Effects of compost and lime amendment on soil acidity and N availability in acid sulfate soil

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Abstract
The aims of this study were to investigate changes in soil acidity, exchangeable and dissolved aluminum (Al) and N availability after application of lime and/or compost. In the Mekong delta, field experiments were established on severely acid sulfate soil recently cultivated with *Momordica cochichiensi.* Before planting, soil samples were taken at 0-20 cm depth for incubation experiments. The results from our field experiments showed that applying 5 kg compost per plant in addition to a basal application of 37.5 g N, 220 g P_2O_5 and 85 g K_2O per plant led to an increase in soil pH and a decrease soil exchangeable Al^{3+} ($P < 0.05$). In incubation experiments, lime ($CaCO_3$) was added at rates of 80 and 202.5 mg/20 g soil, based on the results from lime requirement tests to reach desired pH values. In addition, compost was added solely or in combination with lime at an amount of 1.25 g. The results showed that application of lime at a rate of 80 mg $CaCO_3$/20 g soil in combination with 1.25 g compost increased soil pH from 3.13 to 6.07. This combination also significantly decreased soil exchangeable and dissolved Al and increased soil content of NH_4^+-N. Application of compost alone or in combination of liming enriched soil with both NH_4^+-N and NO_3^--N. A significant increase in soil NO_3^--N after amending acid sulfate soil with compost only, may suggest that compost may be a source of nitrifying microorganisms.

Key words
Acid sulfate soils, liming, compost, dissolved aluminum, nitrogen availability.

Introduction
In an attempt to introduce various beneficial plant species for agricultural production on acid sulfate soils, the growth of *Momordica cochichiensis* has been tested. This species is considered as a high value fruit crop but has not been planted on acid sulfate soils in the Mekong delta. Besides testing the adaptive ability of *Momordica* plant, this study also aimed at establishing a practical recommendation regarding amendments of compost and lime to counteract soil acidity and potentially toxic levels of dissolved aluminum. In parallel with *in situ* experiments, incubation experiments were carried out to investigate changes in soil acidity and dissolved Al combined with addition of N-containing compost affected soil N mineralization.

Methodology
A field experiment was established in Tri Ton district, An Giang province, which is one of the main areas of severely acid sulfate soils in the Mekong delta. The soil is classified as a *Typic Sulfaquepts* (USDA). All plots were fertilized with a basal dressing consisting of 37.5 g N, 220 g P_2O_5 and 85 g K_2O/plant. Before planting, lime ($CaCO_3$) was added to all plots at a rate of 2 tons/ha to counteract acidity and moderate dissolved Al and Fe toxicity. To investigate the effects of compost on soil pH and Al, there were two treatments set up with four replicates each: (1) the control without compost, and (2) sugar-cane filter cake compost added at 5 kg/plant. After planting *Momordica*, soil sampling was carried out at day 48 and at day 82 to monitor changes in soil pH and exchangeable Al content under liming and compost application.
For the incubation experiment, soil was sampled before applying lime and compost. Lime and compost were then added in the laboratory solely or in combination in six following treatments:

(1) Control (without lime and compost)
(2) + 1.25 g compost
(3) + 80 mg $CaCO_3$
(4) + 80 mg $CaCO_3$ and 1.25 g compost
(5) + 202.5 mg $CaCO_3$
(6) + 202.5 mg $CaCO_3$ and 1.25 g compost

The experiment was carried out in completely random design with four replicates for each treatment. Soil sampling was carried out at day 0 and day 28 during the course of incubation. At each sampling date, the pH, titratable acidity, exchangeable Al^{3+}, total dissolved Al as well as the amounts of accumulated mineral N were analyzed.

Results

In situ experiment:

Applying 5 kg compost on a basal application of 2 tons $CaCO_3$/ha per plant reduced soil exchangeable Al^{3+} during 82 days after planting (Figure 1). Soil pH remained at a low level revealing that much more lime needed to be applied.

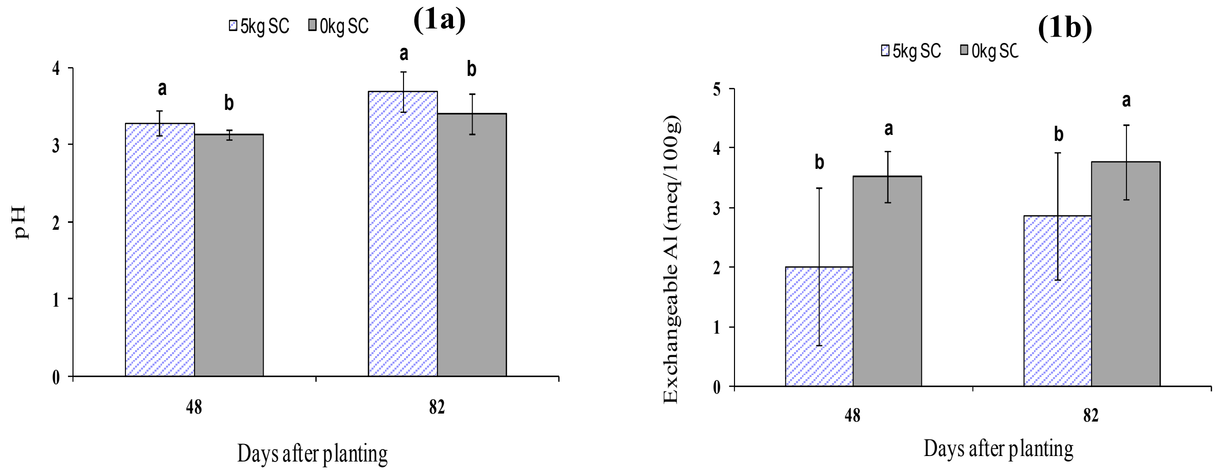

Figure 1. Effects of compost amendment on soil pH (1a) and the contents of exchangeable Al^{3+} (1b). Vertical bars on the columns are standard deviations of mean values (n = 4), "SC" is an abbreviation of sugar cane filter cake compost

Incubation experiment:

Applying lime solely or in combination with compost significantly increased soil pH. Similarly, the contents of titratable acidity, exchangeable Al^{3+} and dissolved Al decreased dramatically with increasing the amounts of amended lime and/or compost. In the treatment where lime was applied at a level of about 200 mg $CaCO_3$/20 g soil, soil acidity was completely neutralized (Table 1 and 2). Applying only compost could either moderate soil acidity or reduce the contents of exchangeable Al^{3+} and dissolved Al. The observed reduction in Al solubility that occurred when compost was applied, may have resulted from chemical reactions between anionic functional groups of organic molecules and solution cation: polyvalent Al can link negatively charged functional groups of organic molecules together and, hence, reduce their solubility by flocculation or binding them to negatively charged exchange sites (Tipping and Woof 1991; Guggenberger *et al.* 1994b).

Net N mineralization was enhanced significantly as lime and compost was applied either solely or in combination. Effects of liming on net N mineralization has attributed to a reduction of Al toxicity and an increase in soil pH that can both result in an increase of total microbial activity (Andersson *et al.* 1994; Ivarson 1997) and a release of labile organic matter (Curtin *et al.* 1998; Andersson 1999). On the other hand, applying only compost (total N content 2.7%) enhanced both NH_4^+-N and NO_3^--N accumulation during the course of the incubation (Figures 2a & 2b). This study indicated that compost might also be a source of soil nitrifiers. Nitrification could be disadvantageous since it increases N losses via leaching and run-off and promotes soil acidity by producing H^+ ions via enzymatically oxidative processes involving NH_4^+ ions. However, this study showed that compost in itself caused an increase in soil pH despite the proton production associated with the formation of nitrate (Table 1; Figure 2b).

Table 1. Changes in pH and titratable acidity in the soil amended with lime and compost during 28-day aerobic incubation. (±) values are standard deviation (n = 3). The mean values followed by the same letter in the same column are not statistically significant. Values of differences followed by superscript **, * and ^{ns} show the differences between the initial and final observed values at 0.001, 0.05 significant levels and no significance, respectively.

Treatments	Initial pH	Final pH	Differences[(a)]	Initial titratable acidity (meq H^+/100 g)	Final titratable acidity (meq H^+/100 g)	Differences
Control (20 g soil)	3.13 f	3.19 f	-0.057*	13.20 (± 0.07) f	9.93 (± 1.412) e	-3.28**
+ 1.25 g compost	3.85 e	4.16 e	-0.310*	7.55 (± 0.11) e	1.28 (± 0.000) c	-6.28**
+ 80 mg $CaCO_3$	4.94 d	4.51 d	0.433*	3.18 (± 0.26) d	2.70 (± 0.075) d	-0.48^{ns}
+ 80 mg $CaCO_3$ and 1.25 g compost	6.07 c	5.02 c	1.047**	0.28 (± 0.04) c	0.15 (± 0.075) b	-0.13^{ns}
+ 202.5 mg $CaCO_3$	7.33 b	6.10 b	1.227**	0.18 (± 0.04) b	0.03 (±0.043) a	-0.15^{ns}
+ 202.5 mg $CaCO_3$ + 1.25 g compost	7.55 a	6.42 a	1.130**	0.03 (± 0.04) a	0.03 (± 0.043) a	0.00^{ns}

(a) Differences between the values of pH and titratable acidity obtained at day 28 and those at day 0 (after amendments) in incubation experiment. (-) values indicate a decrease in the observed parameters during 28-d incubation and vice versa.

Table 2. Changes in the contents of exchangeable Al and dissolved Al at day 28 after amending $CaCO_3$ and compost. (±) values are standard deviation (n = 3). The mean values followed by the same letter in the same column are not statistically significant. Values of differences followed by superscript **, * and ^{ns} show the differences between the initial and final observed values at 0.001, 0.05 significant levels and no significance, respectively.

Treatments	Initial exch. Al^{3+} (meq/100 g)	Final exch. Al^{3+} (meq/100 g)	Differences	Initial dissolved Al (mg/l)	Final dissolved Al (mg/l)	Differences
Control (20 g soil)	10.48 (± 0.04) c	8.68 (± 1.20) c	-1.80*	2.25 (± 0.09) b	2.34 (± 0.42)	0.09^{ns}
+ 1.25 g compost	4.58 (± 0.27) b	0.50 (± 0.11) a	-4.08**	0.46 (± 0.16) a	nd	nd
+ 80 mg $CaCO_3$	0.93 (± 0.35) a	2.30 (± 0.11) b	1.38*	nd	nd	nd
+ 80 mg $CaCO_3$ + 1.25 g compost	nd	nd	nd	nd	nd	nd
+ 202.5 mg $CaCO_3$	nd	nd	nd	nd	nd	nd
+ 202.5 mg $CaCO_3$ + 1.25 g compost	nd	nd	nd	nd	nd	nd

nd: below detection limit

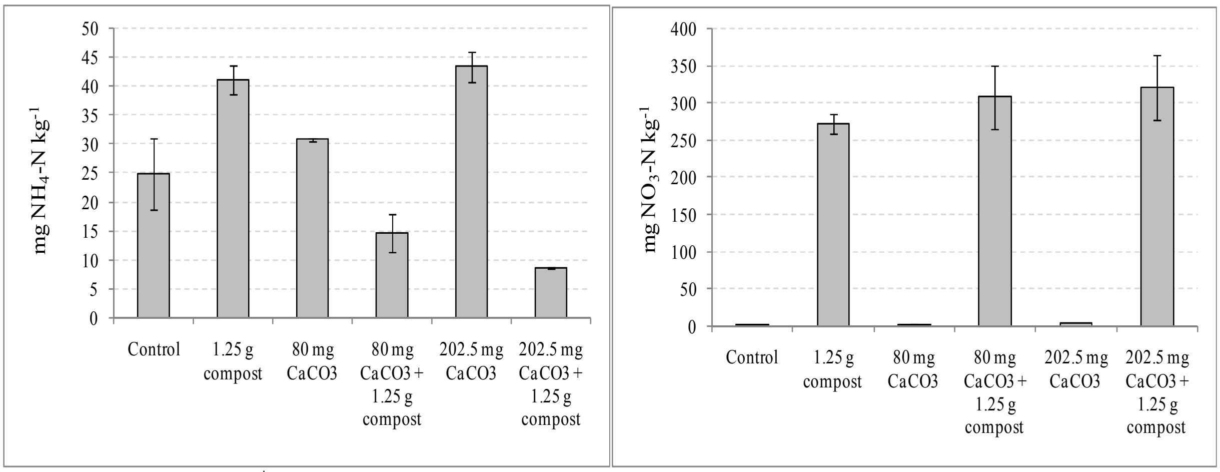

Figure 2. Mineral NH_4^+-N and NO_3^--N released at day 28 over the course of incubation at different rates of liming and compost application

Conclusion

The incubation experiment from this study demonstrated that the application of compost and lime could mitigate soil acidity and Al toxicity as well as improve N availability in the studied acid sulfate soils. Applying lime solely could improve soil pH and N availability. However, amending compost is recommended to be used to further improve soil fertility and soil biological properties.

In a field experiment, the addition of sugar-cane filter cake compost and lime significantly increased soil pH and reduced exchangeable Al. However, changes in soil pH were minor indicating that much more lime needed to be applied to completely counteract acidity in this soil. It is also suggested that the effects from applying lime and compost on soil chemical and biological properties should be taken into long-term consideration.

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