Enhancing chemical properties and maize yield through dolomite application on rock phosphate-amended oxisol

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Abstract. Improving soil quality is vital so plants can adapt to climate change. Indonesia’s acid soils cover about 147.5 million hectares, and are generally acidic, with low levels of calcium and magnesium, and high levels of aluminum. This study aims to study the effect of dolomite application on acid upland soils that have been applied with rock phosphate to improve soil chemical properties and increase maize yields. The research was conducted in Jati Agung using a randomized block design with 5 treatments and 5 replications. The treatment consisted of 5 application levels of dolomite: 0, 500, 1000, 1500, and 2000 kg ha⁻¹. The size of the experimental plot was 10 m x 10 m. Hybrid maize varieties were used as indicators. The results showed that applying dolomite increased soil pH, Ca, Mg, and K levels and decreased exchangeable and Al saturation. It also increases plant height, maize yield, and biomass. The implication of this study is that the application of dolomite 1000 kg ha⁻¹ after rock phosphate is applied can improve soil chemical properties in acid soils.

1 Introduction

The main source of water for upland farming is rainwater. Climate change that occurs causes planning for planting corn to be not ideal. Acid upland soil is one of the potential suboptimal lands that can be optimized for agricultural development in Indonesia. Acid upland soils are formed in areas with high rainfall with acid parent material occupying around 109 million ha [1]; 5.30 million ha of them are available and suitable for agricultural activity in the upland areas. The acid upland soil is characterized by low soil pH (< 5.5), base saturation (<50%), and high Al saturation of >30% [2–4]. Moreover, acid upland soil was also noticed with low content of soil organic carbon, N, P, K, Ca, and Mg [5–7].

Generally, soil Ca and Mg concentrations in acid upland soil are categorized as low [8] and are limiting factors for plant growth and productivity. The application of soil conditioners such as dolomite can be used as a source of Ca and Mg which are needed in upland acid soils. The application of dolomite to acid upland soils in Lampung significantly increased soil pH

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and exchange of Ca and Mg [9]. A similar result showed that dolomite application in Ultisol in Hubei Province, China could increase soil pH [10].

Generally, lime or dolomite is applied at the beginning of planting with the aim of increasing soil pH and reducing the adverse effects of aluminum (Al). However, the effect of dolomite application in acid upland soil with previous rock phosphate application has not been investigated deeply. The aim of this research is to study the effect of the dolomite application on improving soil chemical properties and maize yield in acid upland soil which has been applied rock phosphate previously.

2 Methodology

This research was conducted at Karangrejo Village, Jati Agung Sub-district, South Lampung, Indonesia (-05° 14’ 4.1” S, 105° 23’ 28.8” E), with elevation at 60 m asl, two growing seasons from July 2021 to April 2022. This study was set up in a randomized complete block design with 5 treatments and 5 replications. The treatments consist of 5 rates of dolomite namely 0 (control), 500, 1000, 1500, and 2000 kg ha⁻¹. Urea and KCl dosages were 400 and 100 kg ha⁻¹, rock phosphate 1 t ha⁻¹ and manure 2 t ha⁻¹ for each treatment respectively. The plot size was 10 m x 10 m, maize was planted in a zig-zag cropping pattern. Previous research showed that zig-zag planting could increase maize yield [11]. Hybrid maize varieties were used as indicator plants and were maintained until harvest.

Rock phosphate was given 7 days before dolomite application by spreading it over the surface of the plot and mixing it with the soil. Manure was given at the planting hole to cover the seeds after planting. Urea application was split three times at 10, 25, and 40 DAP as 120, 160, and 120 kg ha⁻¹ respectively. KCl was applied twice at 10 and 25 DAP as 50 kg KCl ha⁻¹ for each application. Urea and KCl were applied in a hole 3 cm away from plants and covered with soil.

Parameter observation consists of plant height, maize, and biomass yield at the first planting time and second planting time including soil chemical properties. Soil samples were collected before rock phosphate application, at 15, 30, and 90 DAP at PS1. Initial soil analysis parameters consist of soil texture, pH H₂O (1:5), C-organic (Waklkey dan Black), N-total (Kejldal), P₂O₅ and K₂O (HCl 25%), P-Bray 1, Ca, Mg, K, Na, and CEC (NH₄OAc 1 N pH 7), Al and H (KCl 1N 3). Soil parameter analysis at 15, 30, and 90 DAP consist of soil pH H₂O (1:5), P-Bray 1, Ca, Mg, K, Na (NH₄OAc 1M pH 7), exchangeable Al and H (KCl 1N).

The total soil base cation is calculated with:  
\[ \text{Total cation} = \text{Ca} + \text{Mg} + \text{K} + \text{Na} \]  
(1)

Aluminum saturation is calculated using the formula by [12] as below:

\[ \text{Al saturation} (\%) = \frac{\text{Al}}{\text{Ca}+\text{Mg}+\text{K}+\text{Na}+\text{Al}+\text{H}} + 100\% \]  
(2)

Maize harvesting is done when the corn looks ripe, the corn cobs are yellow. The size of the harvest plot is 6.3 m x 8 m, as the edge crops are two rows from the left and right plots. Harvesting activities consist of collecting corn, peeling, and shelling then weighing the wet and dry corn including wet and dry biomass.

The observation data of plant growth and yield were analyzed statistically using analysis of variance (ANOVA) at 95% and then followed with the Duncan Multiple Range Test (DMRT) at \( \alpha = 5\% \). Descriptive analyses were also conducted for other parameters.

The soil in the site experiment was classified as Plinthic Hapludox, a loam soil texture, with low soil pH of 4.5 followed by low soil carbon content (< 1.5%). Previous research has proved that organic matter application could increase soil pH, P available, and CEC and decrease Al³⁺ concentration [13,14]. This site also showed low soil N-total, P, and K potential, exchangeable K, CEC, and base saturation, meanwhile, Al saturation (52%) was
categorized as medium. These soil chemical properties in acid upland soil limit maize productivity [15], and the minimum level of Al saturation for maize is 30%.

3 Result and Discussion

3.1 Maize Growth and Yield

Dolomite application at 1000 kg ha\(^{-1}\) could significantly increase plant height compared to the control (Fig. 1). However, the application of dolomite at higher dosages (1500 and 2000 kg ha\(^{-1}\)) did not lead to a significant increase in plant height at the first planting season (PS-1). In contrast to PS-1, the dolomite application at a dosage of 2000 kg ha\(^{-1}\) at the second planting time (PS-2), significantly increases plant height compared to the control.

These results are similar to research in Timor Leste in 2016, where the application of 320 kg ha\(^{-1}\) of dolomite increased the number of pods, plant dry weight, 100 seed weight, and green bean seed dry weight [16].

![Fig. 1. Maize height which dolomite application at in the first and second seasons.](image)

Applying dolomite as 500 kg ha\(^{-1}\) increased maize yield significantly compared to the control (Fig. 2). However, the application of dolomite of more than 500 kg ha\(^{-1}\) showed no significant difference in the yield. Dolomite application at < 1000 kg ha\(^{-1}\) showed an increase in dry maize weight, at >1000 kg ha\(^{-1}\) showed a flattened yield then tended to decrease at 1750 kg ha\(^{-1}\). The maximum corn yield of 11.07 t ha\(^{-1}\) occurred in the application of dolomite 1550 kg ha\(^{-1}\). Based on the correlation equation, showed that the optimum dosage of dolomite at acid upland soil that has been applied rock phosphate previously is around 1000 kg ha\(^{-1}\) (Fig 3).

![Fig. 2. Maize yield and biomass in the first and second seasons.](image)
several studies, where the application of dolomite can increase soil pH [17–20]. This current research is in line with rock phosphate, after one week application should be followed with the dolomite application. Dolomite application will significantly affect soil with low pH (<5.5). To improve the effectiveness of dolomite ha-1 treatment, the same pattern also occurred in 2000 compared to 1500 kg ha-1 at 15 DAP (Table 1). Soil pH increased to 0.47, 0.79, and 0.97 units at 15, 30, and 90 DAP respectively. This current research is in line with several studies, where the application of dolomite can increase soil pH [17–20].

Fig. 3. Correlation between dolomite dosage and maize wet grain in the first and second seasons.

### 3.2 Nutrient Content Improvement

Dolomite as soil ameliorant contains Ca and Mg significantly increased soil pH at 15 DAT with 2000 kg ha⁻¹, at 30 and 90 DAP with 1500 kg ha⁻¹ (Table 1). Soil pH increased to 0.47, 0.79, and 0.97 units at 15, 30, and 90 DAP respectively. This current research is in line with several studies, where the application of dolomite can increase soil pH [17–20].

Table 1. The effect of the dolomite application on soil pH at first planting time.

<table>
<thead>
<tr>
<th>Dolomite dosage (kg ha⁻¹)</th>
<th>15 DAP</th>
<th>30 DAP</th>
<th>90 DAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4.56 b</td>
<td>4.53 c</td>
<td>4.45 c</td>
</tr>
<tr>
<td>500</td>
<td>4.50 b</td>
<td>4.53 c</td>
<td>4.33 c</td>
</tr>
<tr>
<td>1000</td>
<td>4.59 b</td>
<td>4.66 bc</td>
<td>4.40 c</td>
</tr>
<tr>
<td>1500</td>
<td>4.67 b</td>
<td>4.85 b</td>
<td>4.73 b</td>
</tr>
<tr>
<td>2000</td>
<td>5.03 a</td>
<td>5.32 a</td>
<td>5.42 a</td>
</tr>
<tr>
<td>CV (%)</td>
<td>4.49</td>
<td>6.25</td>
<td>5.42</td>
</tr>
</tbody>
</table>

This means values having the same letter in one column are not significantly different at 5% DMRT statistic analysis. DAP: days after planting.

Morocco rock phosphate contains 27.70% - 31.20 P₂O₅ [21,22]. Rock phosphate application will significantly affect soil with low pH (<5.5). To improve the effectiveness of rock phosphate, after one week application should be followed with the dolomite application. Current research showed that applying dolomite at varied dosages could not increase soil P concentration (Table 2).

Table 2. Soil Available P after dolomite application in the first planting time.

<table>
<thead>
<tr>
<th>Dolomite dosage (kg ha⁻¹)</th>
<th>15 DAP</th>
<th>%¹</th>
<th>30 DAP</th>
<th>%¹</th>
<th>90 DAP</th>
<th>%¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>271.71 a</td>
<td>254.62 a</td>
<td>309.68 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>319.32 a</td>
<td>17.5</td>
<td>282.36 a</td>
<td>10.9</td>
<td>273.29 a</td>
<td>-11.8</td>
</tr>
<tr>
<td>1000</td>
<td>327.67 a</td>
<td>20.6</td>
<td>271.89 a</td>
<td>6.8</td>
<td>315.08 a</td>
<td>1.7</td>
</tr>
<tr>
<td>1500</td>
<td>308.48 a</td>
<td>13.5</td>
<td>260.86 a</td>
<td>2.5</td>
<td>302.66 a</td>
<td>-2.3</td>
</tr>
<tr>
<td>2000</td>
<td>297.73 a</td>
<td>9.6</td>
<td>225.96 a</td>
<td>-11.3</td>
<td>268.49 a</td>
<td>-13.3</td>
</tr>
<tr>
<td>CV (%)</td>
<td>23.29</td>
<td>26.21</td>
<td>19.70</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This means values having the same letter in one column are not significantly different at 5% DMRT statistic analysis. DAP: days after planting. ¹increasing/decreasing to control.

Dolomite application as 2000 kg ha⁻¹ significantly increased soil exchangeable Ca compared to the control. Dolomite application at 1500 kg ha⁻¹ significantly increased soil exchangeable Mg compared to control and increased as the dosage of dolomite increased up to 2000 kg ha⁻¹ (Fig. 4). Previous research showed a similar result, that dolomite application...
at acid soil in Centre Lampung could increase soil pH, increase soil Ca and Mg and decrease soil Al³⁺ [23].

Dolomite application at 2000 kg ha⁻¹ significantly increased total cation compared to 0 – 1500 kg ha⁻¹ at 15 DAP (Fig. 5). The different pattern of total cation showed that 1500 kg dolomite ha⁻¹ at 30 and 90 DAP increased total cation significantly compared to 1000 kg dolomite ha⁻¹ treatment, the same pattern also occurred in 2000 compared to 1500 kg dolomite ha⁻¹ treatment. A high concentration of Al in acid upland soil could fix P and not available for plant absorption, antagonistic reaction with K at soil site sorption which leads to decreasing of soil K.

The result showed that at 15 DAP, dolomite application as 2000 kg ha⁻¹ significantly decreased Al saturity compared to others, meanwhile at 30 and 90 DAP, dolomite application at 1500 kg ha⁻¹ gave significant effect on decreasing Al saturity compared to 0 and 500 kg dolomite ha⁻¹ treatments. Dolomite at dosage 2000 kg ha⁻¹ decreased Al saturity significantly compared to 1500 kg dolomite ha⁻¹ treatment (Fig. 5). A high concentration of Al could cover the root surface and interfere with nutrient uptake.

![Fig. 4. Exchangeable Ca and Mg content after dolomite application in the first season.](image1)

![Fig. 5. Cation total and Al saturation after dolomite application in the first season.](image2)

Dolomite application at acid upland soil that has been applied rock phosphate as 1 t ha⁻¹ could increase soil pH and decrease Al³⁺ concentration and saturation. Rock phosphate is a fertilizer that contains high Ca as 30.1%, 48.4 – 55.8% CaO [9]. Meanwhile dolomite as soil ameliorant contains 29.69% CaO and 21.17% MgO [23]. As a soil ameliorant, application of dolomite at acid upland soil that has been applied rock phosphate 1 t ha⁻¹ could increase soil pH (Fig. 5), exchangeable Ca, and Mg.

### 4 Conclusions

Dolomite application on acid upland soils Plinthic Hapludox which was the rock phosphate application was able to

1. Increase plant height, corn yield, and biomass in both the first and second planting seasons. Soil pH, exchangeable Ca and Mg, and total cations increased while exchangeable Al and saturation decreased.
2. The optimal dosage of dolomite on acid upland soils, on which rock phosphate has previously been applied, is 1000 kg ha⁻¹.
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