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The Effectiveness of Heated and Acidified Volcanic Ash on Exchangable K, Ca, Mg of Soil, and Kcl Efficiency for Growth and Yield of Corn (Zea Mays L)

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Abstract

Volcanic ash contains minerals rich in nutrients K, Ca, Mg, and others that can improve soil quality. K element of weathered volcanic ash minerals is expected to reduce the amount of using KCl fertilizer. This study aimed to investigate the effectiveness of the use of Mount Sinabung volcanic ash to increase the elements of K, Ca, Mg marginal soil, and the efficient use of KCl fertilizer on corn. This study designed using a factorial randomized block design consisting of two treatment factors and five replications. The first factor was soil, heated and acidified volcanic ash, i.e. soil without volcanic ash (AO), original volcanic ash+soil (AA), boiled volcanic ash around 100^{o}C+soil (PA), volcanic ash heated using oven by 100^{o}C+soil (PO), volcanic ash HCl+soil (AS). The second factor was KCl fertilizer consisting of three levels, 0.0, 2.5 and 5.0 g/polybag. The results showed that the chemical properties of soil, volcanic ash, heated and acidified volcanic ash such as pH value was acid, the concentrations of exchangeable-K, Ca, and Mg was low. The application of heated or acidified volcanic ash and KCl fertilizer in marginal soils did not increase of exchangeable-K, Ca, except exchangeable-Mg from small to medium. The use of heated and acidified volcanic ash did not interact significantly with all parameters of corn (plant height, leaf area, corncob length, number of rows per cob, the weight of seeds per cob, the weight of 1000 grains and root weight). Volcanic ash only significantly affected leaf area, while KCl fertilizer significantly affected all components of corn. The efficiency value of KCl fertilizer was higher than volcanic ash so that the use of KCl fertilizer was more efficient.

Keywords: *Heating and acidification, K-fertilizer efficiency, mineral weathering, volcanic ash*

1. Introduction

The potential for volcanic ash in Indonesia is quite significant because there are 83 active volcanoes [1]. The Sinabung volcano is one of them. The volcano in Tanah Karo Regency, North Sumatra Province, has erupted again and experienced a continuous eruption from 2010 to 2018. The material of erupted volcanic ash contains various minerals such as feldspar, mica, plagioclase, hypersthene, augite, and hornblende or amphibole [2]-[5]. Volcanic ash contains base elements, P, S and microelements [6]-[7]. Even volcanic ash also contains compounds such as ammonium or nitrate [8].

In the Mount Sinabung volcanic ash, there are minerals as sources of the elements K, Ca, and Mg needed by plants [5]. If these minerals are easily weathered, several nutrients will be released into the soil for plant needs. The ease of weathered minerals including minerals in volcanic ash is determined by many factors, including the structure of mineral bonds and their environmental conditions [9]-[11]. Water, acids (organic and inorganic),

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and temperature are environmental conditions that also determine the level of weathering of minerals. Minerals will decay in the presence of water at specific temperature conditions, but weathering can be accelerated with acids [12]-[13].

Volcanic ash can improve the quality of marginal soil because it will increase the concentration of nutrients in the soil so that it is more fertile to support crop cultivation. Volcanic ash can increase concentrations of P, S, Ca, Mg, and Zn in alfalfa plant tissue, and increase biomass production at the same time [14]. On the other hand, volcanic ash is generally acidic to slightly acidic which can then influence soil pH and plants growth [15]-[17]. Nowadays, the use of KCl fertilizer to overcome the lack of K nutrients in the soil for crop needs is relatively large [18]. The demand for plant for K is the third-largest after N and P [19]. The presence and availability of K in soils in Indonesia tend to be low because it is dominated by acid reacting soils and intensive base washing. Therefore, the use of KCl fertilizer in marginal soils that react acidly is a necessity.

Corn has become an essential commodity in the world because this plant can be made for various types of food and industrial products [20]. Corn, rice, and soybean are superior food crops that have priority development in Indonesia. The target of the corn development program in Indonesia is to fulfil national food sovereignty and also as an export commodity in the global market. The ultimate goal of the national corn development program is to realize community economic independence and increase the foreign exchange of the country. According to the Pusdatin Newsletter (2017), corn production in Indonesia in 2015, 2016, and 2017 was 19.06, 23.58, and 27.90 million tons respectively [21]. This amount will continue to be increased with various efforts, including management of soil quality. The nature of the soil is one of the crucial conditions for the success of corn cultivation, especially in providing sufficient nutrients from various sources to ensure high growth and yield. Thus, this research aims to investigate the effectiveness of the use of volcanic ash to increase marginal soil nutrients such as K, Ca, Mg, and the efficient use of KCl fertilizer on corn plants using volcanic ash.

2. Materials and Method

This study was conducted at the experimental garden of the Faculty of Agriculture, Islamic University of North Sumatra, Medan, Indonesia. The location of this study was at an altitude of ± 25 meters above sea level with a flat topography from 10 August to 10 November 2017. The material used in this study is the volcanic ash material from Sigarang-Garang or Sinabung Mountain, North Sumatra, Indonesia. It was taken at the coordinates of 30°11'27.1"N – 98°24'52.1"E. The soil material used was the marginal type of Ultisols (subsoil of ultisol) originating from experimental gardens of the Faculty of Agriculture, Universitas Islam Sumatera Utara. The corn seeds used were P32 hybrid varieties. This study also used a 40 x 50 cm polybag and KCl fertilizer (60% K_2O). The tools used included hoes, machetes, knives, treatment boards, hand sprayers, gauges, pH, ovens, analytical scales, and other supporting tools for this study.

This study was arranged using a factorial randomized block design (RBD) consisting of two factors. The first factor was heated and acidified volcanic ash and soil, i.e. AO: soil without volcanic ash (control), AA: volcanic ash+soil (169.5 g/polybag), PA: volcanic ash in boiled 100°C+soil (163.5 g/polybag), PO: volcanic ash heated in an oven 100°C+soil (164 g/polybag), and AS: 0.01N HCl acid volcanic ash+soil (174 g/polybag). The second factor was KCl fertilizer consisting of KCl_0: 0 g/polybag, KCl_1: 2.5 g/polybag, KCl_2: 5 g/polybag. The total number of treatment combinations was 15 and 5 safaris repeated as a whole, there were 75 experimental sample units. Volcanic ash was heated at 100°C for 6 hours in an oven with a capacity of 30 kg. After the volcanic ash was heated, then it was

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cooled in a closed room that was not directly influenced by the wind. Cold volcanic ash was mixed with the soil and put into polybags. Volcanic ash was heated in boiling water at 100°C for 6 hours with a dose of 2 kg of volcanic ash and 1 litre of water.

During the mixing process, the water and volcanic ash were stirred until it became mud. After the heating process finished, volcanic ash was cooled with air in a closed room. After that, volcanic ash was mixed with the soil and then put into a polybag. Volcanic ash + 0.01 N HCl around 1 liter/2 kg volcanic ash were then stirred evenly with a wet texture in a pan measuring 60 x 40 cm and were left for 6 hours without direct exposure to wind and placed in the closed room. After that, the volcanic ash and soil were mixed and put into polybags. KCl fertilizer based on the treatment dose was given 2 weeks before the corn seedlings were planted by mixing into the soil and heated and acidified volcanic ash.

The best corn seeds selected by soaking them into cold water for 15 minutes and only the sink seeds could be used. The seeds were planted directly into the holes that have provided before. The number of seeds per hole per polybag was 1-3 seeds. After that, the corn seeds covered with a little soil, and the seeds planted in the afternoon. Then, all treatment polybags arranged in the experimental garden area that had been provided and randomized. The distance between treatments was 50 cm, the distance between polybags was 50 cm, the distance between replications was 100 cm, and the number of plants per polybag was 1 plant. Watering was done in the morning and evening and adjusted to the rainy day. If there was rain, the plant was not watered. Weeding was done according to conditions, and pest and disease control were conducted by spraying insecticides and fungicides at the age of plants 15 and 35 days after planting (DAP).

Before being used, volcanic ash material was analyzed the exchangeable-K, Ca, Mg levels and pH values, and soil material that will be treated was also analyzed some chemical properties like exchangeable K, Ca, Mg and pH. After the study conducted or when the corn crop was harvested with a plant age of 65 DAP marked with yellow clots, and the seeds were hard enough and shiny, soil analysis was carried out again on the pH value and the levels of exchangeable K, Ca, Mg. For soil pH the ratio of water: soil (2.5: 1) was measured using a pH meter (Model 330i) Wissenschaftlich-Technische Werkstatt GmbH, Weilheim, Germany, exchangeable K was analyzed using NH_4OAc extraction pH 7.0 with a flame photometer (Model 410, Sherwood Scientific, Cambric, UK, whereas exchangeable Ca and Mg were analyzed using NH_4OAc pH 7.0 extraction with an Atomic Adsorption Spectrophotometer (Model AA 220, Variant of Sydney Australia). The parameters to see the growth and yield of plants consisted of; (a) plant height (cm) was determined every 2 times in a week started from the neck to the highest leaf tip which straightens the plant leaves upward. This measurement was conducted at intervals of 2 weeks, so that male flowers came out.

For ease and accuracy in measurement, standard stakes were used with a height of 10 cm from the root neck. (b) leaf area (cm^2) was measured when the plant has released male flowers or together with the last observation of plant height, and leaf area measured was the 7th leaf by measuring the length and width of the leaf. Leaf area was calculated using the formula Yt = k x p x l, where: Yt (total leaf area), k (constant), p (i-th leaf length), l (i-th leaf width). (c) corncob length (cm). Measurements were taken from the tip of the cob to the base using the meter after harvest, (d) the number of row heads was calculated after harvesting, and the cobs were removed from the stems of the plants and then peeled off the skin of the corn until it was clean. After that, the counts of the rows of crows on the corn cobs were made, (e) weight of seeds (g) was conducted after harvesting, and then the corn husk was removed after the corn seeds released from the corn stalks then seeds were weighed using analytical scales, (f) weights of 1000 grains of corn seeds (g) was conducted by counting 1000 seeds on each sample plant and then weighed using analytical scales, dan (g) and (g) plant root weight (g) was conducted after the corn plant stems removed from polybags, and the roots were cleaned from the remnants of soil, and then cut the roots of plants from plant stems then weighed using analytical scales.

The data on the determination of levels of exchangeable-K, Ca, and Mg in the soil and volcanic ash were determined based on the criteria for assessing the chemical properties of the soil, the Indonesia Soil Research Center Staff [22]. To see the relationship of these data with plant growth and yields were analyzed using analysis of variance (f-test) with advanced DMRT tests at the 5% significance level. For identifying the efficiency of the use of volcanic ash and KCl fertilizer, the calculation conducted using the equation:

$$\Sigma = \frac{A - B}{A} \text{ X } 100\%$$

Where: Σ (= efficiency value), A (= value of volcanic ash/highest KCl fertilizer), B (= value of volcanic ash/lowest KCl fertilizer).

3. Results and Discussion

3.1 Chemical properties of soil and volcanic ash

The results of the analysis of chemical properties consisting of pH value, the content of exchangeable-K, Ca, Mg in marginal soil, original volcanic ash, heated and acidified volcanic ash as presented in Table 1.

The results of the analysis of the chemical properties of marginal soils before the treatment of volcanic ash and KCl fertilizer showed acidic pH value (5.21), low exchangeable-K (0.16 meq/100g), exchangeable-Ca (3.93 meq/100g) and low exchangeable-Mg (0.93 meq/100g) [22]. The values of these elements indicated that the marginal soil fertility rate used as a growing medium was relatively low (Table 1). Table 1 also showed that the pH value of the original Mount Sinabung volcanic ash, where volcanic ash was heated and acidified ranging from acid to very acid. The pH value of original volcanic ash was 4.62, the pH value of volcanic ash was heated with water at 100°C, volcanic ash was heated in an oven at 100°C, and the volcanic ash acidified with 0.01N HCl was slightly lower than the original volcanic ash with the respective values of 4.58, 4.16, and 4.27.

Table 1: The levels of pH values, exchangeable-K, Ca, Mg in soils, original volcanic ash, heated and acidified volcanic ash.

Sample Codes	Treatments	pH H_2O*	Elements (meq/100 g)*		
			Exc.K	Exc.Ca	Exc.Mg
AO	Marginal soil	5.21^-	0.16^+	3.93^+	0.93^+
AA	Original volcanic ash	4.62^-	0.14^+	3.89^+	0.84^+
PA	Boiled volcanic ash in 100°C water	4.58^-	0.16^+	3.96^+	0.98^+
PO	Heated volcanic ash in a 100°C oven	4.18^-	0.15^+	3.90^+	0.92^+
AS	Acidified volcanic ash HCl 0.01N	4.27^-	0.18^+	4.04^+	1.04^+

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Note: *Criterium by the staff of the Indonesia Soil Research Center, 1983 In [22]; -acid; + low., Exc.(exchangeable)

The content of K, Ca, and Mg in original volcanic ash materials, heated volcanic ash (boiled in water at 100°C and in an oven at 100°C) and acidified volcanic ash were still relatively low [22]. The highest exchangeable K, Ca, and Mg content was found in acidified volcanic ash with HCl 0.01 N with values of 0.18, 4.04, and 1.04 meq/100g respectively.

3.2 The pH value and content of exchangeable K, Ca, Mg

The results of the analysis of the chemical properties of marginal soils applied to a combination of heated, acidified volcanic ash and KCl fertilizer showed that the pH values, exchangeable-K, Ca and Mg contents were varied, and were still categorized as low, except exchangeable-Mg content (Table 2). pH values ranged from 4.91-5.18 (acid), exchangeable-K content of 0.13-0.19 meq/100g (low), exchangeable-Ca 3.73-4.22 meq/100g (low), exchangeable-Mg 0.73-1.13 meq/100g (low-medium). Although the concentration of exchangeable-K and Ca were categorized as low, it generally increased with the application of volcanic ash and manure. The highest exchangeable-K content was seen in the treatment of volcanic ash heated with water at the temperature of 100°C and KCl fertilizer 5 g/pot which was 0.19 meq/100g, while the highest exchangeable-Ca of 4.22 meq/100g was found in the treatment of acidified volcanic ash and 5 g/pot KCl fertilizer.

Exchangeable-Mg content increased from low to medium categories. The lowest value was seen in the treatment of original volcanic ash and KCl 0 g/polybag fertilizer or without KCl fertilizer, while the highest value was found in the treatment of acidified volcanic ash with HCl 0.01N and KCl fertilizer 5.0 g/polybag.

Table 2: The pH value, the content of exchangeable-K, Ca, Mg of soil after volcanic ash treated (original, heated and acidified) and KCl fertilizer application

Treatments	pH H_2O	Elements (meq/100g)*		
		Exc.-K	Exc.-Ca	Exc.-Mg
- $AOKCl_0$	5.16^-	0.13^+	3.91^+	0.79^+
- $AOKCl_1$	5.04^-	0.16^+	3.82^+	0.96^+
- $AOKCl_2$	5.01^-	0.18^+	4.06^+	1.03^+
- $AAKCl_0$	4.97^-	0.12^+	3.73^+	0.73^+
- $AAKCl_1$	4.96^-	0.14^+	4.03^+	0.93^+
- $AAKCl_2$	5.04^-	0.17^+	3.91^+	0.99^+
- $PAKCl_0$	5.19^-	0.14^+	3.85^+	0.84^+
- $PAKCl_1$	5.14^-	0.16^+	4.03^+	1.02^+
- $PAKCl_2$	5.12^-	0.19^+	3.99^+	1.09^+
- $POKCl_0$	5.18^-	0.13^+	3.89^+	0.78^+
- $POKCl_1$	4.91^-	0.16^+	3.78^+	0.95^+
- $POKCl_2$	5.00^-	0.17^+	4.04^+	1.02^+
- $ASKCl_0$	5.01^-	0.14^+	4.02^+	0.92^+
- $ASKCl_1$	5.03^-	0.15^+	3.89^+	1.07^+
- $ASKCl_2$	4.99^-	0.18^+	4.22^+	1.13^{++}

Note: *Criterium by staff of the Indonesia Soil Research Center, 1983 In [22]; acid; $^+$low; $^{++}$medium

3.3 Growth and yields of corn

The recapitulation of the effect of acidified and heated Mount Sinabung volcanic ash using KCl fertilizer on the growth and yield of corn appeared in Table 3.

Table 3: Recapitulation of the effectiveness of volcanic ash, KCl fertilizer efficiency on growth and yield of corn.

No	Parameters	Volcanic Ash	KCl Fertilizer	Interaction
1	Plant height at 6 DAP	ns	**	ns
2	Leaf area	*	**	ns
3	Corncob length	ns	**	ns
4	Number of lines per cob	ns	**	ns
5	Weight of seeds per cob	ns	**	ns
6	Weight of 1000 grain	ns	**	ns
7	Weight of plant root	ns	**	ns

Note: ns = not significant, * = siginificant, ** = very significant

Table 3 showed that volcanic ash combined with KCl fertilizer did not significantly interact with all growth components and yields of corn. However, volcanic ash itself only significantly affected leaf area, and KCl fertilizer also had a very significant effect on all components of corn growth and yield. The highest leaf area due to volcanic ash was achieved in the volcanic ash acidified with 0.01N HCl treatment, which was 513.31 cm^2, while the lowest leaf area was seen in the marginal soil treatment which was 436.88 cm^2 (Table 4). Volcanic ash could linearly increase the leaf area of corn plants (Figure 1a).

Table 4: Influence of volcanic ash and KCl fertilizer on growth and yield of corn.

Treatment	Average growth and yield of corn						
	PHt	LAi	CCl	NRp	GWp	WOg	RWe
Soil/volcanic ash							
AO	182.89	436.88b	18.99	11.89	137.53	226.33	31.5
AA	202.32	474.17ab	19.41	12.32	165.26	229.07	30.8
PA	190.11	443.73b	19.17	12.01	154.17	228.53	31.7
PO	193.23	501.56a	18.94	12.23	157.83	228.80	32.6
AS	196.73	513.31a	19.96	12.58	182.36	229.47	33.7
KCl fertilizer levels							
KCl_0	175.41b	431.10b	18.46b	11.21b	138.12b	225.52b	30.1b
KCl_1	202.13a	478.10ab	19.47a	12.52a	156.41b	228.68a	32.1ab
KCl_2	203.63a	512.60a	19.94a	12.92a	183.76a	231.12a	34.0a

Note : PHt-plant height (cm); LAi-leaf area (cm^2); CCl-corncob length (cm); NRp-number of rows per cob; GWp-grain weight per cob (g); WOg-weight of 1000 grains (g); RWe-root weight (g).
The average number followed by unequal lowercase letters in the same column showed significantly different at the $p<0.05$ level based on the DMRT (Duncan Multiple Range Test).

Table 4 presents KCl fertilizer which had a very significant effect on plant height, leaf area, corncob length, number of rows per cob, seed weight per cob, the weight of 1000 grains, and root weight of corn plants. The highest value of all parameters determined by the corn plant was achieved in the treatment of KCl 5.0 g/polybag, while the lowest was seen in the treatment without KCl fertilizer. The results of the regression analysis showed that KCl fertilizer linearly increased plant height, leaf area, corncob length, number of rows per cob, seed weight per cob, the weight of 1000 seeds, and root weight of corn plants (Figure 1b-h).

3.4 Mount Sinabung volcanic ash and the efficiency of the use of KCl fertilizer

This study also calculated the level of efficiency between the use of volcanic ash and KCl fertilizer for growth and yield of corn on marginal soil of ultisol.

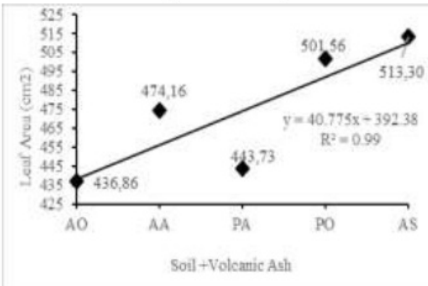

Fig.1a. Relationship between volcanic ash and

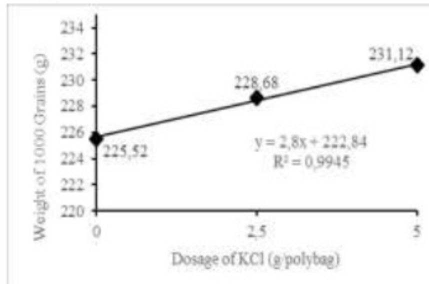

Fig. 1b. Relationship between KCl Fertilizer Dosage and Weight of 1000 Grains

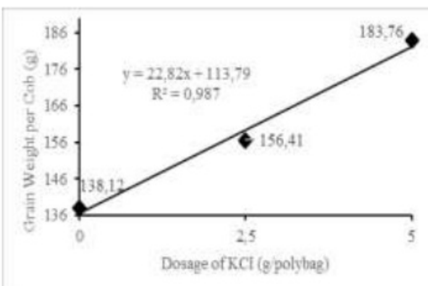

Fig. 1c. Relationship between KCl fertilizer dosage and the grain weight

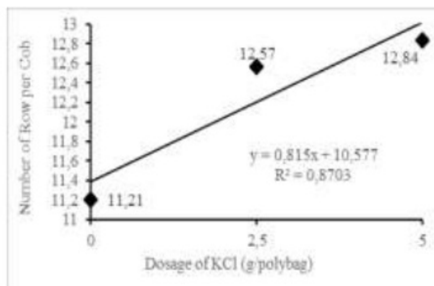

Fig 1d. Relationship between KCl fertilizer dosage and number of row per cob

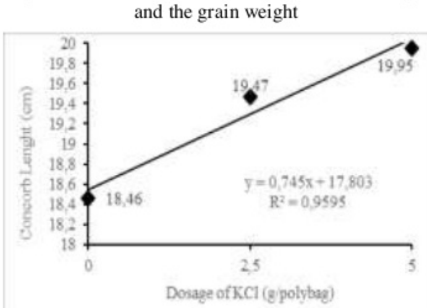

Fig. 1e. Relationship between KCl fertilizer dose and corncob length

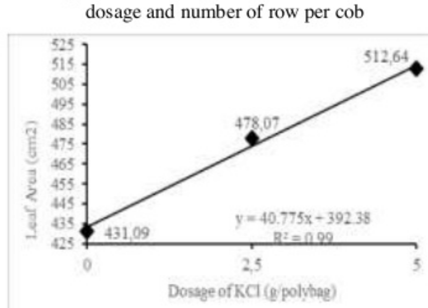

Fig. 1f. Relationship between KCl fertilizer dose and leaf area

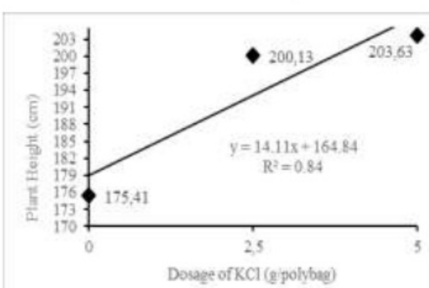

Fig. 1g. Relationship between KCl Fertilizer dosage and corn plant height

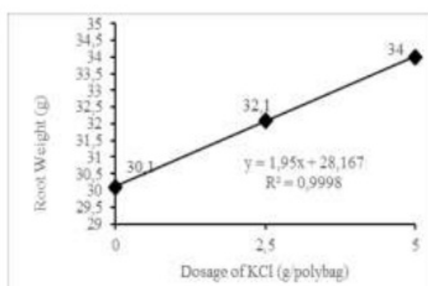

Fig. 1h. Relationship between of KCl Fertilizer dose and root weight

The results of calculations showed that the efficiency value of the use of volcanic ash was 9.94%, while the value of the efficiency of KCl fertilizer use was 12.65% (Table 5). It can be seen from the average efficiency values of all observed corn plant component variables consisting of plant height, leaf area, corncob length, number of rows per cob, the weight of seeds per cob, the weight of 1000 grains, and the weight of root plants. Based on the measurement of corn components, the use of KCl fertilizer was still more efficient than Mount Sinabung volcanic ash.

Table 5: The efficiency value of Mount Sinabung volcanic ash and KCl fertilizer on growth components and corn yields.

No	Observation Parameters	The efficiency of Volcanic Ash (%).	The efficiency of KCl (%)
1	Plant height at 6 DAP (cm)	9.60	13.85
2	Leaf area (cm^2)	14.88	15.89
3	Corncob length (cm)	5.11	7.42
4	Number of lines per cob	5.48	12.69
5	Weight of seeds per cob (g)	24.58	24.83
6	Weight of 1000 grain (g)	1.36	2.42
7	Weight of plant root (g)	8.60	11.47
	Average	9.94	12.65

3.5 Values of pH, exchangeable K, Ca, Mg of soil, original volcanic ash, heated and acidified volcanic ash

Soil materials used as media in this study derived from the subsoil layer of the Ultisol. This soil was also known as one type of soil that has a low pH value (acid), and base saturation was also low due to the intensive leaching of bases. Ultisol is also soil that has characteristics of high clay content, but low clay activity level [23]. Therefore, the content of the elements K, Ca, and Mg in this soil was low. Besides, the organic matter content of this soil was also low. It was a reason that ultisol included one type of low fertile soil. Low fertility soils marked by acidic pH values have had implications for the low availability of macronutrients and the activity of several types of soil organisms and the high solubility of some micronutrients.

The pH value of original volcanic ash, heated and acidified volcanic ash was also categorized as acidic even the value was lower than the pH value of the marginal soil used. The acidity of the pH value of volcanic ash could be caused by the geology of Mount Sinabung volcano rock, which consisted of plio-Pleistocene rocks and sedimentary rocks containing high silica [24]. Therefore, if the volcanic ash material is given into the soil, it will reduce the pH value of the soil. Itis in line with the statement of ref [25], that volcanic ash will affect the pH value of the soil, specifically reducing the pH value of the soil. The low or acidic pH value of Mount Sinabung volcanic ash was also followed by low exchangeable-K, Ca, and Mg content (Table 1). It revealed that primary minerals as a source of these elements had not been weathered completely. There is a lot of information in Mount Sinabung volcanic ash that contains many minerals as a source of K, Ca and Mg elements such as plagioclase, hypersthene, augite, hornblende/amphibole, and volcanic glass in adequate quantities [5].

The content of exchangeable-K and Ca in the soil that was given volcanic ash was still relatively low, while exchangeable-Mg was in the medium category. However, the concentrations of K and Ca were higher than the original soil where exchangeable K

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content was found in the boiled volcanic ash at 100°C treatment, while the highest exchangeable-Ca was achieved in the acidified volcanic ash using HCl 0.01 N treatment. Although the amount of the addition of K, Ca and Mg elements into the soil was relatively small, the process of heating volcanic ash with water at 100°C and acidification using HCl 0.01N has at least helped to weather some of the minerals in volcanic ash and to free the elements so that the amount increases in the soil. Mahler (2008) argued that the amount of nutrients released by a mineral depends on the concentration of the elements contained in the mineral and the level of weathering of the mineral [14]. Therefore, the concentration status of K, Ca and Mg in the soil after application of heated and acidified volcanic ash was associated with low levels of weathering of minerals in volcanic ash. At the same time, the concentration of K, Ca, and Mg elements of the marginal soil (ultisol) were also low. Ultisol was a low base acidic soil. Therefore, a low base saturation value generally less than 35% [11]. The elements of K, Ca, and Mg are also important basic elements besides Na.

3.6 The Growth and Yield of Corn

The various volcanic ash treatments and the tested dose of KCl fertilizer did not interact significantly on all parameters of the corn measured. It can occur due to: i). The number of nutrients contained between the soil, original volcanic ash, and heated and acidified volcanic ash were relatively the same, ii). the amount of K element contained in volcanic ash was low so that the combined amount of nutrients that were free of mineral decay in volcanic ash and nutrients from KCl fertilizer have not been able to influence the growth and yield of corn, iii). Besides, nutrients released by volcanic ash such as K that have the same function or role as nutrients derived from KCl fertilizer to meet the needs of corn plants.

Although the concentrations of K, Ca, Mg elements that was free from mineral, weathering in volcanic ash was low, and volcanic ash itself significantly affected the leaf area of corn. It showed that the content of nutrients released from volcanic ash, especially K, Ca, Mg could only increase the leaf area of corn plants. Figure 1a illustrated the positive linear relationship between volcanic ash and leaf area of corn plants, where volcanic ash was able to influence the development of leaf area by 99%. The growth of the leaf area was determined by the development of the cell wall of the plant. If plants have sufficient K, Ca, and Mg, the cell walls of plants will easily develop. These elements have played a very important role in supporting the development of plant cells [26]-[27]. K element is an essential nutrient that plays a role in increasing leaf area development [28].

Volcanic ash also contains N, P, and these two elements, together with Ca can encourage the development of plant leaf area [14]. The elements of N, P, K, and Mg play a role in producing chlorophyll and increasing the rate of photosynthesis which is beneficial for vegetative growth of plants and the development of leaf [29]. For several other parameters, single volcanic ash has not shown any real effect. Still, the value of each measured corn parameter was higher in the subsoil soil treated with volcanic ash than the marginal soil without volcanic ash (Table 4), even the highest value was generally obtained in soil treatment by applying acidified volcanic ash with HCl 0.01N. There are minerals that contain a number of nutrients both macro and micro in volcanic ash [6], and those minerals are easier weathered with acid solutions [9], [13].

KCl fertilizer was significantly positively correlated to all parameters of corn measured (Figure 1b-h). The pictures described that KCl fertilizer linearly increased the weight of 1000 grains by 99% (1b), grain weight per cob 99% (1c), number of rows per cob 87% (1d), cob length 95% (1e), leaf area 99% (1f), plant height 84% (1g), and root weight 99% (1h). These results indicated that the growth and yield of corn plants were also influenced by KCl fertilizer in the range of 84 to 99%. K elements from KCl fertilizer was able to meet the needs to encourage the growth of corn plants. K could improve the process of photosynthesis, streamline water use, retain turgor, strengthen the stem, activate the enzyme system, and strengthen roots [19].

3.7 The efficiency values of volcanic ash and KCl fertilizer

In this study, the purpose of using KCl fertilizer was also to find out the value or efficiency level of volcanic ash that also contains K element compared to KCl fertilizer. The results obtained in Table 5 showed that the use of KCl fertilizer in corn cultivation was more efficient than the use of Mount Sinabung volcanic ash, or the volcanic ash was not effective yet to replace KCl fertilizer. The fact was apparently due to the concentration of K contained elements and liberated from the volcanic ash of Sinabung was still low (Table 2 & 3). Besides, the treatment of volcanic ash heated by the oven and boiled water at each temperature of 100^oC and acidified volcanic ash with 0.01N HCl also has not been able to weather completely. Hence, the number of nutrients, especially the K element, which can be released, was still low.

The high-efficiency value of KCl fertilizer was also due to the higher K content in KCl fertilizer than volcanic ash. The KCl fertilizer used contained 60% K_2O and was equivalent to 49.80% K (0.83x60) in the KCl fertilizer, and the amount of 49.80% was equal to 1.28 meq/100g. It indicated that the concentration of K in KCl fertilizer was equivalent to 1.28 meq/100g, which classified as very high (Hardjowigeno, 2010). The K content value was higher than that possessed by volcanic ash and was only around 0.14-0.18 meq/100g. Because the efficiency value of KCl fertilizer was higher than the efficiency value of Mount Sinabung volcanic ash, the use of KCl fertilizer as a source of K in corn plants was better and more efficient than volcanic ash.

4. Conclusion

The pH value of marginal soil ultisol and Mount Sinabung volcanic ash was classified as acidic, while the exchangeable-K, Ca, Mg content categorized as low. The heating and acidification of Mount Sinabung volcanic ash did not increase the exchangeable-K, and Ca content, except the exchangeable-Mg content that increased from small to medium categories, which were found in acidified volcanic ash using 0.01N HCl. Simultaneously, volcanic ash and KCl fertilizer could not improve the growth parameters and yield of corn measured. Volcanic ash was only able to increase leaf area, while KCl fertilizer can increase all growth parameters and yields of corn. The use of volcanic ash could not replace KCl fertilizer in corn cultivation, where the efficiency value of KCl fertilizer reached 12.65%. This figure was higher than Mount Sinabung volcanic ash which was only 9.94%.

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