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Research Article

Application of organic matter and biofertilizer to improve growth and yield of maize on soil damaged by volcanic ash of Mount Kelud in East Java

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Abstract: Volcanic ash from the eruption of Mount Kelud in 2014 damaged some agricultural areas grown with maize in Malang of East Java. The purpose of this study was to elucidate the effect of organic fertilizers and biological fertilizers on growth and yield of maize on soils damaged by volcanic ash from the eruption of Mount Kelud. A pot experiment was conducted in the glasshouse of Balitkabi, Kendalpayak, Malang from July 2014 to February 2015. The treatments tested in this study were combinations of three mixtures of soil and volcanic ash (90%:10%, 80%:20%, and 70%:30%), and two doses of biofertilizer (25 and 35 kg / ha). Each treatment was added with 5 t organic matter/ha. A total of 10 kg of each mixture of soil and volcanic ash was placed in a 15 kg plastic pot. Each treatment received 100 kg inorganic fertilizer / kg containing 15% N, 15% P, and 15% K. Three seeds of maize (NK33 variety) were planted in each pot and thin to one plant after one week. The experiment was conducted for 14 weeks. The results showed that application of organic matter and biofertilizer did not significantly improve fertility of soil mixed with volcanic ash from the eruption of Mount Kelud. Yield of maize was not significantly improved by the application of organic matter and biofertilizer on soil mixed with volcanic ash. The contents of carbohydrates and proteins in maize seeds were also not affected by application of organic matter and biofertilizer.

Keywords: *carbohydrate, protein, trichoderma, volcano*

Introduction

Maize (*Zea mays* L.) is one of the ereal crops having strategic and economic values as well as opportunity to be developed due to its position as the main source of carbohydrates and protein after rice. Almost all parts of the maize plant can be utilized for various purposes. In Indonesia, production of maize as a staple food ranks third after rice and cassava. Maize can be used as an alternative staple food because it has several advantages. According to Sugiyono et al. (2004), based on the nutritional value, maize has a higher protein content (9.5%) compared to rice (7.4%). In addition, mineral and vitamin contents between rice and maize are almost the same.

Malang Regency is a regency in East Java with a high potential for maize. In 2011, maize production reached 297,302 t by the use of the land area of 59,108 ha (BPS East Java, 2010). However, the eruption of Mount Kelud on 13 February 2014 caused damage to the maize crop areas in Malang of 3,832 ha (Tim Kajian Cepat BPTP Jawa Timur, Balitkabi, Balittas, Balitjestro, Lolit Sapi Potong, 2014, 2014). Malang Regency area most severely damaged by the eruption of Mount Kelud were Ngantang, Kasembon and Pujon. Forms of physical damage caused by the eruption of Mount Kelud on the plant were dry and dead leaves, fruit rot and fall, as well as dry and dead plants. Young plants usually died, whereas older plants were still alive but living trunks.

Volcanic ash is a material containing high silica and aluminum that can react with the limestone at room temperature and the presence of

water will produce a hydrate having binding or cementation properties (Adamiec et al., 2008). If the rainfall is very high and far exceeds the capacity of the water on the soil surface, it will form a very saturated ground water. According to the Tim Kajian Cepat BPTP Jawa Timur, Balitkabi, Balittas, Balitjestro, Lolit Sapi Potong (2014), one of the short and medium-term efforts that can be done to restore production of maize affected volcanic ash eruption is the addition of organic materials, and or biological fertilizer on agricultural land.

Organic matters are very useful for the improvement of agricultural productivity, conserve nutrients, reduce environmental pollution, and sustainably improve the quality of soil (Sri Adiningsih et al., 1995). Results of several studies suggested that cow manure increases the weight of seed per hectare (Jemrifs et al., 2013). Application of organic fertilizers derived from guano, leucaena prunings, as well as farm yard manures reduced the concentration of Al in acid soils, increased the availability of N and improve the growth of maize (Trisnadewi et al., 2012; Jemrifs et al., 2013).

The term biological fertilizer is used as a collective name for all of the functional groups of soil microbes that can function as a provider of nutrients in the soil to make the nutrients available to plants (Simanungkalit et al., 2006). One of the biological fertilizer that is widely used is the *Trichoderma* biological fertilizers (Akladious and Abbas, 2012). *Trichoderma sp*. is a free-living fungi commonly found in soil and root system and it is known to dissolve phosphate and micro nutrients (Rudresh et al., 2005; Saravanakumar et al., 2013). Interaction *Trichoderma sp*. with plants provides several advantages such as resistance to diseases, stimulates plant growth and tolerance to abiotic stresses (Shukla et al., 2012). Some studies showed that *Trichoderma sp* is able to stimulate plant growth and defense (Harman et al., 2004).

The purpose of this study was to elucidate the effect of organic fertilizers and biological fertilizers on growth and yield of maize on soils damaged by volcanic ash from the eruption of Mount Kelud.

Materials and Methods

Materials used for the study

A pot experiment was conducted in the glasshouse of Balitkabi, Kendalpayak, Malang from July 2014 to February 2015. The materials used in this study were soil, volcanic ash from the eruption of Mount Kelud, maize seeds of NK33 variety, compost, inorganic fertilizer, and biofertilizer of *Trichoderma sp*. The soil used in this study was the topsoil (0-30 cm) of an Andisol collected from agricultural land area of Cangar, Malang. Compost used in this study was the UB compost having the following characteristics, 1.2% N, 1.4% P, 0.63% K, pH 5, C / N ratio 12-13, and 30% water. The volcanic ash was collected from the area of Ngantang that was damaged by the eruption of Mount Kelud. The *Trichoderma* biofertilizer used in this study was produced by PT. Agritani Makmur Mandiri, Jakarta. Seeds of NK33 maize variety were obtained from the Department of Agriculture of Malang.

Soil and volcanic ash analyses

Soil samples were air dried for 7 days and then sieved to pass through a 2 mm sieve. Soil samples that passed through the 2 mm sieve was used for the analyses of texture (pipette method), total N content (Kjeldahl method), content of organic C (Walkey and Black method), content of available P (Bray-1 method), microbial biomass N (chloroform fumigation methods), and cation exchange capacity (saturation method with ammonium acetate at pH 7). All soil analyzes were performed using standard methods Soil Laboratory of Balitkabi, Malang. Results of soil analysis showed soil properties as follows, 0.33% N, 2.92% organic C, CEC 15.1 $cmol^+$ / kg, pH 5.4, 162 mg available P / kg, K 0.20 $cmol^+$ / kg, and microbial biomass N 17.96 mg / kg. Volcanic ash from the eruption of Mount Kelud was collected at a thickness of 3-9 cm, air dried for 7 days, and then sieved to pass through a 2 mm sieve. The volcanic ash has the following characteristics, 34.27% Si, 1% Al, 0.057% Fe, 0.005% Mn, 0.12% Mg, 3.26%, Ca, 0.12% K, 0.43% organic C, pH 3.90, CEC = 0.12 cmol + / kg (Tim Kajian Cepat BPTP Jawa Timur, Balitkabi, Balittas, Balitjestro, Lolit Sapi Potong, 2014),

Treatments and Experimental Design

The treatments tested in this study were combinations of three mixtures of soil and volcanic ash (90%:10%, 80%:20%, and 70%:30%), and two doses of biofertilizer (25 and 35 kg / ha). Each treatment was added with 5 t organic matter/ha. For comparisons, four treatments without addition of biofertilizer and organic matter were also included in the experiment. Ten treatments were arranged in a completely randomized design with three

replications. A total of 10 kg of each mixture of soil and volcanic ash was placed in a 15 kg plastic pot. Each treatment received 100 kg inorganic fertilizer / kg containing 15% N, 15% P, and 15% K. Three seeds of maize (NK33 variety) were planted in each pot and thin to one plant after one week. Plant maintenance that included watering, weeding, and pest control, was done from the beginning of planting until harvest. Plant height was measured at 2,4,6,8, and 14 weeks after planting. At the time of harvest (age of 14 weeks), observations were made for soil total N, soil N microbial biomass, and yield of maize. Data obtained were subjected to analysis of variance followed by LSD test at 5% test to determine the differences of each treatment.

Results and Discussion

Soil total N

Changes in the value of soil total N after 14 weeks of planting are presented in Figure 1. The results indicate that the highest total N of 0.32% was recorded in the control treatment (100% of soil without volcanic ash, and biofertilizer). While the lowest soil total N of 0.11% was observed at the A30T70H35 treatment (a combination of 30% volcanic ash + 70% soil with the addition of 35 kg biofertilizer / ha).

When compared with the results of the initial analysis, the overall value of the total N in the soil was still below that of 0.33% and was still in the criteria of medium-low. A decrease in the content of N-total in the soil was probably due to environmental factors namely the temperature inside the greenhouse that was relatively high. The results were similar to that of previous studies reported by Fiantis (2006) that the addition of volcanic ash did not significantly change the soil chemical properties. According to Rostaman et al. (2011), in the long term volcanic ash can improve soil fertility, but the fertility of the soil will have negative effect in the short term because the mineral ash has not been optimally absorbed by the plants.

Soil N microbial biomass

The highest value of the N microbial biomass was observed in the control treatment (Figure 2). The presence of volcanic ash and biofertilizer in the soil studied did not significantly affect the soil N microbial biomass after 14 days. This was probably related to the environmental conditions during the experiment. The short period of experiment conducted for only 14 days was not sufficient enough to measure the effects of volcanic ash as this material is not easily decomposed (Adamiec et al., 2008). In addition, at the time of the vegetative period, the need of plant for nutrients is still relatively few. This condition causes all forms of N contained in soil can be used by microbes to assimilate form of biomass (Witt et al, 2000).

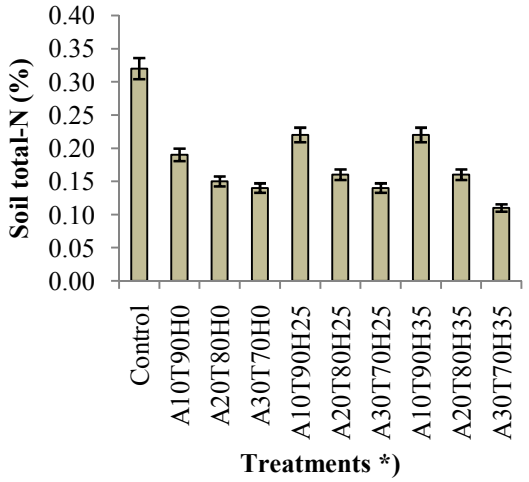

Figure 1. Effect of treatments on total N content in the soil studied after 14 weeks. *) A_{10} = 10% volcanic ash; A_{20} = 20% volcanic ash; A_{30} = 30% volcanic ash; T_{90} = 90% soil; T_{80}% = 80% soil; T_{70}% = 70% soil; H_0 = without biofertilizer; H_{25} = 25kg biofertilizer/ha; H_{35} = 35kg biofertilizer/ha.

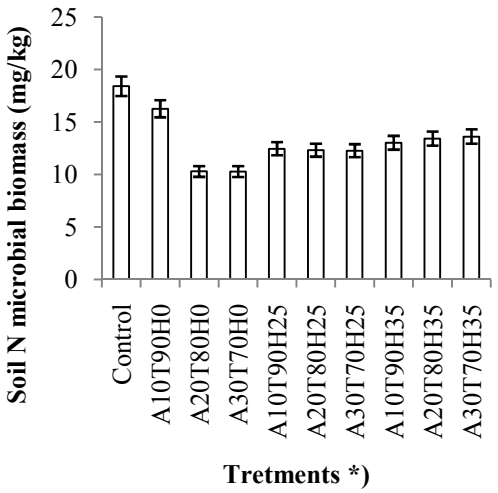

Figure 2. Effect of treatments on N microbial biomass in the soil studied after 14 weeks. *) see Figure 1

The highest N microbial biomass content after that of the control treatment was observed for the mixture of 10% volcanic ash and 90% soil measuring of 16.26 mg / kg. This was presumably because the value of soil total N was also high when compared with other treatments. The activity of microbes that decompose organic fertilizers also produces a number of organic acids triggering the process of N mineralization (Winarso et al., 2011).

Growth of maize

Growth increased along with the increasing age of the plant (Figure 3). The high growth of plants began to occur at 3 and 6 weeks after planting. The highest plant height of 140.33 cm was observed in the control treatment, and the lowest was in the 30% volcanic ash +70% soil treatment with the addition of 35 kg biofertilizer / ha.

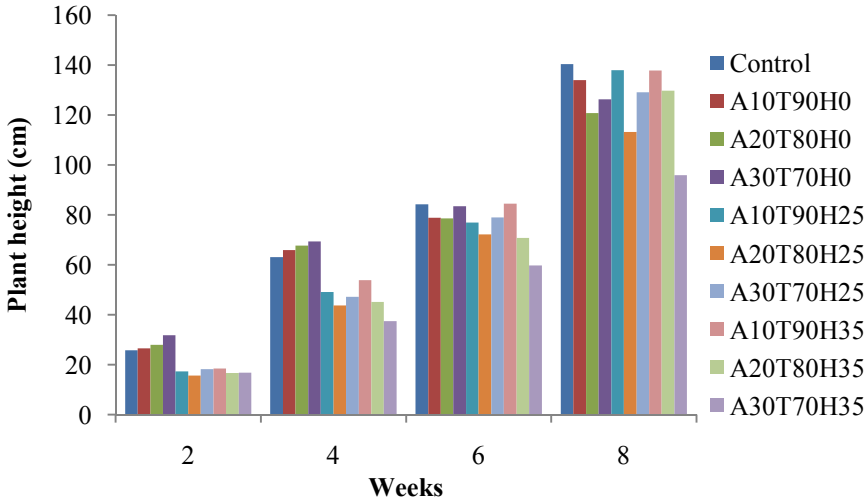

Figure 3. Effect of treatments on height of maize grown for 8 weeks. *) see Fiogure 1.

Results of analysis of variance showed that application of biofertilizer significantly affected the plant height at 2 and 4 weeks. This was presumably because the *Trichoderma* biofertilizer was also able to decompose the added compost that contained N, P, S and other elements that plants need to grow. According to Purwantisari and Hastuti (2009), *Trichoderma sp* which serves to break down organic materials can be utilized by plants in stimulating growth, especially plant height. Lehar (2012) noted that that there was an interaction between the application of *Trichoderma sp.* and the kinds of fertilizer on plant growth components, i.e. plant height of potato at 4-10 weeks, the number of potato leaves at 6, 8, and 10 weeks, and potato leaf area index at 6 and 8 weeks.

The second largest plant height (138 cm) that was observed for the treatment of 20% volcanic ash and 90% soil with the addition of 25 kg biofertilizer/ ha at 8 weeks was directly proportional to the total N in the soil at the same treatment. The higher dose of volcanic ash applied the smaller the percentage of success to improve the chemical and biological properties of the soil, the maize growth and production were all affected by the volcanic ash from the eruption of Mount Kelud. This was supported by the results of previous studies reported by Nurlaeny et. al (2012) that the average plant height decreased with increasing amount of volcanic ash in the soil.

Yield of maize

All treatments significantly affected maize yield. The highest yield (1.62 t / ha) was found in the control treatment, while the lowest yield of 0.71 t / ha was obtained from the A20T80H25, A30T70H25, and A20T80H35 treatments (Figure 4). The yield, however, was very much lower than that normally yielded by the variety that can reach 8.1 t / ha (Nurchayati and Yuliana, 2006). The low yield of maize was probably due to some factors affecting and relating to the parameters that have been previously observed. The data presented in Figure 1 show that the total soil N content was very low. The addition of compost and *Trichoderma* biofertilizer had not been able to

increase availability of N for maize growth. In addition, the harvest period of the maize variety used in this study is only 3 months. It is possible that in a short period of time the addition of organic matter and biofertilizer have not worked optimally to decompose minerals that exist in the volcanic ash. Therefore, the positive effects of compost and biofertilizer could not be seen optimally. Ding et al. (2013) stated that the positive impact of the use of compost on production is evident on long-lived plants.

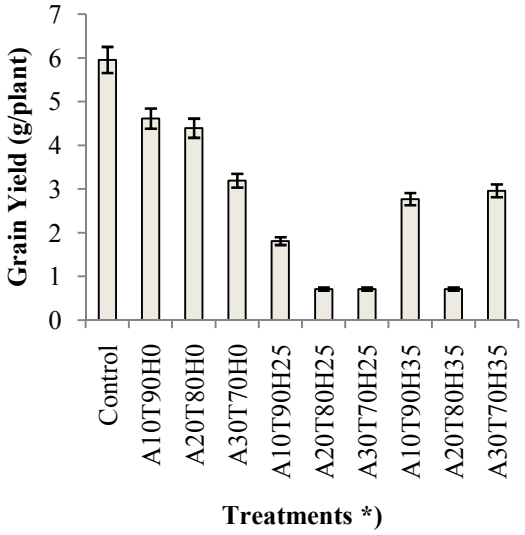

Figure 4. Effect of treatments on maize yield after 8 weeks. *) see Figure 1

Carbohydrate and protein contents in maize grains

The presence of volcanic ash in the soil significantly affected carbohydrates and protein contents of the harvested maize seeds (Figure 5). The highest carbohydrate content was observed in the A20T80H0 treatment (20% volcanic ash +80% soil, without biofertilizer). This figure, however, did not significantly different from that of control treatment. The highest protein content (6.64%) was also obtained by the control treatment. In line with results of other parameters observed for this study, application of organic matter and biofertilizer has not significantly improved soil chemical properties that in turn improve maize yield. This indicates that chemical constituents contained in the volcanic ash did not play any roles in improving soil fertility, but did hinder plant growth and yield.

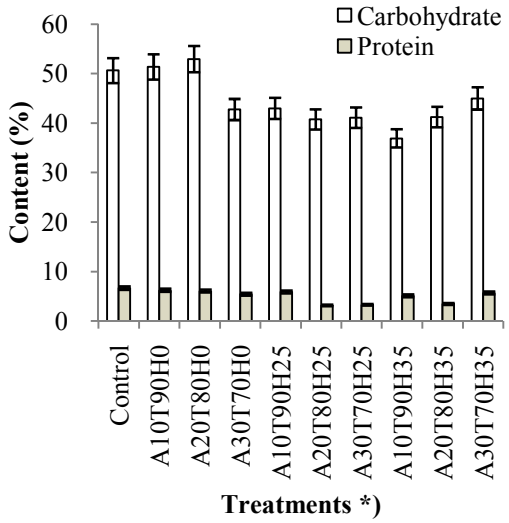

Figure 5. Effect of treatments on carbohydrates and protein contents of maize seeds *) see Figure 1.

Conclusion

Application of organic matter and biofertilizer did not significantly improve fertility of soil mixed with volcanic ash from the eruption of Mount Kelud. Yield of maize was not significantly improved by the application of organic matter and biofertilizer on soil mixed with volcanic ash. The contents of carbohydrates and proteins in maize seeds were also not affected by application of organic matter and biofertilizer.

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