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Short-term effect of lime and gypsum on alleviation of upland acid soil infertility in southern Thailand
Effet à court terme de la chaux et du gypse sur la fertilité des sols acides du sud de la Thaï lande

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High acidity, high exchangeable aluminium and limited plant uptake are common problems in the soils of the humid tropics. Surface application of liming materials is the usual method to increase soil pH, suppress aluminium toxicity, and improve nutrient availability in the topsoil. Alleviating subsoil infertility is more difficult, although in some soils surface application of gypsum has proved to be successful. A field experiment was carried out in southern Thailand (100°40’ E, 6°46’ N, annual rainfall 2850 mm) in order to determine the effects of surface applied lime ($Ca[OH]_2$) and gypsum on soil chemical properties and plant growth. The soil was classified as coarse loamy siliceous Typic Paleudults, contained 14% clay, 0.72% organic C, 4.2 mg kg ^{1} Bray 2 P, 0.06 cmol(+) kg ^{1} exchangeable K, 1.9 cmol(+) kg ^{1} of exchangeable acidity and 62% Al saturation. Four treatments with six replications were studied on a rotation of mungbean and sweet corn: control, lime, gypsum, and lime plus gypsum (L+G). An amount of 2 t ha^{-1} of lime and 5 t ha^{-1} of gypsum was applied twice, one month before the sowing of mungbean and one month before sowing of sweet corn. In the topsoil (0-20 cm) of the lime treatment, pH in water (soil:solution ratio 1:5) increased from 5.0 to 6.0 after the second application, whereas in the gypsum treatment the pH was reduced to about 0.3 and 0.7 unit for the topsoil and subsoil, respectively. Lime application reduced exchangeable Al in the topsoil from 1.0 to 0.1 cmol(+) kg ^{1}, gypsum application reduced it to 0.4 cmol(+) kg ^{1}. Exchangeable Mg in the 0-20 cm layer of the soil treated with gypsum decreased from 0.11 to 0.06 cmol(+) kg ^{1}, but it did not change after lime application. The grain yield of mungbean increased significantly after lime application, but it was not significantly different from the control in the gypsum treatment. The treatments had no significant effect on corn yield, although gypsum decreased biomass at flowering stage.

Keywords : acid soil, liming, gypsum, tropical soil
Mots clés : sol acide, chaulage, gypse, sol tropical

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Introduction

The upland soils of southern Thailand are predominantly Ultisols which are highly weathered, acidic, low in base saturation, low in P availability, and high in exchangeable Al (Soil Survey Division, 1984; Nilnond *et al*., 1986). Plant growth on these soils is limited by soil acidity factors including P, Ca, Mg and K deficiencies (Nilnond *et al*., 1986; Suthipradit *et al*., 1990; Nilnond and Chatupote, 1996). Liming is the most common way to increase soil pH, which results most of the time in higher plant yields (Kamprath, 1984; Ismail *et al*., 1993). However, its action is usually limited to the surface layer as the movement of surface applied lime down the soil profile is extremely slow (Sumner *et al.*, 1986). Although deep liming is an effective way to alleviate subsoil acidity, it requires extremely expensive tillage operations. The other alternative is to alleviate subsoil acidity by surface application of gypsum. Sumner (1993) has summarized that substantial and highly significant yield responses (7-200%) were obtained for many crops in experiments conducted in Brazil, South Africa and the southern United States to surface applications of gypsum at a rate of 1 to 10 t ha^{-1}. Although gypsum applications to acid soils have generally resulted in positive crop growth responses, some studies have shown either no response or even negative responses (Alva and Sumner, 1990), thus indicating the importance of soil properties in determining the effectiveness of gypsum to improve acid soil infertility factors. The climate of southern Thailand is hot and wet (average rainfall over 2500 mm $year^{-1}$). High rainfall may help surface application of lime and gypsum penetrate the subsoil and become beneficial to plant growth.

The objective of this study was to determine the change in soil properties of representative Thai Ultisols as affected by surface application of gypsum, lime, and the combination of lime and gypsum. This paper reports on the effects observed during the first seven months after treatment application.

Materials and methods

A field experiment was conducted at Nathawi research station, Songkla, Thailand (6° 40′ N, 100° 40′ E). The mean annual rainfall is 2,847 mm and the average annual temperature is 27.7 °C. The soil is a coarse loamy siliceous Typic Paleudults, a widespread soil type in the upland areas of southern Thailand (Table 1).

The factorial randomized block experiment had six blocks and four treatments: control; lime (4000 kg $Ca(OH)_2$ ha^{-1}), gypsum (10 t ha^{-1}), and lime plus gypsum (L+G). The amounts of lime and gypsum applied to the L+G treatment were the same as in the lime and gypsum treatments. The same amendment (2000 kg ha^{-1} of lime and 5 t ha^{-1} of gypsum) was applied 26 days before planting the mungbean (10 May) and 28 days before planting the corn (6 September). The size of the plots was 6 x 8 m.

Mungbean and supersweet corn were used as test species. All plots received 20 kg N ha^{-1}, 50 kg P ha^{-1} and 56 kg K ha^{-1} at sowing of mungbean as KNO_3 and triple superphosphate (TSP). In order to prevent any secondary nutrient deficiency, 30 kg Ca ha^{-1}, 20 kg Mg ha^{-1} and 51 kg S ha^{-1} were applied at sowing of the mungbean as gypsum and kieserite. One week after planting supersweet corn, a further 55 kg N ha^{-1} as urea, 20 kg N ha^{-1} and 56 kg K ha^{-1} as KNO_3 and 50 kg P ha^{-1} as TSP were applied. Five weeks after planting of supersweet corn 55 kg N ha^{-1} as urea and 20 kg N ha^{-1} and 56 kg K ha^{-1} as KNO_3 were applied. The fertilizers were banded and incorporated to 10 cm.

Crops were grown under rainfed conditions. Aboveground biomass at the flowering stage and yields were measured (oven dried at 75°C). The crop residues were returned to the surface soil of each plot and incorporated to 15 cm.

Table 1 Selected chemical properties of the soil in Nathawi.

Depth	pH (1:5)		O.C.[a]	Exch. cations (cmol(+) kg ^{1})					Bray 2 P
(cm)	H_2O	$CaCl_2$	(%)	Ca	Mg	K	Na	Al	(mg P kg^{-1})
0-20	4.9	3.8	0.85	0.28	0.11	0.17	0.18	1.13	4.81
20-40	4.8	3.9	0.33	0.07	0.03	0.09	0.17	1.67	1.27
40-60	4.7	3.7	0.20	0.05	0.02	0.07	0.16	2.43	0.55
60-80	4.9	3.7	0.18	0.06	0.02	0.06	0.18	2.59	0.94

O.C.[a] = organic carbon

Soil analysis

Soil samples were collected at 0-20, 20-40, and 40-60 cm depth before treatment applications, at flowering stage of mungbean (30 July), before sowing of corn (24 September), and at the silking stage of corn (29 November).

Soil pH was determined in water and 0.01 M $CaCl_2$ (w/v 1:5). Exchangeable cations were extracted by 1 M NH_4OAc buffered at pH 7.0. Concentrations in Ca and Mg were determined by atomic absorption spectrometry. Concentrations in K and Na were determined by flame photometry. Aluminium was extracted by 1 M KCl and determined by colorimetry. Sulfate was extracted using 0.01M $Ca(H_2PO_4)_2$ and determined by turbidimetry. Organic carbon was measured by the Walkley and Black method. The Bray 2 method (0.03 M NH_4F in 0.10 M HCl) was used to estimate available P.

Results and Discussion

Soil properties

Six months after treatment application, lime and L+G treatments had raised the soil pH of the 0-20 cm layer from 4.9 to 6.1 and 6.0 respectively. However there were no significant differences in soil pH between treatments deeper than 20 cm (Table 2). Application of lime resulted in a significant reduction in exchangeable Al to a 20 cm depth, about 80 days after the first application. The second application of lime reduced exchangeable Al to less than 0.1 cmol(+) kg ^{1}.

Gypsum treatment decreased surface soil pH from 4.8 to 4.5, and subsoil pH (20-60 cm) from 4.8 to 4.1. This effect has been considered as a result of the salt effect in pH measurement (Shainberg *et al*. 1989). The treatment also decreased exchangeable Al in the 0-20 cm layer from 1.01 to 0.40 cmol(+) kg ^{1}. A small decrease in exchangeable Al was also found down to 40 cm when applied with lime. A short term decrease in exchangeable Al may result from the formation of $AlSO_4^+$ species (Pavan *et al*., 1984), as aluminium sulfates are quite stable under acid soil conditions (Sumner, 1993). The decrease in soil pH found in the gypsum treatment may be due to Ca^{2+} ions dissolved from gypsum that replaced H^+ and Al^{3+}, which subsequently hydrolyzed to give H^+. Pavan *et al*. (1984) showed that in soils high in exchangeable Al, H^+ release by hydrolysis was likely to exceed OH^- release causing a soil pH decrease.

The increase in exchangeable Ca from 0.27 to 2.52 cmol(+) kg ^{1} resulting from lime application was restricted to the surface horizon, whereas gypsum and L+G applications resulted in increasing exchangeable Ca significantly down to a depth of 60 cm six months after the first application (Table 2). Shainberg *et al*. (1989) reported a relatively uniform increase in exchangeable Ca throughout the soil profile of an acid soil treated with gypsum. The higher increase in exchangeable Ca in the deeper layers found in the gypsum treatments compared to the lime treatment was probably related to the presence of sulfate ions. Sulfate ions move together with calcium ions in the gypsum treatment whereas hydroxyl ions react immediately with protons in the layer of application. A small increase in exchangeable Ca was also found in the control treatment in the 0-20 cm layer. This increase stemmed probably from the application of TSP, which contained about 13% of Ca.

Exchangeable Mg in the 0-20 cm layer of the soil treated with gypsum decreased from 0.12 to 0.05 cmol(+) kg ^{1} for the gypsum treatment, and from 0.10 to 0.07 cmol(+) kg ^{1} for the L+G treatment. The deeper layers contained similar amounts of exchangeable Mg in all the treatments. Leaching of Mg as a result of gypsum application by exchange between Ca and Mg has often been reported in acid soils (Sumner, 1993). The fact that exchangeable Mg remained unchanged in the control treatment for this experiment may be the result of kieserite application, the Mg applied compensating the losses by plant uptake and leaching.

A significant decrease of exchangeable K 80 days after the first application was found in the 0-20 cm layer of soils treated with lime and gypsum (data not shown). However, there was no significant change in exchangeable K in the deeper layers. After six months, there was no significant difference in exchangeable K between treatments. Crop yields of mungbean were consistently higher in the lime treatments than that in the control (Fig. 1). Differential uptake could account for some decrease of K in these treatments. A decrease in exchangeable K due to higher uptake of K by maize after lime application was reported by Nwachuku and Loganathan (1991). However, after the second application of K, exchangeable K increased in all treatments, and no significant difference was found at the silking stage of corn. The relatively low level in exchangeable K in the gypsum treatment found in this experiment may result from the competitive exchange between Ca and K. Shainberg *et al*. (1989) explained that K behaves in a similar manner as Mg.

Application of gypsum significantly increased extractable SO_4^{2-} deeper than 60 cm (Table 2). The L+G treatment had a lower SO_4^{2-} content in the 0-20 cm layer than the gypsum treatment, but the content was around two-fold higher in the 40-60 cm layer. The results indicate that the lime treatment enhanced the leaching of SO_4^{2-} to a deeper horizon. The anion exchange capacity of the topsoil was probaby reduced by the increase in soil pH due to lime application, increasing the leaching of SO_4^{2-} ions to the subsoil. This effect should have reduced exchangeable Al, but no significant decrease was obtained in this experiment.

Yield and biomass

In both crops application of lime increased plant growth while gypsum application reduced the plant top dry weight of corn (Fig. 1 and Fig. 2). Lime treatments increased mungbean seed dry weight significantly(Fig. 1). Similar results about the effect of lime have often been reported (Kamprath, 1984; Ismail *et al.*, 1993; Nilnond and Chatupote, 1996). The response of crops to liming is mainly a result of neutralization of Al toxicity, supply of Ca and the increasing availability of some plant nutrients like P and S.

The negative effect of gypsum on crop growth found in this experiment did not agree with the review by Sumner (1993). Yield responses were related to improvements in the Ca and S status and/or reductions in the Al status of the soil involved. A reduction of exchangeable Al from about 1.01 to 0.40 cmol(+) kg^{1} in the gypsum treatment may not be enough to eliminate Al toxicity. Results also showed that applied gypsum resulted in decreasing the exchangeable Mg of the topsoil down to 0.05 cmol(+) kg^{1} (Table 2). The combination of low pH, low exchangeable Mg and some exchangeable Al on the soil can explain the poor plant growth in the gypsum treatment. Syed-Omar and Sumner (1991) have demonstrated that in some cases, particularly on very sandy infertile soils, gypsum applications had a negative effect on crop growth due to the preferential removal of Mg from the surface horizon.

Conclusion

Application of lime increased soil pH and reduced exchangeable Al to a negligible level in the surface layer, but had no significant effect below the depth of application. Application of gypsum improved Ca and S status down to 60 cm, and reduced exchangeable Al to deeper layers than lime when applied with lime. However it had adverse effects on the pH and Mg status of the soil and decreased plant growth. In the short term period reported in this article, lime managed to alleviate acid soil infertility whilst gypsum had mainly detrimental effects on soil properties and plant growth.

Acknowledgments

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References

Alva, A.K. and Sumner, M.E. (1990). Amelioration of acid soil infertility by phosphogypsum. Plant and Soil. 128:127-134.

Ismail, H., Shamshuddin, J. and Syed Omar, S.R. (1993). Alleviation of soil acidity in Ultisols and Oxisols for corn growth. Plant and Soil. 151:55-65.

Kamprath, E.J. (1984). Crop response to lime on soil in the tropics. In 'Soil Acidity and Liming.' 2nd ed. (Ed. F. Adams). pp. 349-368. ASA-CSSA-SSSA. Madison, Wisconsin.

Nilnond, C., Panapitukkul, N., Nualsri, J., Pantanahiran, W., Aitken, R.L., and Asher, C.J. (1986). Soil fertility assessment in southern Thailand. Transactions XIII. Congress of the International Society of Soil Science Vol. III, 887-888.

Nilnond, C. and Chatupote, W. (1996). Fertility assessment and nutrient requirements for a pasture legume grown in Kho Hong soil series. Songklanakarin J. Sci. Technol. 18 : 35-42.

Nwachuku, D.A. and Loganathan, P. (1991). The effect of liming on maize yield and soil properties in southern Nigeria. Commun. Soil Sci. Plant Anal. 22:623-639.

Pavan, M.A., Bingham, F.T. and Pratt, P.F. (1984). Redistribution of exchangeable Ca, Mg and Al following lime or gypsum applications to a Brazilian Oxisol. Soil Sci. Soc. Am. J. 48:33-38.

Shainberg, I., Sumner, M.E., Miller, W.P., Farina, M.P.W., Pavan, M.A. and Fey, M.V.(1989). Use of gypsum on soils. Adv. Soil Sci. 9 : 1-111.

Soil Survey Division (1984). General soil map of southern region, Thailand. Scale 1 : 500,000. Department of Land Development, Bangkok.

Suthipradit, S., Laosuwan, S., Jantaraniyom, T. and Anuchan, N. (1990). The effect of lime and some nutrient elements on yields of peanut grown on a Khok Khian soil. Songklanakarin J. Sci. Technol. 12:51-57.

Sumner, M.E. (1993). Gypsum and acid soils : The world scene. Adv. Agron. 51:1-32.

Syed-Omar, S.R. and Sumner, M.E. (1991). Effect of gypsum on soil potassium and magnesium status and growth of alfalfa. Commun. Soil Sci. Plant Anal. 22:2017-2028.

Keywords : acid soil, liming, gypsum, tropical soil

Mots clés : sol acide, chaulage, gypse, sol tropical

Table 2 Change in chemical properties of the Nathawi soil after application of lime and gypsum.

Treatment	pH in water (1:5)						Exchangeable Al (cmol(+) kg ^{1})						Exchangeable Ca (cmol(+) kg ^{1})					
	Before application			After application			Before application			After application			Before application			After application		
	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
Control	5.07	4.66	4.68	4.75	4.41	4.41	0.95	1.61	2.12	0.73	1.46	1.97	0.27	0.07	0.06	0.57	0.21	0.17
Lime	4.96	4.72	4.68	5.98	4.40	4.32	0.91	1.65	2.20	0.08	1.31	2.03	0.27	0.07	0.05	2.52	0.33	0.32
Gypsum	4.80	4.81	4.79	4.54	4.11	4.09	1.01	1.82	2.45	0.40	1.29	2.39	0.22	0.06	0.05	4.31	0.95	0.47
L+G	4.93	4.82	4.82	6.03	4.41	4.12	0.97	1.63	1.97	0.04	1.11	2.03	0.34	0.06	0.05	4.82	1.42	0.81

Table 2 Continued

Treatment	Exchangeable Mg (cmol(+) kg ^{1})						Exchangeable K (cmol(+) kg ^{1})						Extractable SO_4 (mg-S kg ^{1})					
	Before application			After application			Before application			After application			Before application			After application		
	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
Control	0.13	0.03	0.04	0.13	0.05	0.03	0.20	0.10	0.06	0.23	0.10	0.08	17.3	10.6	7.8	13.2	9.1	5.2
Lime	0.11	0.03	0.03	0.15	0.05	0.08	0.17	0.09	0.07	0.21	0.10	0.10	8.1	8.9	7.6	15.0	8.7	4.2
Gypsum	0.12	0.03	0.02	0.05	0.06	0.07	0.16	0.09	0.07	0.21	0.13	0.10	13.2	10.1	7.9	836	190	53.4
L+G	0.10	0.02	0.01	0.07	0.04	0.06	0.17	0.08	0.06	0.19	0.12	0.10	9.3	9.7	7.9	565	185	116

Values are means of six replications
Before application = soil samples taken 7 May 1996
After application = soil samples taken 29 November 1996.
Lime (2 t ha^{-1}) and gypsum (5 t ha^{-1}) were applied twice, on 10 May 1996 and 6 September 1996.

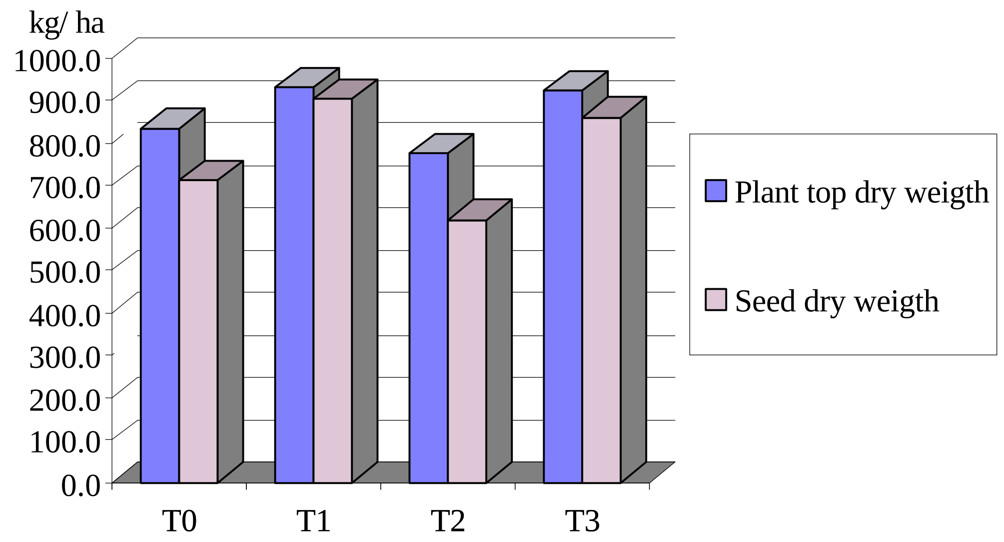

Fig. 1 Mean values of plant top dry weigth and seed dry weigth of mungbean influenced by lime and gypsum treatments (T0 = control; T1 = lime; T2 = gypsum; T3 = lime+gypsum).

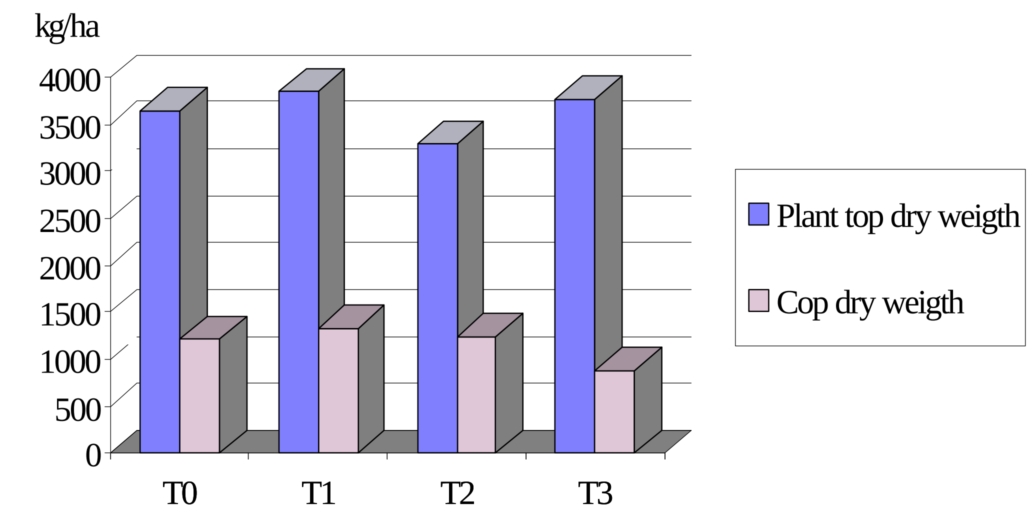

Fig. 2 Mean values of plant top dry weigth and cop dry weigth of supersweet corn influenced by lime and gypsum treatments (T0 = control; T1 = lime; T2 = gypsum; T3 = lime+gypsum).