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Research Article

Utilization of locally available organic matter to improve chemical properties of pyroclastic materials from Mt. Kelud of East Java

S.R. Utami*, C. Agustina, K.S. Wicaksono, B.D. Prasojo, H. Hanifa

Faculty of Agriculture, University of Brawijaya, Jl. Veteran 1, Malang 65145, Indonesia

*corresponding author: sriyutami@gmail.com

Abstract: Pandansari village, Ngantang District was severely affected by Mt. Kelud eruption in 2014. Almost all soil surfaces were covered by the eruption product, leading to serious problems for cultivation. Pyroclastic materials potentially have high content of nutrients, but they are not readily available to plants. As an attempt to improve chemical properties of the pyroclastic materials, we applied locally available organic matters, from four different sources, i.e. leaves of sweet potatoes, *Tithonia diversifolia*, maize, and cow manure. The pyroclastic materials were sieved at 2 mm, placed inside pots (50 x 50 x 50 cm^3), until it reached 30 cm thick. The fresh leaves were chopped into 2 mm size and mixed with the pyroclastic materials at the dosage of 15 Mg/ha. They were incubated and kept at field condition. Selected chemical properties (pH, CEC, sum of basic cations, and the total contents of N, organic C, and available P) were measured before and after 90 days incubation. The results showed that after 90 days, organic matter application significantly increased pH, cation exchange capacity, organic C, and total exchangeable basic cations content. The increases of P-available and total N contents were only detected on cow manure treated materials.

Keywords: *soil amandment, land reclamation, nutrient availability*

Introduction

Mount Kelud (East Java) is one of the very active volcanoes in Indonesia which erupted periodically with different type of eruption in the last period. The last eruption (2014) was very explosive, spreading pyroclastic materials to the northern and western parts of East Java, even to Central Java (Suntoro et al., 2014). Pandansari village, Ngantang region, Malang, was one of the areas severely damaged by the eruption. Volcanic eruptions are disaster, but its eruption materials contain relatively high nutrient, hence it may rejuvenate soil fertility. In the long term, they release nutrients for plants, after undergoing physical and chemical weathering (Lansing et al., 2001). However, in the short term, nutrient availability is normally low. Furthermore, these materials have low content of organic matter, and hence low nutrient holding capacity.

The benefits of incorporating organic matter into the soils were often reported. Bohn et al. (2001) stated that organic matter could increase CEC soils up to 20-70%. Organic matter increases negative charges important for nutrient retention in the soils. Applying organic matter may also reduce nitrate leaching up to 60% (Widowati et al., 2014), a promising solution for–especially-sandy soils, which normally have poor water and nutrient holding capacity and little organic matter (Prasad et al., 2015). A leaching experiment on pyroclastic materials from Mount Bromo and Merapi (Kusumarini et al., 2014) showed that organic matter could accelerate the release of basic cations from the pyroclastic materials. However, this research was laboratory experiment, and had not been validated in the field.

Considering that the volcanic impacted areas are often agriculturally important, problems related to soil limiting factors for crop growth is necessary to overcome. To achieve this objective, an attempt was made to study the organic matter on the chemical properties of pyroclastic materials.

Materials and Methods

Pyroclastic materials from the late eruption of Mt Kelud were taken from Pandansari village, Ngantang. This area was considered as ring 1, the area which most severely affected by the eruption of Mount Kelud. The pyroclastic materials were then air-dried and sieved to 2 mm size. The materials were then transported to Agricultural Experimental Station in Ngijo, Kepuharjo, Karangploso sub district, Malang, in which the field experiment was conducted. The pyroclastic materials were sieved at 2 mm, placed inside pots (50 x 50 x 50 cm^3), until it reached 30 cm thick.

The research using Completely Randomized Design was then conducted, consisting of four treatments, namely Bo = control, without organic matter; BZM = maize leaves; BSP = sweet potato leaves; BTD = *Tithonia diversifolia*; BCM = cow manure application, with three replications. The fresh leaves were chopped in to 2 mm size and mixed with pyroclastic materials at a dosage of 15 Mg/ha. During the experiment, the moisture in the media was maintained at field capacity.

Soil sampling for chemical analysis were taken before and after the experiment (90 days). Soil chemical properties measured were pH, % organic C (Walkley and Black), % total N (Kjehdal), available P (Bray), cation exchange capacity (CEC), the amount of exchangeable Ca, Mg, K, and Na (NH_4OAc pH7). The analyzes were conducted at the Laboratory for Soil Chemistry, Faculty of Agriculture, University of Brawijaya.

Results and Discussion

Chemical properties of initial pyroclastic materials

The selected chemical properties of initial pyroclastic materials from Mt Kelud are presented in Table 1. Pyroclastic materials from the late of Mt Kelud eruption had a pH of 4.3 (very acid). However, the pH of leached materials is normally higher, and increased from time to time. This was indicated in the leaching study on tephra deposits from Talang volcano using de-ionized water, organic and anorganic acids (Fiantis et al., 2010). Carbon and nitrogen apparently occurred in the pyroclastic materials, although its content was extremely low. However, it was containing surprisingly a considerable amount of available P.

Table 1. Selected chemical properties of initial pyroclastic materials.

Properties	Unit	Amount	Criteria
pH-H_2O	-	4.33	very acid
C-organic	%	0.35	very low
Total N	%	0.02	very low
Available P	ppm	45.57	very high
C / N Ratio	-	0.94	
CEC	cmol/kg	2.05	very low
Exchangeable Cations			
• K	cmol/kg	0.10	low
• Na		0.17	low
• Ca		1.05	low
• Mg		0.00	very low
Base Saturation	%	64	moderate

As common for coarse sized materials, cation exchange capacity was very low, and consequently low content of exchangeable basic cations. However, base saturation is medium due to a low CEC. The pyroclastic materials of Mount Kelud contained macro and micro nutrients, which potentially released to the soil. In average, pyroclastic materials from Mt Kelud were mineralogically composed of plagioclase, pirocsenit, opaques, olivine, iddingsite and quartz (Zaennudin, 2009) which then released to macro and micro nutrients (Suntoro et al., 2014). Nevertheless, these elements are still in the form of mineral crystalline that have to weather first before being available for plants.

Chemical characteristics of organic materials

Table 2 shows the content of some element in organic materials used in this study. Maize leaves contained higher content of C-organic, but lower content of N than other green manures. Cow manure had lower organic C and N content than other organic materials used in this study. Having

C/N ratio >15, maize leaves and cow manure were possibly slowly decomposed. Whereas the decomposition rate of sweet potato and *Tithonia diversifolia* leaves was potentially faster because of the low C/N ratio (6.6 and 7.25 respectively).

Sweet potatoes leaves had highest total content of base cations (9.2%), followed by *Tithonia diversifolia* (8.1%), manure (2.4%), and maize leaves (1.5%). *Tithonia diversifolia* leaves had the highest content of Ca and lowest content of Mg. While sweet potato leaves was dominated by K (5.84%) and Na (1.97%), with the highest content of Mg among others. These indicated that sweet potato and *Tithonia diversifolia* leaves were potentially capable to neutralize acidity, because they contain high total amount of basic cations (Utami et al., 2008).

Table 2. Chemical composition of the organic materials used in the study.

Nutrient		Maize	Sweet Potatoes	*Tithonia diversifolia*	Cow Manure
C	%	61.59	50.80	54.10	36.96
N	%	3.32	7.66	7.46	1.97
C/N	-	18.55	6.63	7.25	18.76
P	%	0.44	1.33	0.98	0.40
C/P	-	140	38	55	93
K		0	5.84	4.19	0.34
Na	%	0.17	1.97	1.59	0.70
Ca		0.77	0.85	2.28	0.82
Mg		0.51	0.57	0	0.52

The effect of organic matter on the chemical properties of pyroclastic material

Soil pH

The effect of organic matter application on the chemical properties of pyroclastic material after 90 days incubation is presented in Table 3. The results showed that the pH increased 0.8-1.2 units after the addition of organic matter. However, statistically there were no significant differences between the types of organic materials applied. Similar research in Ultisols Lampung (Utami et al., 2008) showed that 90 Mg/ha application of organic matter significantly increased soil pH and total basic cations. However at a lower dosage (8 Mg/ha), the effect was insignificant. At high dosage, *Tithonia diversifolia* and *Leucaena* leaves were able to neutralize Al toxicity to 0 cmol/kg, due to the high quality (low lignin, polyphenols, and C/N ratio). In contrast, mahogany and coffee litters having low quality (high lignin, polyphenols, and C/N ratio) reached the same level of Al toxicity only after 6-10 weeks incubation.

Table 3. Chemical properties of pyroclastics materials after 90 days incubation with organic materials.

Treatments	pH	C-org	N	P	CEC	Ca	Mg	K	Na	Total	BS*
		%		mg/kg			cmol/kg				%
B_o	5.0	0.53	.0002	27.2	1.61	0.61	0.01	0.10	0.17	1.61	53
B_{ZM}	6.0	1.08	.0011	25.0	14.53	1.78	0.61	0.09	0.14	2.62	18
B_{SP}	6.0	1.15	.0008	22.9	15.43	1.72	1.10	0.12	0.19	3.13	20
B_{TD}	5.6	1.16	.0009	22.7	12.13	1.93	1.02	0.07	0.11	3.13	26
B_{CM}	5.9	1.01	.0005	37.4	14.11	2:01	1.15	0.1	0.16	3.42	24

*BS = Base Saturation

Total organic carbon and nitrogen

The addition of organic matter increased the 0.08-0.22% organic C compared to control. The highest percentage of organic C occurred in BTD (*Tithonia diversifolia* leaves) and BSW (sweet potatoes leaves). In the study of new tephra from Mt. Talang, Fiantis et al. (2016) found that total carbon (TC) was increased significantly from initially 0.19 to 1.75% in the tephra layer or eight times higher after 48 months incubation. The study also indicated that higher TC storage occurred in the 2.5 cm than 5.0 cm tephra layer. On the contrary, lesser amount of TC was found in the single tephra without soil underneath. Based on this study, similarly we could expect that only little increment of organic C in this study which used 30 cm thick pyroclastics materials.

The results also showed that N total content increased after 90 days incubation, although in negligible amount. The total content of N, however did not correspond to the total content in the original organic matter. This means that in the short term (3 months), the addition of organic material might not able to increase N total content in the pyroclastics.

Cation exchange capacity and sum of basic cations

Cation exchange capacity shows the ability of soil to hold and release nutrients. The results showed that CEC in the organic matter treated pyroclastics were higher than the untreated one. Organic matter potentially increased negative charges to the soil, and hence increased CEC (Utami et al., 2002). The negative charges, especially the variable charges were normally dependant on the pH. A slight increase of pH may increase negative variable charges, hence increased CEC of the materials.

In general, sum of basic cations in the organic matter treated pyroclastics were higher than untreated ones. Organic matter application increased the content of exchangeable Ca, Mg, K, but not Na. Increasing the number of cations are likely not only from green manure or manure, but also the release of the cation from the pyroclastic materials itself. In the leaching experiment studied by Kusumarini et al. (2014), the total amount of exchangeable base cations in the leachate and the remaining in the pyroclastic materials from Mt. Merapi and Bromo were greater than the initial materials and the added organic materials. This indicated that they could be released gradually from the pyroclastics materials. In other side however, leaching processes may also occur. This was indicated by the lower content of basic cations in the untreated pyroclastic materials after 90 days incubation compared to the initial content (before treatment).

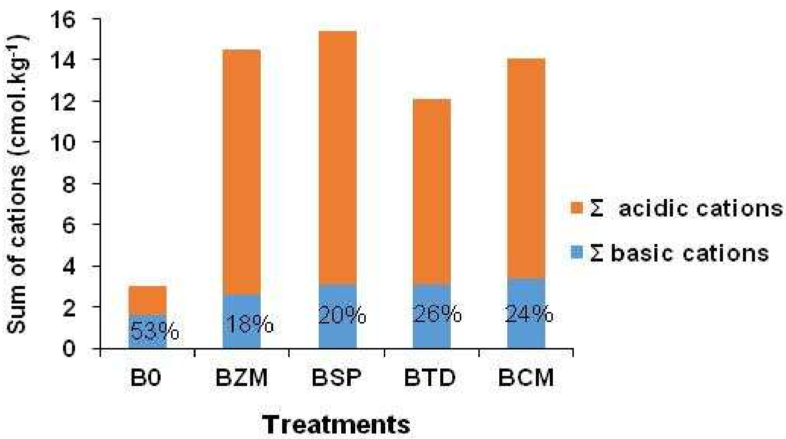

Figure 1. Sum of base cations and acidity as affected by various treatments.
Note: The numbers in the box show the percentage of base saturation.

The highest total amount of exchangeable cations present in manure treatment. However, basic saturation in the untreated pyroclastic materials was higher compared to the organic treated materials. Base saturation is calculated relative to the CEC, so that even though the sum of basic cations in untreated materials was low, base saturation could be higher due to a lower CEC (Figure 1). It means, base saturation is not an ideal fertility indicator to be used as a basis for soil fertility management (Utami et al., 2007).

Soil phosphorus availability

In general, the addition of organic matter actually reduces the amount of available P in the pyroclastic materials, except for manure. Manure treatment significantly increased the amount of available P in the eruption material. Increasing amount of P could be derived from organic matter or pyroclastic materials itself. When we compared the four organic sources, we assumed that P mineralization from maize leaves was rather slow, due to a low content of P and consequently high

C/P ratio. In contrast, sweet potato, *Tithonia diversifolia* leaves and cow manure containedhigher P content and low C/P ratio (<100), then we could expect a faster mineralization rate of phosphorus (Utami et al., 2006). Such conditions do not occur in this study, indicating that the release of P from organic materials depends on many factors other than the C/P in organic materials applied. Availability of P is still relatively low although the pH was increased.

Conclusion

The addition of organic materials generally increased pH, cation exchange capacity, organic-C content, the total amount of exchangeable basic cations and total N. The amount of exchangeable Na tended to decrease on the organic matter treated materials. The total amount of basic cations that were lower in the untreated materials resulted in a higher base saturation, because of a lower CEC. The increase contents of P-available and total N were only detected on cow manure treated materials.

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