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Research Article

Environmental adaptability of *Canavalia virosa* and *Flemingia congesta* to sandy ash soil of Merapi Volcano, Java

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Abstract: Studies on volcanic ash of Mount Merapi erupted in 2010 are limited to only characterization of mineralogical, physical, chemical, and biological properties of the volcanic ash. In order to speed up rehabilitation of soils affected by the volcanic ash, it is necessary to study the application of suitable plant species, which is called bio-mechanic conservation. The purpose of this study was to test the environmental adaptability of *Canavalia virosa* and *Flemingia congesta* in sandy soil covered by volcanic ash of Mount Merapi. This study was carried out using 2x4 Split-plot randomized block design with three replicates. The main plot of the design was plant species (*Canavalia virosa* and *Flemingia congesta*), while the sub plot was the dose of organic matter application (0, 20, 40, and 60 t / ha). Soil parameters measured were N-total, P-total, available P, available K, and organic matter contents. Plant parameters measured were plant dry weight and plant height. The results showed no significant differences in soil N, P and K contents of all treatments tested in this study after 9 weeks, except C organic content. *Canavalia virosa* grew well until 9 weeks, whereas *Flemingia congesta* started to die a 9 weeks after planting.

***Keywords**: Canavalia virosa, Flemingia congesta, organic matter*

Introduction

In 2010, Mount Merapi of Java erupted twice. At the first eruption of October 26, 2010, the Mount Merapi released hot cloud to the southern slopes. At the second eruption of November 5, 2010, the Mount Merapi released various size materials. Large materials flowed to southeast to pass through the river area. Ash and sand flowed to the southern and the western slopes of mount. Volcanic ash that fell to soil surface underwent cementation and hardening processes causing the increase of soil bulk density and the decrease of porosity and permeability (Idjudin et al., 2012).

The Mount Merapi volcanic ash is characteristically different from the dry soil dust frequently encountered in the dry season. The volcanic ash was formed from freezing magma that was explosively erupted. Most of the ash grains have tapered shape with high silica content making the ash has a high absorption property to water or water vapour. Hartosuwarno (2010) reported that using 400x magnification microscopic measurement, the volcanic ash erupted by Mount Merapi in 2010 had varied forms, from very angled (tapered), angled to circle. If the volcanic ash cling to the leaves it cannot be dissolved with rain water, but instead stick to leaves and absorb rainwater. Therefore, during the eruption of Mount Merapi, in the locations affected by thick ash including Srumbung region Magelang regency, there were canopy collapsed when it rained. Many branches of trees that were initially upright were bent until broken because the volcanic ash that sticks became very heavy when wet. Grasses, shrubs, and tuber crops were all covered by ash and sand erupted the Mount Merapi.

Efforts have been made to restore soils affected by Mount Merapi eruption. One of them is revegetation using tree plants provided by the local government. As the supports are very limited, it is necessary to explore other local tree species. *Canavalia virosa* that can easily be found in the coastal area dominated by sandy soils, and *Flemingia congesta* that is resistant to drought and commonly found in the rubber plantation areas, are probably potential to be used for rehabilitation of volcanic ash affected soils. *Canavalia virosa* is a type of annual legume that can be found throughout the year in the coastal sandy soils. This plant is capable to fix N from the air and it thus can be used as a pioneer plant for improvement of marginal lands. Naturally, this plant reproduces with roots that grow in the segments of the tendrils. The roots that appear on tendril segments grow into shoots. Under favaourable environmental conditions, the plant can be reproduced by seed. *Canavalia virosa* is able to grow on sandy soils that are dry and nutrient-poor. Root nodules of *Canavalia virosa* can still be found to 70 cm depth from the surface of sandy soils (BPTP, 2009).

According to Wardoyo et al. (2009), one of coastal sand vegetations that requires least water is *Canavalia virosa* in comparison with of three other plant species, i.e. *Calotropis gigantea*, *Casuarina equisetifolia*, and *Spinifex littoreus*. Based on results of a pot experiment conducted in a glasshouse by Suhardjo (2010), the growth of *Canavalia virosa*, was the best at a mixture of Mount Merapi sand and organic matter. The plant height, leaf number, stem diameter, and biomass weight were 95,47cm, 54 leaves, 0,8cm, and 4 kg, respectively, compared to that grew on a mixture of sand and organic matter that had plant height, leaf number, stem diameter, and biomass weight of 93,7cm, 35 strands, 0,7cm, and 2.5 kg, respectively.

Flemingia congesta is a conservation plant commonly grown in rubber plantations or used as erosion control in critical hilly areas, which is grown by means of strip cropping. The plant is also used as a shade of plantation. According to Sukmana et al. (1985), the plant is also resistant to drought in all types of soil, so it is also considered suitable for Merapi volcanic ash. A study on *Flemingia congesta* has been conducted by Wardoyo (1995) in a glasshouse using volcanic ash from the western slopes of Mount Merapi, precisely in upstream of S. Putih. The results showed that the average germination percentage of *Flemingia congesta* was 78.13%, the average plant height of *Flemingia congesta* at 2 months was of 17.34 cm, wilting point moisture of *Flemingia congesta* was at 1.5% water content. Therefore, *Flemingia congesta* that is also resistant to drought is suitable as a possible conservation plant at Mount Merapi volcanic ash area.

The purpose of this study was to examine the environmental adaptation of Canavalia virosa and *Flemingia congesta* in sandy soil areas of Mount Merapi volcanic ash.

Materials and Methods

The study was conducted at the Village area Ngablak Village, Srumbung, Magelang (7º30'30"-7º36 '30"S and 110º26'30"-110º31'10 "E) during one year (2013). The area, which is located on the western slopes of Merapi, has annual rainfall of 2263.5 mm / year, with average temperature of 22-29ºC, and an altitude of 650 m above sea level. The thickness of Mount Merapi eruption material was in average of 15 cm.

Results of laboratory analysis of soil from Mount Merapi eruption area prior to the study are presented in Table 1. The texture of the soil was generally in the form of sand (82.52% of coarse sand and 7,21% of fine sand). The chemical properties of the soil were similar to that reported by Fibrianty et al. (2011), i.e. pH of 5.31, 1.49% C organic, 0.13% total N, 18.67 mg/kg available P, CEC of(8.84 cmol$^{(+)}$/kg, and exchangeable K of 2.28 cmol$^{(+)}$/kg.

Table 1. Chemical composition of soil and organic matter used for the study

Physical and Chemical properties	**Soil**	**Organic Matter (Cow Manure)**
Texture (% weight)		-
Coarse sand	82.35	-
Fine sand	7.25	-
Silt	8.78	-
Clay	1.62	-
Bulk density (g/cm^3)	1.54	-
Particle density (g/cm^3)	2.64	-
Porosity (%)	42.02	-
Organic matter (%)	-	21.65
C-organic (%)	0.04	12.56
N-total (%)	0.004	1.61
C/N ratio	10	20.26
Moisture content (%)	0.16	7.69

Treatments tested in this study were combinations of plant species (*Canavalia virosa* and *Flemingia congesta*) and dose of organic matter application (0, 20, 40 and 60 t/ha). Organic matter used for this study was cow manure having bulk density of 0.50 g/cm^3. Characteristics of organic matter used for this study are presented in Table 1. *Canavalia virosa* and *Flemingia congesta* were planted from May to July 2013 with 193.9 mm of rainfall in May, 2.4 mm in June, and 0 mm in July. *Canavalia virosa* and *Flemingia congesta* were planted in the form of seed after being treated with hot water to cope with the dormancy period. Three *Canavalia virosa* seeds per hole were planted with 20 cm x 40 cm spacing. Five *Flemingia congesta* seeds per hole were also planted with 20 cm x 40 cm spacing.

Each treatment was conducted in a 2 x 5 m experimental plot. Soil at each experimental plot was ploughed at 20 cm deep, so there was a mixture of new material (15 cm) and old material (5 cm). The bulk density of the soil after tillage was 1.41 g / cm^3. The experimental design used for this study was randomized block design in a Split-plot pattern of 2x4 with three replicates. The main plots were plant species, and the subplots were doses of organic matter. Plant maintenance was only conducted for weeding with no water and fertilizer that was similar to natural field conditions. Sampling of soil and plant was conducted at 9 weeks after planting. Composite soils samples from each plot were collected from 0-20 cm depth.

Parameters measured were N-total method Kjedal, P-total the soil with extract method HCl 25%, P-available methods Bray I and K-available methods Flame photometer, soil organic matter by the method of Walkley and Black, plant dry weight, plant height. The data obtained were subjected to statistical analysis with F 5% test, followed by Duncan test at 5 %.

Results and Discussion

Plant height generally increased with increasing dose of organic matter applied, except for the dose of 60 t/ha (Table 2). This was probably because the incubation period conducted was not long enough so that the ability of the soil to bind to organic material was still limited. Thus, exchanged nutrient for plant growth was also limited. A similar trend was also observed for plant dry weight although the dry weight of *Canavalia virosa* was higher than that of *Flemingia congesta*. Based on field observations, starting from the end of week 9 *Flemingia congesta* began to die because it could not stand to drought. There was no rain since the first day of planting.

Based on the performance of the plants (plant height and dry weight biomass plants), up to week 9 *Canavalia virosa* grew better than *Flemingia congesta*. *Canavalia virosa* was still alive at week 9 while *Flemingia congesta* began to die leaving only few trees. Plant height of *Canavalia virosa* at 20 t organic matter/ha treatment was still greater than that reported earlier by Suhardjo (2010) that reached only 95.47 cm.

Table 2. Plant height and plant dry weight at 9 weeks after planting

Parameters/ Plants	**Dose Organic Matter Applied (t/ha)**				**Average**
	0	**20**	**40**	**60**	
Plant height (cm)					
– *Canavalia virosa*	45.67 c	108.44 a	84.44 b	59.56 bc	74.53 a
– *Flemingia congesta*	41.67 a	45.11 a	44.56 a	42.89 a	43.56b b
The plant dry weight (g/plant)					
– *Canavalia virosa*	7.83 bc	17.77 a	12.97 ab	6.90 c	11.37 a
– *Flemingia congesta*	7.10 bc	12.17 a	10.37 ab	12.30 a	10.48 a

Remarks: Average of three replications. Mean separation in a raw by DMRT at 5% level

Soil N, P and K contents were not significantly different between plants and doses of organic matter applied to each plant (Table 3). The relatively high available P in the soils was probably due to addition of organic P from organic matter applied. Soil available K was considered low. Although the total K in the form of K_2O of Mount Merapi cold lava was relatively high, the soluble and mineralized K remained low. The content of soil organic matter increased with increasing doses of organic materials added. This was because of the increase of organic matter held by soil aggregates. At the time of preparation of the study, the rainfall was still high (193.9 mm/month) with rainfall erosivity of the respected month was 124.59. However, when the experiment was started the rainfall was very low even there was no rain for a month. This caused *Flemingia congesta* could not survive at 9 weeks after planting, yet *Canavalia virosa* still grew well. According to Wardoyo et al. (2014) at the same location, the degree of erosion that was considered strong covered 12.947 ha and that was considered medium covered 14.665 ha. In those zones, *Canavalia virosa* is used for controlling erosion.

Table 3. Total N, total P, available P, available K, and Organic Matter contents in soil at 9 weeks after planting

Parameters/ Plants	**Dose Organic Matter Applied (t/ha)**				**Average**
	0	**20**	**40**	**60**	
N-total (%)					
– *Canavalia virosa*	0.15 a	0.15 a	0.15 a	0.15 a	0.15 a
– *Flemingia congesta*	0.15 a	0.15 a	0.15 a	0.15 a	0.15 a
P-total (%)					
– *Canavalia virosa*	0.06 a	0.06 a	0.06 a	0.06 a	0.06 a
– *Flemingia congesta*	0.06 a	0.06 a	0.06 a	0.06 a	0.06 a
P-available (mg/kg)					
– *Canavalia virosa*	17.25 a	17.09 a	17.34 a	16.87 a	17.32 a
– *Flemingia congesta*	17.10 a	17.49 a	17.67 a	17.01 a	17.14 a
K-available (mg/kg)					
– *Canavalia virosa*	0.03 a	0.03 a	0.03 a	0.28 a	0.029 a
– *Flemingia congesta*	0.03 a	0.03 a	0.03 a	0.28 a	0.029 a
Organic Matter (%)					
– *Canavalia virosa*	0.12 d	1.22 c	2.12 b	2.58 a	1.51 a
– *Flemingia congesta*	0.11 d	1.21 c	2.08 b	2.49 a	1.47 a

Remarks: Average of three replications. Mean separation in a raw by DMRT at 5% level

Conclusion

Canavalia virosa was more suitable than *Flemingia congesta* for conservation of land affected by the eruption of Merapi. At week 9, *Flemingia congesta* began to die because it could not stand to drought.

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