Archives of Agriculture and Environmental Science 4(2): 213-218 (2019)
https://doi.org/10.26832/24566632.2019.0402013

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: www.aesacademy.org

ORIGINAL RESEARCH ARTICLE

Effectiveness of fulvic acid to the growth of *Swietenia macrophylla* King. with addition phosphate at post mining land in Indonesia

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ARTICLE HISTORY

Received: 16 May 2019
Revised received: 26 May 2019
Accepted: 05 June 2019

Keywords

Fulvic acid
Phosphate fertilizer
Post mining
Revegetation
Swietenia macrophylla King.

ABSTRACT

Mining activities would cause a decrease in carrying capacity and land function due to erosion, changes in soil structure, loss of vegetation, pollution, nutrient depletion and increasing Al^{3+} levels so that soil pH conditions will be low. This study aims to increase the *Swietenia macrophylla* King growth response at the gold mining land that can be used as a tool for consideration in revegetation activities. The design used in this experiment was a complete randomized design (CRD) factorial with 2 factors. The first factor was the application of fulvic acid (F_0 = control, F_1 = concentration of 2% (2 ml of fulvic acid plus 98 ml of water), F_2 = 3% (3 ml of fulvic acid plus 97 ml of water), F_3 = 5 % (5 ml of fulvic acid plus 95 ml of water) and the second factor was the application of phosphate fertilizer (P_0 = 0 g / polybag, P_1 = 10 g / polybag, P_2 = 15 g / polybag and P_3 = 20 g / polybag) were used for preparation of different treatments. The treatment of fulvic acid significantly affected the growth of *S. macrophylla* for parameters of diameter, total dry weight, and root dry weight of *S. macrophylla*. The single effect of phosphate fertilizer treatment had a significant effect on high growth, diametert, total wet weight, and total dry weight of *S. macrophylla*. The interaction of fulvic acid and phosphate fertilizer significantly affected the diameter, total dry weight and root dry weight of *S. macrophylla*. F_2P_3 treatment (3% fulvic acid and 20 g phosphate fertilizer is the best combination treatment. Therefore, application of fulvic acid and phosphate fertilizer on post mining soil improves soil fertility and decreases Al elements which are toxic to plants.

Citation of this article: Wasis, B. and Arifani, D.O. (2019). Effectiveness of fulvic acid to the growth of *Swietenia macrophylla* King. with addition phosphate at post mining land in Indonesia. *Archives of Agriculture and Environmental Science*, 4(2): 213-218, https://dx.doi.org/10.26832/24566632.2019.0402013

INTRODUCTION

Mining activities provide substantial regional and state income. However, mining activities also have a negative impact on damage to forest ecosystems, loss of soil solum, damage to soil horizons, damage to soil properties, erosion and environmental pollution (Wasis and Angga, 2017, Wasis *et al*., 2018). Regulation requires every company holding an IUP (mining business license) to improve and reduce the negative impact of mining activities carried out. In line with the regulations listed in Law, Indonesia No. 41 of 1999 concerning Forestry Article 45 Paragraph 2, reclamation in former forest areas of mining areas must be carried out by mining permit holders in accordance with the stages of mining activities. Reclamation and rehabilitation are mandatory activities on ex-mining land, but in the implementation of reclamation and rehabilitation activities on post mining land there are obstacles, namely the condition of marginal land. Former gold mine land has chemical properties that do not support plant growth, which has a low value of cation exchange capacity, low soil fertility, low infiltration rate, resulting in inundation that has an impact on increasing alumunium (Al) concentrations that are toxic (Wahyudi, 2007; Wasis and Angga, 2017). Determination of the type that is adaptive to damaged soil conditions needs to be done, one type of adaptive that can grow on marginal land is Swietenia *macrophylla* King.

Constraints in planting *S. macrophylla* in fact often fail which are characterized by slow, stunted growth and often experience symptoms of necrosis. Failures that occur are suspected of mining residual minerals and are toxic to plants. The toxicity caused can be overcome by adding fulvic acid (Wahyudi, 2007; Wasis and Angga, 2017). The addition of fulvic acid can increase pH and reduce the content of minerals that are toxic to plants, but the effectiveness of fulvic acid is influenced by the presence of phosphates available in the soil (Wahyudi, 2007). This study was conducted to determine the effect of phosphate on the effectiveness of fulvic acid in the growth of *S. macrophylla* plants on ex-gold mine land.

MATERIALS AND METHODS

Experimental design

The study was conducted in January - April 2017. Toxic soil samples were taken from the PT Cibaliung Sumberdaya in Banten Regency, Banten Province, Indonesia. Testing of toxic nutrient minerals was carried out at the Laboratory of Chemical and Soil Fertility, Department of Land Resources, Faculty of Agriculture, IPB University. Observation of the growth of *S. macrophylla* in the Greenhouse of the Laboratory of Forest Ecology, Department of Silviculture, Faculty of Forestry, IPB University, Bogor, Indonesia. The tools used in this study were the Global Positioning System (GPS), location maps, hoes, pitchforks, polybags of size 10 cm × 15 cm (diameter × height), 50 cm ruler, sterophome bowl, plant sprinklers, digital cameras, analytical scales 4 digits, ovens, label paper, tallysheet, markers. The material used is the seeds of *S. macrophylla*. Phosphate fertilizers in the form of SP36, fulvic acid, toxic soil media, compost in the form of manure, and water.

Soil sampling and soil analysis

Our soil samples were taken purposive sampling, in locations that have high Al or Fe content, and low pH. The soil tested came from composite soil from 5 locations adjacent to each other. The distance between pickup points is 2-3 m and at the third point or midpoint does mapping using GPS. The pattern of soil sampling can be seen in Figure 1. Furthermore, soil sampling is carried out by drilling techniques with a depth of approximately 30 cm with a diameter of approximately 15 cm below the surface of the ground after the gold mine mine. The analysis of soil properties includes pH, cation exchange capacity (CEC), C organic, nitrogen, aluminum (Al), calcium (Ca), magnesium (Mg) and phosphorus (P).

Preparation of cultivation media and plantation

Land originated from post gold mining land at PT Cibaliung Sumberdaya, Banten Regency, Banten Province, Indonesia. The filtered soil is then sieved using a sieve made of 1 m × 1 m sand wire to separate the gravel from the ground. Plant media used in the form of soil and compost mixed with a ratio of 3: 1. Then put into a polybag with a size of 10 cm × 15 cm.

Seedlings of *S. macrophylla* are weaned into a planting medium that contains soil from post mining land. Weaning is done in the afternoon. The steps taken in weaning the seedlings of *S. macrophylla* are removed from the previous planting media and cleaned. The root of the seed is then soaked in water for 30 minutes. Then the seedlings of *S. macrophylla* are planted according to the prescribed treatment. Seedling maintenance is carried out by watering (field capacity) every morning around 07.00 WIB and in the afternoon at 17.00 WIB, if the soil still feels wet it is not necessary to do watering again. Other maintenance is carried out in the form of eradicating weeds.

Data collection

Data collection was conducted every week in the period of January - April 2017. Data collection was done by doing measurement of height and diameter of the seedlings of *S. macrophylla*. Beside that, total wet weight and total dry weight measurements of *S. macrophylla* were done after the harvesting. The harvested plants of *S. macrophylla* were separated between the root and shoot. Then, seedlings of *S. macrophylla* were dried off in the oven at 80°C as long as 24 hours (Wasis and Fathia, 2011; Wasis and Angga, 2017). After that, *S. macrophylla* seedlings were weighed again to know the dry weight. In other hand, two samples of soil / tailing (planting medium) were analyzed to know the soil characteristics. The two samples of these medium were soil / medium with control treatment and the best treatment which gave the best growth prefromance of *S. macrophylla*.

Methodology and data analysis

Experimental design used was factorial completely randomized design with two factors. The first factor is the treatment of fulvic acid, which is F_0 = control, F_1 = concentration of 2% (2 ml of fulvic-acid plus 98 ml of water), F_2 = 3% (3 ml of fulvic-acid plus 97 ml of water), F_3 = 5 % (5 ml of fulvic-acid plus 95 ml of water). The second factor is phosphate dosing, namely P_0 = 0 g / polybag, P_1 = 10 g / polybag, P_2 = 15 g / polybag and P_3 = 20 g / polybag. So that the total plant used is 80 plants. Data obtained from observations and measurements in the field were analyzed using experimental designs, which can be described in a linear method (Stell and Torries, 1991; Mattjik and Sumertajaya, 2006). Only if there is significant effect, Duncan's Multiple Range Test will be measured for getting further statistic data.

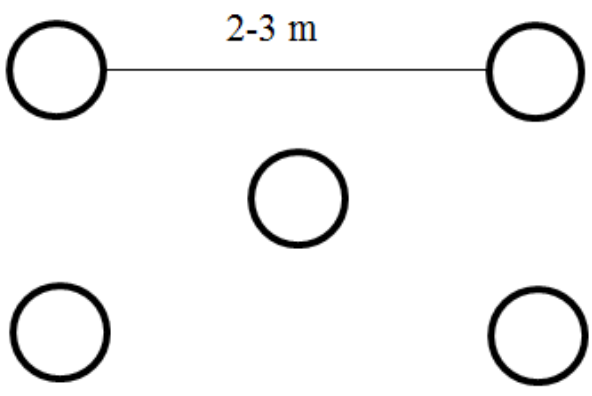

Figure 1. *Technique used for collection of soil samples during the study.*

RESULTS AND DISCUSSION

Effects of fulvic-acid and phosphate treatments on the growth parameters *of S. macrophylla*

The results of analysis of variance showed that a single treatment of fulvic acid had a significant effect on growth in diameter, total dry weight, and roots dry weight of *S. macrophylla*. The single treatment of phosphate fertilizer had a significant effect on high, diameter, total wet weight and total dry weight of *S. macrophylla*. While the interaction treatment significantly affected the growth of diameter, total dry weight, and root dry weight of *S. macrophylla* (Table 1).

The best application of phosphate fertilizer is shown by giving 20 g of phosphate fertilizer (P_3) with an average plant growth of 18.84 cm of *S. macrophylla* and an increase in the percentage of control by 52% (Table 2). According to Wasis and Noviani (2010), the provision of fertilizer provides better results for the growth of plant seeds, but beyond that there are external factors that influence the growth of plant seeds in addition to the provision of inorganic fertilizers.

Duncan's test results showed that the administration of fulvic acid with a concentration of 1% and the treatment of phosphate fertilizer at 20 g (F_1P_3) was the best combination treatment, and had a significant effect on all treatments tested, the combination treatment had a growth rate of 3.36 cm. of *S. macrophylla* with a percentage increase in diameter growth to control (F_0P_0) of 42%. The lowest growth of the diameter is in the treatment of the combination of fulvic acid with a concentration of 3% and phosphate fertilizer treatment of 10 g (F_2P_1) which has a growth average diameter of 1.64 cm of *S. macrophylla* and a percentage decrease in diameter growth to control (F_0P_0) of 31% (Table 3).

The Duncan test results showed that the best treatment was 15 g of phosphate fertilizer (P_2) with a total wet weight of 23.56 g and an increase in the percentage of control (P_0) of 40%. These results indicate that the treatment of fulvic acid at a dose of 5% is not sufficient for nutrient requirements for plants, it is shown that a single treatment and interaction treatment has no significant effect (Table 4). N nutrient content in fulvic acid ranges from 0.7-2.6% (Tan, 1991).

Table 1. Effect of fulvic acid and phosphate fertilizer impact on growth of *S. macrophylla*.

Parameter	Treatment		
	Fulvic acid	Phosphate fertilizer	Fulfic acid and phosphate fertilizer
Height	0.996tn	0.001*	0.107tn
Diameter	0.023*	0.002*	0.005*
Total wet weight	0.986tn	0.005*	0.060tn
Total dry weight	<.0001*	0.021*	0.050*
Root dry weight	<.0001*	0.068tn	0.018*
Root shoot ratio	0.255tn	0.237tn	0.157tn

Table 2. Duncan's test of the effect of phosphate fertilizer on the high increase in *S. macrophylla*.

Treatment	Average height growth (cm)	Percent increase (%)
P_0	12.4125a	0%
P_1	13.4000a	8%
P_2	13.6438a	10%
P_3	18.8437b	52%

Table 3. Duncan Test effect of combination treatment on the growth of diameter of *S. macrophylla*.

Treatment	Average diameter growth (cm)	Percent increase (%)
F_1P_3	3.3650a	42%
F_1P_2	3.1200ab	32%
F_2P_3	2.9525abc	24%
F_2P_2	2.6950abcd	14%
F_0P_3	2.6900abcd	13%
F_3P_2	2.6700abcd	13%
F_0P_2	2.6200abcd	10%
F_1P_1	2.6100abcd	10%
F_0P_1	2.5550abcd	8%
F_3P_1	2.4100bcde	2%
F_0P_0	2.3725bcde	0%
F_1P_0	2.3625bcde	0%
F_3P_3	2.3150bcde	-2%
F_2P_0	2.1950cde	-7%
F_3P_0	1.9675de	-17%
F_2P_1	1.6375e	-31%

Table 4. Duncan Test single effect of phosphate fertilizer on total wet weight of *S. macrophylla*.

Treatment	Average total wet weight (g)	Percent increase (%)
P_2	23.5569a	40%
P_3	21.6113a	29%
P_1	21.0369a	25%
P_0	16.7938b	0%

Table 5. Duncan test effect of treatment combinations on total dry weight of *S. macrophylla*.

Treatment	Average total dry weight (g)	Percent increase (%)
F_2P_3	12.6675a	57%
F_3P_2	12.3175ab	53%
F_2P_2	12.1350ab	50%
F_1P_2	11.9800ab	48%
F_3P_1	11.2350abc	39%
F_1P_1	11.1175abc	38%
F_3P_0	10.8850abc	35%
F_2P_1	9.8650abcd	22%
F_3P_3	9.4450abcd	17%
F_1P_3	8.8700bcd	10%
F_1P_0	8.1650cd	1%
F_0P_0	8.0675cd	0%
F_0P_2	7.6400cd	-5%
F_0P_3	7.2675d	-10%
F_0P_1	7.0350d	-13%
F_2P_0	7.0175d	-13%

Table 6. Duncan test the effect of treatment combinations on the dry weight of roots of *S. macrophylla*.

Treatment	Average root dry weight (g)	Percent increase (%)
F_2P_3	4.1400a	91%
F_2P_2	3.9400ab	82%
F_3P_0	3.6550ab	68%
F_3P_1	3.6450ab	68%
F_1P_2	3.5450ab	63%
F_3P_2	3.5000ab	61%
F_2P_1	2.9575abc	36%
F_3P_3	2.7650abcd	27%
F_1P_3	2.6525abcd	22%
F_0P_0	2.1700bcd	0%
F_1P_0	1.6600cd	-24%
F_0P_2	1.5450cd	-29%
F_1P_1	1.5075cd	-31%
F_0P_3	1.3425cd	-38%
F_2P_0	1.3025cd	-40%
F_0P_1	1.0500d	-52%

Table 7. Effects of most effective fulvic acid and phosphate treatment (F_2P_3) on the characteristics of post mining soil.

Parameter	Post mining soil	Fulvic acid and and phosphate fertilizers (F_2P_3)	Percent change (%)
pH	3.34	4.92	+1.58
Organic C (%)	3.02	11.16	+8.14
Total nitrogen (%)	0.06	0.26	+0.20
Phosphorous (ppm)	1.99	1502.21	+1500.22
Calcium (Ca cmol/kg)	0.59	9.41	+8.82
Magnesium (Mg cmol/kg)	0.25	2.70	+2.45
Potasium (K cmol/kg)	0.10	4.59	+4.49
Sodium (Na cmol/kg)	0.18	1.43	+1.25
CEC (cmol/kg)	9.89	15.66	+5.77
Alumunium (cmol/kg)	10.44	0.00	-10.44

The Duncan test results showed that the best combination treatment was 3% fulvic acid and 20 g phosphate fertilizer (F_2P_3) which had a total dry weight of 12.67 g of *S. macrophylla* with a percentage of 57% increase in control (Table 5). Total dry weight of *S. macrophylla* is the main parameter used as a reference because it shows the main biomass of plants which is the end result of the ecophysiological process, which expresses environmental (ecological) and physiological factors (Wasis and Noviani, 2010).

The Duncan test results in Table 6 show that the treatment of F_2P_3 (3% fulvic acid and 20 g phosphate fertilizer) is the best combination treatment with an average dry root weight of 4.14 g of *S. macrophylla* and a 91% increase in the percentage of control (Table 6). Fulvic acid stimulate growth plants through a variety of mechanisms that appear from several parameters, one of which is root weight. Fulvic acid absorbed by plants can increase cell permeability so that nutrient uptake also increases (Hardjowigeno, 2003; Wahyudi, 2007).

In Figure 2, overall plant shoot growth of *S. macrophylla* tends to be higher than root, which has a value above 1. The treatment of fulvic acid with a concentration of 5% (F_3) showed a relatively plant growth pattern which has a root shoot ratio of 1 (one) which means that there is a growth balance of roots and shoots of *S. macrophylla*. The value of root shoot ratio can be used to see the balance between root capability in absorbing water and nutrients as well as the ability of plant shoot in the process of transpiration and the rate of photosynthesis. Plant growth is called has well performance when it has a value of shoot root ratio ranging from 1-3 (Mokany, Raison and Prokushkin, 2006; Wasis and Andika, 2017).

Effects of fulvic-acid and phosphate treatments on the soil characteristics

This study shows that the treatment increases soil pH by 1.58, which is from 3.34 on post mining soil to 4.93 in the best treatment (F_2P_3) (Figure 2). This is caused by the addition of fulvic acid and phosphate fertilizer on post mining soil. The addition of compost or organic matter has an effect on soil improvement, especially the physical and chemical properties of the soil. The addition of organic matter in the form of compost has an effect on changes in pH. Organic acids can bind H^+ ions through carboxyl groups that have a negative charge (Ani, 2007; Hardjowigeno, 2003).

The treatment of fulvic acid and phosphate fertilizer reduced toxic Al levels on post mining soil by 10.44 cmol / kg where from 10.44 cmol / kg to post mining soil it became 0 cmol / kg at the best treatment (F_2P_3). The decrease in Al value is due to the treatment of fulvic acid and phosphate fertilizer to be able to bind to free Al^{3+} ions, causing Al levels to decrease significantly. The decrease in Al will increase the available P-land because Al^{3+} is a metal that can bind P to form compounds that cannot dissolve and reduce soil pH due to the increased concentration of H^+ ions in the soil (Tan, 1993; Rahmawati, 2011; Prengki *et al.*, 2017).

The overall treatment of fulvic acid and phosphate fertilizer increases macro nutrients compared to post mining soil. It can be seen in Table 7 that the nutrient content in the soil experienced a significant increase such as nutrients N, P, K, Ca and Mg. Cation exchange capacity is one of the important parameters in determining soil fertility. In table 7, the treatment of fulvic acid and phosphate fertilizer can increase the CEC on land by 5.77 cmol / kg, from 9.89 cmol / kg to post mining soil to 15.66 cmol / kg at the best treatment F_2P_3. This shows that the treatment of fulvic acid will cause an improvement in soil CEC (Table 7).

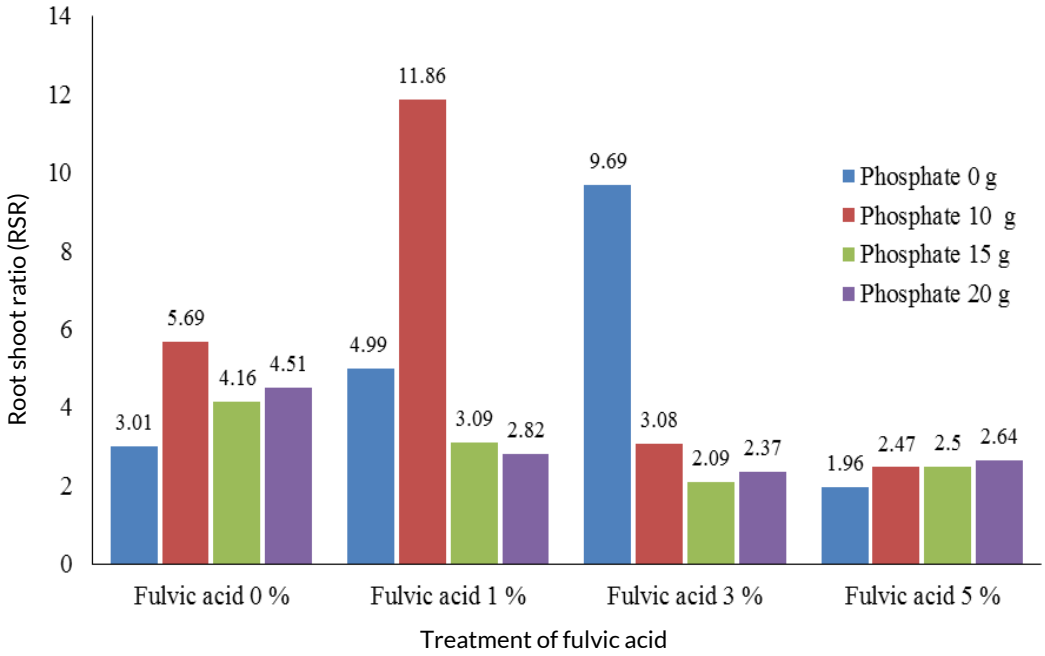

Figure 2. *Effect of combination treatment of fulvic acid and phosphate fertilizers on root shoot ratio.*

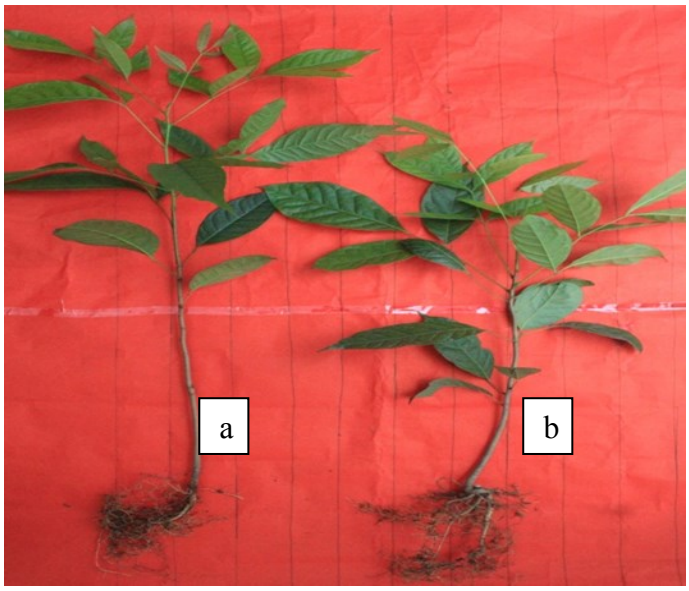

Figure 3. *Seedling physical condition of S. macrophylla with treatment (a) F_2P_3 and (b) F_0P_0 (control).*

Conclusion

The treatment of fulvic acid significantly affected the growth of *S. macrophylla* for parameters of diameter, total dry weight, and root dry weight. The single effect of phosphate fertilizer treatment had a significant effect on high growth, diametert, total wet weight, and total dry weight of *S. macrophylla*. The interaction of fulvic acid and phosphate fertilizer significantly affected the diameter, total dry weight and root dry weight of *S. macrophylla*. F_2P_3 treatment (3% fulvic acid and 20 g phosphate fertilizer is the best combination treatment. Moreover, addition of fulvic acid and phosphate fertilizer on post mining soil improves soil fertility and decreases Al elements which are toxic to plants.

ACKNOWLEDGEMENT

We would like to thank to the Forest Ecology Laboratory, Forest Influence Laboratory, and the chairman of Department of Silviculture, Bogor Agricultural Institute (IPB), without their help and support, this research would not have been possible.

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