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Research Article
Bacterial and Fungi Phosphate Solubilization Effect to Increase Nutrient Uptake and Potatoes (*Solanum tuberosum* L.) Production on Andisol Sinabung Area

Mariani Sembiring and Fauzi

Faculty of Agriculture, Universitas Sumatera Utara, Padang Bulan, 20155 Medan, Indonesia

Abstract
Background and Objective: Deficiency of Phosphorus (P) in soil results in reduction of food production since all plants require an adequate supply of P for its growth and development. The availability of phosphorus in Andisol soil is very low only circa 0.1% of the total soil P. Phosphate solubilizing microbes can increase soil available P so that growth and crop production can be increased. This study aims to find a type of superior microbe that is able to increase the availability of phosphorus and potato production on Andisol Sinabung area. **Materials and Methods:** This study was conducted in Kutarayat village, Naman Teran District. The research design used in this study was a randomized block design non factorial with three replications, as for the treatment being tested is without application of microbial solubilization phosphate (M0), *Burkholderia cepacia*1 (M1), *Bacillus licheniformis* (M2), *Burkholderia metallica* (M3), *Burkholderia cenocepacia* (M4), *Burkholderia cepacia*2 (M5) and fungi phosphate solubilization are *Penicillium* sp. 1 TMS (M6), *Talaromyces pinophilus* (M7), *Aspergillus terreus* (M8), *Aspergillus awamori* (M9), *Penicillium* sp. (M10). The parameter of observations are total soil P analysis, soil P availability, nitrogen (N) uptake, phosphorus (P) uptake and potassium (K) uptake of plant in vegetative period and potato production. The data were subjected to analysis of variance (ANOVA) procedures the SAS version 12 computer programs and comparison of means were tested for significance using least significant difference (LSD) $p = 0.05$. **Results:** The research results showed that microbial phosphate solubilization is able to increase the P availability at 2.47-71.08%, nutrient uptake at 1-89.4% and total production at 9.3-68%. **Conclusion:** It was concluded that best treatment in increasing the availability of P and the production of the potato plant is application of fungi phosphate solubilization, *Talaromyces pinophilus* treatment (M7).

Key words: Andisol, microbial phosphate solubilization, *Talaromyces pinophilus*, phosphorus nutrients, food production

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Corresponding Author: Mariani Sembiring, Faculty of Agriculture, Universitas Sumatera Utara, Padang Bulan, 20155 Medan, Indonesia Tel: 061-8213236

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Andisols in Sinabung area is good for horticulture crops production such as potato and cabbage. Andisol is formed from volcanic materials that have a relatively low availability of phosphorus due to the adsorption by allophane[1-3]. The Volcanic ash soil is rich in minerals that contain lots of Al and Fe capable of binding phosphorus so it is not available to plants[2,3]. Mukhlis *et al.*[4], who conducted the research in the village Kutarayat, Naman Teran District obtained P retention in range around 92.94-99.91%, this showed that the P retention in these areas is very high.

Phosphorus (P) is an element that is often the limiting factor of plant growth[5-7]. The main source of P is rock, which is not renewable, causing a limitation for this source. P is derived from the parent material and mostly insoluble, except in certain circumstances. Phosphorus (P) element is the 2nd essential element after N which plays an important role in photosynthesis and root development[6-9]. In acid soils, microorganisms activity is dominated by the fungi because the fungi growth optimum at pH 3-5.5. The growth of fungi will be decreases when pH increased. In the soil, fungi are formed vegetative mycelium or spores. The research results of Sinaga *et al.*[10] and Sembiring *et al.*[11] showed that soil pH in Andisol affected by the eruption of Mount Sinabung ranged from 3.7-4.7 which fall into the category of very acid. This will affect the amount and type of microbe that can live on the such soil condition.

Potato plants are horticultural crops which are widely cultivated around Mount Sinabung which need high of P nutrient. According to Sembiring *et al.*[11] application of *T. pinophilus* can increase the availability of P by 9.63-49.78% and yield of potato increased by 0.3-28.87% which planted in Andisol affected by the eruption of Mount Sinabung. Marbun *et al.*[12] application of fungi phosphate solubilizing and organic matter can increase P uptake and growth of the potato crop in Andisol affected by the eruption of Mount Sinabung. This study evaluated the superior types of phosphate solubilization microorganisms to increase the availability of P, nutrient uptake and potato production at Andisol in the area of sinabung.

MATERIALS AND METHODS

Materials: This research was conducted at Kutarayat village, Naman Teran District With a thickness of ash eruptions <2 cm. The study was conducted from July-December, 2016. Soil chemical analysis and plant nutrient uptake was conducted in Laboratory Research and Development center, Bahilang Tebing Tinggi. Characteristics chemical of Andisol soil for this study is a follows pH H_2O 4.21, C organic 4.7% (method Walkley and black titration) N 0.61% (method Kjedahl-Titrimetry) P total 0.14%, P available 66.26 ppm (method Bray II) and CEC 26.77 ME kg^{-1}. The materials used as isolated bacterial phosphate solubilization are *Burkholderia cepacia*1, *Bacillus licheniformis*, *Burkholderia metallica*, *Burkholderia cenocepacia*, *Burkholderia cepacia*2 and fungi phosphate solubilization are *Penicillium* sp. 1 TMS, *Talaromyces pinophilus*, *Aspergillus terreus*, *Aspergillus awamori*, *Penicillium* sp. which were isolated from the rhizosphere of potato plants that affected by the eruption of Mount Sinabung and have been tested for their ability to dissolve phosphate. Microbial isolates were cultured using Pikovskaya media with composition per liter of aquades: Glukosa 10 g, $Ca_3(PO_4)_2$ 5 g, $(NH_4)_2SO_4$ 0.5 g, KCl 0.2 g, $MgSO_4.7H_2O$ 0.1 g, $MnSO_4$ 0.002 g, $FeSO_4$ 0.002 g, yeast extract 0.5 g, agar 20 g and aquades. The others material were Granola potato seed (G3), urea fertilizer 6.8 g, 9.75 g SP-36, 10 g KCl.

Methods: The research design used in this study was a randomized block design non factorial with 3 replications, without application of phosphate solubilizing microbes (M0), *Burkholderia cepacia*1 (M1), *Bacillus licheniformis* (M2), *Burkholderia metallica* (M3), *Burkholderia cenocepacia* (M4), *Burkholderia cepacia*2 (M5) and fungi phosphate solubilization are *Penicillium* sp. 1 TMS (M6), *Talaromices pinophilus* (M7), *Aspergillus terreus* (M8), *Aspergillus awamori* (M9) and *Penicillium* sp. (M10).

Plot size is 0.6×4.20 m, the distance between plots within a block is 30 cm and spacing between blocks is 50 cm. The application of microbial phosphate solubilizing was applied around the roots with a dose of 20 mL/plant (8×10^8) and the application time was 2 weeks after the plants grow. Pest and disease control was conducted by applying insecticides Marshall 200 EC (carbosulfan 200.11 g L^{-1}) at a dose of 2.5-3 mL L^{-1} and fungicide dithane M-45 80 WP (chemical material Mankozeb 80%) with a dose of 1.2-2.4 g L^{-1}.

Parameters: Analysis 33 soil and plant samples were taken after the plant was 45 days after the plants grow. For the parameters of crop production samples were taken after the plant was 3 months after planting (in accordance with the criteria of harvesting potatoes).The parameters observed were soil pH H_2O 1:2.5 (test method elektrometriy), P total H_2SO_4: $HClO_4$ (1:1), P available (methods Bray II), plant dry weight, analysis nitrogen (method Kjedahl-Titrimetry), phosphorus (methods of detection Spectrophotometry) and potassium (methods of detection flame photometry) uptake of plant is calculated by total nutrient in plants multiplied by dry weight of plant (g/plant),and tuber size is by weighing the tuber in accordance with a predetermined size i.e., A criteria (>100 g/tuber), B criteria (>50-100 g/tuber), C criteria (15-50 g/tuber) and D criteria (<15 g/tuber).

Statistical analysis: The data were subjected to analysis method used was one-way (ANOVA) and comparison of means were tested for significance using least significant difference (LSD) p = 0.05[13].

RESULTS

The result of statistics analysis showed that the application of microbial phosphate solubilization gave no significant effect on pH soil, P total and significantly affected parameters of P available (Table 1). Soil pH by the microbial phosphate solubilization treatment showed that the use of microbial phosphate solubilization can increase soil pH when compared with no application (M0) i.e., 4.48 mean while *B. metallica* (M3) treatment i.e. 5.31. Soil pH parameters by the treatment of *B. metallica* (M3) were higher when compared with the other treatments, although not statistically significant. Application of microbial phosphate solubilization can increase P total when compared with no application (M0) i.e., 2158.88 mean while (M10) was 2315.43. Increase in P is 7.25% compared with controls. P available in soil by the microbes phosphate solubilizing treatment can improve P availability when compared with no application (M0). The application of microbial phosphate solubilization can increase the availability of P in Andisol affected by the eruption of Mount Sinabung. Increased of P availability by (M6) treatment was 47.71% when compared with the control.

Based on the treatment statistical analysis of bacterial and fungal phosphate solubilization can increase absorption of nutrient elements nitrogen (N), phosphorus (P) and potassium (K) on potato (Table 2). Nitrogen uptake treatment of microbes phosphate solubilizing can increase N uptake when compared with no application (M0). Increasing N uptake by *T. pinophilus* treatment (M7) amounted to 92.16% when compared with controls. The Application of bacteria phosphate solubilization treatment of *B. licheniformis* (M2) can increase N uptake by 77.43% when compared to the controls. The applications of fungal phosphate solubilization able to increase N uptake better when compared to bacteria phosphate solubilization. *T. pinophilus* treatment (M7) was higher by 8.3% when compared to *B. licheniformis* (M2). P uptake by microbial phosphate solubilization treatment

Table 1: Average score of soil pH, soil total P and P available by the microbial phosphate solubilization treatment

Treatments	Soil pH	P total (ppm)	P available (ppm)
Without application (M0)	4.48	2158.88	100.91^{ab}
*B. cepacia*1 (M1)	4.95	2284.22	122.18^{bc}
B. licheniformis (M2)	4.51	2243.38	108.12^{ab}
B. metallica (M3)	5.31	2212.01	103.40^{ab}
B. cenocepacia (M4)	4.36	2205.04	107.48^{ab}
*B. cepacia*2 (M5)	4.82	2322.12	116.53^{ab}
Penicillium sp. 1 TMS (M6)	4.94	2251.07	149.06^{cdef}
T. pinophilus (M7)	5.09	2341.01	141.73^{cde}
A. terreus (M8)	5.33	2173.83	101.43^{b}
A. awamori (M9)	5.22	2288.67	109.97^{bc}
Penicillium sp. 2 (M10)	5.28	2315.43	86.33^{a}

Means in a columns followed by a common letter are not significantly different at 0.05 level by LSD

Table 2: Average score of nutrient uptake of N, P and K by the microbial phosphate solubilization treatment (mg/plant)

Treatments	N uptake (mg/plant)	P uptake (mg/plant)	K uptake (mg/plant)
Without application (M0)	124.73^{a}	13.04^{a}	174.20
*B. cepacia*1 (M1)	138.36^{a}	12.76^{a}	156.68
B. licheniformis (M2)	221.31^{cdr}	17.43^{cd}	246.00
B. metallica (M3)	131.55^{a}	11.56^{a}	153.33
B. cenocepacia (M4)	145.58^{a}	13.05^{a}	157.78
*B. cepacia*2 (M5)	185.97^{abc}	19.45^{de}	212.28
Penicillium sp. 1 TMS (M6)	153.21^{a}	14.26^{ab}	163.81
T. pinophilus (M7)	239.68^{def}	24.76^{f}	295.85
A. terreus (M8)	151.10^{a}	12.55^{a}	154.96
A. awamori (M9)	167.16^{ab}	13.53^{a}	188.16
Penicillium sp. 2 (M10)	189.92^{abcd}	16.60^{bc}	217.60

Means in a columns followed by a common letter are not significantly different at 0.05 level by LSD

Table 3: Average score of total production and tuber weight by the microbial phosphate solubilization treatment (mg/plant)

Treatments	Total production (g/plant)	A criteria (>100 g/tuber)	B criteria (>50-100 g/tuber)	C criteria (15-50 g/tuber)	D criteria (<15 g/tuber)
Without Application (M0)	555.00^{bcd}	430.00^{abcd}	108.33^{ab}	28.33	8.33
*B. cepacia*1 (M1)	653.33^{fg}	416.67^{abc}	180.00^{ghi}	30.00	36.67
B. licheniformis (M2)	933.33^{j}	726.67^{j}	150.00^{defgh}	46.67	10.00
B. metallica (M3)	526.67^{ab}	396.67^{ab}	93.33^{a}	20.00	8.33
B. cenocepacia (M4)	646.67^{f}	483.33^{cde}	146.67^{defg}	11.67	8.33
*B. cepacia*2 (M5)	643.33^{bc}	531.67^{ghi}	73.33^{a}	26.67	20.00
Penicillium sp. 1 TMS (M6)	606.67^{e}	373.33^{fg}	110.00^{abc}	20.00	13.33
T. pinophilus (M7)	816.67^{hi}	623.33^{fgh}	143.33^{bcdef}	183.33	10.00
A. terreus (M8)	510.00^{a}	313.33^{a}	63.33^{a}	33.33	10.00
A. awamori (M9)	493.33^{a}	316.67^{a}	116.67^{abcd}	13.33	8.33
Penicillium sp. 2 (M10)	693.33^{gh}	503.33^{def}	133.33^{bcde}	60.00	18.33

Means in a columns followed by a common letter are not significantly different at 0.05 level by LSD

significantly improve $p<0.05$ P uptake of plants. K uptake by the application of microbial phosphate solubilization did not give significant effect in increasing the K uptake. The application of microbial phosphate solubilization can improve K uptake when compared with no application (M0). Improvement of K uptake by *T. pinophilus* treatment (M7) amounted to 69.83% when compared with controls.

From the observation and analysis of the statistics showed that the application of microbial phosphate solubilization give no real effect on the production of potato plants to more clearly seen in Table 3 showed the total potato production by the applications of microbial phosphate solubilization significantly $p<0.05$ increase the total production. The application of microbial phosphate solubilization can increase the total of crop production when compared with no application (M0). The increasing of total production by *B. licheniformis* treatment (M2) amounted to 68.17% when compared with controls.

DISCUSSION

The application of bacterial phosphate solubilization *B. cepacia*1 (M1) treatment can improve P availability by 21.08% when compared with the control. The applications of *Penicillium* sp. 1 TMS (M6) treatment is higher by 22% when compared with the *B. cepacia*1 (M1). Application of fungi phosphate solubilization able to increase the availability of P better when compared with bacterial phosphate solubilization (Table 1). The research results of Sembiring *et al.*[14] showed that the application of combination microbial phosphate solubilization with organic matter can increase P availability 13.3% in Andisol affected by the eruption of Mount Sinabung. Mechanism of P bound by Al, Fe, Ca and Mg can be done in the presence of organic acids through the process chelating so that P becomes available and can be absorbed by plants[15-17].

The application of *T. pinophilus* (M7) was 24.76 mg/plant the used of microbes phosphate solubilization treatment can increase P uptake of plants in Andisol affected by Mount Sinabung eruption. P uptake improvement by *T. pinophilus* treatment (M7) amounted to 89.87% when compared with controls. The Application of bacteria phosphate solubilization treatment *B. cepacia*2 (M5) can improve P uptake by 49.16% when compared to the controls. The applications of fungi phosphate solubilization able to increase P uptake by plants better when compared to bacterial phosphate solubilization. *T. pinophilus* (M7) treatment was 27.3% higher when compared with *B. cepacia*2 (Table 2). Ritonga *et al.*[18] and Sembiring *et al.*[19-20] stated that the application of *T. pinophilus* without cow dung can increase P uptake 21, 15% and growth and production of plants 24.96%. The application of bacteria phosphate solubilization, *B. licheniformis* (M2) treatment can increase K uptake by 41.22% when compared to the controls. The applications of fungal phosphate solubilization are able to increase K uptake by plants better when compared to bacterial phosphate solubilization. *T. pinophilus* treatment was higher 20% when compared with the (M2). Bacterial phosphate solubilization, *B. licheniformis* treatment was 15.88% higher when compared with the *B. cepacia*2 treatment. In the K uptake parameters, *T. pinophilus* treatment (M7) was able to increase P uptake better in potato plants when compared with other treatments. The dissolution of fungal phosphate solubilization is greater than the bacterial because fungi have hyphae that able to bind the particles of P mineral in the soil[9,10,21,22].

The applications of fungal phosphate solubilization, *T. pinophilus* treatment can increase total crop production amounted to 47.15% when compared with controls. The applications of bacteria phosphate solubilization are able to increase total crop production better when compared with fungi phosphate solubilization. *B. licheniformis* treatment was 14.28% higher when compared with *T. pinophilus*. In total production parameters *B. licheniformis* treatment is able to increase total production of potato better when compared with other treatments, this is because phosphorus is the 2nd key element for plant nutrients which also influence the growth and crop production[6,8,9]. The inoculation of phosphate solubilizing microorganisms (PSM) endowed with phytohormone-producing ability is likely to have a synergistic and productive effect, which might increase P uptake, growth and yield of various crops[7,21,23,24].

In Table 3 potato tuber size A criteria with the application of microbial phosphate solubilization significantly $p<0.05$ increase the size of the potato tuber size A criteria. The microbes also produce vitamins, amino acids, growth promoting substance such as IAA and gibberellin acid that can improve plant growth[25-28]. The application of microbial phosphate solubilization can increase the size of potato tuber A criteria when compared with no application (M0) i.e., 430 g/plant, while by *B. licheniformis* was 726.67 g/plant. The increase in total production of *B. licheniformis* treatment amounted to 68.99% when compared with controls. The applications of fungi phosphate solubilization, *T. pinophilus* treatment can increase the size of the potato tuber A criteria by 44.96% when compared to the controls. The applications of bacterial phosphate solubilization are able to increase the size of the potato tuber A criteria better when compared with fungal phosphate solubilization. *B. licheniformis* treatment was 16.58% higher when compared with *T. pinophilus* (M7). In the potato tuber size parameter criteria A, treatment of *B. icheniformis* (M2) is able to increase the size of the potato tuber A criteria when compared with other treatments. The experiment conducted by Malboobi *et al.*[28] showed that the combinations of either *P. agglomerans* or *M. laevaniforman*s trains with *P. putida* led to higher biomass and yield of potato plants by about 20–25% in green house and in field trials.

Potato tuber size B criteria with the application of microbial phosphate solubilization significantly $p<0.05$ increase the size of the potato tuber B criteria. The application of microbial phosphate solubilization can increase the size of potato tuber criteria B when compared with no application (M0) i.e., 108.33 g/plant, while by *B. cepacia*1 is 180 g/plant, the used of application of microbes phosphate solubilization can increase the size of the potato tuber criteria B in Andisol affected by Mount Sinabung eruption. Increasing production of B criteria crop by *B. cepacia*1 (M1) treatment amounted to 66.16% when compared with controls. The application of fungal phosphate solubilization, *T. pinophilus* treatment (M7) can increase the size of the potato tuber criteria B by 32.08% when compared to the controls. The applications of bacterial phosphate solubilization are able to increase the size of the potato tuber criteria B better when compared with fungal phosphate solubilization. *B. licheniformis* (M2) treatment is 25.58% higher when compared with *T. pinophilus*. In the potato tuber size parameter B criteria by the treatment of *B. licheniformis* is able to increase the size of the potato tuber criteria B better when compared with other treatments. The application of microbial phosphate solubilization did not significantly affect tuber size criteria C and D.

CONCLUSION

This study showed that microbial phosphate solubilizing was able to increase P availability to 47.71%, N uptake became 77.43%, P uptake became 49.16%, K uptake became 41.22% and total production became 68%. This also proves that *T. pinophilus* is the best treatment of increasing potato production in Andisol Sinabung Area.

SIGNIFICANCE STATEMENTS

This study found a type of superior phosphate solubilization microbe capable of increasing the availability of phosphorus nutrients, N, P, K uptake and production of potato. This study will help researchers to increase the growth and production of potatoes in Andisol soil affected by mount Sinabung eruption.

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