Liming of acid soil and the interaction with soil pH and corn productivity

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Abstract. Liming is the dominant technology to treat acidic soils, which is indicated by low soil pH. Improvement of soil pH can be made using dolomite application to overcome aluminum (Al) toxicity and release phosphate and potassium nutrients to become available for plants. This study aims to test the effectiveness of dolomite in improving soil pH, corn productivity, and dolomite dose. Field testing was done in Pasar VI Kwala Mencirim Village, Sei Bingai District, Langkat Regency, North Sumatra from April to August 2020 using a non-factorial randomized block design with seven treatments and four replications: Dolomite 0 X (D0) 0 ton ha\(^{-1}\), Dolomite 0.5 X (D1) 1 ton ha\(^{-1}\), Dolomite 1.0 X (D2) 2 ton ha\(^{-1}\), Dolomite 1.5 X (D3) 3 ton ha\(^{-1}\), Dolomite 2.0 X (D4) 4 ton ha\(^{-1}\), Dolomite 2.5 X (D5) 5 ton ha\(^{-1}\), and Standard Dolomite (DS) 2 ton ha\(^{-1}\). Dolomite treatment was given one week before planting by sowing evenly on the experimental plot. The results showed that dolomite application to D1, D2, D3, and D4 could increase soil pH, resulting in higher plant height and corn production than D0 and DS. The optimum dose of dolomite is 2 ton ha\(^{-1}\) on acid soils. Liming acid soil can increase soil pH from acid to neutral and increase corn production by 1.91 times compared to without dolomite application.

1. Introduction
Acid dry land is characterized by pH <5.0 and base saturation <50%. Soils with an acidic pH in dry land are Entisols, Inceptisols, Ultisols, Oxisols, and Spodosols with wet climates and high rainfall [1]. The area of acid dry land in Indonesia is 102.8 million ha or 69.4% of the total dry land [2].

Low soil pH is associated with high Al levels, causing high phosphorus (P) fixation to become unavailable to plants. The content of alkalis is exchangeable, and cation exchange capacity (CEC) is also low. The iron (Fe) and manganese (Mn) content is close to poisoning limits and is deficient in biotic elements [3, 4].

To overcome low soil pH, liming is the dominant conventional technology used. Prevention of soil acidity in acid soils is primarily done to treat Al poisoning. Lime given to the soil will bind Al and Fe elements, which if the levels are excessive it will be toxic to plants. Increasing soil pH will also free P and potassium (K), originally bound to become free and available to plants.

Dolomite is a limestone containing magnesium carbonate (MgCO\(_3\)) in an amount approximately equivalent to the stone's calcium carbonate (CaCO\(_3\)) content. Limestone containing MgCO\(_3\) in lesser proportions is referred to as Mg limestone or dolomitic limestone. Pure dolomite is 54.3% CaCO\(_3\) and 45.7% MgCO\(_3\) or, expressed another way, is composed of 30.4% CaO, 21.8% MgO, and 47.8% CO\(_3\)\(^{-2}\) [5].
Following the conditions for the circulation of soil amendments regulated by the Regulation of the Minister of Agriculture Number 01 of 2019, where each fertilizer and soil repairer to be marketed must go through a quality and effectiveness testing, lime to be traded must be tested first. According to the Minister of Agriculture Regulation Number 01 of 2019, the principle of testing is by providing ameliorant treatment on soils with low pH or low CEC following the use of a soil repairer. The effectiveness of soil amendments can be seen from soil amendments' application on the soil's physical or chemical properties and its impact on plants. This study aims to test the effectiveness of dolomite in improving soil pH, corn productivity, and dolomite dose.

2. Methods

2.1. Scope
The scope of testing includes soil sampling for analysis of soil chemical properties, including pH, H₂O, Al exchangeable (Alexch), nitrogen (N), P, K, calcium (Ca), magnesium (Mg), Fe; by calculating the need for soil amendment according to the results of soil pH; preparing experimental designs for planting activities in the field; implementation activities starting from tillage to harvest; and generating the effectiveness test reports.

2.2. Location and time
Field testing was carried out on the land owned by farmers in Pasar VI Kwala Mencirim Village, Kec. Sei Bingai, Langkat Regency, North Sumatra starting from April to August, 2020. The dolomite quality test was implemented at the Indonesian Oil Palm Research Institute (IOPRI) Laboratory. Soil analysis test was carried out at the Assessment Institute for Agricultural Technology (AIAT) North Sumatra Laboratory.

2.3. Materials and tools
The materials used in this study were hybrid corn seeds, dolomite (which were tested for its effectiveness), urea fertilizers, SP36, and KCl as standard fertilizer treatments.

The tools used included cultivation tools (hoes, wooden dibber, rakes, sprayers, and gauges), tape measures, and scales.

2.4. Procedure
Testing the effectiveness of dolomite was carried out in the low pH soils and corn plants as indicator crops. This study used a non-factorial randomized complete block design with seven treatments. The number of repetitions is following the formula (p-1) (u-1) ≥ 15 so that four replicates were obtained, where (7-1) (4-1) ≥15. The dolomite dose level treatments carried out were dolomite 0 X (D0) dose 0 ton ha⁻¹, dolomite 0.5 X (D1) dose 1 ton ha⁻¹, dolomite 1.0 X (D2) dose 2 ton ha⁻¹, dolomite 1.5 X (D3) dose 3 tons ha⁻¹, dolomite 2.0 X (D4) dose 4 tons ha⁻¹, dolomite 2.5 X (D5) dose 5 tons ha⁻¹, and standard dolomite (DS) dose 2 tons ha⁻¹.

Dolomite was expected to improve soil chemical properties, especially improving soil pH and increasing corn's plant height and yield. Dolomite dosage recommendation was determined based on Alexch, where the analysis showed that the Alexch value was 2.1 me 100 g⁻¹. The average dose of lime needed for one me was 1 ton ha⁻¹, so for an Alexch value of 2.1 me, the dose of lime was 2 ton ha⁻¹. Dolomite treatment was given one week before planting by sowing evenly on the experimental plot.

Urea fertilizer 350 kg ha⁻¹, SP36 100 kg ha⁻¹, and KCl 75 kg ha⁻¹ were given the basic treatment for all treatments for optimal plant height. Urea fertilizer was presented at the age of 7 to 10 days after planting and 30-35 days after planting. While SP36 and KCl were given once at the period of 7-10 days after planting. Observation of the sufficiency of N was carried out at the age of 45 days after planting using the Leaf Color Chart. Fertilizer application was made by burying it next to the plants in a plant row.
2.4.1. Observation parameters. The parameters observed in the soil analysis before the implementation of the test were soil texture (i.e., the percentage of sand, dust, and clay particles), pH of H₂O and KCl 1N (1: 5), C-organic and N-total, P₂O₅ and K₂O extracted HCl 25%, P₂O₅ available extractor depending on pH. After treatment, the parameters observed increased soil pH at weeks 2, 4, 6, 8, and 12 (soil pH H₂O 1: 2.5) and growth (plant height 2, 4, 6, and 8 weeks after planting). The yield parameter observed was corn production (kg ha⁻¹). The effectiveness of dolomite was assessed by comparing the Relative Agronomic Effectiveness (RAE) value of standard treatment with dolomite treatment.

2.4.2. Data processing. To the effect of the treatment given, the analysis used and analysis of variance (ANOVA) and a further test of significant differences between treatments using the Duncan Multiple Range Test (DMRT) at a 5% confidence interval for plant height and production data using IBM and SPSS software statistics 20. The results of soil pH measurements were made in graphic form. The effectiveness of the fertilizers tested was calculated using the Relative Agronomy Effectiveness (RAE) value. RAE is the ratio between the increase in yield due to the use of a fertilizer with the increase in yield with the use of standard fertilizers multiplied by 10⁰ [6] with the formula:

\[
\text{RAE} = \left[\frac{(\text{yield of tested fertilizer} - \text{control})}{(\text{yield of standard fertilizer} - \text{control})}\right] - 1 \times 100\% \quad (1)
\]

3. Results and discussion

3.1. The results of the dolomite
The quality test results showed that the dolomite had met the minimum technical requirements for dolomite based on SNI 02-2804-2005. The quality test results are shown in table 1.

Table 1. Dolomite quality test.

| Parameters          | Value (%) | Method                        |
|---------------------|-----------|-------------------------------|
| CaO a               | 30.09     | SNI 02.2804.2005              |
| MgO a               | 19.78     | SNI 02.2804.2005              |
| Al₂O₃ a             | 1.31      | Spectrophotometry             |
| Fe₂O₃               | 0.33      | AAS                           |
| SiO₂                | 0.92      | SNI 02.2804.2005              |
| Neutralization power a | 115.92   | SNI 02.2804.2005              |
| Fineness 25 mesh    | 100.00    | SNI 02.2804.2005              |
| Fineness 80 mesh    | 99.09     | SNI 02.2804.2005              |
| Water content       | 0.09      | SNI 02.2804.2005              |

a based on the dry weight.

SNI 02-2804-1992 is the Indonesian National Standard (SNI) which fosters dolomite fertilizer standards that aim to support government programs in the context of developing the fertilizer industry as well as protection of fertilizer producers and consumers, ensuring the quality of products guaranteed domestically with specified quality requirements and improve the competitiveness of domestic products with foreign products [7]. Atomic absorption spectrophotometry (frequently referred to as AAS) was elemental analytical chemistry to determine Ca, Mg, Cu, Fe, Mn, and Zn. The principle of operation is the reverse of that for emission in that absorption by ground-state atoms of emitted radiation from the same element is utilized [5].

3.2. Soil analysis prior to testing
The results of soil analysis are shown in table 2. The soil analysis results showed a low soil pH (acid) of 4.76 so that the application of dolomite is appropriate for the land. Soil C-organic content was very high. Total soil N is moderate, available soil P and K were low, Mg content was low, micronutrient
content was sufficient, and soil texture from calculating percentage sand, silt, and clay was classified as loamy sand (United States Department of Agriculture soil texture triangle).

Table 2. Soil characteristic prior to testing.

| Type of analysis | Unit  | Value   | Method             |
|------------------|-------|---------|--------------------|
| C-organic        | %     | 5.24    | IK 5.0 (Spectrophotometer) |
| N total          | %     | 0.54    | IK 6.0 (Kjeldahl)   |
| P Bray I         | ppm   | 6.56    | IK 7.0 (Spectrophotometer) |
| Kexch            | me 100 g⁻¹ | 0.13   | IK 8.0 AAS          |
| pH               |       | 4.76    | IK 3.0 (Electrometry) |
| Alexch           | me 100 g⁻¹ | 1.41   | IK 4.0 (Titrimetry) |
| Ca               | me 100 g⁻¹ | 3.35   | IK 8.0 (AAS)        |
| Mg               | me 100 g⁻¹ | 0.66   | IK 8.0 (AAS)        |
| Cu               | ppm   | 4.00    | IK 8.0 (AAS)        |
| Zn               | ppm   | 5.00    | IK 8.0 (AAS)        |
| Mn               | ppm   | 24.00   | IK 8.0 (AAS)        |
| Fe               | ppm   | 32.00   | IK 8.0 (AAS)        |
| Sand             | %     | 75.31   | IK 9.0 (Hydrometer) |
| Silt             | %     | 22.22   | IK 9.0 (Hydrometer) |
| Clay             | %     | 2.47    | IK 9.0 (Hydrometer) |
| CEC              | me 100 g⁻¹ | 28.77  | Distillation        |

The laboratory uses a standardized method or work instruction (IK) for all tests within its scope (IK Method) is generally accepted (international) and cannot be trusted or validated. The laboratory has the appropriate equipment and relevant equipment and approved handling and preparation of equipment.

3.3. Variable results of soil pH measurements

The effect of dolomite on soil pH has shown in table 3. The soil pH measurements showed that dolomite affected increasing soil pH at weeks 2, 4 and 6. Whereas at weeks 8 and 12, the increase in soil pH was no longer happening again. The highest increase in soil pH was at week 2 of treatment D4 (dolomite 4 ton ha⁻¹) and D5 (dolomite 2 ton ha⁻¹) of 5.77. There was an increase in soil pH by 0.98 from the control treatment without dolomite application. Furthermore, at week four, the soil pH reached 6.86 in treatment D5, and the soil pH became 7.0 at week 6.

Table 3. Soil pH measurements at 2, 4, 6, 8, and 12 weeks after dolomite application.

| Treatment | 2nd weeks | 4th weeks | 6th weeks | 8th weeks | 12th weeks |
|-----------|-----------|-----------|-----------|-----------|------------|
| D0        | 4.79      | 4.79      | 4.79      | 4.79      | 4.79       |
| D1        | 4.93      | 5.02      | 5.80      | 5.80      | 5.80       |
| D2        | 5.41      | 6.38      | 6.50      | 6.50      | 6.50       |
| D3        | 5.52      | 6.50      | 6.50      | 6.50      | 6.50       |
| D4        | 5.77      | 6.72      | 6.80      | 6.80      | 6.80       |
| D5        | 5.77      | 6.86      | 7.00      | 7.00      | 7.00       |
| D6        | 5.10      | 5.60      | 6.00      | 6.60      | 6.60       |

The pH value showed the concentration of H⁺ ions in the soil solution, which is expressed as –log[H⁺]. Increasing the concentration of H⁺ increased the potential of the solution as measured by the tool and was converted to the pH scale. Soils with a pH less than 6.6 are defined as acid soils, pH above
7.5 alkalines, and pH 6.6-7.5 neutral [8]. Acid soils need to be increased in pH to neutral soils so that nutrients become available to plants. Lime application to acidic soils has been shown to increase soil pH [9, 10, 11] and reduce Al saturation [12, 13, 14].

3.4. Analysis of the results of plant height measurements
The dolomite application on corn plant height was observed at 2, 4, 6, and 8 weeks after planting. The parameters observed were plant height. The results of ANOVA and DMRT analysis on corn plant height are shown in Table 4. ANOVA analysis showed that dolomite significantly affected corn plant height at weeks 2, 4, 6, and 8 days after planting compared to control treatment. The dolomite application on corn plant height compared to the control treatment (without dolomite) and standard dolomite was significantly different from weeks 4, 6, and 8.

| Treatment | 2nd week | 4th week | 6th week | 8th week |
|-----------|----------|----------|----------|----------|
| D0        | 12.5a    | 63.5a    | 112.5a   | 168.75a  |
| D1        | 13.375b  | 76.25b   | 115b     | 195a     |
| D2        | 13.75b   | 80c      | 138.75b  | 211.25b  |
| D3        | 13.375b  | 80c      | 118.75b  | 211.875b |
| D4        | 14.5b    | 82.5c    | 127.5b   | 206.875b |
| D5        | 15.25c   | 78.25c   | 137.5b   | 210b     |
| DS        | 13.375b  | 70a      | 115a     | 193.125a |

The numbers in the same column followed by the same letters show no significant difference according to the DMRT level of 5%.

The pH change in H⁺ ion concentration of the soil per se was not the reason plants respond differently to a change in soil pH. Still, the response was due to the change in concentration of elements in the soil solution and the change in availability of an element for root absorption [5]. Dolomite application on acid soils could increase nutrient concentration and took up more nutrients in the soil. Therefore, nutrients are easily absorbed by plants, and thus, it can increase the corn plant height. Lime application to acidic soils has been shown to increase plant height of corn [10, 15], soybean [11], peanut [12], and rice [13].

3.5. Analysis of the measurement of corn production
ANOVA analysis and further DMRT tests on corn production showed that dolomite application significantly affected corn production (cob without husk) compared to the control treatment (without dolomite) and standard dolomite treatment. The highest corn production was found in the D2 treatment (dolomite 2 ton ha⁻¹) of 8,050 kg ha⁻¹ and the lowest was in the control treatment, namely 4,210 kg ha⁻¹. Meanwhile, corn production between dolomite treatments was significantly different between D1 and D2 to D5 treatments. It showed that D1 treatment (dolomite 1 ton ha⁻¹) did not affect corn production. The effect of dolomite application on corn production has shown in Table 5.

Dolomite application did not directly provide nutrients and micronutrients for plants but directly affected soil pH. Soil pH significantly affects the two essential elements, such as P, and most micronutrients, Cu, Fe, Mn, Mo, and Zn. Besides, soil pH also influences nonessential elements such as Al, which can be toxic to plants at high concentrations [5]. Lime application to acidic soils has been shown to increase the production of corn [14], soybean [11], rice [13], and cassava [16].
Table 5. Corn production (cobs without husks).

| Treatment | Production (kg plot⁻¹) | Production (kg ha⁻¹) |
|-----------|------------------------|----------------------|
| D0        | 8.42a                  | 4,210a               |
| D1        | 11.9a                  | 5,950a               |
| D2        | 16.1b                  | 8,050b               |
| D3        | 11.05b                 | 5,525b               |
| D4        | 11.7b                  | 5,850b               |
| D5        | 11.27b                 | 5,635b               |
| DS        | 8.83a                  | 4,415a               |

The numbers in the same column followed by the same letters show no significant difference according to the DMRT level of 5%.

3.6. Analysis of the results of measuring the relative agronomic effectiveness
RAE is a measurement of the effectiveness of a fertilizer. Fertilizer is declared agronomically effective if it has a relative agronomic effectiveness value > 95%. If the relative agronomic effectiveness value is more than 95%, fertilizer application can increase the yield more excellent than the treatment without dolomite and fertilizers (standard dolomite). The RAE measurement results for dolomite applications show RAE values > 95% in all dolomite applications. The highest RAE value was in the D2 treatment (dolomite 2 ton ha⁻¹), namely 269%. The results of RAE calculations for all treatments can be seen in table 6.

Table 6. Value calculation of RAE (%).

| Treatment | RAE (%) |
|-----------|---------|
| D0        | -       |
| D1        | 137.2   |
| D2        | 269.4   |
| D3        | 122.3   |
| D4        | 196.7   |
| D5        | 203.3   |
| DS        | -       |

3.7. The criteria for passing the effectiveness test
The criteria for passing the dolomite effectiveness test are increasing soil pH, plant height, production, and passing the agronomic test with an RAE value > 95%. The test results show that dolomite can increase soil pH to decrease the soil's acidity and even approaches neutral. In addition, dolomite can also increase plant growth with higher plant height than the control treatment and standard dolomite treatment and increase maize production compared to the control treatment (without dolomite application) and dolomite standard treatment. The RAE value of all tested dolomite treatments was > 95% (table 6), meaning that the dolomite passed the effectiveness test criteria.

3.8. General discussion
In this test, the use of the dolomite could improve soil properties by increasing soil pH. Soil pH shows the level of soil acidity. Low pH indicates high acidity. According to [17], Al poisoning is the most important growth-limiting factor in acid soils, particularly those with low pH values. Applying lime to acidic soils can increase soil pH by decreasing levels of interchangeable Al. Using lime with the right amount can reduce the activity of H⁺ ions in the soil, so that the pH can increase. In addition, to increase soil pH, the lime application also supplies Ca and Mg to the soil. It stimulates the activity of microorganisms and, in turn, could accelerate the degradation of organic matter, increases the availability of P, increases N fixation by soil and soil organisms, improves soil physical properties, and
reduces the activity of elements that can toxic the plants [18]. Therefore, dolomite application to acid soil can increase plant growth. As obtained from the test results, dolomite application can increased plant height compared to control treatment (without dolomite). Likewise, application dolomite gave higher yields for corn crop production than control treatment (without dolomite) and standard dolomite treatment.

4. Conclusions
The results show that the application of the dolomite can increase soil pH in acid soils. The dolomite provision resulted in higher plant height and higher corn production than the control treatment (without dolomite) and standard dolomite treatment. Based on the calculation of relative agronomic effectiveness (RAE), it is known that all dolomite treatments have RAE > 95%. Therefore, the optimum dose of dolomite that can be applied is 2 ton ha⁻¹ on acid soils.

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