The effectiveness of aglime ameliorant to improve soil pH and maize (*Zea mays* L.) growth and production in Langkat Regency

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Abstract. Tropical climatic conditions accompanied by high rainfall are supporting factors for soil acidification in Indonesia's drylands. One of the conventional management technologies that are most widely used to improve soil acidity is liming. This study observed the effectiveness of various doses of Aglime ameliorant for improving acid soil and its effect on the growth of maize (*Zea mays* L.). The study was conducted in Pasar VI Kwala Mencirim Village, Sei Bingai District, Langkat Regency, North Sumatra from June to October 2020. The experimental design of this study was a non-factorial randomized bock design consisted of 7 treatments of Aglime ameliorant dosage with four replications. The results showed that the application of various doses of Aglime ameliorant was able to increase soil pH, height, and maize production which the highest pH value, height, and production were obtained at Aglime dose of 5 tons Ha^{-1} (AL 5). The effectiveness of Aglime ameliorant to increase soil pH is reflected in the relative agronomic effectiveness (RAE) which is overall > 95% (101,7 – 274,5%) for the tested Aglime dose of 1 to 5 tons per hectare (AL1-AL5).

1 Introduction

Dryland in Indonesia based on its climatic conditions is divided into wet climate and dry climate dry land with an area of 133,722,331 and 10,750,881 hectares, respectively [1]. Approximately 78.71% of the wet climate dry land area is acidic, while only 23.17% of the dry climate dry land is acidic. The higher percentage of soil acidification in wet climate dryland was caused by the leaching of alkaline cations due to high rainfall. Utilization of acid dry land as agricultural land has several main obstacles related to low soil fertility including low pH and organic matter, deficiency of P, K, Ca, and Mg as well as the availability of toxic elements that have the potential to poison crops such as high Al, Fe and Mn [2]. These toxic Al and Fe ions will bind macronutrients, especially P (phosphorus) and S (sulfur) elements so that they become unavailable to plants even though the amount in the soil is abundant. High soil acidity is also related to the high availability of micro-elements that have the

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potential to poison plants such as zinc (Zn), copper (Cu), and cobalt (Co) [3], low exchangeable bases, and CEC of base saturations <50%, the iron, and manganese content is close to toxicity limits and is poor in biotic elements [4].

Maize is one of Indonesia's strategic food crop commodities with a self-sufficiency target in 2017 [5]. The Ministry of Agriculture through the UPSUS program succeeded in increasing maize production in 2015 by 47.48% in 2017 (28.92 million tons), but this production decreased again in 2019 by 21.88% to 22.59 million tons [6]. One of the factors that influenced this decline was land-use competition due to limited land because it is known that Indonesia's self-sufficiency target is not only for maize but also for rice and soybeans. One of the available solution is to use suboptimal land such as acid dry land but as previously mentioned, soil acidification in dry land can be an inhibiting factor, so to overcome this, varieties selection and liming are solutions that are commonly used. The variety used in this study was the Bisi18 hybrid maize. [7] reported that the use of the Bisi-18 variety on acid dry land without land quality management had no effect on plant height but had an effect on maize production with a production difference of up to 26.31% (2.4 tons) with the management of biochar applications. To support the production of the varieties used, liming to increase soil pH is required.

Liming is a conventional technology that is most widely applied to increase soil pH. One of the materials that can be used in liming acid soils besides dolomite is Aglime. Aglime does not contain magnesium like dolomite. To be precise and efficient, the dose can be determined based on the soil Al-dd value while its effectiveness can be achieved through the application of mixing it into the 20 cm soil layer [8]. The Aglime application will increase the pH of acidic soil which further has an impact on increasing available soil P, Ca content, and decreasing Al-dd levels in the soil in alluvial lowland soils [8]. The application of lime on acidic dry land was able to increase height, number of filled pods per clump, and soybean production and increase Ca content in the soil [9]. The quality of Aglime is an important factor in increasing the effectiveness of Aglime in increasing acid soil pH and supporting plant growth. Characteristics to determine the quality of Aglime that are commonly used include purity, fineness, and type of lime material because it is related to the speed of solubility and acid-neutralizing capacity of the Aglime. Based on the description above, this research was carried out to observe the effectiveness of doses of lime ameliorant on improving acid soil pH and its effect on the growth of maize (*Zea mays* L.).

2 Materials and methods

2.1 Location and experimental set-up

The research was conducted on farmer's dry land in Pasar VI Kwala Mencirim Village, Sei Bingai District, Langkat Regency, North Sumatra from June to October 2020. The materials used were hybrid maize seeds, Aglime ameliorant, inorganic fertilizers (SP36, Urea, and KCl) were used as the standard treatments. The cultivation tools used were sprayers and hoes rakes and also other tools such as scale, tape measure, sack, plastic, book, and stationery. The devices used to process research data were computers and IBM SPSS 20 statistical software.

The research of the effectiveness of Aglime ameliorant was carried out on acid soils and used maize as an indicator crop. The experimental design of this study was a non-factorial randomized bock design consisted of 7 treatments and 4 replications. The Aglime dose was determined by the soil Al-dd value in a ratio of 1:1, which is an average of 1 ton Ha^{-1} for the soil Al-dd value of 1 me 100 g^{-1}, this is in accordance with [8]. Accordingly, for the soil Al-dd value of 2.1 me 100 g^{-1} (Table 3), the Aglime doses in this study was determined to be 2 tons Ha. Based on the recommendation Aglime dose (2 tons Ha^{-1}), the treatment doses was

determined to be 0.5;1; 1.5;2; and 2.5 times of the recommended dose as shown in Table 1. The Aglime will be applied 1 week before planting by sprinkled it evenly on each experimental plot.

Table 1. Treatment levels of Aglime dose (ton Ha^{-1})

No	Treatment	Code	Dose (ton Ha^{-1})
1	Ag Lime 0 Recommendation	AL0	0
2	Ag Lime 0.5 Recommendation	AL1	1
3	Ag Lime 1.0 Recommendation	AL2	2
4	Ag Lime 1.5 Recommendation	AL3	3
5	Ag Lime 2.0 Recommendation	AL4	4
6	Ag Lime 2.5 Recommendation	AL5	5
7	Standard Aglime	ALS	2

The number of fertilizers applied to all treatments as basal fertilizers to support optimal plant growth were Urea 350 kg Ha^{-1}, SP36 100 kg Ha^{-1}, and KCl 75 kg Ha^{-1}. Urea fertilizer was applied at 7-10 and 30-35 days after planting (DAP), while SP-36 and KCl were applied once at 7-10 DAP. The fertilizers were applied by buried next to the plants in a row of plants.

2.2 Observation and data analysis

The soil and Aglime parameters observed were initial soil analysis consisted of textures, soil pH H_2O and KCl, organic C, total N, P, K, and available P (Table 2); initial Aglime analysis consisted of $CaCO_3$, CaO, Al_2O_3+ Fe_2O_3, Pb, Cd, Hg, As, and fineness on 6 and 60 Mesh (Table 3); the increase of soil pH on 2nd, 4t, 6th, 8th, and 12th week; and the effectiveness of Aglime ameliorant by comparing the RAE value of standard treatment with Aglime treatment. The crop parameters observed were plant height and corn cobs production.

Soil pH data on the 2nd, 4th, 6th, 8th, and 12th weeks are presented in graphical form. Analysis of variance (ANOVA) was used to analyzed data of plant height and maize cobs production. Significances differences between treatments were analyzed using the Duncan Multiple Range Test (DMRT) at a 95% confidence level. The Relative Agronomy Effectiveness (RAE) value was used to calculate the effectiveness of Aglime. RAE is the ratio between the increase of yield due to the use of a fertilizer with the yield increase with the use of standard fertilizers multiplied by 100, with the formula [10]:

$$\text{RAE} = \frac{Yield\ of\ tested\ fertilizer - control}{Yield\ of\ standard\ fertilizer - control}\ x\ 100\%$$

3 Results and discussions

3.1 The quality of Aglime ameliorant

The quality test of the Aglime ameliorant was conducted in the Indonesian Oil Palm Research Laboratory. The analysis results presented in Table 2 showed that the Aglime used has met the criteria required in Indonesian National Standard 482:2018. Based on its content, Aglime is mostly used by farmers is divided into calcite and dolomite. The analysis results in table 2 showed that the Aglime tested is calcite, which mostly contains $CaCO_3$, while dolomite contains a mixture of $CaCO_3$ and $MgCO_3$. By the unit weight, $CaCO_3$ has a lower neutralizing capacity than $MgCO_3$, but the dissolution reaction rate is higher [11] following the statement of Stevens and [12] that the solubility of calcite is about 2 times faster than dolomite.

Fineness is one of the important physical criteria related to the effectiveness and efficiency of Aglime, it is shown in Table 2 that 100% of the Aglime used passes a 60 mesh sieve. [13] stated that the finer the Aglime is applied, the faster the reaction between Aglime and soil in increasing soil pH so the amount of lime needed will reduce. [14] added that the dissolution reaction of Aglime is influenced by the surface area where the greater the surface area per unit weight of Aglime in contact with the soil, the solubility and effectiveness in increasing the pH also increases.

Table 2. The results of the Aglime ameliorant quality analysis

Parameters	Method	Unit	Value	Value-based on INS 482:2018
$CaCO_3$	Calculation	%	98.77	-
CaO	AOAC.917.01.2016	%	55.35	Min 44
Al_2O_3+ Fe_2O_3	AOAC.964.01.2016	%	0.48	Max 1.5
Pb	AAS	ppm	<0.06	Max 50
Cd	AAS	ppm	<0.002	Max 10
Hg	AAS	ppm	<0.01	Max 1
As	AAS	ppm	<0.002	Max 10
Fineness 6 Mesh	Sieve	%	100.00	-
Fineness 60 Mesh	Sieve	%	100.00	Min 55

**) Based on the dry weight*

3.2 Soil analysis

The initial soil analysis was conducted in the Soil and Plant Laboratory of Assessment Institute for Agricultural Technology (AIAT) North Sumatra. The results of the initial soil analysis are listed in the Table 3 and the criteria are determined according to [15]. The soil pH is acidic (4.76), so the application of Aglime to increase soil pH is required. Soil organic C content, total N, available P, K, Ca, and Mg were high, moderate, low, very low and low respectively while the micronutrients such as Cu, and Zn were sufficient; Mn was very high, Fe was high, and CEC was moderate. The soil texture was loamy sand (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167).

Table 3. The results of initial soil analysis

Parameters	Value	Analysis Method
Organic C (%)	3.22	IK 5.0 (Spectrophotometer)
Total N (%)	0.32	IK 6.0 (Kjeldahl)
P Bray I (ppm)	8.71	IK 7.0 (Spectrophotometer)
K-dd (me/100 g)	0.33	IK 8.0 AAS
pH	4.34	IK 3.0 (Electrometry)
Al-dd (me/100 g)	2.10	IK 4.0 (Titrimetry)
Ca (me/100 g)	1.03	IK 8.0 (AAS)
Mg (me/100 g)	0.40	IK 8.0 (AAS)
Cu (ppm)	1	IK 8.0 (AAS)
Zn (ppm)	6	IK 8.0 (AAS)
Mn (ppm)	31	IK 8.0 (AAS)
Fe (ppm)	31	IK 8.0 (AAS)
Textures Sand (%) Silt (%) Clay (%)	 81.71 16.00 2.29	IK 9.0 (Hydrometer)
CEC (me/100 g)	20.60	Direct distillation

3.3 Soil pH measurements

Soil pH is an early indicator of soil fertility that describes the level of soil acidity and alkalinity which its value determined by the concentration of H^+ ions in the soil. As a master soil variable, pH has a very important influence on various soil properties (physical, chemical, biological) and reactions that contribute to plant growth and production [16]. Neutral soil pH ranging from 6.5 to 7.5 is the best pH value for plants because in this pH range there is an equilibrium between macro and micronutrients in the soil. [17] explained that soil pH affects nutrient availability either directly by increasing the availability of Mn, Zn, Zu, and Fe and decreasing N, K, Ca, Mg, and S at low pH or indirectly increasing the availability of P and B at low and high pH. In addition, high concentrations of toxic elements such as Al in acid soils can affect the performance of plant roots to absorb nutrients thereby limiting plant growth and production [18].

It is shown in Table 4 that Aglime application affects increasing soil pH on the 2nd, 4th, 6th, 8th, and 12th week. The highest increase in soil pH in the 2nd week was found in AL4 and AL5 treatments of 1.73 and 2.43 respectively from the initial soil pH to 6.07 and 6.77 with slightly acid and neutral categories. Table 4 showed that up to the 12th week, the highest soil pH value was shown in AL4 (6.98) and AL5 (7.12) treatments with a total increase of 60.82 and 64.05 % respectively compared to the initial soil pH value. The increasing of soil pH by

Aglime occurs because the H^+, Fe^{2+}, Al^{3+}, Mn^{4+}, and Cu^{2+} ions at the adsorption site are replaced by Ca2+ and or Mg2+ ions depending on the type of lime [19].

Table 4. Soil pH measurement on 2nd, 4th, 6th, 8th, and 12th week after Aglime application

Treatment	pH				
	2nd week	4th week	6th week	8th week	12th week
AL0	4.34	4.34	4.34	4.34	4.34
AL1	5.36	5.44	5.8	5.91	5.95
AL2	5.66	5.82	6.5	6.6	6.67
AL3	6.03	6.73	6.5	6.55	6.59
AL4	6.07	6.79	6.8	6.9	6.98
AL5	6.67	6.97	7.0	7.05	7.12
ALS	5.84	5.72	6.0	6.2	6.41

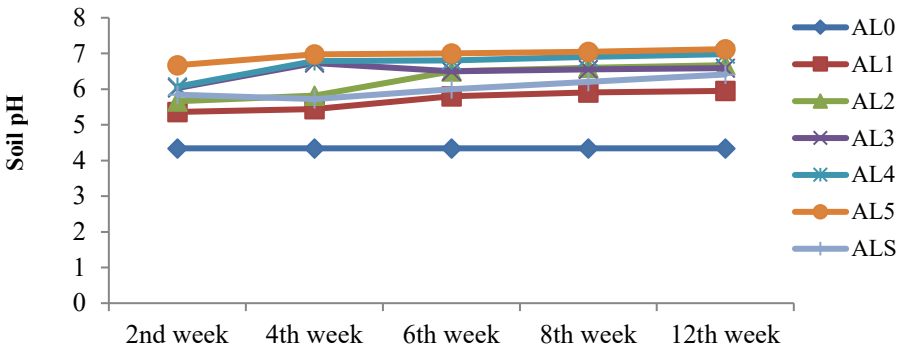

Fig 1. Graph of pH soil changes

3.4 Plant height

It was found that plant height was significantly affected by the application of Aglime at weeks 2, 4, 6, and 8 compared to the control treatment (Table 5). Increasing the Aglime dose in this study positively increased the height of the maize plant where the average value of the maize plant height in the application of Aglime doses of 4 and 5 tonnes Ha^{-1} for the entire observation time was not significantly different. Generally, the application of Aglime (AL1-AL4) showed a higher height than the control but not for the standard Aglime treatment. The effect of Aglime application on higher maize height was also reported by other researchers such as [20,21,22]. The increase in the availability of most of the nutrients needed by maize due to the increase in pH by liming has a positive impact on the growth of maize plants [23]. Increasing the pH value of the soil in the range of 6-7 as in this study contributes to the increase and absorption of plant nutrients such as N and P, which each function to increase vegetative growth and plant roots [24].

Table 5. Analysis results of maize plant height in Week After Planting (WAP)

Treatment	Height			
	2 WAP	**4 WAP**	**6 WAP**	**8 WAP**
AL0	11,25c	62.75d	108.75e	200d
AL1	13.25b	70.50c	115.75d	205c
AL2	13.87b	72.25c	120.50c	212.50b
AL3	14.37a	74.75b	124.25b	216.25b
AL4	14.75a	78.25a	128.25a	216.87a
AL5	15a	78.75a	128.25a	220.62a
ALS	13.62b	72.25c	117.50d	208.75c

Note: This means follow different letter (s) along the same column are statistically different based DMRT test at p = 0.05

3.5 Maize production (cobs without husks)

It was revealed that maize production was significantly affected by the application of Aglime to the soil. The highest maize production was found in the AL5 treatment (Aglime 5 tons Ha^{-1}) with a total production of 6337.5 tons Ha^{-1} while the lowest production was found in the control treatment of 4312.5 tons Ha^{-1}. The average maize production in AL1 treatment was not significantly different from the control (AL0) and standard Aglime (ALS) treatment but was significantly different from other treatments (AL2-AL5). The average maize production is at 1 ton Ha^{-1} (AL1). Aglime dose treatment was not significantly different from the 2 and 3 ton Ha^{-1} Aglime dose treatment (AL2 and AL3) also the standard lime treatment 1 ton Ha^{-1} (ALS) but significantly different from the maize production average on treatment doses 4 and 5 ton Ha-1 (AL4 and AL 5). Compared to the average maize production in the control treatment, the application of Aglime was able to increase the average maize production by 2.50-10.31 %.

According to the data in Table 6, the increase in the Aglime dose actually increases maize production, this is related to the effect of increasing pH on increasing the availability of K macronutrient which plays an important role in improving growth and increasing crop yield [25]. Increasing the Aglime dose will increase the concentration of Ca nutrients in the soil. Ca nutrient has an antagonistic interaction with K nutrient so that the balance of its concentration in the soil needs to be considered so as not to interfere with each other [26]. However, in this study, it was shown that the antagonism of the two nutrients did not occur, which may be due to the soil texture which is dominated by sand (Table 3). Putra [27] explained that due to the difference in valence, the increase in Ca due to lime application contributed to K fixation in soils with high clay content.

Table 6. Analysis results of maize production (cobs without husks)

Treatment	Production kg $plot^{-1}$	Production kg Ha^{-1}
AL0	8.6d	4321.5d
AL1	10.1c	5062.5c

Treatment	Production kg plot^{-1}	Production kg Ha^{-1}
AL2	10.3c	5137.5c
AL3	10.8c	5375c
AL4	11.4b	5687.5b
AL5	12.7a	6337.5a
ALS	10.1c	5050c

Note: Means follow different letter (s) along the same column are statistically different based DMRT test at p = 0.05

3.6 Relative agronomic effectiveness (RAE)

Fertilizer effectiveness which is calculated as relative agronomic effectiveness (RAE) is based on the vegetative growth rate, production, and/or quality of agricultural products [28]. Expressed as a percentage, the relative agronomic effectiveness (RAE) value is the ratio between the increasing yield due to the application of the tested fertilizer and the increasing yield with the application of a standard or recommended fertilizers. A fertilizer is declared to be agronomic effective if it has a relative agronomic effectiveness value above the relative agronomic effectiveness value of standard fertilizer (100%) [29]. Table 7 shows the RAE value > 100% for all Aglime application doses with the highest RAE value (274.5 %) was shown in the AL5 treatment (5 tons Ha^{-1}). This indicated that the AL5 treatment in this study was the most effective in increasing soil pH which supported the growth and production of maize.

Table 7. Measurement results of Relative Agronomic Effectiveness (%)

Treatment	**Relative Agronomic Effectiveness (%)**
AL0	-
AL1	101.7
AL2	111.8
AL3	144
AL4	186
AL5	274.5
ALS	100

The effectiveness of lime to increase soil pH is determined by various internal factors including source, purity, characteristics, fineness, dosage, and composition as well as external factors such as method, time, frequency, and depth of application [30]. The effect of the dose is clearly seen in table 7 where the more Aglime is applied, the higher the RAE value. The effect of the dose is also supported by the characteristics of the Aglime used. Regarding it's characteristics which is difficult to dissolve, the fineness of Aglime and incubation time affect the increase in soil pH. This statement is supported by [14] in their research that the increase in soil pH is in line with the increase in incubation time and lime fineness where the value of the increase is greater in Aglime than dolomite. The same pattern was found in the results of this study, as shown in table 4, it can be seen that there was an

increase in soil pH with a change of 0.45-1.01 after 10 weeks (comparison of soil pH data from 2 to 12 WAP). The fineness of the Aglime used in the study that passed the 60 mesh sieve indicates that the lime has a large surface area in contact with the soil when applied and according to [14] has the potential to provide a maximum pH increase value.

4 Conclusions

The test results showed that the application of Aglime was able to increase the pH value of acidic soil to slightly acidic and neutral. The increase in pH due to the application of Aglime in this study further gave higher maize production and plant height compared to treatments of control and standard Aglime application. The relative value of agronomic effectiveness (RAE) for all treatments of tested agricultural lime doses was > 100%. Based on the parameters tested, the dose of 5 tons Ha^{-1} is the dose that gives the maximum contribution on soil pH, growth, and maize production on acid dry land.

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