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Chemical properties of an Oxisol after gypsum application

Extrato de saturação e condutividade elétrica de um Latossolo vermelho eutroférico após a gessagem

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Abstract

Gypsum utilization is a critical practice in agriculture because of the high solubility and consequent relative neutralization of subsurface toxic aluminum. However, it has been observed that in most cases, gypsum is being randomly utilized without scientifically established parameters or even the need to use it as a soil amendment at all. The objective of this study was to evaluate the chemical composition and electrical conductivity of an Oxisol's saturation extract under different gypsum doses (0, 1.0, 2.0, 4.0, and 8.0 Mg ha⁻¹). This experiment was conducted in a greenhouse environment. Soil columns (V = 1.57 dm³) were filled with sifted (2 mm) soil collected from the upper layer (0-20 cm). The experimental design adopted was completely randomized with five repetitions. The treatments consisted of a 5 × 2 factorial through five gypsum doses (0.0, 1.0, 2.0, 4.0, and 8.0 Mg ha⁻¹ of gypsum consisting of 224.1 g kg⁻¹ S, 314.8 g kg⁻¹ CaO, and 7 g kg⁻¹ P₂O₅) and two depth evaluations (0-10 and 10-20 cm). After the treatments, soil from both 0-10 cm and 10-20 cm layers was removed from the columns, sifted once (2 mm), and subjected to vacuum extraction to assess the saturation extract. The data acquired was processed and submitted to variance analysis (when due) and adjusted to regression equations when statistically relevant. Significant increases were observed for Ca, Mg, K, P, and S, although Al, Si, and pH presented no statistically significant difference. The electrical conductivity value of this soil in particular is directly related to the gypsum dose.

Key words: Agricultural gypsum. Leaching. Salinization.

Resumo

A aplicação do gesso agrícola é importante na agricultura por sua alta solubilidade e consequente neutralização relativa do alumínio tóxico na camada superficial do solo. Entretanto, tem-se observado a ocorrência de aplicações com base em critérios aleatórios, sem embasamento científico coerente com a experimentação agrícola. O objetivo desse estudo foi avaliar a composição química e condutividade elétrica do extrato de saturação de um Latossolo Vermelho eutroférico sob diferentes doses de gesso (0; 1,0; 2,0; 4,0 Mg ha⁻¹). O experimento foi conduzido em ambiente de casa de vegetação. Colunas de solo (V = 1,57 dm³) foram preenchidas com solo peneirado (2 mm) coletado na camada superficial (0-20 cm). O delineamento experimental utilizado foi inteiramente casualizado, com cinco repetições. Os tratamentos testados resultaram de um fatorial 5 x 2 em que os fatores foram cinco doses de gesso (0,0 – 1,0 – 2,0 – 4,0 e 8,0 Mg ha⁻¹ de gesso agrícola (224,1 g kg⁻¹ de S, 314,8 g kg⁻¹ de CaO e 7 g kg⁻¹ de P₂O₅) e 2 profundidades de amostragem (0-10 e 10-20 cm). Após os tratamentos, ambas as camadas de solo (0-10 cm e 10-20 cm) foram removidas das colunas, peneiradas (2 mm) e submetidas a extração à vácuo para obtenção do extrato de saturação. Os dados obtidos foram submetidos a análises de variância e ajustados às equações de regressão, quando diferiram estatisticamente. Enquanto os teores de Al, Si, e o pH do extrato de saturação do solo não foram influenciados, os teores de Ca, Mg, K, P e S aumentam em função da aplicação superficial de doses de gesso agrícola. Após a aplicação de diferentes doses

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de gesso agrícola, não ocorreram variações significativas nos teores de P, Si, Al e do pH da camada subsuperficial (10-20) do solo. A condutividade elétrica (CE) do extrato de saturação do solo estudado aumentou com o aumento das doses de gesso.

Palavras-chave: Gesso agrícola. Lixiviação. Salinização.

Introduction

Agricultural gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is produced from apatite (phosphate rock) treated with sulfuric acid during the initial phase of phosphoric acid production. The obtained phosphoric acid is later used in phosphate fertilizer production as triple superphosphate (TSP), monoammonium phosphate (MAP), and diammonium phosphate (DAP).

According to Korndörfer (2008), agricultural gypsum presents solubility of approximately 2.0 g L^{-1} . Pavan (1984) notes that its use is important for areas where there are chemical impediments in subsurface layers due to free aluminum in solution, which limits plants' root system development.

The benefits of agricultural gypsum for soil management have been known for a long time. However, agricultural gypsum application is a technique that depends on research to better define methods for deciding doses as per the consequences of their use.

Previous studies offer divergent results. Forloni (2008) suggests applying doses of up to 32 t ha^{-1} of gypsum, based only on potential cation exchange capacity (CEC) increments observed, shoot biomass production, and yield of corn crop. Knowing that calcium ions in solution affect the estimation of potential CEC, it becomes evident that this method is inadequate for defining the need for gypsum in soils. On the other hand, suggestions such as those of Malavolta et al. (2006) indicate that gypsum doses should not exceed 25% of the recommended liming. According to Raji et al. (2008), gypsum should only be applied in areas with exchangeable Al above 40% and exchangeable Ca below $0.4 \text{ cmol}_c \text{ dm}^{-3}$ in the 0-40 cm layer.

There is a need to evaluate, with better precision, the impacts of agricultural gypsum application on different soil attributes. According to Jalali and

Rowell (2009) and Maria et al. (1993), increased calcium concentration in soil solutions can promote leaching of potassium and other ions, generating an undesirable disequilibrium between soil base cations. However, Sousa et al. (2005) note that the high mobility of gypsum in the arable layers is associated with nutrients leaching to deeper layers, favoring crops' root development and reducing possible damage during drought periods. Farina et al. (1988) observed that gypsum surface application resulted in the increase of Ca, Mg, and SO_4 -S levels in subsurface soils.

In light of the need for new evaluations of the effects of agricultural gypsum on soil properties, this experiment aimed to evaluate electrical conductivity; Ca, Mg, K, S, P, and Al levels; and pH of saturation extract of Red Latosol.

Material and Methods

The experiment was performed in a private laboratory situated in Londrina City, Paraná.

The soil used was collected at the surface layer (0-20 cm) of a Red Latosol from Alvorada do Sul City, Paraná (Latitude: $-23^\circ 19' 0.02''\text{S}$ and Longitude: $-51^\circ 10' 37.33''\text{W}$), with the following physical and chemical attributes: 130 g kg^{-1} sand, 180 g kg^{-1} silt, 690 g kg^{-1} clay, $\text{pH H}_2\text{O} = 5.58$, $\text{Ca} = 8.84 \text{ cmol}_c \text{ dm}^{-3}$, $\text{Mg} = 2.33 \text{ cmol}_c \text{ dm}^{-3}$, $\text{K} = 0.37 \text{ cmol}_c \text{ dm}^{-3}$, $\text{CEC}_{\text{pH}7} = 17.94 \text{ cmol}_c \text{ dm}^{-3}$, $\text{H}^+ + \text{Al}^{3+} = 6.39 \text{ cmol}_c \text{ dm}^{-3}$, $\text{Al}^{3+} = 0.0 \text{ cmol}_c \text{ dm}^{-3}$, $\text{S-SO}_4 = 5.13 \text{ mg dm}^{-3}$, $\text{P-Mehlich} = 12.46 \text{ mg dm}^{-3}$, $\text{P-Rem} = 19.66 \text{ mg}$, and $\text{V} = 64.3\%$. Before experiment installation, soil was sieved using a 2.0 mm sieve and corrected by liming with calcite limestone and fertilizing with potassium chloride, aiming to increase Ca and K saturation to 65% and 5%, respectively (KINSEY, 2009). Chemical analysis was performed after making these corrections (Table 1).

Table 1. Results of soil chemical analysis after correction and before experiment installation.

pH CaCl ₂	pH H ₂ O	Ca ²⁺	Mg ²⁺	K ⁺	H ⁺ +Al ³⁺	Al ³⁺	CEC effective	CEC pH _{7.00}	V (%)	P-rem	P	S-SO ₄	Vp (m ³ m ⁻³)
----- cmol _c dm ⁻³ -----							----- mg dm ⁻³ -----						
5.37	5.98	10.95	2.25	0.92	4.18	0.00	14.13	18.31	77.15	19.89	14.54	6.04	0.2483

V = Base saturation; P-rem = Remaining phosphorus; Vp = Volume of pores. Extractors: KCl 1N (Ca²⁺, Mg²⁺, Al³⁺) Mehlich-1 (P and K), CH₃COONH₄ (S-SO₄).

The experimental design was completely randomized, with 5 replications. The tested treatments resulted in a 5 × 2 factorial, where 5 gypsum doses (0.0, 1.0, 2.0, 4.0, and 8.0 Mg ha⁻¹ of agricultural gypsum comprising 224.1 g kg⁻¹ S and 314.8 g kg⁻¹ CaO) and 2 layers (0-10 and 20-30 cm) were evaluated.

The PVC columns used in this study were built using two pipes 100 mm in diameter and 100 mm tall. The pipes were connected using insulating tape, forming a column with a height of 200 mm. Before filling with sieved earth (2.0 mm sieve), the columns were sealed with paraffin on the inner surface to avoid preferential flux in the soil-column interface. The bottom of the column was sealed using a plastic film with small holes (1.0 mm²) to drain the percolated water. The columns were filled with sieved earth to reach a density of 1.2 g dm⁻³.

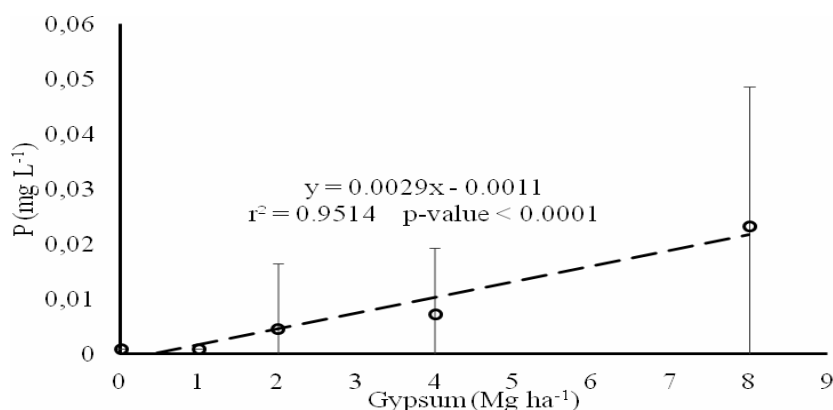
After filling the columns, gypsum was applied on the surface in the respective doses. In sequence, the columns were irrigated (1000 mL h⁻¹) with deionized water using three times the total volume of pores. After complete drainage, the columns were allowed to stand for 24 h. After this period, the columns were disassembled and the earth was air-dried for 24 h. The 0-10 and 10-20 cm layers were separated and sent to the laboratory to carry out chemical analysis

of the saturation extract (saturate-paste) extracted by vacuum in a Kitasato. In each saturation extract, the Ca, Mg, K, Al, Si, P, and S levels were quantified using an Argon inductively coupled plasma (ICP-AES), as described in Montaser and Fassel (1976). Soil electrical conductivity and pH were evaluated in previously calibrated conductivity meter and pH meter (CPRM, 2007).

Analysis of variance (ANOVA) was performed using SISVAR 4.3 and, when necessary, means were compared using Tukey test at 5% or polynomial regressions were adjusted.

Results and Discussion

No change in phosphorous content was observed between the layers, indicating that the tested doses affected phosphorous mobilization, despite the high addition of sulfate (Table 1). However, linear increases in P levels of the saturation extract as a function of gypsum doses were observed (Figure 1). The observed rate of increase was 0.0029 mg L⁻¹ per Mg of gypsum applied. These increases certainly are associated with phosphorus content in the agricultural gypsum used, which comprised 7 g kg⁻¹ P₂O₅, since no important changes occurred in P-Mehlich and P-Rem before and after applications (Table 2).

Figure 1. Variation in P levels in saturation extract as a function of gypsum doses applied on the surface.**Table 2.** Results of soil chemical analysis before correction and experiment installation.

pH CaCl ₂	pH H ₂ O	Ca ²⁺	Mg ²⁺	K ⁺	H ⁺ +Al ³⁺	Al ³⁺	CEC effective	CEC pH _{7.00}	V (%)	P-rem	P	S-SO ₄	Vp (m ³ m ⁻³)
----- cmol _c dm ⁻³ -----													
5.09	5.58	8.84	2.33	0.37	6.39	0.00	11.54	17.94	64.32	19.66	12.46	5.13	0.2483
----- mg dm ⁻³ -----													

V = Base saturation; P-rem = Remaining phosphorus; Vp = Volume of pores. Extractors: KCl 1N (Ca²⁺, Mg²⁺, Al³⁺) Mehlich-1 (P and K), CH₃COONH₄ (S-SO₄).

The application of agricultural gypsum up to 8.0 Mg ha⁻¹ did not significantly change the pH of the soil or the levels of Al or Si. However, increases were noted in the Ca, Mg, K, P, and S levels (Tables 3, 4, 5, 6 and 7). These results agree with the observations of Leite et al. (2007), but are different from the results reported by Tavares Filho (2012), who did not note increases in the Mg and K levels in the saturation extract of a saline-sodic

soil from Pernambuco, which received doses of mineral gypsum. The increase in Ca, Mg, K, P, and S levels can be explained by dissolution of gypsum, which contains Ca and S, and by ion extraction at the colloidal surface caused by the high amounts of Ca added in the treatments. The mean values for Ca levels were adjusted in a linear model in both layers studied, with increases of 79.567 mg L⁻¹ and 50.225 mg L⁻¹ per ton of gypsum in the 0-10 and 10-20 cm layers, respectively (Figure 2).

Table 3. Analysis of variance result (p-value) of the evaluated variables.

Variation cause	Ca	Mg	K	S	P	Al	Si	pH	Conduct.
Dose (D)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0049	0.1882	0.059	0.0741	< 0.0001
Depth (De)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.3799	0.068	0.4366	0.088	< 0.0001
D x De	< 0.0001	0.0448	< 0.0001	< 0.0001	0.843	0.106	0.9018	0.171	0.1382

Table 4. Variation in average Ca levels (mg L⁻¹) of soil saturation extract as a function of the surface-applied gypsum doses and sampling depth.

Depth (cm)	Gypsum doses (Mg ha ⁻¹)				
	0	2	4	6	8
0-10	134.47a	145.25a	302.96a	481.70 ^a	739.57a
10-20	65.79b	93.31a	148.87b	251.24b	458.13b
CV (%) = 14.99	MMD = 54.07				

* Means followed by the same letter in the columns did not differ by Tukey test at 5%.

Table 5. Variation in average Mg levels (mg L⁻¹) of soil saturation extract as a function of the surface-applied gypsum doses and sampling depth.

Depth (cm)	Gypsum doses (Mg ha ⁻¹)				
	0	2	4	6	8
0-10	31.21a	35.414a	50.66a	68.52 ^a	90.01a
10-20	14.35b	24.08b	30.55b	51.09b	85.20a
CV (%) = 12.23	MMD = 7.52				

* Means followed by the same letter in the columns did not differ by Tukey test at 5%.

Table 6. Variation in average K levels (mg L⁻¹) of soil saturation extract as a function of the surface-applied gypsum doses and sampling depth.

Depth (cm)	Gypsum doses (Mg ha ⁻¹)				
	0	2	4	6	8
0-10	16.71a	17.85a	27.30a	37.16 ^a	44.37a
10-20	11.27a	19.33 ^a	22.53 ^a	53.91b	180.20b
CV (%) = 17.17	MMD = 9.45				

* Means followed by the same letter in the columns did not differ by Tukey test at 5%.

Table 7. Variation in average S levels (mg L⁻¹) of soil saturation extract as a function of the surface-applied gypsum doses and sampling depth.

Depth (cm)	Gypsum doses (Mg ha ⁻¹)				
	0	2	4	6	8
0-10	7.91a	31.91a	224.89a	446.91 ^a	597.00a
10-20	7.12a	27.08a	65.43b	131.28b	226.47b
CV (%) = 16.84	MMD = 38.01				

* Means followed by the same letter in the columns did not differ by Tukey test at 5%.

In the 0-10 cm layer, the values of Mg, K, and S (Figures 3, 4, and 5), adjusted to second degree models, did not reach the maximum values at the

tested doses. In the 10-20 cm layer, linear increases corresponding to 8.89, 3.65, and 28.068 g L⁻¹ per Mg of gypsum were observed, respectively.

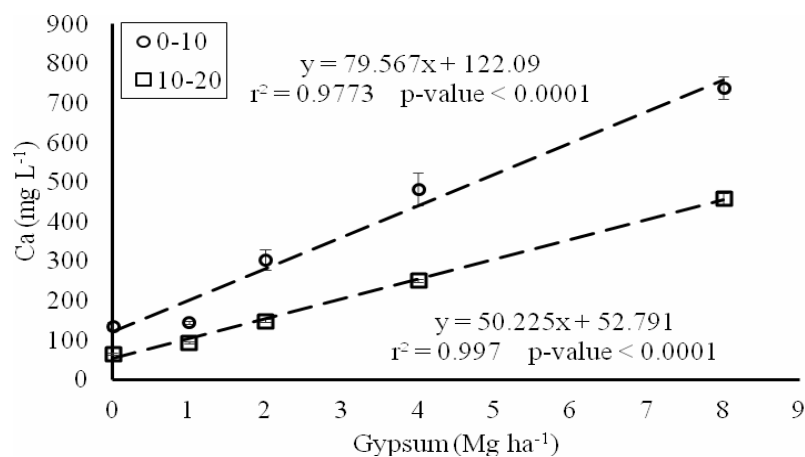
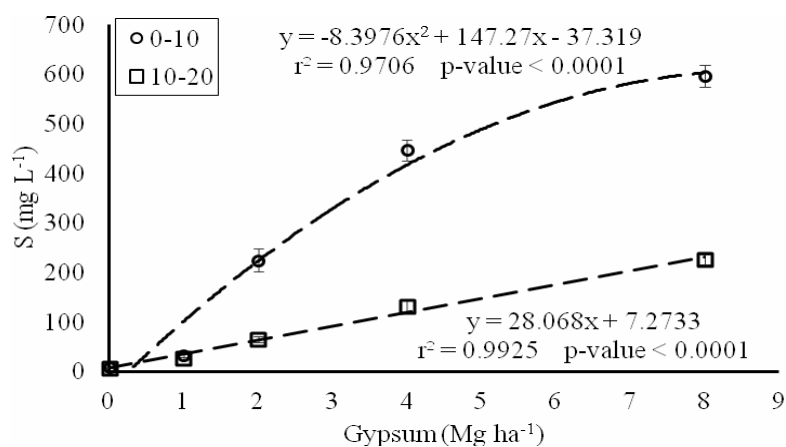
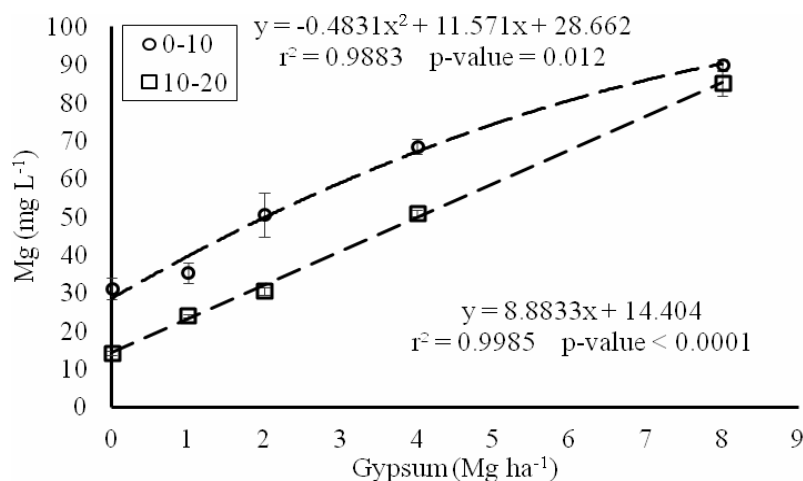
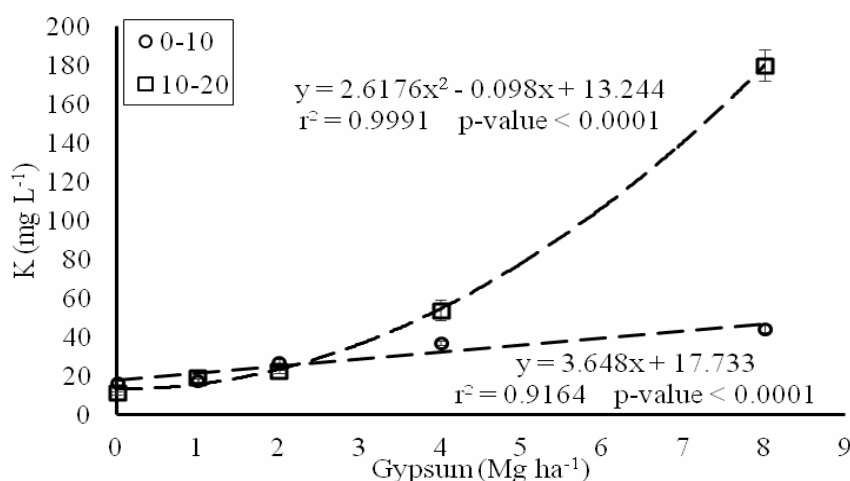
Figure 2. Variation in Ca levels in saturation extract of the studied layers as a function of gypsum applied on the surface.**Figure 3.** Variation in S levels in saturation extract of the studied layers as a function of gypsum applied on the surface.**Figure 4** Variation in Mg levels in saturation extract of the studied layers as a function of gypsum applied on the surface.

Figure 5. Variation in K levels in saturation extract of the studied layers as a function of gypsum applied on surface.

Consistent with the results obtained by Barros et al. (2009), the values of electrical conductivity in the saturation extract were significantly influenced by depth and gypsum dose, but without any interaction between them. The highest values were observed in

the surface layer of 0-10 cm (Figure 6), while for dose effect, the variation was greater, adjusted to a linear model, with an increase of 0.34677 mS cm⁻¹ per Mg of gypsum applied (Figure 7).

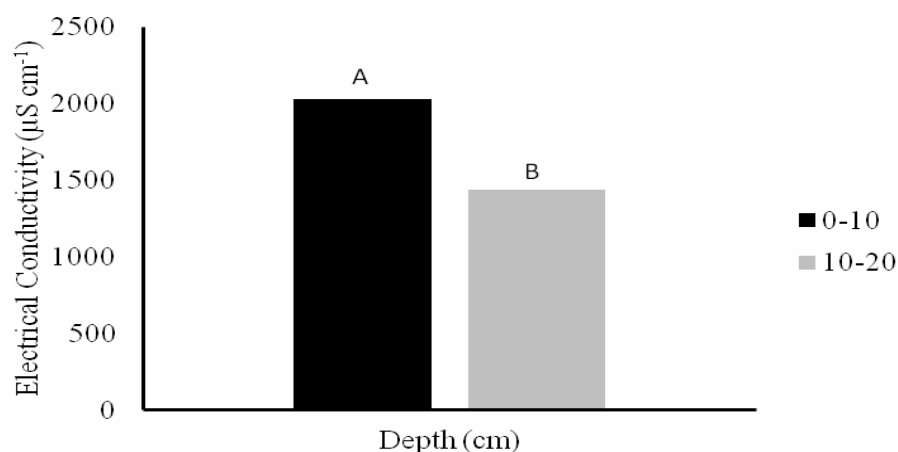
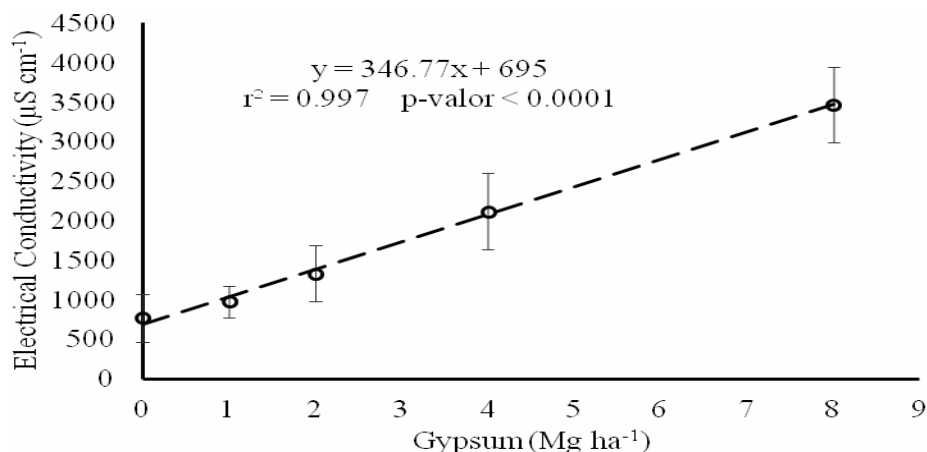
Figure 6. Values of electrical conductivity of the saturation extract at the studied depths.

Figure 7. Variation in electrical conductivity of the saturation extract as a function of gypsum doses applied on the surface.



Conclusion

While Al and Si levels and pH of soil saturation extract were not affected, the Ca, Mg, K, P, and S levels increased in both layers as a function of surface application of agricultural gypsum.

After the application of gypsum, no changes were noted in the Si and Al levels and pH in the soil subsurface layer.

The electrical conductivity of soil saturation extract increased as a function of agricultural gypsum dose.

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