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Nutrients uptake of corn plant as affected by rock dust addition treated by heating and humic material

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Abstract. Silicate rocks are a natural substance that contains many essential nutrients for plants, but the applications of silicate rocks dust as fertilizer in agriculture are very limited. The nutrients derived from silicate rock dust were very slowly available. As a result, its effect on plant growth is not significant. The effort that can be done to accelerate the availability of nutrients from silicate rocks dust fertilizer is through heating treatment and giving humic materials. This research was conducted using a split-plot designed by three factors; namely, the heating temperature (at 25°C, 300°C, and 700°C) as the main plot, rock types (Trachyte, diorite, and basalt), and the solvent (KOH 0.1 N, rainwater, lignite humic and peat humic) as the subplot. The results showed that the rock dust fertilizer treated with peat humic significantly influenced the plant height 14 days after planting (DAP). Besides, basalt rock dust fertilizer can significantly influence plants' height at 21, 28, and 35 DAP. The highest dry weight of corn plants was obtained in the treatment of basalt rock dust treated by heating to a temperature of 700°C with the solvent peat humic. Nutrient uptake of potassium (K) in corn plants tended to be higher in the treatment within the rock dust treated by heating to a temperature of 300°C using lignite humic solvent.

1. Introduction

Indonesia is rich in volcanoes that stretch from Sumatera, Java, Nusa Tenggara, Sulawesi and Maluku. The results of volcanic eruptions include volcanic rocks that contain various minerals. On the other hand, Indonesia has a poor land quality, that it runs along the east coast of Sumatra and Kalimantan. Many people hope that volcanic eruptions can be used to supply minerals for these poor soils.

Minerals will undergo a weathering process, both physically and chemically. In this weathering process, some nutrients will be released according to what they contain. Rock weathering reactions occur continuously, run slowly, but certainly produce several nutrients that plants can use. Research results by [1, 2, 3] showed that silicate rock dust contains many kinds of essential nutrients for plants and may be used as compound fertilizers (multi-nutrient fertilizers). Iskandar and Irwanti [4] stated that silicate rock dust fertilizer in agriculture is highly limited. In general, it is quite slowly available in the soil, so its effect on plant growth has no significant impact in the short term.

Several practical ways to accelerate the dissolution of nutrients from silicate rock dust fertilizer into soil solutions have been studied, for example, through acidulation of gneiss with strong acid/H₂SO₄ [5] and intensive milling (high-energy milling) [6]. This milling technique has been used to produce rock

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fertilizers from natural phosphates [6], basalt, dolerite, gneiss, and K-feldspar [5, 7]. Coroneus et al. and Hinsinger et al. [8, 9] concluded that using granite rock flour as much as 20 tons/ha was ineffective as a K source for *Ryegrass* growth because it required an extremely high rock flour dose, and it was not economical ways. Ahmad [10] explained that the basalt silicate rock incubated with lignite humic acid for five weeks could increase nutrient release from these rocks. Still, this study did not have a significant effect on plants.

14 Organic acids can dissolve minerals. The solubility of cations from minerals is highly dependent on the position of the cations in the mineral crystals and the overall crystal structure [11]. The high content of carboxylate and phenolic groups in humified humic compounds makes these compounds can be used to accelerate the rock weathering process. Setyowati and Ulfin [12] stated that humic acid is the main organic compound that was found in soil and peat. Humic acid can interact very strongly with various metals to form humic metal complexes, which affects the metal's adsorption-desorption properties. [13] reported that adding humic acid to sand soils showed a positive effect on plant biomass productivity. The increase in vegetative growth is directly related to the humic acid concentration. According to [14], giving humic acid extracted from brown coal can increase plant growth.

One of the alternatives to increase the availability of nutrients from rock dust fertilizer to be utilized is a heating process. The research results by [15] that calcining or heating rock phosphate at temperatures up to 1,050°C resulted in very different phosphorus (P) fertilizers and plant growth, where the maximum effectiveness of calcination was obtained at temperatures between 500°C and 650°C.

Based on the explanation above, it is hoped that by heating process and adding solvents (peat humic and lignite humic) to rock dust (Trachyte, diorite, and basalt), can accelerate the mineral weathering process. Therefore, those rocks can easily release certain cations from the crystal structure minerals into the soil solution and the availability of nutrients for plants can increase. In this study, corn was used as an indicator of plant nutrient absorption to see the availability of nutrients from the weathering of trachyte, diorite and basalt rock.

2. Methods **19**

This research was conducted using a split-plot designed by three factors, namely the heating process (temperature 25 °C, 300 °C, and 700 °C) as the main plot, type of rocks (trachyte, diorite, and basalt) and solvent types (KOH 0.1 N, rainwater, lignite humic and peat humic) as the subplot.

2.1. Materials

The materials used in this experiment were Basalt rock (obtained from Kappang Village, Camba District, Maros Regency), Diorite (obtained from Mariapulana Village, Camba District, Maros Regency), Trachyte (obtained from Mangilu Village, Bungoro District, Pangkep Regency), Province of South Sulawesi. Solvent for peat humic compounds and lignite, KOH 0.1 N, and rainwater. Humic compounds were extracted from peat from the Berbak National Park, Regency. Tanjung Jabung, Jambi Province, and lignite originated from Central Tarakan District, Tarakan City, East Kalimantan Province. quartz sand from the district Tulang Bawang, Lampung. The plants' indicator used were corn (*Zea mays* L.) using Super Bee varieties.

2.2. Rock dust procedure

Rocks (Trachyte, Diorite and Basalt) were grinded and sieved with a size <60 µm [10], Diorite and Basalt, heated at a high temperature at 300 °C and 700 °C maintained for six consecutive hours, and Trachyte was not heated (room temperature/25 °C).

2.3. Humic extraction

The extraction was carried out based on the properties of humic acid, which is alkaline-soluble and acid-insoluble. The extract used at this extraction stage was 0.1 N KOH. 400 g of peat and lignite material was taken, then the following extraction steps were carried out [16, 10]:

The first separation stage was carried out by adding 0.1 N KOH to obtain humic material dissolved in the KOH base and removing the non-humic material, which was the insoluble part. Furthermore, shaking the solution for about 3 hours to ensure that the KOH solution is homogeneously mixed with the materials used. The last step was the separation process, which was centrifuged at 2,500 rpm for 15 minutes and filtered using filter paper. This separation process aimed to separate the humic material solution from the residue that does not settle but floats on the solution's surface.

2.4. Preparation of media planting

Sand for planting media was washed clean by soaking it in a washing tub and watering it repeatedly until the water was clear. After the sand has been washed clean, it was put into each experimental pot for about 2.5 kg per pot.

2.5. Treatment and planting

Rock dust that had been heated according to heating treatment for 19 g/pot or 15 tons/ha was soaked for 6 hours in a 20% concentration of solvent treatment, then dried for one week (4 days in the oven). After that, the rock dust was moved to the planting medium (2.5 kg with 20% moisture content) and incubated for two weeks. After that, three corn seeds were planted in each experimental pot; after ten days, two plants were maintained for each pot. The basic fertilizers of Diammonium Phosphate and Urea were given together with rock dust.

2.6. Parameters

There were several parameters observed for this study, such as plant height (cm), plant dry weight (g), and potassium (K) levels (%).

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3. Results and discussion

3.1. Plant height (cm)

Figure 1 shows that the growth of corn at 14 HST using rock dust fertilization with peat humic solvent and rainwater was higher than the KOH solvent. Still, it was not significantly different from the corn treated with humic lignite solvent. This is because peat humic and lignite both produce humic acid, but peat humic content has greater humic acid content. The solubility of peat humic is influenced by the content of its functional groups. Humic peat has a higher content of carboxylate and phenolic functional groups than humate lignite. The group dissociation in humic acid occurs in its carboxyl group so that humic acid can absorb metals [17]. It is possible that humic application can increase the solubility of rock dust so that nutrients are available for the growth of corn.

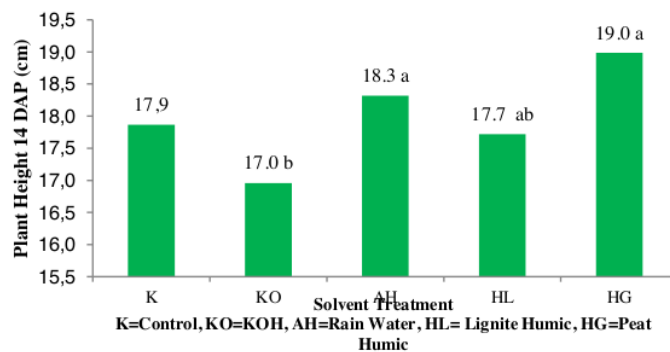


Figure 1. Effect of rock dust fertilization treated with solvents on plant height (cm) at 14 DAP (similar code shows that the value is not different ($p > 0.05$)).

According to the research results by [18],¹³ the application of humic acid has significantly increased the effectiveness of natural phosphate on the height and diameter of cacao seedlings. Besides, [19] explained that the provision of humic materials and fly ash has a significant effect on increasing the height difference of Meranti plants.

Plant height growth at 21 DAP, 28 DAP and 35 DAP was significantly influenced by the type of rock dust fertilization (figure 2). Figure 2 shows an increase in plant height growth due to the type of fertilization with basalt rock dust > diorite > trachyte, along with the characteristics of the rock dust type, namely alkaline > intermediate > acidic.

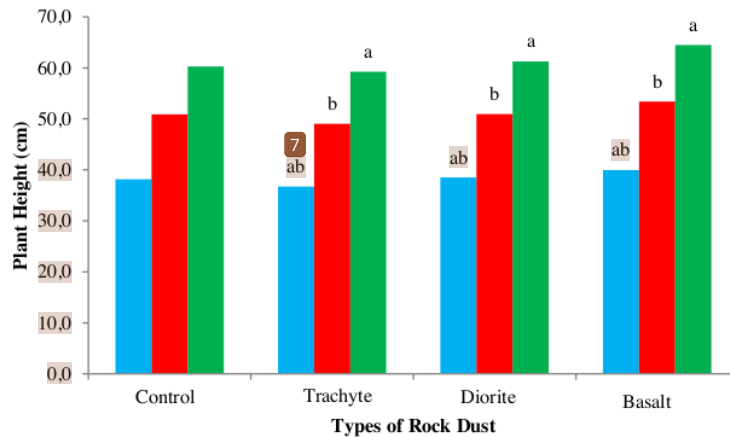


Figure 2. The effect of rock dust fertilization on plant height (cm) at 21 DAP, 28 DAP and 35 DAP (similar code shows that the value is not different ($p > 0.05$)).

3.2. Plant dry weight (g)

In figure 3, it can be seen that basalt rock dust fertilization with the heating temperature at 700 °C produces a higher plant dry weight compared to other treatments. Perhaps this is due to heating which at 700°C can increase the release of nutrient elements in rock dust so that nutrients are available for plant growth.

Brady [20] stated that temperature affects the weathering of minerals and rocks mechanically, namely mechanical disintegration. According to Gilluly et al. [21], there are two stages: mechanical disintegration and chemical decomposition in the mineral weathering process. These two weathering processes take place together, preceded by a mechanical disintegration process, followed by a chemical decomposition process. Several research results explained, for example [15], that the heating process can increase the solubility of phosphate and the maximum dissolved phosphate at 450 °C - 650 °C, then the amount of P available to plants will also increase compared to treatment without heating, and in turn, plant can grow better. K plays a role in carbohydrate metabolism (formation, breakdown, and translocation of starch) and accelerates the growth of meristematic tissue. Besides, K can also increase plant dry weight [22].

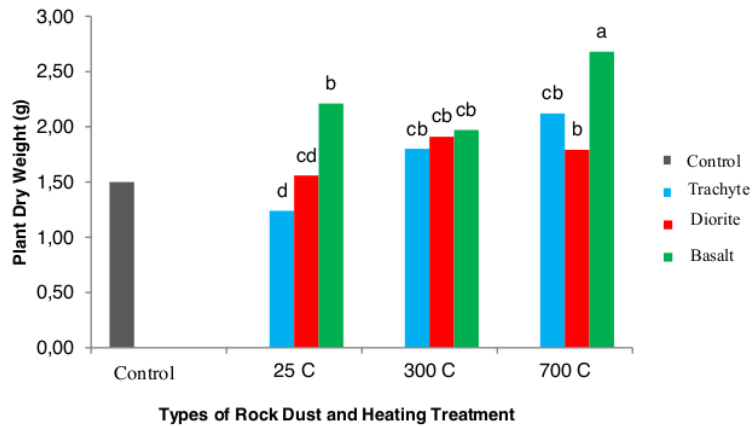


Figure 3. The effect of heating-treated rock flour fertilization on the dry weight of corn plants 35 DAP (similar code shows that the value is not different ($p > 0.05$)).

Based on the type of rock dust (figure 4), basalt rock dust tended to have a higher effect on the dry weight of corn, which was then followed by the effect of diorite and trachyte rock dust on corn dry weight. This is because basalt rock contains higher alkaline nutrients, especially calcium (Ca) and magnesium (Mg). Priyono and Gilkes [23] explained that K-silicate rock dust fertilizer could increase plant biomass.

Figure 4 shows that the dry weight of corn plants at 35 DAP due to basalt rock dust fertilization with peat humic solvent was higher than other treatments [10]. This is because humic acid is a simple and complex organic acid with a high molecular weight, making it the most effective organic acid in dissolving minerals. The dissolution of minerals by simple organic acids is more due to the role of hydrogen (H^+) ions, whereas the dissolution of minerals by complex organic acids, humic acid is through the influence of acid anions in chelating formation. Organic acids with strong chelating capacity are more effective in dissolving minerals than weak ones [24].

Based on the study, humic acid can stimulate root growth [25, 26]. Root growth is important because it can be a key indicator of how a better plant can take up nutrients and air in the soil. The higher the root growth, the wider the absorption area to support the growth of canopy dry weight. According to Eyheraguibel et al. [27], dedicating humate to corn seed germination under hydroponic conditions would increase the proportion of germination rate and leaf biomass. This effect was associated with higher air efficiency, indicating that the plant produced higher biomass than without humate.

Several studies showed that the application of humic acid could increase the wet weight and dry weight of the roots of tomato seedlings [28], significantly increase the fresh weight (30.1%) and dry weight (56.6%) of *Vicia faba* L. Akinci [29], humic at a dose of 0.2% is more effective against the dry weight of wheat plants in calcareous soil conditions [30], increasing the accumulation of dry matter for tomato plants [31]. Humic materials complement mineral fertilizers can increase the yield and quality of cowpea plants on sand soils [32]. Application of humic material to corn plants under salt pressure in greenhouse conditions can increase the dry weight of the plant [33].

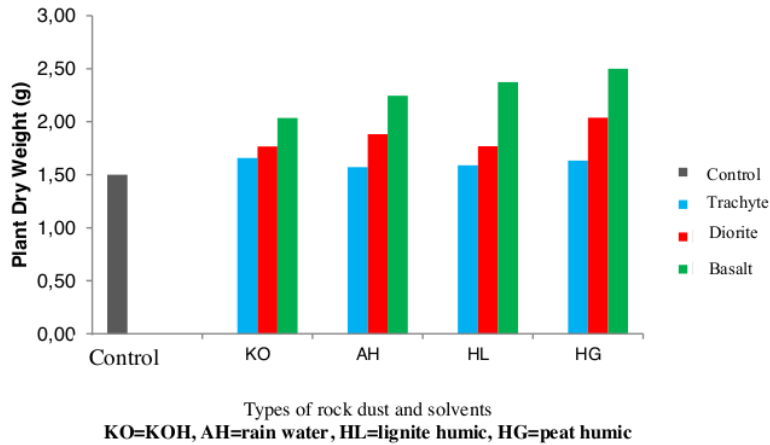


Figure 4. The effect of rock dust fertilization treated with solvents on the dry weight of corn plants in 35 DAP.

3.3. Potassium level (%)

Table 1 shows that the K nutrient content due to fertilizing Trachyte and diorite rock dust was not affected by heating treatment. In contrast, basalt rock dust fertilization is influenced by heating treatment. Fertilization of rock treated with the heating temperature at 300°C showed that the plant's K content (3.06%) was higher than the heating temperature at 700°C and 25°C. This is due to the destruction of the rock's mineral crystal structure, which is in an amorphous phase. This situation causes the nutrients contained in the rock to easily be separated from their crystal structure to be available for plant growth [10].

Table 1. The effect of heating-treated rock dust fertilization on K level (%) corn 35 DAP.

Type of Rock	Heating temperature		
	25 °C	300 °C	700 °C
Control	0.75		
Trachyte	1.39 de	1.35 de	1.16 e
Diorite	1.50 cd	1.44 cde	1.70 c
Basalt	2.08 b	3.06 a	1.47 cd

Note: similar code shows that the value is not different ($p > 0.05$).
 different code shows that the value is significantly different ($p < 0.05$).

Higher heating temperature (700°C) in rock dust causes lower plant K nutrient content; this is probably related to its structure over the heating process. High-temperature heating can cause the evaporation of these elements and damage the mineral structure [34]. Gilkes and Palmer [15] stated that at temperatures above 700°C, the solubility of the material would decrease due to the crystallization of the residual amorphous material. Francisco et al. [39] stated that heating of crandallite rock phosphate above 500°C causes recrystallization of the rock crystal structure.

Table 2. The effect of rock dust fertilization treated with solvents on K level (%) corn 35 DAP.

Type of Rock	Solvents			
	KO	AH	HL	HG
	K level of ... (%)			
Control	0.75			
Trachyte	1.30 d	1.45 cd	1.17 d	1.24 d
Diorite	1.64 bcd	1.49 cd	1.59 bcd	1.50 cd
Basalt	2.10 ab	2.12 ab	2.40 a	1.97 abc

Note : similar code shows that the value is not different ($p > 0.05$).

different code shows that the value is significantly different ($p < 0.05$).

(KO=KOH, AH=rain water, HL=lignite humic, HG=peat humic).

Table 2 shows that the K nutrient content due to the fertilization of trachyte rock dust, diorite, and basalt was not affected by the solvent treatment. However, in basalt rock for all types of solvents, the K level was higher than in trachyte and diorite rocks [10]. The previous heating treatment (table 1) also showed that the K nutrient content in basalt rock was higher than the heating treatment and other rocks. This was because the nutrient solubility level of basalt rock is higher than that of Trachyte and diorite.

The research of Priyono and Gilkes [35] showed that basalt rock with dry milling treatment could release up to 73% of K. Ahmad [10] reported that igneous porphyry basalt rock could release K nutrients with peat humic salt solvent. After 5x incubation in porphyry basalt igneous rock, the highest total release is greater than diorite porphyry igneous rock and porphyry trachyte [10].

Applying humic lignite as a solvent to rock dust tends to increase the K and Mg content in plants more than the peat humic material solvent. This is due to peat's humic acid, which has a lower decomposition rate than lignite [36]. According to Tan [37], the chemical composition of humic compounds is influenced by the original material and the climate. The different decomposition levels of organic matter will affect the properties, functions, and content of the humic compounds formed. The low decomposition of organic matter is directly proportional to the content of its humic compounds. An extremely high decomposition of organic matter will reduce the functional content of humic compounds. The results by Tahir [38] reported that the application of humic acid from lignite could increase the K concentration in the soil, which plants can absorb for growth.

Humic acid affects the root system of plants so that plants can absorb nutrients better [28]. Besides, the stimulation of ion uptake in application with humic materials can affect membranes [25]. This is related to the hydrophobic and hydrophilic properties of the membrane layer in humic acid [40]. Therefore, humic acid can interact with the phospholipid structure of the cell membrane and react as a nutrient carrier in plants. [29], state that humic acid in cell membranes will increase the permeability for some ions and reduce the permeability of other ions. The increase in the uptake of certain nutrients in the membrane supports the study of a significant increase in plasma membrane H^+ ATPase activity in the roots of corn plants.

4. Conclusions

Fertilization with basalt rock dust added with humic solvent showed the best corn plant height in 35 DAP. The highest levels of nutrients and nutrient uptake of K were obtained due to heating treatment at 300 °C in rock dust. Based on rock type, it is shown that the highest nutrient uptake in corn is due to basalt rock dust. Application of solvent to rock dust showed no significant effect on growth and nutrient uptake of corn plants.

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