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Effectiveness of Various Mulch towards Chemical Fertility, Soil Erosion and Crops Production of Potato (*Solanum tuberosum*, Linn) in Andisol of Ranupani, East Java

Nurhidayati[1,2]*, Zaenal Kusuma[3], Sudarto[3]

[1]East Kutai High Education of Agriculture, Indonesia
[2]Agriculture, University of Brawijaya, Jl. Veteran Malang, Indonesia
[3]Department of Soil Sciences, University of Brawijaya, Jl. Veteran Malang, Indonesia

*Corres.author: hidasoil@gmail.com, phone: +6282 335 868 639

Abstract: Ranupani is a buffer zone of Bromo Tengger Semeru National Park (BTSNP) which has great potential erosion, due to the steep slope, excessive agricultural intensification and non-optimal conservation behavior. The purpose of this study is to determine the effectiveness of mulch related to the changes in the chemical fertility, erosion and potato production on Andisol of Ranupani. We used a randomized block design (RBD) in five levels of mulch treatments, i.e. M_0 = without mulch, M_1= black silver plastic, M_2= *Chromolaena odorata*, M_3= Bokashi, and M_4= *Imperata clyndrica*. Observations were made on 14, 45, 75 and 105 Days after Treatments (DaT). The results showed that the Bokashi mulch (M_3) was most effectively improved the chemical fertility as follows: C of 9.19%, N of 7.69%, P of 76.01% compared to M_0. M_3 treatment also increase 34.9% the tuber weight of 7.88 ton.ha^{-1} from no mulch 21.25 ton.ha^{-1} and more effective in reducing loss of C 12.83 % compared without mulch. Black silver plastic mulch (M_1) was most effectively decreased the erosion for 80.1% and 19.62% of P loss from without mulch. M_4 effectively lowering the N losses of 13.79% and K of 35.7%. We found positive correlation between the $P_{initial}$ and P_{Total}, P_{Total} and Weight tuber, and $K_{initial}$ to K_{Total}. There is a positive and strong correlation between changes in chemical fertility especially P ($r = 0.93$, $R^2 = 0.88$) and K ($r = 0.90$, $R^2 = 0.81$) to the weight of tuber production.
Keywords: chemical fertility, nutrient losses, mulch technology, sediment.

Introduction

Forest conversion into agriculture on sloping lands need to get more serious concern, especially if the land continuously managed with agricultural intensification. The lack concern on the intensification of agricultural land management may lead to higher rates of erosion [1]. The erosion can cause the accumulation of C Organic and the loss of nutrient through the surface runoff [2]. The exceeded rate of erosion off the threshold causes soil degradation, declining water quality and eutrophication in the water bodies.

Seeing the adverse impacts of agricultural intensification, the concept of integrated farming was chosen as a solution to minimize the impact of agricultural intensification. Integrated farming aims to combine economic, ecological and social value in a single management system. This system emphasize more attention on protecting the soil from erosion, improving soil fertility, decreasing the nutrient losses, as well as improving the soil aeration and structure [3].

Erosion in Ranupani classified in the level of very severe erosions, which is estimated of 234.936 ton.year^{-1} in a land area of 275.86 hectares or equivalent to 85.16 ton.year^{-1}, with the value of the debris flow I

was 796.5 ton.year^{-1} and debris II at 291.5 ton.year^{-1}, thus exceed 180 ton.year^{-1}. The second debris flow stream down into the Ranupani Lake was estimated for 194.161.98 m^3.year^{-1} [4].

Efforts to reduce erosion and improving the chemical fertility on the sloping area performed by applying the mulch system thus increase the production of potatoes and decrease the erosion in Ranupani. Therefore, our study aimed to determine the effectiveness of several mulch treatments on the changes in the parameter of chemical fertility, erosion and potato production on Andisol of Ranupani.

Materials and Methods

The study was carried out in March to November 2013, in Bromo Tengger Semeru National Park, Lumajang Regency, East Java. Research was located in Ranupani Village at the slope land area of 1,120 m^2 with rainfall of 2,110 mm.year^{-1} and temperature 7-22°C. Soil analysis was conducted in Soil Chemical Laboratory in Department of Soil Science, Faculty of Agriculture, University of Brawijaya, Malang. We used non-factorial randomized block design as follows (Table 1).

Table 1. Mulch Treatment

Code	Mulch Treatments	Mulch (ton.ha^{-1})
M_0	Without Mulch	-
M_1	Plastic Black Silver	-
M_2	*Chromolaena*	10
M_3	Bokashi	10
M_4	*Imperata*	10

Organic mulch material included dried *Chromolaena* and *Imperata* which chopped into smaller sizes. Bokashi is comprised of goat manure, rice bran, rice husk charcoal and *Thitonia diversifolia* that fermented with EM-4. The quality of soil nutrients, mulch and decomposition duration are given in Table 2.

Table 2. Soil Nutrient, Mulch and Duration of Mulch Decomposition

Mulch Treatments	C (%)	N (%)	P (%)	K (mg.100g^{-1})	Decomposition (DaT)
Before studied	2.61	0.38	11.43	0.51	-
Without Much (M_0)	0	0	0	0	0
Black Silver Plastic (M_1)	0	0	0	0	105
Chromolaena (M_2)	17.31	1.56	1.12	0.63	72
Bokashi (M_3)	15.95	0.98	1.60	0.32	65
Imperata (M_4)	15.21	0.92	0.59	0.27	105

Description: C= Carbon; N=Nitrogen; P= Phosphate; K= Kalium; DaT= Days after Treatment

Experiment land consisted of 60 destructive and 60 non-destructive plots. Soil chemical parameters were sampled in the destructive plots, while sediment and nutrient losses concentrations on non-destructive plots. Each block made of 3 m x 1.8 m. Potatoes planting made with space of 70 cm x 70 cm x 30 cm. The observed parameters were production and Total NPK in 14, 45, 75, 105 DaT, sediment and nutrient loss concentrations. Treatments were analyzed by F-test and LSD 5% followed by Effectiveness Test. We also analyzed the regression correlation with statistical analysis by SAS software and Microsoft Excel.

Results and Discussion

Mulching effectiveness of the Chemical Fertility Improvement

Bokashi mulch (M_3) have better effectiveness in improving the fertility of organic C 0.27%, from 2,98% compared to M_0 (3.25%). N_{Total} is 0.013% of 0.16 M_0 (0.18%), whereas P_{Total} 11.94% than 15.72% of M_0 (27.67%). Mulch of *Chromolaena* (M_2) has a better effectiveness in improving K_{Total} as much 6.6 mg.100g^{-1} from M_0 3.93 mg.100g^{-1} (Fig.1).

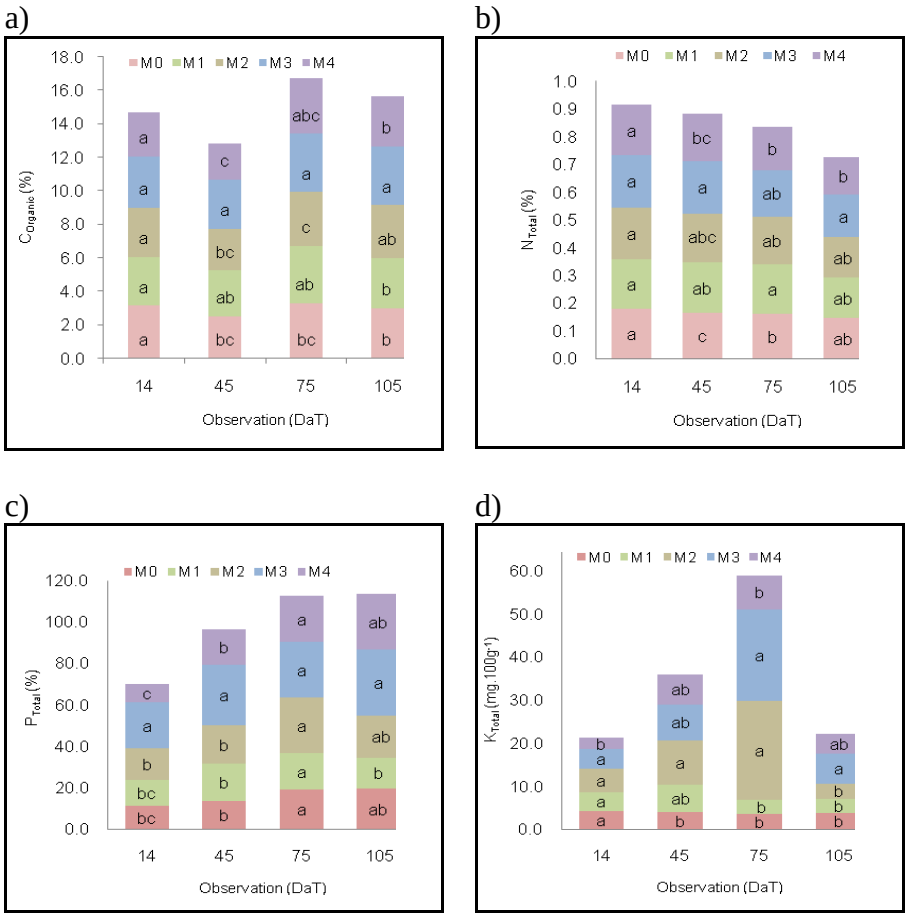

Figure 1. Nutrients on the mulch treatment: a) $C_{Organic}$, b) N_{Total}, c) P_{Total} and d) K_{Total} Description: M_0 = Without mulch; M_1 = Silver Black Plastic; M_2= *Chromolaena* M_3= Bokashi, M_4 = *Imperata*, DaT = Days after Treatment

Nutrients of Bokashi mulch had a significant effect on the enhancement of C, N, and P. Fermentation results of Bokashi stimulate the development of other beneficial microorganisms for soil fertility and plants, such as nitrogen-fixing bacteria, phosphate solvent and antagonistic microorganisms against the plant diseases. Additionally, bokashi composed of *Thitonia diversifolia* in its materials. The soil under the mulch of *Tithonia* contains *arbuscular* mycorrhyza [5,6]; spores fungi which enhances the absorption of nutrients from soil into biomass. The more microbes and fungi grew more organic matter available in the soil to increase the chemical fertility.

The high increase in C, N, and P on bokashi mulch treatment occurs due to bokashi mineralized into inorganic materials. This change proceeds by numbers of microorganisms that generated from the production of bokashi, includes *Lactobacillus* sp., yeast, *Actinomycetes*, and *Streptomyces*. Microorganism such as *Lactobacillus* sp. and *Streptomyces* decompose the substrate of cellulose, hemicelluloses and lignin [7], while fungiform *Actinomycetes* bacteria as antibiotic for root disease [8] accelerate the decomposition thus increased the mobilization of C, N, P, and S from the soil into the root system.

The existence of arbuscular Mycorrhiza on *Thitonia* [5,6] can increase the phosphatase activity that crucial in providing P in the soil [5]. The decomposition process of organic matter produces dissolved organic acids such as citric acid, malic acid, and acetic acid that essential for the binding of Fe and Al to provide $P_{available}$ [9]. Mahli [10] described that organic matter were decomposed and mineralized. The addition of manure can increase the $P_{available}$ to plants, and reduce dependence on inorganic fertilizer requirement for crops [11].

Relations of $P_{initial}$ - $K_{initial}$ and P_{Total} – K_{total}

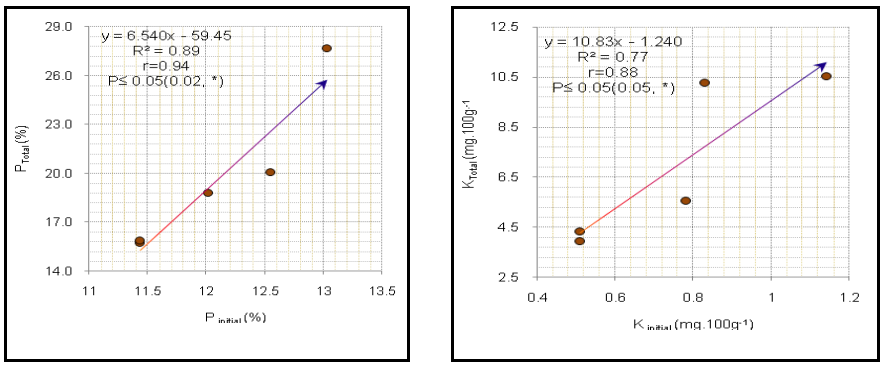

Figure 2 . Nutrient Correlation between a) the $P_{initial}$ and P_{Total}, b) $K_{initial}$ and K_{Total}.

Regression analysis in Fig.2) implies that the relationship between $P_{initial}$ and P_{Total} is positive. Increasing initial $P_{initial}$ leads to increasing of P_{Total}. The correlation value expressed by the coefficient (r) of 0.94 means that the relationship is very strong. Whereas the coefficient of determination (R^2) = 0.89 means that the increase in P_{Total} of 89 as influenced by the $P_{initial}$, and 11% were influenced by other factors. The highest $P_{initial}$ value (13.03%) contained in the Bokashi mulch (M_3), improving 27.67% of P_{Total}, which 76.01% more effective than 15.72% of M_0 (without mulch).

Regression analysis implies that the correlation of $K_{initial}$ and K_{Total} is positive (Fig.2b). Increasing $K_{initial}$ leads to increasing K_{Total}. Correlation coefficient (r) = 0.88 means that the relationship is fairly strong. The coefficient of determination (R^2) = 0.77, implied that the improvement of 77.1% Total K in 75 DaT influenced by the $K_{initial}$, and 22.9% influenced by other factors. The highest value of $K_{initial}$ (11.14 mg.100g^{-1}) contained in the *Chromolaena* mulch and improve K_{Total} of 10.53 mg.100g^{-1}, which id 167.96% more effective than no mulch (3.93 mg.100g^{-1}).

Strong correlation of P_{Total} and K_{Total} occurred because of the high nutrient content of P in the Bokashi mulch (M_3) and K on *Chromolaena* mulch (M_2). Whereas high P mineralization occurred because P in Bokashi mulch turns into inorganic P.

Improvement of physical-chemical soil fertility by Bokashi mulch is supported by studies on soybean plants in Andisol [12] which suggested that the addition of organic matter improve the biological activity by microbes. It then affects the P mineralization by soil nematodes, either directly or indirectly. The large amounts of crop residue add the C to the soil, thus increasing soybean production in Andisol. The increased production of Turnip and Sweet Potato by 13% due to the effect of the straw mulch that improve the total nutrient of N and P by 18-43% at the 0-30 cm soil surface [13].

Mulch Effectiveness on Erosion

Table 3. Effects of Mulch on Sediment and Nutrient Concentrations in the Sediments

Mulch Treatments	Sediment and Nutrient Concentrations in Sediments									
	Sediment (ton.ha^{-1})		C (%)		N (%)		P (%)		K (mg.100g^{-1})	
Without Much (M_0)	54.39	a	2.63	ab	0.15	a	11.50	a	3.26	bc
Black Silver Plastic (M_1)	10.82	c	3.01	a	0.15	a	9.24	a	6.46	a
Chromolaena (M_2)	25.80	b	2.50	ab	0.15	a	12.29	a	4.80	ab
Bokashi (M_3)	19.65	bc	2.29	b	0.15	a	15.09	a	3.48	bc
Imperata (M_4)	19.69	bc	2.53	ab	0.13	b	12.43	a	2.10	c
LSD 5%	5.78	s	0.72	s	0.02	s	5.92	ns	2.43	s

Description: The numbers accompanied by different small letters in the same column indicate significant differences according to LSD test at α = 0.05 level; DaT = days after treatment

a) b)

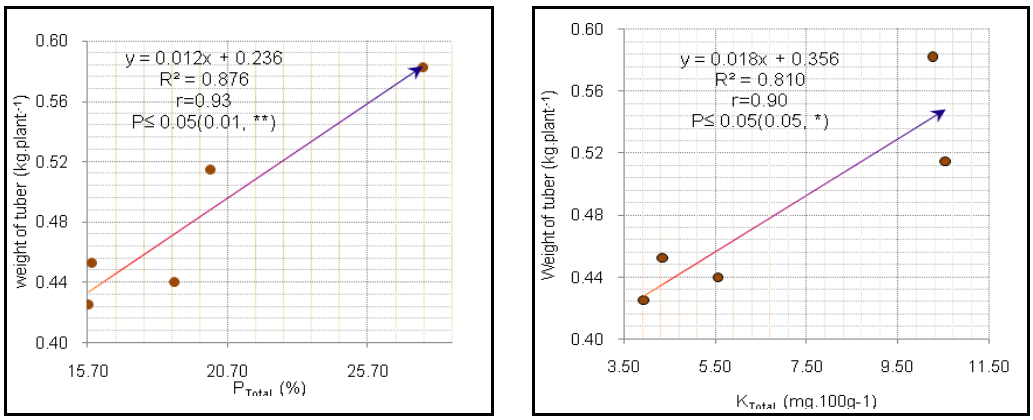

Figure 3. Correlation of a) P_{Total} and b) Kalium to the weight of tuber

Black silver plastic has a better effectiveness to decrease the erosion for 43.57 ton.ha^{-1} from 54.39 ton.ha^{-1} (80.1%) than without mulch (Table 3 and Fig.3). This is due to a direct rain splash on the plant hole, causing less surface runoff thus also lead less soil loss. In contrast, rain splash on organic mulch dissolve the mulch and soil, thus losing more soil than the plastic mulch.

Nutrient Losses and Deprivation

Soil loss due to erosion decrease the nutrients in the soil, loss of nutrients that transported by surface runoff [14]. Bokashi mulch (M_3) showed a better effectiveness to decrease 12.83% loss of C compared without mulch. Plastic mulch on the contrary raises the largest C lost 3.01% compared without mulch. Mulch of *Imperata* (M_4) has better efficiency for 0.02% decline the N losses of 0.14% than without mulch and a decrease in 35.7% loss of K (1.17 mg.100g^{-1} from 3.26 mg.100g^{-1}) compared without mulch. Plastic mulch has better effectiveness to decrease P loss for 19.62% compared with no mulch.

Table 4. Nutrients Balance of C and N

Treatments	C (kg.ha^{-1})			N (kg.ha^{-1})		
	Input	output	uptake assumptions	Input	output	uptake assumptions
M_0	23.93	14.30	9.62	84.97	0.792	84.18
M_1	23.93	3.26	20.66	84.97	0.156	84.81
M_2	41.24	6.44	34.79	86.53	0.367	86.16
M_3	39.88	4.50	35.37	85.95	0.297	85.65
M_4	39.14	4.98	34.15	85.89	0.246	85.64

Description : M_0 = Without mulch, M_1= black silver plastic, M_2= *Chromolaena odorata*, M_3 = Bokashi and M_4 = *Imperata clyndrica*

Table 5. Nutriens Balance of P and K

Treatments	P (kg.ha^{-1})			K (kg.ha^{-1})		
	Input	output	uptake assumptions	Input	output	uptake assumptions
M0	137.40	0.00500	137.40	50.480	0.01775	50.46
M1	137.40	0.00021	137.40	50.480	0.00699	50.47
M2	138.52	0.00246	138.52	51.110	0.01239	51.10
M3	139.00	0.00180	139.00	50.800	0.00684	50.79
M4	137.99	0.00124	137.99	50.750	0.00413	50.75

Description : M_0 = Without mulch, M_1= black silver plastic, M_2= *Chromolaena odorata*, M_3 = Bokashi and M_4 = *Imperata clyndrica*

Loss of C, N, P, and K through leaching deprivate the soil and harm the plants, causes the non-optimal nutrient absorption. Poor nutrient absorption resulting in non-optimal soil fertility, nutrient deficiency, growth and development of plants are not optimum and crop production is not as expected. Nutrients balance per plot trial in Ranupani showed in Table 4 and 5. Mulch of Bokashi has better effectiveness on assuming C_{uptake} for 267.52% and P_{uptake} assumptions for 1.17% compared with no mulch. Mulch of *Chromolaena* has better effectiveness on assuming N_{uptake} of 1.75% and assuming K_{uptake} of 1.26% compared with no mulch.

The role of Bokashi mulch tend to be more effective for organic C and $P_{availability}$ to plants, and *Chromolaena* mulch more effective to provide N and K for plants. Loss of C, N, P, and K is greater in sediment concentration, but it still can be absorbed by plants, although uptake by the root system less than the maximum. This is due to the previous intensive cultivation of land and steep slopes which lead to reduce the production of potatoes. This was confirmed by Griffin [15], that straw mulching for a total of 3 ton.ha^{-1} on the soil of *Typic Haplorthods* reduce erosion and loss of P for 50%. Griffin also described the declining in production due to minimal ground cover, low return of crop residues and steep slopes.

The amount of surface runoff is also affected by soil processing [1]. Loss of organic matter and N were less found in the area with no cultivation and less mulch than area with conventional cultivation in Andisol Patzcuaro, Central Mexico.

Correlation between Chemical Fertility to the Production Crops

Simple regression analysis showed positive correlation between the weights of tubers with Total P (Fig. 3a). The more increasing of applied P, then the weight of the tubers will increase. Correlation coefficient of r = 0.93 means a very strong relationship. The coefficient of determination R^2 = 0.88 implied that the increase in weight of tubers affected by Total P for 87.6%, while 12.4% influenced by other factors.

Regression results in Fig.3b showed that the positive correlation between the weight of tubers with total K. If the Total K increases, the weight of the bulbs will also increase. Correlation coefficient of r = 0.90 showed a very strong correlation. The coefficient of determination R^2= 0,81 means that the increase in weight of tubers affected by Total K of 81%, while 19% are influenced by other factors.

The opinion was emphasized [16,17] that straw mulch is more stable and more effective in maintaining the soil moisture compared to the plastic mulch. It proved to be the amount of water vapor of infiltration process is able to achieve at a depth of 90 cm, while plastic mulch is only achieved the depth of 70 cm. Soil moisture is closely linked to the availability of nutrients for plants because the water supply became a decisive factor for enhancement and improvement of nutrient uptake by plants. Hou *et al.* [18] planted potatoes in the summer of 2006 and winter of 2007. The results showed that removing the mulch in 60 days after planting (in 2006) produced the highest tuber crops of 66.3 ton.ha^{-1}, 53.25% higher compared with no mulch of 58.2 ton.ha^{-1}. Otherwise in 2007, removing the mulch on 60, 90 days after planting and until harvest time, has no significant difference. Although M_{60} showed the highest results of 42 ton.ha^{-1}, which is 57.61% higher than no mulch (30.9 ton.ha^{-1}).

Conclusion

Bokashi Mulch (M_3) has better effectiveness on fertility improvement of C, N, and P, otherwise *Chromolaena* mulch is more effective on improving K. Silver black plastic (M_1) has a better effectiveness to decrease erosion. Nutrient loss of P, N and K, were minimized by *Imperata* mulching, while loss of C minimized by Bokashi mulching. There is a strong correlation between $P_{initial}$ to the increase in P_{Total} (r = 0.94); highest P found in Bokashi. Whereas $K_{initial}$ to the improvement of K_{Total} (r = 0.88), with the highest K found in *Chromolaena* mulch. P_{Total} has a strong correlation to the weight of tubers (r = 0.93), as well as K total to tuber weight (r = 0.90). Increasing of potato production strongly influenced by P Total <K Total <C <N total.

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