The effect of liquid organic fertilizer and phosphate solubilising bacteria *Bacillus* sp on potato growth (*Solanum tuberosum*) in andisol soil

A E Marpaung¹, H Hanum² and M Sembiring²

¹Postgraduate Student of Agriculture Faculty, Universitas Sumatera Utara, Medan 20155, Indonesia
²Faculty of Agriculture, Universitas Sumatera Utara, Medan 20155, Indonesia

E-mail: agustinamarpaung@yahoo.com

Abstract. Andisol is a soil type which has very strong characteristic of binding phosphate nutrients, because bound by allophone clay minerals which can retain P up to 97.8%. Therefore, P in the soil not available for plants, while the total P in the soil is high. The availability of P for plants can be done by giving organic material and phosphate solubilising microbes. The aim of study is to determine the effect of using liquid organic fertilizer (LOF) and phosphate solubilising bacteria (PSB) *Bacillus* sp on potato growth in andisol soil. The design used was a factorial randomized block design with three replications. The treatments are first factor the LOF concentration {0 (control), 40.80 and 120 ml L⁻¹ water} and the second factor the PSB *Bacillus* sp type {without bacteria (control), *Bacillus cereus, Bacillus pseudomycoides* and *Bacillus amyloliquefaciens*}. The results showed that the application of LOF with dose 40-120 ml L⁻¹ water could not increase the potatoes growth compared to control. Application of PSB can increase the height and diameter (1.00 – 6.35%) wet and dry weight (1.57 – 27.28%) of potatoes plants compared to control. The application of 40 ml L⁻¹ water LOF and PSB *Bacillus amyloliquefaciens* increased the number of potato tillers 41.36% from the control.

1. Introduction

Andisol soil has the characteristic having the high phosphate retention, so that P in the soil to be unavailable to plants and can reduce the growth and the yield of plants. Andisols formed by volcanic ash and dominated by amorphous minerals. Characteristic of the soils containing amorphous minerals is high P retention (> 85%), so that the availability of phosphate (P) in the soil decreases, which causes P in the soil to be unavailable for plants [1].

Phosphorus in soil can classify to three forms: free phosphate ions in soil solution, inorganic phosphorus and organic phosphorus [2]. Primarily mineralized of organic phosphorus by microbial extracellular phosphomonoesterase [3]. Phosphate nutrients is very important to plant growth and yield. Phosphate nutrient (P) is one of the essential element which an important in photosynthesis and root development. [4] said that plant growth can be slow, weak, and stunted if deficiency of P. So that needed the Andisol soil management directed to reduce the high absorbed P, which causes the phosphate availability for plants to be very low. The availability of P in Andisol soil can be done by applying phosphate solubilising microbes and organic fertilizer. Phosphate solubilising microbes are...
bacteria and fungi. Strains from the genus Bacillus, Pseudomonas and Rhizobium are most potential to solvents the phosphate. Genus of Pseudomonas sp and Bacillus sp are potential to dissolve phosphate in peat soil [5]. According to the [6, 7] research, produce the organic acids and the enzyme acid phosphatase is the principle of the mineral phosphate dissolution mechanism to mineralization of organic phosphate in the soil.

In addition, giving the organic fertilizers is very important too to increase the plant growth and yield. Organic fertilizers can be made from organic materials waste, in the form of solids or liquids. Some of the results of research on liquid organic fertilizers can increase plant growth and production, including mustard greens [8], cabbage [9], tomatoes [10], soybeans [11], sweet corn [12], and potatoes [13].

Potato (Solanum tuberosum L.) is one of the major horticultural crops which growth in highland and needs P in huge amount to increase the growth and production. For providing P nutrient for plants, giving the phosphate solubilising bacteria and liquid organic fertilizer is one of the ways that can be done. Therefore, the objective of this study was to determine the effect of using liquid organic fertilizer (LOF) and phosphate solubilising bacteria (PSB) Bacillus sp on the potato growth in andisol soil.

2. Methods and procedure

The research was conducted in Tongkoh Village, Dolat Rayat District, Karo Regency with the soil characteristics: pH H₂O 5.20, C 4.55%, N 0.59%, P total 279.45 mg 100 g⁻¹, P available 10.70 ppm, 26.92 mg 100 g⁻¹ K, and CEC 21.55 cmol kg⁻¹. The materials used in this study were potato seeds generation-2 of Granola variety, rabbit urine, coconut water, fish fertilizer, bran, fish teillation, phosphate solubilizing bacteria from the collection of the Berastagi Experimental Farm (Bacillus cereus, Bacillus pseudomycoïdes and Bacillus amyloliquefaciens) which were isolated from the rhizosphere of the potato plants and had been tested for their ability to dissolve phosphate.

This study used Factorial Randomized Block Design with two factors and 3 replications. Factor I was liquid organic fertilizer (LOF) concentration {0 (control), 40, 80 and 120 ml L⁻¹ water}. Factor II was phosphate solubilising bacteria (PSB) Bacillus sp type {without bacteria (control), Bacillus cereus, Bacillus pseudomycoïdes and Bacillus amyloliquefaciens}. Each treatment had 24 plants. Size of plot was 2.4 x 2.2 m, the distance between plots in the block was 40 cm, and the distance between blocks was 1 m. Each of the plot consist of two shed and using the plastic mulch. The base fertilizers applied were SS-Amorphoph 13 g plant⁻¹ + ZA 38 g plant⁻¹ + TSP 10 g plant⁻¹ + Patenkali Butir 30 g plant⁻¹. Insecticide sipermetrin 50 g/l (2 cc L⁻¹ water), profenofos, klorantranilipol 50 g L⁻¹, imidakloprid (1 cc L⁻¹ water), emamektin benzoat (0.5–1.0 cc L⁻¹ water), fungicide mankozeb or difenokonasol 250 g (2 g L⁻¹ water) and weeding was done to prevent weed growth.

Inoculation of each PSB with population 109 cfu/mL spreaded around potato roots 2 week after potato planted in the field. The application of liquid organic fertilizer with a concentration according to the treatment tested was carried out at planting, 2, 4, and 6 weeks after planting as much as 200 ml per planting hole per application by watering. The parameters measured were: increasing of plant height and diameter, tillers number, plant fresh weight and plant dry weight, measured at the end of the vegetative period. Statistical Analysis: To determine the significant differences among the treatments, data was analyzed using Anova and means were compared with Duncan test (P= 0.05).

3. Result and Discussion

3.1. Plant Height and Diameter Increasing

The application of liquid organic fertilizer (LOF) had a significant effect on the increase in plant height and diameter, but the treatment of the phosphate solubilizing bacteria (PSB) Bacillus sp type did not have a significant effect (table 1). At the age of 4-8 weeks after planting, the increase in height and diameter of the plants in the treatment without LOF was significantly higher than the treatment...
with LOF. This shows that the concentration of LOF given is very high, thus inhibiting the vegetative
growth of potato plants.

**Table 1.** Effect of liquid organic fertilizer (LOF) concentration and phosphate solubilising bacteria
(PSB) Bacillus sp type to plant height and diameter increasing.

| Treatments                  | Height increasing (cm) | Diameter increasing (cm) |
|-----------------------------|------------------------|--------------------------|
|                             | 4 WAP | 6 WAP | 8 WAP | 4 WAP | 6 WAP | 8 WAP |
| LOF Concentration           |       |       |       |       |       |       |
| 0                           | 5.86a | 26.71a| 39.09a| 11.45a| 38.18a| 47.09a|
| 40 ml L⁻¹ water             | 5.16a | 21.59b| 33.35b| 9.77a | 34.80b| 42.77a|
| 80 ml L⁻¹ water             | 5.80a | 24.26ab| 36.71ab| 10.28a| 34.90b| 42.65a|
| 120 ml L⁻¹ water            |       |       |       |       |       |       |
| PSB Bacillus sp type        |       |       |       |       |       |       |
| Without PSB                 | 5.27a | 22.05a| 35.31a| 9.68a | 33.98a| 42.92a|
| Bacillus cereus             | 5.31a | 21.70a| 35.82a| 10.47a| 34.83a| 44.08a|
| Bacillus pseudomycoides     | 5.77a | 24.97a| 36.63a| 11.25a| 36.46a| 45.83a|
| Bacillus amyloliqufaciens   | 5.61a | 26.69a| 36.56a| 10.25a| 36.33a| 43.89a|
| CV (%)                      | 16.49 | 16.56 | 12.68 | 15.71 | 9.73  | 10.83 |

Means followed by the same letter on the same column is not significant different by Duncan test at 5% level.
WAP = Week after plant.

Given the phosphate solubilizing bacteria Bacillus sp type resulted an increase in plant height and
diameter that was not significantly different from without phosphate solubilizing bacteria, but there
was a tendency that from 4 - 8 weeks of age after plants with PSB Bacillus sp was an increase the
height and diameter of potato plants respectively, 1.00- 3.60% and 1.42 – 6.35% of control. This is
supported by the results of research [14] that the application of phosphate solubilizing bacteria can
increase the height of peanut plants by 17.50%. According to [15] giving phosphate solubilizing
bacteria (Bacillus cereus) could increase the height of potato plants by 15% from the control treatment.
Plant height and diameter with giving the LOF and PSB continued to increase from the age of 4, 6 to 8
WAP. The increase in plant height is directly proportional to the increase in plant diameter (figure 1).

### 3.2. Tillers Number

The application of liquid organic fertilizer and the phosphate solubilizing bacteria Bacillus sp type had
a significant effect on tillers number (table 2). The highest tillers number was obtained in the treatment
of liquid organic fertilizer with a concentration of 40 ml L⁻¹ water and B. amyloliqufaciens, ie 3.53.
This indicated that the treatment of LOF with a concentration of 40 ml L⁻¹ water and B.
amyloliqufaciens was able to increase the growth of potato tillers 41.36% from the control treatment,
which would have the potential for tuber formation for yield. This is supported by the results of
research [16] that the application of liquid organic fertilizer can increase the tillers number of potatoes
by 6.6% - 28.28%. The results of the study [15] also stated that giving phosphate solubilizing bacteria
(Bacillus cereus) could increase the tillers number of potato plants 32% of the control.
Figure 1. The plant height and diameter increasing with applying liquid organic fertilizer (LOF) concentration and phosphate solubilising bacteria (PSB) Bacillus sp type.

Table 2. Interaction between liquid organic fertilizer (LOF) concentration and phosphate solubilising bacteria (PSB) Bacillus sp type to tillers number.

| LOF Concentration | PSB Bacillus sp type | Without PSB | B. cereus | B. pseudomycoides | B. amyloliquefaciens |
|-------------------|----------------------|-------------|-----------|-------------------|---------------------|
| 0                 | 2.07 d               | 2.93 abc    | 3.07 abc  | 2.73 abcd         |
| 40 ml L^{-1} water| 2.27 cd              | 2.27 cd     | 2.67 abcd | 3.53 a            |
| 80 ml L^{-1} water| 2.3 d                | 2.73 abcd   | 2.73 abcd | 3.27 ab           |
| 120 ml L^{-1} water| 3.20 abc            | 2.07 d      | 2.53 bcd  | 2.07 d            |

CV (%) 17.07

Means followed by the same letter on the same rows and columns is not significant different by Duncan test at 5% level.

3.3. Plant Fresh and Dry Weight

The treatment of liquid organic fertilizer concentration and phosphate solubilising bacteria of Bacillus sp type had no significant effect on the fresh weight of potato plants. Meanwhile, on the dry weight of potato plants, the treatment of phosphate solubilising bacteria Bacillus sp type gave a significant effect, but not on the treatment of liquid organic fertilizer concentration (table 3).

Giving the phosphate solubilising bacteria Bacillus amyloliquefaciens was able to increase the dry weight of shoot of potato plant by 27.28% from the control treatment. The treatment of B. amyloliquefaciens was not significantly different from B. pseudomycoides but significantly different from B. cereus. According to [17] giving phosphate solubilising bacteria (B. cepacia) can increase the dry weight of shoot potato plant ie 50.07 – 113.73% compared to control.
Table 3. Effect of liquid organic fertilizer (LOF) concentration and phosphate solubilising bacteria (PSB) Bacillus sp type to plant fresh and dry weight.

| Treatmenets          | Fresh weight (kg) | Dry weight (g) |
|----------------------|-------------------|----------------|
| LOF concentration    |                   |                |
| 0                    | 0.63 a            | 55.64 a        |
| 40 ml L⁻¹ water      | 0.48 a            | 45.21 a        |
| 80 ml L⁻¹ water      | 0.52 a            | 47.84 a        |
| 120 ml L⁻¹ water     | 0.60 a            | 55.58 a        |
| PSB Bacillus sp type |                   |                |
| Without PSB          | 0.8 a             | 44.43 b        |
| Bacillus cereus      | 0.50 a            | 45.14 b        |
| Bacillus pseudomycoides | 0.58 a        | 53.60 ab       |
| Bacillus amyloliquefaciens | 0.66 a    | 61.10 a        |
| CV (%)               | 26.37             | 26.86          |

Means followed by the same letter on the same column is not significant different by Duncan test at 5% level.

4. Conclusion

Application the liquid organic fertilizer with dose 40-120 ml L⁻¹ water could not increase the potatoes growth compared to control. Application phosphate solubilising bacteria can increase the height (1.00-3.60%) and diameter (1.42 – 6.35%) of potato plant, fresh (4.00 – 27.27%) and dry (1.57 – 27.28%) weight of shoot potato plants compared to control. The application of 40 ml L⁻¹ water the liquid organic fertilizer and phosphate solubilising bacteria Bacillus amyloliquefaciens can increase the tillers number of potato 41.36% from the control.

References

[1] Sukarman and Dariah A 2014 Tanah Andosol di Indonesia Karakteristik, Potensi, Kendala dan Pengelolaan (Bogor: Badan Penelitian dan Pengembangan Pertanian) p 156
[2] Shen J, Yuan l, Zhang J, Li H, Bai Z, Chen X, Zhang W and Zhang F 2011 Phosphorus dynamics: from soil to plant Plant Physiol. 156 (3) 997–1005
[3] Nannipieri P, Giagnoni L, Landi L and Renella G 2011 Role of phosphatase enzymes in soil Phosphorus in Action vol 26, ed E K Buennemann, A Oberson and E Frossard (New York: Springer-Verlag Berlin Heidelberg) p 215–243
[4] Sumarni N, Rosliani R, Basuki R S and Hilman Y 2012 Respons tanaman bawang merah terhadap pemupukan fosfat pada beberapa tingkat kesuburan lahan (status P-tanah) J. Hort. 22 p 130
[5] Larasati E D, Rukmi I, Kusdiyantini E and Ginting R C B 2018 Isolasi dan identifikasi pelarut fosfat dari tanah gambut Bioma 20 p 8
[6] Ranjan A, Mahalakshmi M R and Sridevi M 2013 Isolation and characterization of phosphate-solubilising bacterial species from different crop fields of Salem, Tamil Nadu, India Int. J. Nutr. Pharmacol. Neurol. Dis. 3 p 29
[7] Jones D L and Oburger E 2011 Solubilization of phosphorus by soil microorganism Phosphorus in Action vol 26, ed E K Buennemann, A Oberson and E Frossard (New York: Springer-Verlag Berlin Heidelberg) p 169–198
[8] Manullang G S, Rahmi A and Astuti P 2014 Pengaruh jenis dan konsentrasi pupuk organik cair terhadap pertumbuhan dan hasil tanaman sawi (Brassica juncea L.) varietas tosakan Jurnal AGRIFOR XIII 33–40
[9] Marpaung A E, Udiarto B K, Lukman L and Hardiyanto 2018 Potensi pemanfaatan formulasi pupuk organik sumber daya lokal untuk budidaya kubis J. Hort. 28 191
[10] Marliah A, Hayati M and Muliansyah I 2012 Pemanfaatan pupuk organik cair terhadap pertumbuhan dan hasil beberapa varietas tomat (Lycopersicum esculentum L.) Jurnal Agrista
[11] Hamzah S 2014 Pupuk organik cair dan pupuk kandang ayam berpengaruh kepada pertumbuhan dan produksi kedelai (Glycine max L.) Agrium \textbf{1} 228

[12] Syofia I, Munar A and Sofian M 2014 Pengaruh pupuk organik cair terhadap pertumbuhan dan hasil dua varietas tanaman jagung manis (Zea Mays Saccharata Sturt) Agrium \textbf{18} 208

[13] Marpaung A E, Karo B and Tarigan R 2014 Pemanfaatan pupuk organik cair dan teknik penanaman dalam peningkatan pertumbuhan dan hasil kentang J. Hort. \textbf{24} 49

[14] Wang T, Liu M Q and Li H X 2014 Inoculation of phosphate-solubilizing bacteria Bacillus thuringiensis B1 increases available phosphorus and growth of peanut in acidic soil Acta Agriculturae Scandinavica, Section B – Soil & Plant Science \textbf{64} 252

[15] Ali A M, Awad M Y M, Hegab S A, Gawad A M A E and Eissa M A 2020 Effect of potassium solubilizing bacteria (Bacillus cereus) on growth and yield of potato Journal of Plant Nutrition \textbf{44} 411-420

[16] Karamina H and Fikrina W 2016 Aplikasi pupuk organik cair pada tanaman kentang varietas granola di dataran medium Jurnal Kultivasi \textbf{15} 157

[17] Sembiring M, Elfiati D, Sutarta E S and Sabrina T 2016 Effect of Burkholderia cepacia and SP-36 on available phosphate and potato production on Andisol impacted by Mount Sinabung Eruption, North Sumatera, Indonesia Journal of Applied Horticulture \textbf{18} 234