Potential Nutrient Carriers of Easily Weathered Minerals from Pyroclastic Materials of Mount Merapi, Yogyakarta

Kurniati[1,3*], *Suwardi*[1], *Budi* Mulyanto[1], *Budi* Nugroho[1], *Nirmala* Juita[2], *Welly* Herman[1], and *Latifah*[4]

[1]Department of Soil Science and Land Resource, IPB University, 16680, Bogor, Indonesia
[2]Department of Soil Science, Faculty of Agriculture, Hasanuddin University, 90245, Makassar, Indonesia
[3]Agroecotechnology Study Program, Faculty of Agriculture and Forestry, Sulawesi Barat University, 22559, Majene, Indonesia
[4]Agroecotechnology Study Program, Faculty of Agriculture, Malikussaleh University, 24355, Aceh, Indonesia

Abstract. The eruption of Mount Merapi has had a negative impact on the community; however, on the other hand, it also has positive aspects that cannot be ignored. One of the major benefits associated with the eruption of this mountain is its ability to fertilize and restore the quality of the surrounding soil. This process of soil restoration involves the use of volcanic materials resulting from the eruption, specifically known as rejuvination or soil rejuvenation. In the concept of soil rejuvenation, pyroclastic materials play an important role due to their nutrient-rich content. These pyroclastic materials consist of various types of rocks and minerals, which have great potential to make a positive contribution in providing nutrients needed by plants. Based on the results of X-Ray diffraction analysis, the pyroclastic material from Mount Merapi is dominated by the mineral Albite, accounting for 81.3%. This mineral has the property of being easily weathered and susceptible to weathering agents. Volcanic materials from Mount Merapi can be utilized as agrominerals, this concept involves using volcanic material as a source of nutrients for plants since it contains both macro and micro nutrients required by plants.

1 Introduction

All living things on the surface of the Earth require a source of life and a place to live in order to carry out their activities properly. Almost all forms of life on Earth's surface are inseparable from the Earth's role and the influence of the surrounding environment. The part of the Earth that directly impacts the lives of living things is the uppermost layer of the Earth, which we call soil. Mineral soils are formed from rocks that consist of various types of minerals as the parent material for soil. Two important aspects related to the function of minerals and rocks in agriculture are (1) the pedological aspect, where minerals and rocks serve as parent

* Corresponding author: kurniati25atikah@gmail.com

materials for mineral soils, acting as a genetic factor that determines the characteristics and properties of the formed soil and its productivity, and (2) the farm management aspect, wherein geological materials are used as raw materials or directly applied as fertilizers or soil conditioners. It is an important fact that rocks are abundant natural materials on the Earth's surface that can be utilized to maintain or increase soil productivity, enhance the quantity and quality of agricultural products, and restore degraded environmental (ecological) conditions. The ability of minerals to provide nutrients to the soil and plants depends on the type of mineral they originate from. The source of rocks and minerals that are consistently renewed is from volcanoes.

Indonesia is situated within the Pacific Ring of Fire, which is the epicenter of earthquake sources and home to most of the world's volcanoes. Merapi is one of the 129 active volcanoes in Indonesia and is the most active and youngest volcano in Java, with the main hazard being pyroclastic flows. The volcano, which is administratively located in Central Java Province and Yogyakarta Special Region, is a strato-volcano with andesitic-basaltic magma content. The mountain has an altitude of 2978 meters, a diameter of 28 kilometers, an area of 300-400 square kilometers, and a volume of 150 cubic kilometers. Eruptions of Merapi occur frequently with an average cycle ranging from 2 to 5 years [1].

The eruption of Mount Merapi had a negative impact on the community; however, on the other hand, there were significant benefits, namely the re-fertilization of the existing soil. The process of rejuvenating the soil with nutrient-rich materials is often known as rejuvinalization. Shortly after the occurrence of pyroclastic flows, the process of soil formation begins through the weathering of the elements and minerals contained therein. In agriculture, apart from continuously contributing new materials to the soil formation process, pyroclastic materials also offer an appropriate environment for plant growth by providing essential nutrients found within these minerals [2].

In general, plants require at least 17 types of nutrients throughout their life. Nine macronutrients are found in plant tissues at levels exceeding 0.1% of the dry weight (C, H, O, N, K, Ca, Mg, P, S) and eight micronutrients at levels less than 100 µg/g of dry weight. (B, Cl, Cu, Fe, Mn, Mo, Ni, Zn) [3]. In addition to macronutrients and micronutrients, there are also nutrients categorized as beneficial nutrients, such as: Co, Na, and Si. Essential nutrients C, H, O are obtained from CO2, H2O, O2 and organic matter, respectively. While other essential nutrients can be found in aluminosilicate minerals, ferromagnesian silicates, and additional minerals within rocks [4]. Among macronutrients, potassium is the most commonly used rock mineral as a source of supply, such as feldspar [5], lava, granite, diorite, diabase, basalt, and volcanic ash [6], gneiss, syenite, and amphibole, also using basalt, diabase, phonolite and lava minerals as sources of Ca, Mg and Fe [6]. Furthermore [6] developed these rock minerals to serve as a source of micronutrients for plants.

Volcanic materials resulting from volcanic eruptions typically contain numerous primary minerals that have the potential to serve as nutrient sources for plants. The rate at which these primary minerals weather, and thus become valuable for plants, is strongly influenced by the composition of the constituent cations. Minerals that are easily weathered, commonly referred to as weatherable primary minerals, typically exhibit a dominant presence of alkali and alkaline earth metal contents, such as Na, K, Ca, and Mg. Therefore, this study aims to determine the primary mineral content of pyroclastic materials from the 2010 eruption of Mount Merapi, which has the potential to provide nutrients to plants.

2 Methods

Pyroclastic materials were collected from Mount Merapi, Yogyakarta, with sampling points located at 7°32.5' N and 110°26.5' E. This area was one of those affected by the Merapi eruption in 2010. The X-Ray Diffraction (XRD) analysis of pyroclastic materials was carried

out at the Mineral and Coal Technology Laboratory (TekMira) in Bandung. This analysis aims to provide information regarding the content of easily weathered primary minerals found in the pyroclastic material samples. The results of mineral analysis were quantitatively and descriptively assessed, with mineral content being presented through graphical representation. The research activities were conducted from April to August 2023.

3 Discussion

Based on the results of quantitative X-Ray Diffraction analysis, it is evident that the mineral content of pyroclastic materials is primarily composed of plagioclase mineral groups, particularly Albite, followed by Augite, with Magnetite being the least abundant mineral. Further details can be found in the table below (table 1 and figure 1).

Table 1. Mineral composition contained in pyroclastic materials.

Sample Type	Mineral Type	Quantitative analysis (%)
Pyroclastic sand	Albite	81,3
	Augite	15,5
	Magnetite	3,2

Source: Results of analysis X-Ray Difraction, 2023

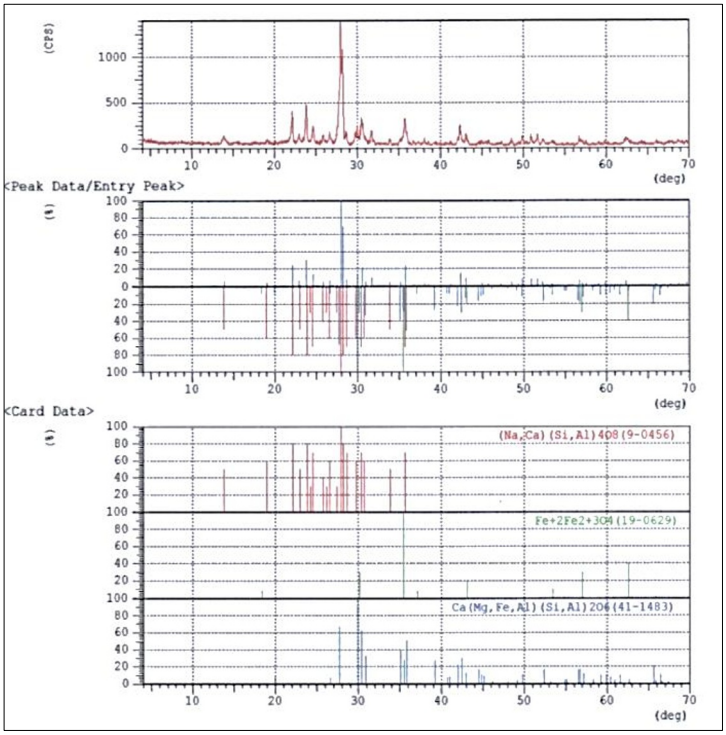

Fig. 1. Peak graph of X-Ray diffraction analysis.

Table 2. Mineral chemical formula and mineral content percentage

Mineral phase identification	Mineral chemical formula	Quantitative analysis (%)	Error of fit (%)
Albite	$NaAlSi_3O_8$	81.3	1.14
Augite	$(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$	15.5	1.14
Magnetite	Fe_3O_4	3.2	0.35

Source: Results of analysis X-Ray Difraction, 2023

Based on the results of the analysis using X-Ray Diffraction (X-RD) (table 1 and 2), it is evident that the pyroclastic material from Mount Merapi contains primary easily weathered minerals, with albite making up 81.3% and augite 15.5%. The chemical formula of these two minerals illustrates that they are highly susceptible to weathering. Albite is composed of ($NaAlSi_3O_8$) and augite of (Ca, Na) (Mg, Fe, Al, Ti) (Si, Al)$_2O_6$. When viewed from the mineral element content, albite contains essential nutrients required by plants, such as Na. Similarly, augite contains elements like Ca, Mg, and Na, which can serve as essential nutrients for plants.

The volcanic ash material released during the eruption process is believed to have significant value, mainly because of its rich nutrient content. However, for the nutrients present in primary minerals to be absorbed by plants, they must undergo a process of weathering or dissolution, transforming into readily available cations or anions for plants [7]. Damage to agricultural land affected by volcanic ash material is temporary because the land will rejuvenate through the supply of fresh materials rich in macronutrients (Ca, Mg, K, S), micronutrients (Zn, Fe, Cu, Mn), and beneficial nutrients (Si and Na) [8].

The utilization of primary minerals in rocks as a source of plant nutrients is often referred to as agrogeology or agromineral. It is literally defined as the utilization of geological resources (minerals) to enhance soil productivity [9 ; 10]. The utilization is accomplished through the use of naturally occurring geological materials, whether they are processed or unprocessed.

Many experts have attempted to utilize volcanic materials for the reclamation of marginal soils, leading to improved plant growth. Experiments involving the use of volcanic ash to reclaim ombrogenous peat soil in Kalimantan have resulted in a significant increase in the growth and nutrient uptake of calcium (Ca), magnesium (Mg), potassium (K), copper (Cu), zinc (Zn), manganese (Mn), and iron (Fe) in corn plants [11]. The use of volcanic ash to enhance soybean productivity was also conducted by Setiadi [12], and the application of 12% volcanic ash to peat soil yielded the best results. Bakken [13] It has been stated that igneous rocks containing K (such as residual Feldspar) can meet 30% of the potassium (K) element requirements for grass plants. Additionally, the use of fine basalt powder and basaltic tuff can enhance peanut production in coarse soils [9]. According to the results of Ismon's [14] research in 2006, the utilization of harzburgite at rates of 54 and 432 kg MgO/ha was effective in increasing the dry weight of trubus and phosphorus (P) uptake in corn plants grown on Typic Kandiudult soil.

4 Conclusion

Merapi's pyroclastic material originates from basaltic andesite magma with a dominant primary weatherable mineral content in the form of plagioclase (albite). The utilization of volcanic material as agromineral can be carried out due to the potential nutrient content within the minerals, which fall under the category of easily weathered minerals.

References

1. Pusat Vulkanologi dan Mitigasi Bencana Geologi. Balai Penyelidikan dan Pengembangan Teknologi Kegunungapian. **292** (2006)
2. D. Fiantis, M. Nelson, V. Ranst, E., J. Shamshuddin, N.P. Qa¬foku, M.Sci **6** (2009)
3. Welch, R. M. Crit Rev Plant Sci. **14** (1995)
4. A. Harley, R. Gilkes. Nut.Cyc.Agr. **56** (2000)
5. S. Scovino, J., I., D. Rowell. Fert Res **17** (1988)
6. Blum, W.E.H., B. Herbinger, A. Mentler, F. Ottner, M. Pollack, E. Unger, W.W. Wenzel. Z Pflanzenernaehr Bodenk. **152** (1989)
7. N. Kusumarini, S.R. Utami, Z. Kusuma. J.Tan.SDL **1** (2014)
8. E. Hanudin. *Pendekatan Agrogeologi dalam Pemulihan Lahan Pertanian Pasca Erupsi Merapi, in* prosiding Seminar Nasional, Surakarta (2011)
9. Van Straaten, P. Upsala. Zambia, **78** (1985)
10. E. Hanudin, S., N., H. Utami. *Absorption of Ca, K, Mg and Na in Corn on The ombregenous Peat as Affected by Volcanic Ash and Flying Ash*, in proceeding of Bogor Symposium and Workshop on Tropical Peat Management. 14-15 July 2009, Bogor Indonesia (2009)
11. B. Setiadi. Disertasi. UGM. **205** (1996)
12. Bakken, A.K., H. Gautneb, K. Myhr. Nut.Cyc.Agr. **47** (1997)
13. Bakken, A.K., H. Gautneb, T. Sveistrup and K. Cycling in Agroecosystem **56** (2000)
14. Ismon, L. J.trop soil **11** (2006)