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## Enhancing potato (*Solanum tuberosum* L.) yield by using biological organic fertilizers and soil conservation practices on the slope andisol

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**Abstract.** The purposes of this research were to determine the influence of biological organic fertilizer (BOF), chemical fertilizer and methods of soil conservation to decrease soil erosion and to enhance potato yield. This study used 3 factors, first factor is P1 (20 tons chicken manure ha<sup>-1</sup>), P2-P6 (20, 15, 10, 5 and 2,5 tons BOF ha<sup>-1</sup>); second factor is K1 (1 ton ZA ha<sup>-1</sup> + 250 kgs Phonska ha<sup>-1</sup>), K2 (300 kgs Urea ha<sup>-1</sup> + 500 kgs SP-36ha<sup>-1</sup> + 300 kgs KCl ha<sup>-1</sup> + 200 kgs CaCO<sub>3</sub>ha<sup>-1</sup>), K3 (1/2 K2 dose) and K4 (1/4 K2 dose) and third factor is L1 (the same direction slope), L2 (10% angel to contour) and L3 (parallel with contour). The observed variables were potato yield, soil erosion and P uptake. The result showed the highest potato yield in L3 was 16.33 tons ha<sup>-1</sup>. In the same BOF dose compared to chicken manure enhanced potato yields up 2 tons ha<sup>-1</sup>. Using of inorganic fertilizer with at K2 or K3 or K4 add more potato yield 0.2 tons ha<sup>-1</sup> compared to inorganic fertilizer. The correlation between Potato yield and soil erosion was -0.99, while potato yield and P sorption was 0.76.

### 1. Introduction

Andisol is a soil type distributes widely in highland areas. The acreage of andisol in Indonesia reaches 5.39 million hectares. This soil type is suitable for vegetable cultivation especially cabbage, carrot and potato due to its fertile soil [1]. Potato is a high value cultivated commodity at highland areas with this soil type in Indonesia. Central Java is one centre of potato production, where produced 2,729,758 quintals in 2016 [2]. The production decreased by 10% from the previous years due to factors such as settlement, plant pests and diseases, quality of seeds, and soil fertility.

The main problem in andisol corresponds with soil fertility is low Phosphate (P) availability and soil erosion. The low phosphate availability is caused absorption by allophane minerals, Fe and Al hydrate oxides and Al-humus complexes [3]. Based on that problem, we use biological organic fertilizers containing phosphate-solubilizing microorganisms (PSMs), inorganic fertilizers, and conservation practices. Biological organic fertilizer (BOF) was composed from chicken manure added to the Humate-Fulvat (HF) extract of potato leaves with 0.05 N NaOH for a week incubation at a dose of 5 percent [4], phosphate-solubilizing microorganisms (PSMs) in carrier media (population 107 CFU/g) with a dose 10 L in 20 tons of chicken manures [5], Plant growth promoting rhizobacteria (PGPR) in carrier media (population 107 CFU/g) with a dose of 10 L/20 tons of chicken manure [6], and potato root extract with 10 percent acetonitrile for a week incubation as a signal quorum sensing (SQS) at dose of 5% [7].



Soil losses due to erosion at the andisol land could be overcome by using ridging or hilling and terrace ring practices or contour [8, 9]. The practices reduce soil losses from the land, improve soil quality and increase potato production. The purposes of this research were to determine the influence of biological organic fertilizer (BOF), chemical fertilizer and practices of soil conservation in decreasing soil erosion and enhancing potato yield on sloping andisol.

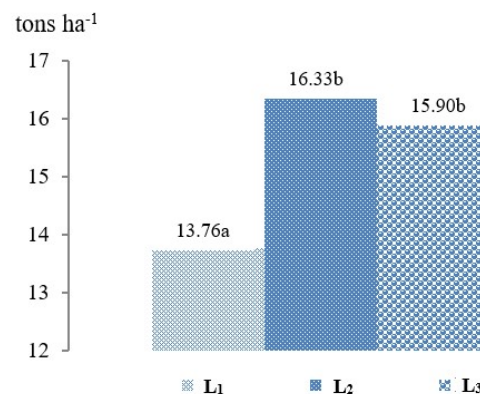
## 2. Methods

The research was carried out at Kaligua Area, Brebes, Central Java, Indonesia. The study used a randomized block design with 3 factors, namely (1) organic fertilizers (P) with 6 levels of  $P_1$  (control),  $P_2$ - $P_6$  (20, 15, 10, 5 and 2.5 tons of BOF $ha^{-1}$ ); (2) inorganic fertilizers (K) with 4 levels, namely  $K_1$  (1 ton ZA $ha^{-1}$  and 250 kgs Phonskaha $^{-1}$ ),  $K_2$  (300 kgs Urea $ha^{-1}$ , 500 kgs SP-36  $ha^{-1}$ , 300 kgs KCl $ha^{-1}$ ) and 200 kgs limestone $ha^{-1}$ ,  $K_3$  (1/2  $K_2$ ) and  $K_4$  (1/4  $K_2$ ) and; (3) land slope with 3 levels, namely  $L_1$  (the same direction/parallel with slope),  $L_2$  (angel 10 percent to contour) and  $L_3$  (the same direction/parallel with contour). We planted potato seeds Granola variety. The observed variables were potato yield, P sorption and erosion.

## 3. Results and discussions

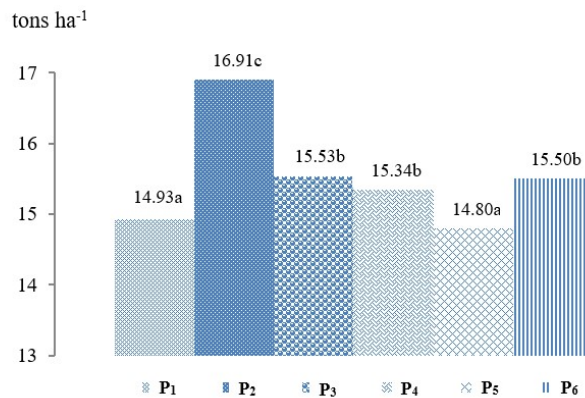
### 3.1. Potato yield

The highest yield (tuber) was obtained at cropping with the angel 10 percent to contour pattern ( $L_2$ ) i.e. 16.33 tons  $ha^{-1}$ , followed by the parallel with contour ( $L_1$ ), ca. 15.9 tons $ha^{-1}$  (**Figure1**; [5]). Cropping patterns based on farmers's way (the parallel with slope) yielded only 13.76 tons $ha^{-1}$ . Based on this result, it is a good indication to improve planting system of potato in sloping areas through application of contour conservation. Application minimum tillage and contour cultivation was recommended by [10].



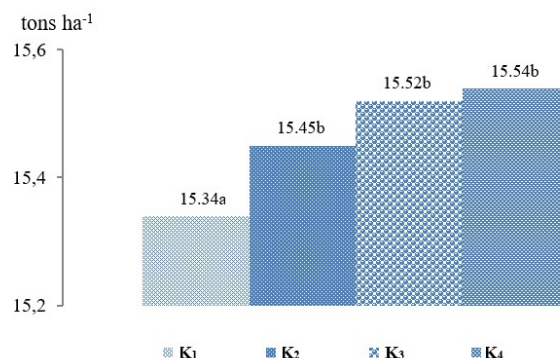
**Figure1.** Potato yield (ton  $ha^{-1}$ ) on three cropping patterns based on contour direction at Kaligua Brebes Province of Central Java.  $L_1$  (the parallel with slope),  $L_2$  (the angel 10% to contour) and  $L_3$  (the parallel with contour).

Application of the chicken manure enriched with biological organic compounds (biological organic fertilizer, BOF) could increase potato yield [11]. Enriched chicken manure at 20 tons/  $ha$  increased addition of the tuber yield up to 2 tons $ha^{-1}$  compared to the chicken manure only yielded tuber ca. 15 tons $ha^{-1}$ . Application of BOF at 2.5, 5, 10 and 15 tons $ha^{-1}$ , added the tuber only ca. 0.5 tons $ha^{-1}$ , compared to application of chicken manure 20 tons $ha^{-1}$ .



**Figure 2.** Potato yield (tonha<sup>-1</sup>) in application six doses of organic matter at Kaligua Brebes Province of Central Java. P<sub>1</sub> = 20 tons chicken manureha<sup>-1</sup>, P<sub>2</sub>-P<sub>6</sub> = 20, 15, 10, 5 and 2,5 tons BOFha<sup>-1</sup>.

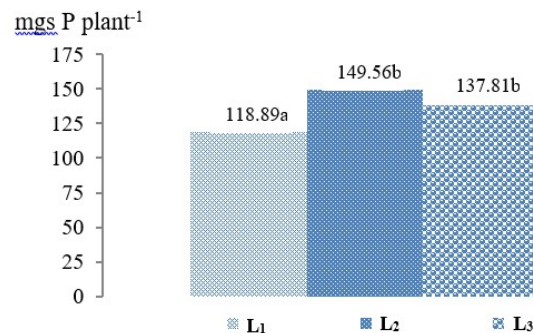
Application of inorganic fertilizers increased potato yield (**Figure 3**). The treatment K<sub>2</sub> (300 kgs Urea, 500 kgs SP-36 and 200 kgs KCl), K<sub>3</sub> (1/2 K<sub>2</sub>) and K<sub>4</sub> (1/4 K<sub>2</sub>) produced tuber more than 0.2 tons tuberha<sup>-1</sup> compared to farmer's way K<sub>1</sub> (1 ton ZA and 250 kgs Phonska) that only yielded 15.3 tons tuberha<sup>-1</sup>. The potato yield at K<sub>2</sub>, K<sub>3</sub>, and K<sub>4</sub> fertilization were not different statistically, ca. 15.5 tons ha<sup>-1</sup>.



**Figure 3.** Potato yield (tonha<sup>-1</sup>) at application four doses of inorganic fertilizer, at Kaligua Brebes Province of Central Java. K<sub>1</sub> (1 ton ZA and 250 kgs Phonskaha<sup>-1</sup>), K<sub>2</sub> (300 kgs Urea, 500 kgs SP-36 and 200 kgs KClha<sup>-1</sup>), K<sub>3</sub> (1/2 K<sub>2</sub>) and K<sub>4</sub> (1/4 K<sub>2</sub>)

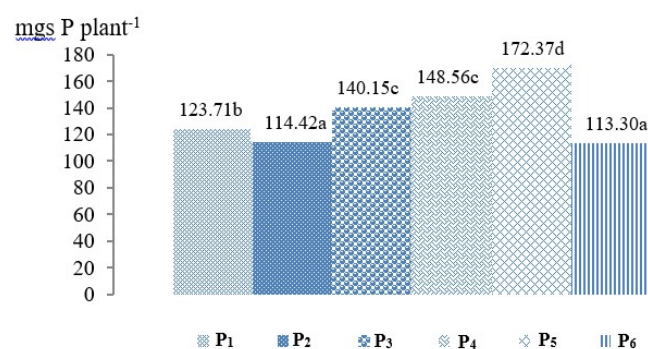
### 3.2. Phosphorous Sorption

The highest P sorption value (149.56 mgs Pplant<sup>-1</sup>) occurred at L<sub>2</sub> treatment (the 10 percent at an angle in the same direction with contour pattern) (**Figure 4**). This conservation method was able to reduce soil erosion. In this case, soil erosion was minimized. Nutrients and organic matters were used optimally by plant. It was different with L<sub>1</sub> (in the same direction with slope).



**Figure 4.** Phosphorous sorption by potato plant (mg P plant<sup>-1</sup>) at three cropping patterns based on contour direction at Kaligua Brebes Province of Central Java. L<sub>1</sub> (in the same direction with slope), L<sub>2</sub> (10 percent at an angle in the same direction with contour) and L<sub>3</sub> (in the same direction with contour).

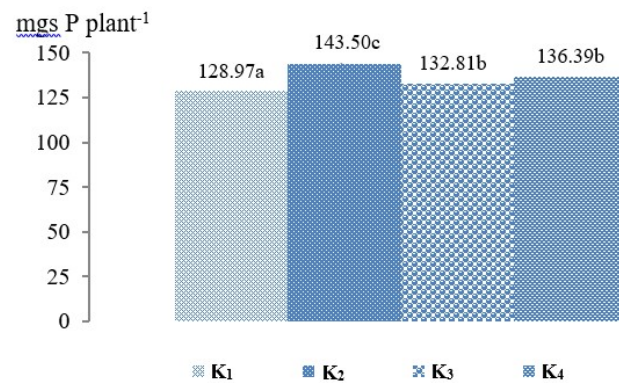
The P<sub>5</sub> treatment that was application of biological organic fertilizer 10 tons ha<sup>-1</sup> showed the highest P sorption value ca. 172.37 mgs P plant<sup>-1</sup> was greater than the others (**Figure 5**). [12] explained that the application of organic fertilizer can increase the availability of P in the soil that shown in high P uptake by plants. The addition of phosphate soluble microorganisms (PSMs) and humic acid to biological organic fertilizers is thought increase P uptake by plants. Biological organic fertilizers containing PSMs can increase the P dissolved ability, because PSMs produce organic acids, including citrate, malate, and acetate [13]. Dissolved P support easier P absorption for plants. According to [14] increasing phosphorus uptake by plants is related to the role of humic acid in increasing phosphorus efficiency in the soil due to the process of preventing P fixation in the soil and increasing availability of P for plants.



**Figure 5.** Phosphorous sorption of potato plant (mgs P plant<sup>-1</sup>) at application of six doses of organic matter at Kaligua Brebes Central Java, (P<sub>1</sub> = 20 tons chicken manure ha<sup>-1</sup>, P<sub>2</sub>-P<sub>6</sub> = 20, 15, 10, 5 and 2.5 tons BOF ha<sup>-1</sup>)

The highest P sorption value ca. 143.50 mgs P plant<sup>-1</sup> occurred at K<sub>2</sub> treatment (recommended dose, 300 kgs Urea ha<sup>-1</sup> + 500 kgs SP-36 ha<sup>-1</sup> + 300 kgs KCl ha<sup>-1</sup> + 200 kgs limestone ha<sup>-1</sup>) (**Figure 6**). Chemical fertilization can increase nutrients in the soil. According to [15], the addition of N element

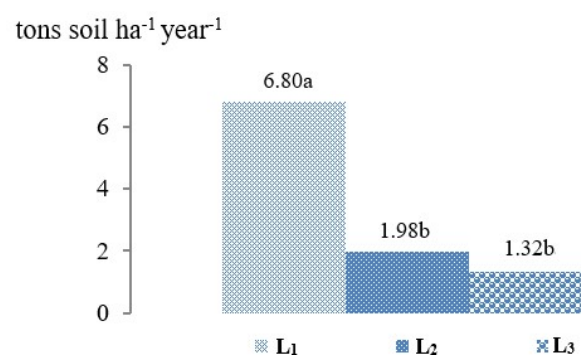
from chemical fertilizers can increase root growth and development, so that P absorption is more effective. SP-36 fertilizer is thought to give the best result because it increases P sorption. [16] said that SP-36 can increase P uptake of maize plants.



**Figure 6.** Phosphorous sorption of potato plant (mg P plant<sup>-1</sup>) at application four dose of inorganic fertilizer at Kaligua Brebes, Province of Central Java. K<sub>1</sub> (1 ton ZA and 250 kgs Phonskaha<sup>-1</sup>), K<sub>2</sub>(300 kgs Urea, 500 kgs SP-36 and 200 kgs KClha<sup>-1</sup>), K<sub>3</sub> (1/2 K<sub>2</sub>) and K<sub>4</sub> (1/4 K<sub>2</sub>)

### 3.3. Soil erosion

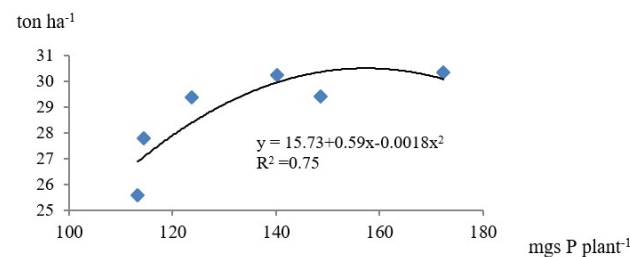
The application of conservation practices can reduce the soil erosion by 75.77 percent compared to the control. Erosion at L<sub>1</sub> treatment caused losses soil materials up to 6.80 tons soil ha<sup>-1</sup> year<sup>-1</sup>. It was different with other practices (L<sub>2</sub> and L<sub>3</sub>) that only caused soil losses lower than the first. Soil erosion at L<sub>2</sub> only was 1.98 tons soil ha<sup>-1</sup> year<sup>-1</sup> and L<sub>3</sub> was 1.32 tons soil ha<sup>-1</sup> year<sup>-1</sup> (**Figure 7**). Tolerable soil losses at andisol is only 13.5 ton soil ha<sup>-1</sup> year<sup>-1</sup>[17], but at least conservation method or practice that applied at L<sub>2</sub> and L<sub>3</sub> are able to reduce the soil erosion compared L<sub>1</sub>. Conservation practice in potato farming using contour parallel cropping system (cutting slopes) is able to reduce the rate of soil erosion up to 53.27 percent compared to the control (no conservation)[18].



**Figure 7.** Soil erosion (tons soilha<sup>-1</sup> year<sup>-1</sup>) at three cropping patterns based on contour direction at Kaligua Brebes, Province of Central Java. L<sub>1</sub> (the parallel with slope), L<sub>2</sub> (the angle 10percentto contour) and L<sub>3</sub> (the parallel with contour).

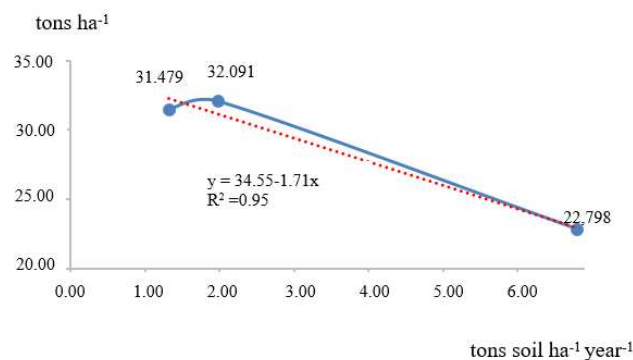
### 3.4. Regression and correlation analysis of potato yield

The relation between potato yield (tuber) and potato P sorption was quadratic pattern, in mathematic equation  $y = 15.73 + 0.59x - 0.0018x^2$  (Figure 8). The correlation between yield and P sorption was positive,  $r^2 = 0.76$ . It was close correlation.



**Figure 8.** Regression of potato yield with potato P sorption at andisol Kaligua Brebes, Province of Central Java

Correlation between potato yield and the soil erosion was negative,  $r^2 = -0.99$ . It inferred opposite directions. The increase in erosion rate cause decrease in potato yield (Figure 9).



**Figure 9.** Regression of potato yield with soil erosion at Kaligua Brebes, Central Java

## 4. Conclusion

The highest potato yield at 10 percent an angle in the same direction with contour pattern was 16.33 tons ha<sup>-1</sup>, while the potato yield in the same direction with slope was 13.76 tons ha<sup>-1</sup>. Biological organic fertilizer (BOF) at 20 tons ha<sup>-1</sup> increased addition the potato yield up to 2 tons ha<sup>-1</sup>, higher than the same dose chicken manure used. Fertilization of 300 kgs Urea, 500 kgs SP-36 and 200 kgs KCl ha<sup>-1</sup> (or 1/2 or 1/4 dose) increased addition the yield of potatoes more than 0.2 tons ha<sup>-1</sup> than the dose of inorganic fertilizer the farmers usually used (1 ton ZA and 250 kgs Phonska ha<sup>-1</sup>). The lowest erosion occurred at the treatment of 10 percent an angle in the same direction with contour pattern with an erosion of 1.32 tons soil ha<sup>-1</sup>/year. The correlation between potato yields and P sorption was positive, 0.76. The correlation between potato yield and soil erosion was negative, 0.99.

## Acknowledgments

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