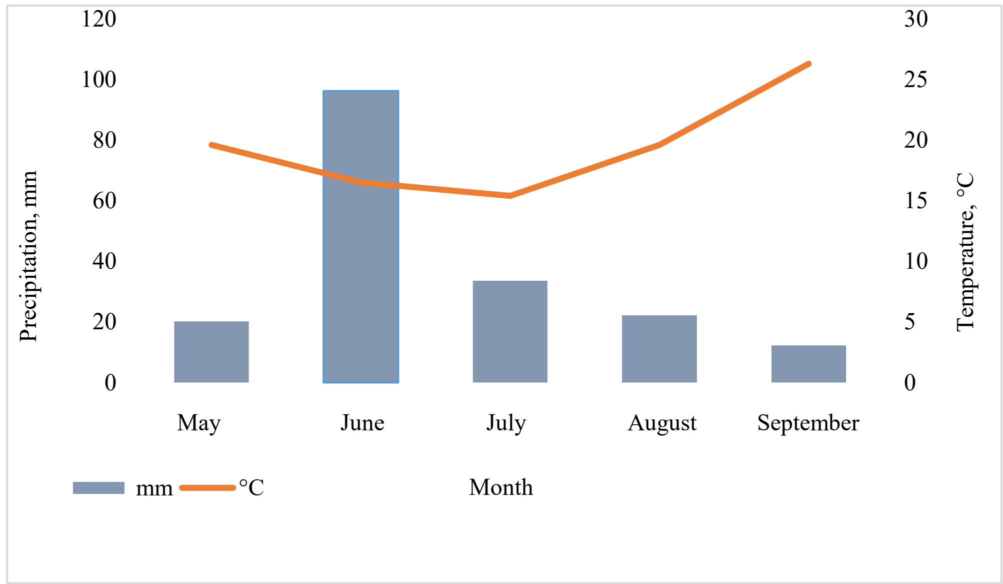

Figure 1. *Rainfall and average temperature from May 10 to September 30, 2021. Campo experimental Agronómico S.A.*

The investigation was constituted by an infinite population, where the selection of samples was ex profeso (on purpose), composed of a crop of Wheat Triticum aestivum l. (var. Tbio sonic), where the total area of the land is 23 m x 100 m, on which the treatments were applied.

The experimental design was a factorial design (AxB) where A indicates four doses of agricultural gypsum (0, 1, 2 and 4 t.ha-1) plus a control and factor B indicates two forms of incorporation of agricultural gypsum (superficial and incorporated). They were distributed in completely random blocks, with 10 treatments and 4 repetitions, totaling 40 experimental units (UE). Each experimental unit was made up of the following dimensions: 1 m in length, 5 m in width and 3 m in width of the central path. The total area of the experiment was 2300 m2, that is, 23 m wide and 100 m long

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Table 1. Treatment description.

Treatment	Factor A	Dosis (t/ha-1)	Factor B
	Agrícultural plaster		F. de aplication
T1	Witness		
T2	Plaster	0	Surface
T3	Plaster	1	Surface
T4	Plaster	2	Surface
T5	Plaster	4	Surface
T6	Witness		
T7	Plaster	0	Incorported
T8	Plaster	1	Incorporated
T9	Plaster	2	Incorporated
T10	Plaster	4	Incorporated

In the control dolomitic lime was not applied, however, for the treatment with 0 t.ha-1 dolomitic lime was applied. Soil samples were extracted from the 0 - 20 cm and 20 - 40 cm layers of each experimental unit, with a cylindrical probe, then the sample was placed in a standard model cellulose bag from the company Agronomic S.A. identifying it by experimental unit and was sent to the soil laboratory of Agronomic S.A. for your analysis.

A subsoiler pass was made to decompact the soil throughout the experimental plot, later, a harrow was passed to level the soil for a good one for the application of lime and agricultural plaster and leave a good sowing layer. These were applied in two ways, superficial and incorporated, the first was applied manually on the seedbed and the second was also applied manually, being incorporated with a drag pass.

It is important to clarify that both agricultural gypsum and agricultural lime were applied in July 2020, where it was experimented with soybean cultivation using the same wheat variables for its evaluation, therefore, this research is a continuation of the same experiment

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Table 2. Soil analysis results.

Abreviature	Determination	Unit	0 - 20 cm	20 - 40 cm
pH $CaCl_2$	pH $CaCl_2$	-	4.92	5.00
H+Al	H+Al	cmolc/dm^3	5.39	5.00
Al^{3+}	Aluminium	cmolc/dm^3	0.36	0.29
%m	Al^{3+} saturation	%	7.50	6.01
MO	Organic matter	g/dm^3	25.67	24.09
Ca^{2+}	Calcium	cmolc/dm^3	3.84	3.89
Mg^{2+}	Magnesium	cmolc/dm^3	1.50	1.56
K^+	Potasium	cmolc/dm^3	0.15	0.22
P	Phosphorus	mg/dm^3	18.18	14.44
SB	Base sum	cmolc/dm^3	5.50	5.67
V	Base saturation	%	50.49	53.08
Sand	>0.02 mm	%	-	30.63
Silt	0.002-0.02 mm	%	-	11.50
Clay	<0.002 mm	%	-	57.87

According to the results obtained from the analyzes established in the laboratory of Agronomic S.A. Subsequent standardized fertilization doses with N-P-K were carried out for each treatment and corresponding blocks. and the amount of fertilizer to apply was determined through formulas and rules of three. The nitrogen source was urea. the potassium source was potassium chloride. and the phosphorus source was triple superphosphate.

Sowing was carried out with a seeder-fertilizer machine on May 20. 2021. at a depth of approximately 3 cm. which had 26 rows/E.U. at a distance between plants of 0.17 m. totalizando de esta manera 105 hileras en toda la parcela experimental.

The crop was monitored to detect the presence of weeds. insects and diseases. when their presence was detected. the corresponding controls were carried out with the doses and type of product

The harvest was carried out on September 30. 2021 using scythes in the useful plot (3 m x 1 m) of each experimental unit (5 m x 10 m). later. the samples were taken to a threshing machine for shelling and then weighed. the grains in a precision balance to obtain the yield of each treatment

The measurement variables were: grain yield. number of grains/ear. weight of a thousand seeds and hectoliter weight.

For grain yield. the grains of the useful plot (3 m x 1 m) were weighed. Of each treatment and repetitions that were averaged and expressed in t.ha-1.

To determine the number of grains/ear. samples of 10 ears were taken from the useful plot of each experimental unit. Then the total grains of each spike were counted and their average was calculated.

The weight of a thousand seeds was obtained by taking sub-samples of 100 grains from the useful plot of each experimental unit of harvested grains. Subsequently. the grains were weighed on a precision balance.

then said weight was extrapolated to 1000 grains. whose results were expressed in grams.

Hectoliter weight. was determined using the hectoliter weight measurement scale where exactly one liter of grain and the scale fit. and it was translated to the weight of that liter. determined in grams.

The results were subjected to analysis of variance (ANAVA). with the help of the statistical program InfoStat and for the comparison of means. Duncan's test was used at 5% probability of error.

Results

Under the conditions in which the experiment was carried out. the following results are presented:
Table 3 shows the analysis of variance. the comparison of means. and the coefficient of variation of the productive parameters depending on the agricultural gypsum and the forms of application.

Table 3. Grain yield. number of grains/ear. weight of thousand seeds and hectoliter weight in different doses of agricultural gypsum and its forms of application. .

Treatment	Grain yield ($t.ha^{-1}$)		N° Grains/ ear (ud)		weight of thousand seeds (g)		hectoliter weight ($kg.hl^{-1}$)	
Factor A (Plaster dosis $t.ha^{-1}$)								
4	2.1	A	39.2	A	32.6	A	70.9	A
2	1.8	AB	39.2	A	32.0	A	71.2	A
1	2.0	A	37.4	A	32.4	A	70.6	A
0	1.7	B	36.6	A	32.3	A	71.9	A
Witness	1.5	C	27.7	B	31.6	A	72.7	A
p-valor	0.0002		<0.0001		0.8829	ns	0.1966	ns
Factor B (application form)								
Surface	1.9	A	36.5	A	32.3	A	71.1	A
Incorporated	1.7	A	35.5	A	32.1	A	71.8	A
p-valor	0.059	ns	0.3031	ns	0.8227	ns	0.2094	ns
p-valor AxB	0.1706	ns	0.4004	ns	0.268	ns	0.6441	ns
CV%	13.24		8.45		8.45		2.61	

ns: non significant CV: variation coefficient AxB: interaction.

Grain yield t.ha-1

The analysis of the variance of the grain yield variable shows that it presented significance to the effect of the doses of agricultural gypsum. factor A of the investigation. However. the forms of application. which consists of factor B of the investigation and the AxB interaction. did not present significance. The coefficient of variation was 13%. which gives high reliability to the results

In the comparison of means by Duncan's test at 5%. it can be seen that the best grain yields were presented with the application of gypsum doses of 4 t.ha-1. 1 t.ha-1 and 2 t. ha-1 respectively. although in the latter a statistically significant difference is observed from the previous ones

Test weight

In the analysis of variance of the hectoliter weight variable of the wheat grain. no significance was observed due to the effect of the applied doses of agricultural gypsum (factor A). forms of application (factor B) and interaction (AxB). Its coefficient of variation was 2.6%. which indicates high reliability of the results.

Thousand seed weight

The analysis of variance of the variable weight of thousand seeds. where no significance is observed due to the effect of the dose of agricultural gypsum (factor A). also the forms of application (factor B) and interaction (AxB). did not present significance. The coefficient of variation was 8.4%. relatively homogeneous. with high reliability of the results

Number of grains per spike

The analysis of variance of the variable number of grains per spike (<0.0001). where it indicates that there was significance due to the effect of the doses of agricultural plaster (factor A). however. no significance was observed due to the effect of the forms of application (factor B) and by interaction (AxB). The coefficient of variation was 8.4%. which gives it high reliability.
In the comparison of the means with Duncan's test at 5%. it is observed that the best results in the number of grains/ear. were presented with the application of the doses of 2 and 4 t.ha-1 correspondingly. although they do not differ statistically of the treatments with 0 and 1 t.ha-1 of agricultural plaster.

Discussion

Grain yield

The grain yield presented significance with the addition of agricultural gypsum. In the same way. Caires et al. (2002). Rampim et al. (2011). Steinbach & Álvarez (2014) and Novaczyk (2021). reported significance for the effect of agricultural gypsum on grain yield.

The best results were observed in the dose of 4 t.ha-1 and 1 t.ha-1. This result agrees with the work of Watanabe (2013) and Schimidt et al. (2016). with the application of 2 t.ha-1 of agricultural gypsum. they obtained similar grain yields.

This is explained by the increase in exchangeable Ca and the movement of exchangeable Mg in the soil. which is caused by the application of gypsum. That facilitated the uptake of these elements by the plant. reflecting positively on the yield of the wheat grain (Caires et al.. 2002).

The lack of significance in factor B (form of application) is explained by Hideo et al. (2015). state that agricultural gypsum does not require incorporation with agricultural implements due to its high solubility and infiltration in the soil. Sulfate is incorporated into the MOS and therefore into the microbial biomass. so that they act as a source and reservoir for sulfate (Olivera et al. cited by Giménez. 2017).

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Thousand seed weight and hectoliter weight

Thousand seed weight and test weight were not significantly influenced by the effect of agricultural gypsum. These data agree with the research carried out by Gambaudo et al. (2006) and Watanabe (2013). where they did not observe significance in the weight of a thousand seeds.

Schmidt et al. (2016) and Fano (2015). report that they did not find significance in hectoliter weight based on agricultural gypsum either.

Medeiros et al.; Nora et al.. cited by Zavilenski et al. (2019). in the same way. found a reduction in the seed quality variables. Because. when applying gypsum. the saturation of the soil by Ca2+ increases. which causes the preferential absorption of this cation and this leads to imbalances in the assimilation of K+ and Mg^{2+}.

Number of grains per spike

The agricultural gypsum presented significant differences in the number of grains/ear. This is because gypsum considerably increases the efficiency of nitrogen use by increasing root growth. This maximizes the absorption of nitrate by plants for the formation of tillers. which in turn increases the potential number of grains and spikes (Caires et al.. 1999).

This result differs from the work of Da Rossa (2018). where no significant differences were found in the number of grains/ear depending on the agricultural gypsum. This was due to high rainfall. which could have leached SO42- and bases such as Mg2+ and K+

The dose of 2 and 4 t.ha-1 presented an average of 39 grains/ear. This result agrees with the work of Da Rosa (2018). who obtained 38 grains/ear at a rate of 2 t.ha-1 of agricultural gypsum

Conclusions

The grain yield. the number of grains/ear are influenced by the effect of agricultural gypsum. however. the forms of application have not influenced these parameters. The weight of a thousand seeds and the hectoliter weight have not been influenced by the addition of agricultural gypsum or by the forms of application.

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