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Cientific Paper

Effect of chemical correctives and sources of phosphorus in soils degraded by salts cultivated with millet (*Pennisetum glaucum* L.)

José Carlos de Menezes Júnior[1]

Rivaldo Vital dos Santos[2]

Abstract

The correction of the soil salinity requires, besides the concentration reduction of soluble salts and sodium in the soil profile, the increase of the fertility in seeking satisfactory productions. The objective of this study was to evaluate the effect of chemicals correctives and phosphorus sources on pH and phosphorus availability in a soil degraded by salts. The experimental test was conducted in a greenhouse belonging to the CSTR/UFCG, in the city of Patos, PB. The soil used in the experiment came from the Irrigated Perimeter of São Gonçalo, belonging to the municipality of Sousa, PB. The experiment was conducted in a completely randomized design in a factorial scheme 2 x 2 x 4, regarding to the correctives (gypsum and sulfuric acid), to sources of phosphorus (phosphoric acid and super simple) and to P doses (0, 70, 140 and 210 mg dm^{-3}) with three replications. Soil was packed in pots, remaining incubated after the application of correctives for 20 days, then, was done the washing, and more 20 days after the addition of the phosphate sources. Soon after, millet was cultivated. The use of gypsum as corrective and application of phosphoric acid promoted greater availability of phosphorus in soil, resulting in a greater vegetal production of millet.

Keywords: Recovery; salinity; fertility; pH.

Efeito de corretivos químicos e fontes de fósforo em solo degradado por sais cultivado com milheto (*Pennisetum glaucum* L.)

Resumo

A correção de solos com problema de salinidade requer, além da redução da concentração de sais solúveis e do sódio no perfil do solo, o aumento da fertilidade visando a produções satisfatórias. O objetivo do trabalho foi avaliar o efeito de corretivos químicos e fontes de fósforo no pH e disponibilidade de fósforo em um solo degradado por sais. O ensaio experimental foi desenvolvido em telado pertencente ao CSTR/UFCG, em Patos, PB. O solo utilizado no experimento proveio do Perímetro Irrigado de São Gonçalo, pertencente ao município de Sousa, PB. O experimento foi desenvolvido em um delineamento inteiramente casualizado no esquema fatorial 2 x 2 x 4, referente aos corretivos (gesso e ácido sulfúrico), às fontes de fósforo (ácido fosfórico e superfosfato simples) e às doses de P (0, 70, 140 e 210 mg dm^{-3}), com três repetições. Acondicionou-se o solo em vasos, permanecendo incubado após a aplicação dos corretivos durante 20 dias; em seguida, foi efetuada lavagem, e mais 20 dias após a adição das fontes fosfatadas. Logo depois, cultivado o milheto. O emprego de gesso como corretivo e aplicação de ácido fosfórico promoveram maiores disponibilidade de fósforo no solo, resultando uma maior produção vegetal de milheto.

Palavras-chave: Recuperação; salinidade; fertilidade; pH.

Efecto de los correctivos químicos y fuentes de fósforo en suelo degradads por sales y cultivados con mijo perla (*Pennisetum glaucum* L.)

Resumen

Corrección de suelos con problema de salinidad requiere, además de reducir la concentración de sales solubles y de sodio en el perfil del suelo, el aumento de la fertilidad visando producciones satisfactorias. El objetivo de este estudio fue evaluar el efecto de correctivos químicos y fuentes de fósforo sobre el pH y la disponibilidad de fósforo en un suelo degradado por sales. El estudio experimental se llevó a cabo en un invernadero perteneciente a la CSTR/UFCG en Patos-PB. El suelo utilizado en el experimento es proveniente del perímetro irrigado de São Gonçalo, que pertenece a la municipalidad de

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1 Agricultural Engineer, Masters in Animal Science by the CSTR/UFCG, Universidade Federal de Campina Grande, campus Patos, PB, Brazil, E-mail: jcmenezesjr@hotmail.com (author for correspondence).

2 Agricultural Engineer, Professor CSTR/UFCG, Universidade Federal de Campina Grande, campus Patos, PB, Brazil, E-mail: rvital@cstr.ufcg.edu.br

Sousa-PB. El experimento se realizó en un diseño completamente al azar en arreglo factorial 2 x 2 x 4 relativo a los correctivos (yeso y ácido sulfúrico), a las fuentes de fósforo (ácido fosfórico y superfosfato simple) y los niveles de fósforo (0, 70, 140 y 210 mg dm^{-3}), con tres repeticiones. El suelo fue acondicionado en contenedores y después del aporte de los correctivos permaneció incubado durante 20 días, luego después fue lavado, y 20 días después se aportó las fuentes de fósforo. Poco después fue cultivado el mijo perla. El uso de yeso como correctivo y la aplicación de ácido fosfórico indujo a una mayor disponibilidad de fósforo en el suelo, lo que resulta en una mayor producción vegetal del mijo perla.

Palabras clave: la recuperación; salinidad; fertilidad; pH.

Introduction

The practice of a sustainable agriculture is, today, globally required for meeting the food necessities of the population which continuously grows. For this, the maintenance of fertility and the humidity necessary to the soil are preponderant factors for a satisfactory agricultural production.

The soils affected by salts, common in arid and semi-arid regions, when possess problems of sodicity normally present, alkaline reaction, with pH values superior to 8.5 and elevated concentration of sodium cations adsorbed in the exchangeable complex, resulting in a impermeable soil and of hard management. Besides this, the excess of soluble salts leads to reduction of the osmotic potential of the soil solution, hampering the absorption of water by the plant.

In general, soils severely affected by salts are fertilely poor (FREITAS et al., 2007), in this way, the probable impacts as result of the salinization include the loss of soil productivity, which constitutes a serious inconvenience to the management of most of the cultivated plants of economic importance, since they do not dispose of the ideal fertility conditions (BARROS et al., 2005).

These factors limit the agricultural production, mainly in regions with high evaporation rates and irregular rainfall distribution. Conditions in which the salts are deposited in the soil and are accumulate whenever the water evaporates or is consumed by the plants; ultimately, with decrease of the soil humidity.

For the rehabilitation of these soils there is the necessity of using a corrective which reduces the concentration of the carbonates and bicarbonates ions. The neutralization of such ions eliminates its indirect and direct effects on the plants and decreases the pH of the soils solution under conditions of sodicity, improving the soil fertility.

However, when the saline-sodic soils are corrected with gypsum, due to the formation of phosphates of insoluble calcium, occur the reduction in the contents of available phosphorus and, because of this, when these soils are correct, it is necessary to adopt practices which reduce the precipitation of the phosphorus. Thus as in normal soils, the provision of a satisfactory nutritional level is necessary to maximize the production of the crops in saline conditions. Nevertheless, there is the necessity of applying fertilizers which can improve the soil fertility, without compromising the process of the recuperation of these soils. Thereby, associated to the soil correction, the nutritional improvement constitutes an alternative to increase the productivity of the crops submitted to saline environments (QADAR, 1998).

The study had as objective to assess the influence of the application of correctives and sources of phosphorus in the pH and availability of phosphorus in a soil degraded by salts.

Material and Methods

The experimental essay was developed in a greenhouse of the Center of Health and Rural Technology, UFCG, *campus* Patos, located in the semi-arid region of the Paraíba State. The soil was collected at a depth of 0-30 cm in the Irrigated Perimeter of São Gonçalo, in the municipality of Sousa-PB. Presenting the following chemical characteristics: pH = 10.57; CE = 20.3 dS m^{-1}; MO = 5.05 g kg^{-1}; P = 10.64 mg dm^{-3}; K = 77.10 mg dm^{-3}; and Na, H+Al, Ca, Mg, SB and CTC, 21.2; 0.0; 0.30; 0.15; 21.85; and 21.85 $cmol_c$ dm^{-3} respectively, and V = 100%.

For the correction of the soil salinity the necessity of gypsum as quantified starting from the modification of the Shoonover method suggested by CHAUHAN and CHAUHAN (1978), applying 34 g kg^{-1} of gypsum (100% NG). As for the determination of the necessity of sulfuric acid, a pre-essay was installed applying increasing doses of acid (0; 1; 2; 3; 4; 5; and 6 mL kg^{-1}) in vessels containing 1 kg of soil. At the end of 30 days, analyzing this soil, it was observed that the dose of H_2SO_4, equivalent to 3.4 mL kg^{-1} of soil, was sufficient to reduce the pH of the soil to 6.5.

The experiment was built in an entirely randomized design in the factorial scheme 2 x 2 x 4, with three repetitions. Corresponding to incorporation of the two correctives, gypsum and sulfuric acid, of two sources of phosphorus, simple superphosphate and phosphoric acid, and of the application of increasing doses of P (0; 70; 140 and 210 mg dm^{-3}). The soil was placed in plastic pots containing 7 kg. After the application of both correctives, the soil remained incubated for 20 days. Passed the incubation period, was made a washing of the soil, applying an extra flow of water, equivalent to two times the number of pores. Soon after, it were applied the sources and doses equivalents of phosphorus, remaining incubated for more 20 days. Ending the time determined for the incubation, soil samples were retrieved for the determination of the contents of available P, from the extractor Mehlich 1, and pH of the soil.

Next, it was applied a basic fertilization, with the addition of 60 mg kg^{-1} of N and 70 mg kg^{-1} K_2O in the soil. Then, at the sowing, it was used 10 seeds of millet (*Pennisetum glaucum* L.) per pot, eight days after the emergence of the seedlings and stabilization of the germination process was done the thinning, keeping the two most vigorous plants in each experimental plot. During the experimental period was applied non saline water, basing in the daily weighing of the pots, compensating the losses by evaporation, in a way that the content of water was kept close to 70% of the field capacity. After 60 days, computed from the thinning of the seedlings, it was collected samples of the plants, which were place in paper bags and put to dry in a greenhouse with forced ventilation at 65 °C during 72 hours, for the determination of the production of vegetal dry mass.

Results and Discussion

In a general way, the use of the phosphorus fertilizers associated to the correctives resulted in a significant reduction of the soil pH, except referring to the simple superphosphate in the presence of gypsum. For the further situations the values of pH have adapted themselves linearly in function of the increasing doses of phosphorus (Figure 1).

The applications of the increasing doses of phosphorus in the saline-sodic soils, independent of the source, provided a pH reduction. Quantitatively both sources of phosphoric fertilizer presented linear behavior ($p<0.01$). According to HAYNES (1986), the acidifications provided by the sources of fertilizers are derived from the reactions of transformation of ammonium or amide, liberating hydrogen in the nitrification process, which promotes the decrease of the pH of the soil. MIRSA et al. (2007) assessing the influence of correctives and leaching in the recovery of alkaline soil observed that the addition of

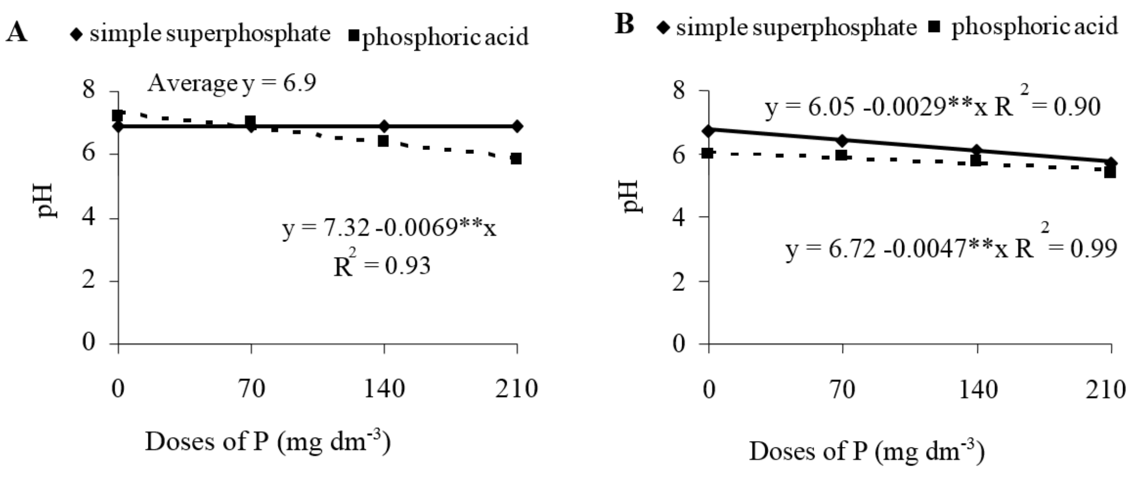

Figure 1. Contents of pH of the soil treated with gypsum (A) and sulfuric acid (B) in function of the sources and doses of phosphorus.

phosphorus on these soils promoted a pH reduction.

Although the simple superphosphate is considered a fertilizer of neutral reaction, the application of the same significantly reduced the soil pH, decreasing to 0.16 units of pH for each 70 mg dm^{-3} of P applied to the soil (Table 1). BRAGA and AMARAL (1971) also observed a distinguished reduce in the soil pH, using triple superphosphate as a phosphorus source, probably, due to the soil acidification caused by the hydrolysis of the fertilizer, originating the formation of phosphoric acid. It can be also observed, a significant difference in the contents of pH of the soil in function of the phosphorus sources, where the treatment with phosphoric acid presented greater efficiency in the reduction of the pH in relation to the simple superphosphate. In accordance with DOMINGUEZ VIVANCOS (1993), the use of H_3PO_4, besides providing nutrients for the plants, liberates the hydrogen on the soil in a faster way, being its reactions of great interest to reduce the pH of the soil. Reductions in the pH due to the application of phosphoric acid were also observed by ZANINI et al. (2007) and SILVA and MAROUELLI, (2001).

It was not found significant effect among the interaction of the correctives with the sources of phosphorus and its respective doses, however, it was observed a greater availability of phosphorus in the plots treated with agricultural gypsum in relation to the treatments in the presence of sulfuric acid (Table 2). Contradicting the fact observed by GOEDERT and LOBATO (1984), HAMMOND et al. (1986) and SANZONOWICZ and GOEDERT (1986). These authors affirm that the calcium contributes for the lower solubilization of the phosphorus in the soil, taking into consideration that the gypsum is a calcium source. Still, VITAL et al. (2005) applying increasing doses of gypsum in a saline-sodic, obtained an increase in the contents of phosphorus available in the soil. On the other hand, RASHID (2006) during the recovery of a sodic soil with gypsum, observed a decrease of extractable P due to its conversion in compounds of Ca-P, which are less soluble.

The addition of both phosphorus fertilizers resulted in meaningful increases in the concentrations of phosphorus in the soil (Figure 2). It was verified as for the action of the acid fertilizer in the provision of phosphorus, the data adjusted in a quadratic form. While in the simple superphosphate is observed a linear effect on the contents of available phosphorus in the soil with the increment of the levels of fertilizer. Comparing the sources of fertilizer as for the availability of phosphorus in the soil, it is also observed supremacy of the phosphoric acid in relation to the simple superphosphate. Such results confirmed not only the efficiency of the phosphoric acid as source of phosphorus, due to the greater solubility, but also, its greater efficacy in the immediate construction of the fertility of soils with low initial content of this nutrient. ZANINI et al. (2007), ZANINI et al. (2007), assessing the distribution of phosphorus in the wet bulb, applied

Table 1. Contents of soil pH in function of the doses of phosphorus in each respective source.

Doses of P (mg dm^{-3})	**Sources of phosphorus**	
	Simple superphosphate	**Phosphoric acid**
0	6.8	6.7
70	6.7	6.4
140	6.5	6.1
210	6.3	5.6
Effect	Linear **	Linear **
Average	6.6 a	6.1 b

Identical lowercase letters in the same line do not statistically differ by the Tukey test at 5% of probability

Table 2. Average content of phosphorus in the presence of each corrective.

Correctives	**Phosphorus (mg dm^{-3})**
Gypsum	75.01 a
Sulfuric acid	64.14 b

Averages followed by the same letter do not differ, by the Tukey test at 5% of probability.

via drip irrigation with phosphoric acid, verified that the increase of doses of the phosphoric acid (90 and 120 kg ha^{-1} of P_2O_5) provided more contents of phosphorus in the soil.

Comparing the use of chemical conditioners, the plots treated with gypsum presented greater average values of vegetal dry mass (Table 3). Such behavior can be attributed, probably, to the physical improvement of the soil in function of the gypsum incorporation, thus providing a better development of the root system, consequently in a better nutrition, resulting in a larger production of the plants. For

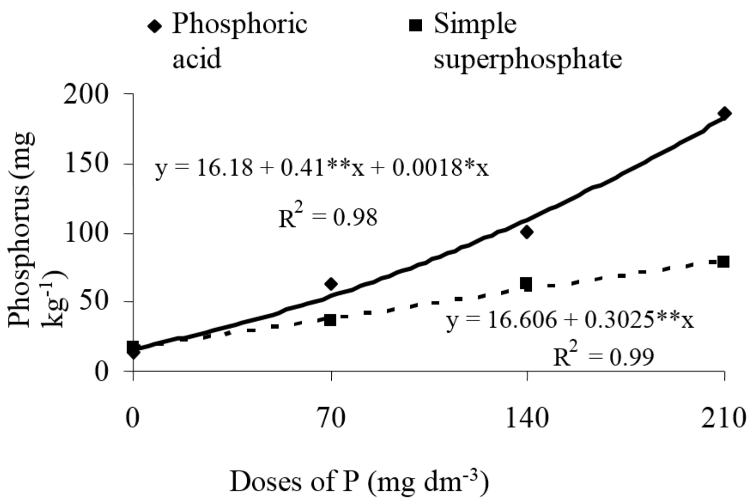

Figure 2. Contents of phosphorus in the soil in function of the doses and sources of phosphorus.

Table 3. Production of dry mass of millet in each corrective.

Correctives	Dry mass (g pot^{-1})
Gypsum	13.45 a
Sulfuric acid	9.60 b

Averages followed by the same letter do not differ, by the Tukey test at 5% of probability.

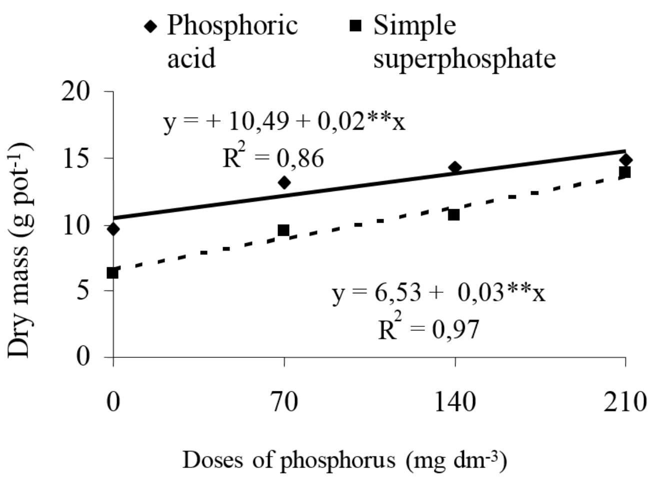

Figure 3. Production of dry mass of the millet in function of doses and sources of phosphorus.

PIMENTEL (1999), as more developed the root system better is going to be the development of the aerial part of the plants. CARVALHO and RAIJ (1997) related that the application of gypsum in the soil followed by leaching, results in better root system development and larger water and nutrients absorption by the roots of the plants. Besides the attenuating action of the harmful effects of salinity, VITAL (2002) verified that the gypsum exercised positive effect on the availability of nutrients and in the initial growth of the cashew tree cultivated in saline-sodic soil.

As for the vegetal production in function of the use of phosphorus fertilizers (Figure 3), the obtained data adjusted linearly indicating that the tested doses were not sufficient to attend the demand of the plants. However, the use of phosphoric acid resulted in greater production of dry mass as the aerial part of the millet. Probably in response to the presence of more elevated contents of phosphorus in the soil observed in this treatment (Figure 2), providing in this way, a greater growth of the plants. This effect is directly linked to the better speed of liberation of the nutrient by the larger solubility of the phosphoric acid compared to the simple superphosphate, minimizing the effect of the competition soil/plant, because according to NOVAIS and SMYTH (1999), the fixation of the phosphorus by the colloids of the soil is given in a preferential form.

Conclusion

For the conditions of soil studied, the use of gypsum as corrective and, among the sources of phosphorus evaluated, the application of phosphoric acid promoted greater availability of phosphorus, consequently greater vegetal production of millet, being, in this way, recommended for programs of recovery of areas degraded by salts.

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