

**Research Article**

**The use of volcanic ash from the eruption of Mount Kelud in East Java for improving yield of sweet potato grown on a sandy soil**

**H. Melsandi \*, S. Prijono**

Department of Soil Science, Faculty of Agriculture, Brawijaya University, Jalan Veteran No1., Malang 65145, Indonesia

\* corresponding author: heni080993@gmail.com

**Abstract:** The purpose of this study was to explore the effect of volcanic ash from the eruption of Mount Kelud and compost on the soil properties and production of sweet potato on a sandy soil. The treatments of this study were (a) a combination of and volcanic ash with the proportion of 100: 0, 90:10, 80:20, and 70:30 (% weight), (b) the addition of compost (2.5 and 5 t / ha), and (c) two varieties of sweet potato (Manohara and Ayamurazaki). The soil used in this study is the topsoil (0-30 cm) Psament or sandy Entisol obtained from sweet potato cultivation location in Sumber Pasir Village of Pakis District, South Malang. Ten kilograms of planting medium (soil + volcanic ash) for each treatment was placed in a 15 kg plastic pot. Sixteen treatments arranged in a factorial completely randomized design with three replications. The results showed that application of Mount Kelud volcanic ash and compost was able to improve soil permeability, soil pH, organic C, and K-total, but did not significantly affect total N content, available P and K total land. The highest fresh tuber weights of 373.51 g / plant or 19.92 t / ha and 393.09 g / plant or 20.96 t / ha for Manohara and Ayumurazaki varieties, respectively, were observed in the treatment of 10% volcanic ash + 5 t compost / ha. The carbohydrate content of Manohara variety was higher than that of Ayamurazaki variety at each treatment. The highest carbohydrate content of the Manohara variety (23.52%) was obtained through application of 20% volcanic ash + 2.5 t compost/ha, while that of the Ayamurazaki variety (22.42%) was obtained through application of 30% volcanic ash + 2.5 t/ha.

**Keywords:** soil permeability, sweet potato, volcanic ash

**Introduction**

Sweet potato is one of the crops that have privileges in terms of nutritional value that is rich in fiber, complex carbohydrates, and low in calories. In addition, Jaya (2013) notes that another advantage of the sweet potato contains high amount of vitamin B. Production of sweet potato East Java in 2014 was 393.2 thousand tons of wet tubers with productivity of 21.9 t / ha (BPS Jawa Timur, 2014). This figure was lower than the average production of 25.95 t/ha (Jedeng, 2011). This indicates the magnitude of the chance to increase the productivity of sweet potatoes in East Java. The production of sweet potato in the dry land area of East Java is still low because it is associated with upland soil properties which are dominated by sandy soil.

Sandy soil is a limiting factor of plant growth. In addition to causing plants do not thrive due to lack of water which made up 70% of large-sized soil particles (0.02 to 2 mm), dry land is also extremely vulnerable to nutrient deficiencies or compounds that plants need in small amounts such as iron (Fe), Manganese (Mn), or the number of the macro, such as phosphate available, as well as plant nutrient cycling by soil microbes to be disrupted (Jedeng, 2011). According to Sukisno et al. (2011), the soil which is dominated by the sand fraction have a low aggregate stability, low water-holding capacity, low ion exchange capacity, and no or less able to withstand the elements nutrient is given so the nutrients become available for plants carried away by the soil solution. Polakitan and Taulu (2009) stated that sweet potato requires

the availability of adequate water and not tolerate poor drainage.

Relation to dry land dominated by sandy soil, in 2014, precisely on Thursday February 13 at 22:50 pm, Kelud in East Java experience the peak of the eruption of volcanic eruptions form lava bursts (rock, sand, dust, and gas). Kelud eruption caused agricultural land covered with volcanic ash. If left alone so the volcanic ash would quickly undergo sedimentation and hardening. Volcanic ash prone to sedimentation and hardening will be very suitable if applied on sandy soil as adhesive soil particles to increase the ability of soil to retain water. In addition, the results of the preliminary analysis of the chemical content of Mount Kelud volcanic ash showed that the volcanic ash contained 55.54% SiO<sub>2</sub>. This high silicate content would be beneficial to increase the strength and resistance of plants to pests and diseases. Likewise, the content of essential macro and micro nutrients is expected to add to the fertility of the soil. According to Soil Research Institute (2005), Si can replace P fixation by Al and Fe so that P becomes available to plants.

The addition of organic matter or compost is expected to increase the total soil K levels. This is because the sweet potato as a starch-producing plants, need soil with a high BO and K in an amount more than the required other plants in general because of the element of K was instrumental in the enlargement of the tubers (Fitter and Hay, 2002). Organic materials such as compost has the ability to improve soil physical properties, one of the materials forming soil aggregates, add nutrients nitrogen and phosphorus, organic matter supply, and improve the lives of the soil microorganisms (Atmojo, 2003; and Zubir et al., 2013). The purpose of this study was to explore the effect of volcanic ash from the eruption of Mount Kelud and compost on the soil properties and production of sweet potato on a sandy soil.

## **Materials and Methods**

Experiments conducted in a glasshouse of Tuber Crops Research Institute, Malang from July 2014 to February 2015. The treatments of this study were (a) a combination of and volcanic ash with the proportion of 100: 0, 90:10, 80:20, and 70:30 (% weight), (b) the addition of compost (2.5 and 5 t / ha), and (c) two varieties of sweet potato (Manohara and Ayamurazaki). The soil used in this study is the topsoil (0-30 cm) Psament or sandy Entisol obtained from sweet potato cultivation location in Sumber Pasir Village of

Pakis District, South Malang. Results of preliminary analyses performed in soil laboratories, Faculty of Agriculture, Brawijaya University showed that the soil has the following properties: 4.76 cmol<sup>+</sup> Ca/ kg; 0.99% C-organic, cmol<sup>+</sup> 0.37 K / kg; CEC 12.80 cmol<sup>+</sup> / kg; Cmol + 6.15 mg / kg-1; 0.09% N; Microbial Biomass N 9.44 mg / kg; 67.00 mg P available / kg, 58.38% sand; 23.78% of dust; 17.84% of clay; Permeability 39.31 cm/hour, and pH 5.70. Volcanic ash from the eruption of Mount Kelud was the same as that used in the study Hardianita (2015). Ten kilograms of planting medium (soil + volcanic ash) for each treatment was placed in a 15 kg plastic pot. Sixteen treatments arranged in a factorial completely randomized design with three replications. Seeds taken from shoot cuttings of sweet potato varieties and varieties Ayamurazaki Manohara aged two to three months with a length of 25 cm were planted in each pot. Before planting, all pots received 100 kg NPK / ha as basal fertilizer. During the experiment, conducted periodic maintenance included weeding, control of weeds, pests and diseases, and the addition of water so as not to disturb the water supply for plant growth. Sweet potato was harvested when at 16 weeks after planting. Observations made at harvest included the number of tubers, tuber wet weight, and carbohydrate content. At the time of harvest, changes in soil properties (permeability, texture, pH, content of N, P, organic C and K) were also observed. The data obtained were subjected to analysis of variance followed by LSD test at the level of 5%.

## **Results and Discussion**

### *Soil permeability and texture*

In the treatment of planted varieties Manohara, the highest permeability (11.95 cm / hour) are in treatment 30% ash + 5 t compost / ha, while the lowest (6.68 cm / h) on the treatment of 10% ash + 5 t compost / ha (Figure 1). In the treatment Ayamurazaki planted varieties, the highest permeability (13.82 cm / hour) are in treatment 30% ash + 2,5 t compost / ha, whereas the lowest (7:02 cm / h) on the treatment of 10% ash + 5 t compost / ha (Figure 1).

When compared with the value of the initial soil permeability (39.31 cm / hour), the results of this study showed that the higher the proportion of volcanic ash in soils then the slower the permeability of the soil. This is because the nature of the volcanic ash prone to sedimentation and hardening, so it acts as an adhesive particles of soil to improve the soil's ability to retain water. Volcanic ash used in this study contains 34.27%

S1. According Yukamgo and Yuwono (2007), Si is an element that can form a stable polymer such as C and behave like Al in the form of minerals. Relating to the nature of volcanic ash that has fine particles, then if exposed to water spray will become clogged, making it difficult for water to enter and difficult to grow roots (Tim Faculty of Agriculture, 2014) necessitating the addition of organic matter. One of them is compost, is one forming soil aggregates, which have a role as an adhesive material between the soil particles to unite into soil aggregates. Atmojo (2003), states that the addition of organic matter in sandy soils

will increase the medium-sized pores and lower the macro pores. Therefore, the addition of volcanic ash and compost was able to improve soil permeability. The results showed that the volcanic ash and compost dose did not significantly affect soil texture (Figure 2). All treatments showed the same texture with the initial analysis of sandy loam soil. This is due to the mineral content has not experienced the weathering of volcanic ash in the short term, so it will not change the texture of the soil in the short term.

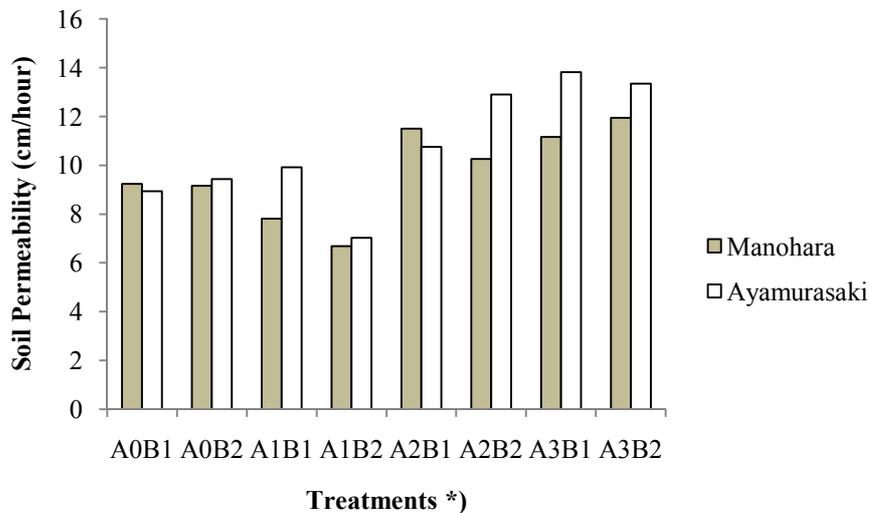


Figure 1. Effects of application of volcanic ash and compost on permeability of a sandy soil. \*) A0 = 100% soil, A1 = 10% volcanic ash + 90% soil, A2 = 20% volcanic ash + 70% soil, A3 = 30% volcanic ash + 70% soil, B1 = 2.5 t compost/ha, B2 = 5 t compost/ha

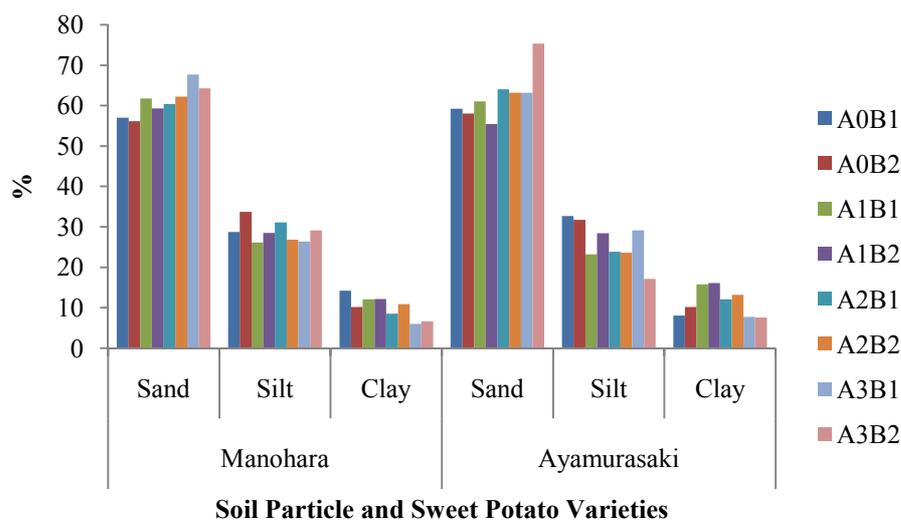


Figure 2. Effects of application of volcanic ash and compost on texture of a sandy soil. \*) treatments see Figure 1

**Soil pH, N, C, P and K**

Treatment volcanic ash and compost significant ( $p \geq 0.05$ ) to pH changes, N, P, C and K soil (Table 1). In the treatments planted with Manohara variety, the highest pH (6.51) was observed in 10% of treatment volcanic ash + 2.5 t compost / ha, and the lowest (5.82) in the treatment of 30% ash + 5 t compost / ha. In the treatment Ayamurazaki planted varieties, the highest pH (6.81) are in treatment 10% ash + 2.5 t compost / ha, and the lowest (5.12) in the treatment of 30% ash + 2.5 t compost / ha. According to the Land Research Center (1983), all treatments showed values slightly acidic to neutral pH, suitable for plant growth. Results of analysis pH of all treatments showed increased pH than the pH of the soil analysis before beginning treatment. Results of this study supported research results of

Rostaman et al. (2011) that application of volcanic ash will increase the pH of Oxisol soils.

In the treatment of planted varieties Manohara, the highest total N content (0.073%) contained in the volcanic ash treatment of 10% + 5 t compost / ha, and the lowest (0.043%) in the treatment of 30% ash + 2.5 t compost / ha. In the treatment Ayamurazaki planted varieties, the highest total N content (0.076%) are also present in volcanic ash treatment of 10% + 5 t compost / ha, and the lowest (0.035%) in the treatment of 30% ash + 2.5 t compost / ha. This shows that the higher the content of volcanic ash in the soil total N content decreased. The addition of compost up to 5 t / ha had not been able to increase total soil N content. This is due to the volcanic ash contains minerals that have not undergone weathering making it unavailable for absorption plant (Rostaman et al., 2011).

Table 1. Effects of application of volcanic ash and compost on pH, and contents of total N, organic C, available P, and total K of a sandy soil used for growing Manohara and Ayamurazaki sweet potato varieties.

Manohara Variety										
Treatments*)	pH		N (%)		Organic C (%)		Available P (mg/kg)		K (cmol <sup>+</sup> /kg)	
A <sub>0</sub> B <sub>1</sub>	6.36	c	0.066	d	1.43	a	58.84	c	0.39	b
A <sub>0</sub> B <sub>2</sub>	6.33	c	0.060	c	1.84	cd	51.87	a	0.35	ab
A <sub>1</sub> B <sub>1</sub>	<b>6.51</b>	d	0.059	c	1.68	bc	55.25	b	0.46	c
A <sub>1</sub> B <sub>2</sub>	6.15	b	<b>0.073</b>	d	<b>3.31</b>	e	<b>73.96</b>	e	<b>0.48</b>	c
A <sub>2</sub> B <sub>1</sub>	6.18	b	0.044	a	1.58	ab	59.46	c	0.35	ab
A <sub>2</sub> B <sub>2</sub>	6.43	cd	0.045	a	2.03	de	66.48	d	0.47	c
A <sub>3</sub> B <sub>1</sub>	5.72	a	0.043	a	1.65	b	57.60	c	0.33	a
A <sub>3</sub> B <sub>2</sub>	5.82	a	0.047	b	1.61	b	58.01	c	0.33	a
LSD 5%	0.13		0.002		0.18		2.20		0.05	
Ayamurazaki Variety										
Treatments*)	pH		N (%)		Organic C (%)		Available P (mg/kg)		K (cmol <sup>+</sup> /kg)	
A <sub>0</sub> B <sub>1</sub>	6.35	cd	0.075	d	1.81	b	58.56	c	0.52	de
A <sub>0</sub> B <sub>2</sub>	6.37	cd	0.072	d	1.95	b	59.72	c	<b>0.58</b>	e
A <sub>1</sub> B <sub>1</sub>	6.43	d	0.071	d	1.90	b	51.14	b	0.53	e
A <sub>1</sub> B <sub>2</sub>	<b>6.81</b>	e	<b>0.076</b>	d	<b>2.68</b>	d	<b>67.77</b>	d	0.43	bc
A <sub>2</sub> B <sub>1</sub>	5.42	a	0.044	b	2.54	cd	47.70	a	0.32	a
A <sub>2</sub> B <sub>2</sub>	6.04	bc	0.056	bc	2.44	c	50.55	b	0.35	a
A <sub>3</sub> B <sub>1</sub>	5.21	a	0.035	a	1.34	a	51.70	b	0.46	cd
A <sub>3</sub> B <sub>2</sub>	5.80	b	0.046	bc	1.77	ab	51.65	b	0.38	ab
LSD 5%	0.36		0.005		0.42		2.80		0.06	

Remarks: figures accompanied by same letters indicate no significance differences at LSD level of 5% \*) see Figure 1.

In the treatments planted with Manohara variety, the highest content of organic C (3.31%) obtained in the treatment of 10% ash + 5 t compost / ha, and the lowest (1.43%) contained in the volcanic ash treatment 0% + 2.5 t compost / ha. In the treatments planted with Ayamurazaki variety, the highest organic C content (2.68%) was in the

treatment of 10% ash + 2.5 t compost / ha, and the lowest (1.34%) was in the treatment of 30% ash + 5 t compost / ha. The higher content of organic C than the initial content was due to the addition of compost. Compost is organic material that is able to increase the value of C-organic soil. C-organic

also relates to the availability of nutrients, including P available (Syekhfani, 1997).

Interaction between volcanic ash and compost significantly affect the amount of available P in the soil. In the treatment of volcanic ash and compost planted with varieties Manohara, P provided the highest (73.96 mg / kg) treatment of 10% found in volcanic ash + 2.5 t compost / ha, and the lowest (51.87 mg / kg) present in volcanic ash treatment 0% + 2.5 t compost / ha. In the treatment of planted varieties Ayamurazaki, P provided the highest (67.77 mg / kg) present in volcanic ash treatment of 10% + 5 t compost / ha, and the lowest (47.7 mg / kg) in the treatment of 20% ash + 2.5 t compost / ha. P content is available on the ground early before treatment applications worth 67 mg / kg.

More high content of P available in the soil planted with varieties Manohara higher than the planted varieties showed lower Ayamurazaki P uptake by Manohara varieties compared to varieties Ayamurazaki. It is then associated with lower production of tuber varieties compared to varieties Ayamurazaki Manohara (Table 2). It was observed that the pH value of in the treatment of varieties Manohara mostly higher than the pH value of the soil treatment Ayamurazaki varieties, thus affecting the availability of P for plants. According to Foth (1990), P element in plants

contribute to the transfer of energy from photosynthesis or glycolysis, then P is converted into unstable pyrophosphate bond in the form of adenosine triphosphate (ATP), which will release 760 Kcal / mol when ATP is hydrolyzed to form ADP and P organic. ATP synthesis is required in various biochemical reactions such as the synthesis of lipids, starch, and protein, to mechanize the active uptake of nutrients and transport through the membrane (Samekto, 2008).

#### *Yield of sweet potato*

Application of volcanic ash and compost did not significantly affect the number of tubers and the fresh weight of Manohara and Ayamurazaki varieties (Table 2). The highest fresh tuber weight of Manohara variety (373.51 g / plant or 19.92 t / ha) was observed for the treatment of 10% volcanic ash + 5 t compost / ha, and the lowest (131.66 g / plant or 7:02 t / ha) was for the treatment of 0% volcanic ash + 2.5 t compost / ha. The highest fresh tuber weight of Ayamurazaki variety (393.09 g / plant or 20.96 t / ha) was found in the treatment of 10% ash + 5 t compost / ha, and the lowest (207.30 g / plant or 11:06 t / ha) was found in the treatment of 0% volcanic ash + 5 t compost / ha.

Table 2. Effects of application of volcanic ash and compost on yields of Manohara and Ayamurazaki sweet potato varieties grown on a sandy soil for 16 weeks.

Manohara Variety						
Treatments*)	Number of tubers	Weight of fresh tubers (g/plant)			Carbohydrate (%)	
A <sub>0</sub> B <sub>1</sub>	3.33	131.66	a		20.81	a
A <sub>0</sub> B <sub>2</sub>	3.33	183.28	ab		21.05	a
A <sub>1</sub> B <sub>1</sub>	3.33	318.14	d		23.13	c
A <sub>1</sub> B <sub>2</sub>	3.00	373.51	e		21.74	ab
A <sub>2</sub> B <sub>1</sub>	4.00	276.91	bc		23.52	c
A <sub>2</sub> B <sub>2</sub>	3.67	281.53	cd		20.49	a
A <sub>3</sub> B <sub>1</sub>	3.67	357.32	e		22.33	bc
A <sub>3</sub> B <sub>2</sub>	3.67	303.45	cd		21.25	ab
LSD 5%	ns	37.05			1.24	
Ayamurazaki Variety						
Treatments*)	Number of tubers	Weight of fresh tubers (g/plant)			Carbohydrate (%)	
A <sub>0</sub> B <sub>1</sub>	3.67	207.30	A		21.36	cd
A <sub>0</sub> B <sub>2</sub>	4.00	245.06	ab		20.56	bc
A <sub>1</sub> B <sub>1</sub>	4.33	282.71	b		19.74	ab
A <sub>1</sub> B <sub>2</sub>	3.67	<b>393.09</b>	d		18.37	a
A <sub>2</sub> B <sub>1</sub>	4.33	363.36	cd		20.02	bc
A <sub>2</sub> B <sub>2</sub>	<b>4.67</b>	287.89	b		19.92	b
A <sub>3</sub> B <sub>1</sub>	4.67	295.83	b		<b>22.42</b>	d
A <sub>3</sub> B <sub>2</sub>	4.00	299.72	bc		22.37	d
LSD 5%	tn	63.66			1.41	

Remarks: figures accompanied by same letters indicate no significance differences at LSD level of 5% \*) see Figure 1.

It can be concluded that application of volcanic ash and compost resulted in the higher yield of Ayamurazaki variety than Manohara variety. The highest carbohydrate content of Manohara variety (23.52%) was found in the treatment of 20% ash + 2.5 t compost / ha, and the lowest (20.49%) was in the treatment of 20% ash + 5 t compost / ha (Table 2). For Ayamurazaki variety, the highest carbohydrate content (22.42%) was in the treatment of 30% ash + 2.5 t compost / ha, and the lowest was in the treatment of 10% ash treatment + 2.5 t compost / ha.

The carbohydrate contents measured in the two varieties of sweet potato used in this study were lower than that of other studies, i.e. 33.65% (Salim and Putri, 2015), and 35.17% (Ginter et al., 2011) for the Manohara variety, and 26.99% (Ginter et al., 2011) for the Ayamurazaki variety. This indicates that the carbohydrate content of sweet potato is affected by the environmental conditions (Wijaya and Rukmi, 2015). According to Rosmarkam and Yuwono (2002), carbohydrate content of sweet potato is related to the shortages of K, because it will inhibit the enzyme activity resulting in the accumulation of certain compounds.

## Conclusion

Application of Mount Kelud volcanic ash and compost was able to improve soil permeability, soil pH, organic C, and K-total, but did not significantly affect total N content, available P and K total land. The treatment of 10% volcanic ash + 5 t compost / ha resulted in the highest fresh tuber weight for Manohara and Ayamurazaki varieties. The highest carbohydrate content of the Manohara variety was obtained through application of 20% volcanic ash + 2.5 t compost/ha, while that of the Ayamurazaki variety was obtained through application of 30% volcanic ash + 2.5 t/ha.

## Acknowledgements

The first author thanks the Indofood Riset Nugraha (IRN) 2014 for financial support to carry out this study to fulfill the requirement of bachelor degree in agricultural sciences at the Brawijaya University. The first author also thanks staff of Balitkabi for their kind assistance and guidance in conducting this experiment.

## References

Atmojo, S.W. 2003. Role of Organic Matter in Soil Fertility and Its Management. Sebelas Maret University Press 2003, Surakarta.

- BPS Jawa Timur. 2014. Productions of Paddy and Secondary Crops. <http://www.jatim.bps.go.id>. Accessed on March 16, 2014.
- Fitter A.H. and Hay, R.K.M. 2002. Environmental Physiology of Plants. 3rd edition. Academic Press San Diego.
- Foth, H.D. 1990. Fundamentals of Soil Science. 8th edition, Wiley, 384 pages.
- Hardianita, S. and Nuraini, Y. 2015. 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. *Journal of Degraded and Mining Lands Management* 2 (4): 415-420, doi: 10.15243/jdmlm.2015.024.415.
- Jaya, E.F.P. 2013 The use of antioxidants and beta-carotene of purple sweet Potato in non-alcoholic beverages manufacturing. *Media Gizi Masyarakat Indonesia* 2 (2) : 54 – 57.
- Jedeng, I.W. 2011. Effect of type and dose of organic fertilizer on growth and yield of purple local variety of sweet potato (*Ipomoea batatas* (L.) Lamb). Thesis, Postgraduate Program, Universitas Udayana, Denpasar.
- Polakitan, A. and Taulu, L. 2009. Test adaptation some new varieties of sweet potato in wetland after rice in Minahasa. Regional Seminar on Agricultural Technology Innovation to Support the Agricultural Development Program, North Sulawesi Province.
- Rosmarkam, A. and Yuwono N.W. 2002. The Science of Soil Fertility. Kanisius, Yogyakarta.
- Rostaman, T., Kasno, A. and Anggria, L. 2011. Improvement of soil properties with volcanic ash on oxisols. *Balai Penelitian Tanah* 32: 357 – 367.
- Salim, A.R. and Putri, W.D.R. 2015. Effect of temperature and time of annealing on physico-chemical properties of flour generated from white sweet potato of Manohara variety. *Jurnal Pangan dan Agroindustri* 3(2) : 602 – 609.
- Samekto, R. 2008. Fertilizer Application. PT Citra Aji Parama, Yogyakarta.
- Sukisno, Hindarto K.S., Hasanudin, and Wicaksono A.H. 2011. Mapping of Potential and Status of degraded soils to Support Biomass Productivity in Lebong Regency. Proceedings of the National Seminar on Agriculture: Controlling on conversion of Agricultural Land Functions.
- Syekhfani. 1997. Nutrients-Water-Soil-Plant. Department of Soil Science, Faculty of Agriculture Brawijaya University, Malang.
- Wijaya, Y. and Rukmi, W.D. 2015. Characterization of artificial rice flour made from orange sweet potato modified by sodium tripolyphosphate. *Jurnal Pangan dan Agroindustri* 3 (1) : 1-10.
- Yukamgo, E. and Yuwono N.W. 2007 Role of silicon as an important element on sugar cane plant. *Jurnal Ilmu Tanah dan Lingkungan* 7 (2) : 103 – 116.
- Zubir, M., Subaedah, S. and Koes, F. 2013. Growth analysis of maize (*Zea mays* L.) with the application of *Crotalaria juncea* and *Calopogonium muconoides* green manures accompanied with N and P fertilizers. National Seminar on Cereals, pp. 259-266..