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Application of organic fertilizer and phosphate solubilizing bacteria to increase the growth and yield of potatoes in Andisol

Abstract. Andisol has low phosphate (P) nutrient content due to high P fixation by allophane minerals, which affects crop production. The application of organic fertilizers and phosphate solubilizing bacteria can increase the availability of P in the soil in order to increase the production of potato plants. This study aimed to evaluate the effect of different types of organic fertilizer and phosphate solubilizing bacteria (PSB) on potato production. The research was conducted from August to November 2020 in the installation of research and assessment of agricultural technology Berastagi, Karo Regency, with an altitude of ± 1,340 m above sea level and the soil order is Andisol. The experimental design used a factorial randomized completely block design with four replications. The first factor was a different type of organic fertilizer (liquid organic fertilizer and chicken manure) and the second factor was a different type of phosphate solubilizing bacteria (PSB) {without PSB (control), *Bacillus cereus*, *Bacillus pseudomycoides*, and *Bacillus amyloliquefaciens*}. Results showed that chicken manure was able to increase the growth and yield of potatoes per plot. Phosphate solubilizing bacteria *B. pseudomycoides* could increase potato yields. The interaction of chicken manure and *B. pseudomycoides* was able to increase potato yield by 33.79% - 56.24% and the percentage of big tubers to 32.60% - 70.23% and decrease the grade of small tubers to 43.61% - 72.32% compared to without PSB. Phosphate solubilizing bacteria *Bacillus pseudomycoides* and chicken manure fertilization had the potential to be applied for increasing potato production in Andisol.

Keywords: *Bacillus* sp. · Organic fertilizer · *Solanum tuberosum*

Pemberian pupuk organik dan bakteri pelarut fosfat untuk meningkatkan pertumbuhan dan hasil kentang di tanah Andisol

Sari. Andisol memiliki kandungan hara P yang rendah karena fiksasi P yang tinggi oleh mineral alofan, yang mempengaruhi produksi tanaman. Aplikasi pupuk organik dan bakteri pelarut fosfat dapat meningkatkan ketersediaan P dalam tanah untuk meningkatkan produksi tanaman kentang. Penelitian ini bertujuan untuk mendapatkan jenis pupuk organik dan bakteri pelarut fosfat (BPF) terbaik untuk meningkatkan produksi kentang pada andisol. Penelitian dilaksanakan pada bulan Agustus sampai dengan November 2020 di Instalasi Penelitian dan Pengkajian Teknologi Pertanian Berastagi Kabupaten Karo dengan ketinggian tempat ± 1.340 m dpl dan ordo tanah Andisol. Rancangan yang digunakan adalah rancangan acak kelompok faktorial dengan empat ulangan. Perlakuan yang diteliti adalah pertama jenis pupuk organik (pupuk organik cair dan kotoran ayam) dan faktor kedua jenis bakteri pelarut fosfat (PSB) {tanpa BPF (kontrol), *Bacillus cereus, Bacillus pseudomycoides*, dan *Bacillus amyloliquefaciens*}. Hasil penelitian menunjukkan bahwa jenis pupuk organik kandang ayam mampu meningkatkan pertumbuhan dan hasil tanaman kentang. Bakteri pelarut fosfat *B. pseudomycoides* dapat meningkatkan hasil kentang per plot. Interaksi pupuk organik kotoran ayam dan bakteri pelarut fosfat *B. pseudomycoides* mampu meningkatkan hasil kentang sebesar 33,81% - 56,26% dan persentase umbi besar 32,60% - 70,23% dan menurunkan persentase umbi kecil 43,61% - 72,32% dari tanpa BPF.

Kata kunci: *Bacillus* sp. · Pupuk organik · *Solanum tuberosum*

Manuscript received : 19 August 2022, Revision accepted : 29 November 2022, Published : 21 December 2022
DOI: http://dx.doi.org/10.24198/kultivasi.v21i3.41485

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Introduction

The andisol is found in Indonesia, one of which is in the Karo Regency area located in a volcanic area that is used as agricultural land. The This soil has a very strong characteristics of binding phosphate nutrients because most of them are bound by non-crystalline clay minerals namely allophane, imogolite, and ferrihydrite. Allophane was able to retain P up to 97.8%. Therefore, there is less P available for plants, for about 0.1% of the total P, event though the total P in the soil is high (Zhu and Whelan, 2018). The P nutrient content in Dolat Rayat village according to the results of the 2019 Balitsa soil laboratory test is medium P-available for about 10.70 ppm; very high P-total for about 279.45 mg/100 g; and very high P-retention for about 98.48%.

The economy in Karo Regency is strongly influenced by the agricultural sector, where one commodity that is widely cultivated by farmers is potatoes. The need for potatoes continues to increase due to population growth, as well as changes in consumption patterns in several developing countries. In Karo Regency according to statistical data, potato productivity in 2020-2021 increased from 19,14 tons ha^{-1} to 21,17 tons ha^{-1} (BPS 2022b). In Indonesia, potato productivity in 2020-2021 is reach 19.55 tons ha^{-1} to 18,74 tons ha^{-1} [BPS 2022a]. Based on these data, the productivity of potato plants in a nation is still low, because according to the agriculture ministry potato productivity can reach 20-25 tons ha^{-1}. This shows that the productivity of potato plants is still low, so proper handling of cultivation is needed, especially in increasing the availability of P in Andisols, therefore production can increase. Increasing potato productivity can be done by handling the right cultivation, one of which is fertilization. Fertilization can be done by using chemical fertilizers and organic fertilizers.

Organic fertilizers have an important role in improving the physical, chemical, and biological properties of the soil. The nutrient content of organic fertilizers is relatively low, but their role in soil chemical properties far exceeds that of synthetic chemical fertilizers (Hartatik *et al.* 2015). Organic fertilizers are available in solid and liquid forms. Where the application can be done through the soil and leaves (special for liquid fertilizer). The Application of brown algae liquid fertilizer that was sprinkled on the soil was better than spraying on plants to increase total soil N, fresh weight of leaves, and tubers of Dayak onions (Milala, 2018). According to following by Ekawati and Saputri, (2018) stated that the application of vinasse liquid fertilizer by spraying it on the leaves or watering it into the soil did not affect the growth of Dayak onions. The application of chicken manure with a dosage of 6 ton ha^{-1} gave a better effect to plant height, while the dosage of 12 ton ha^{-1} gave the best effect on the weight of tuber per potato plant Granola Variety (Yusdian *et al.* 2018). The application of chicken manure at a dose of 10 tons per hectare produces the highest plant height, number of leaves, number of tubers, and tuber production (Budianto *et al.* 2015).

Phosphate solubilizing bacteria (PSB) are soil bacteria that can dissolve phosphate. The bacteria convert the insoluble phosphate to the soluble form through the production of organic acids and make it available for plant absorption and nutrition. In addition, it is also useful as a biological fertilizer because it produces the growth hormone (Satyaprakash *et al.* 2015). The chemical phosphate dissolution mechanism is the main phosphate dissolution mechanism carried out by microorganisms. These microorganisms excrete several low molecular weight organic acids such as oxalic, succinic, tartrate, citrate, lactate, -ketoglutarate, acetate, formic, propionic, glycolic, glutamic, glyoxylate, malic, and fumarate. Furthermore, these organic acids will react with phosphate-binding materials such as Al^{3+} in allophane minerals in Andisol soil, forming stable organic chelates so that they can free-bound phosphate ions and can be absorbed by plants. The principle of the dissolution mechanism of phosphate minerals is in the production of organic acids and the enzyme acid phosphatase plays a role in the mineralization of organic phosphate in the soil. (Setiawati and Pranoto, 2015).

Based on the research results of Ulfyati and Zulaika (2015), *Bacillus* sp is one of the phosphate solubilizing bacteria that can dissolve phosphate. Marpaung and Susilowati, (2021) also found several types of phosphate solubilizing bacteria *Bacillus* sp in Andisol soil, namely *B. cereus, B. amyloliquefaciens*, and *B. pseudomycoides*. One of the *Bacillus* species that can increase the availability of phosphate nutrients in the soil is *B. subtilis, B.*

amiloliquefaciens, B. pumilus (Borriss 2015), and *B. mycoides* (Setiawati and Pranoto, 2015). Where one of the other roles of rhizobacteria plant growth promoters is phosphate solvent. *Bacillus amyloliquefaciens* can increase P and N uptake in maize (Vinci *et al.* 2018) and *B. cereus* acts as a plant growth promoter (Aziz *et al.*, 2012; Hassan and Bano, 2015).

This study's aim was to obtain the best types of organic fertilizers and phosphate solubilizing bacteria (PSB) to increase potato yields on andisol soil. This study hypothesizes that applying phosphate-solubilizing bacteria that interact with organic fertilizers can increase the potato yield on Andisol.

Materials and Methods

The research was conducted from August to November 2020 on the IP2TP (Installation of Agricultural Technology Research and Assessment) Berastagi, Dolat Rayat District, Karo Regency, with an altitude of ± 1,340 m above sea level and the soil order is Andisol. The materials used in this study were potato seeds of the Granola variety generation-2, liquid organic fertilizer (rabbit urine, coconut water, fish waste fertilizer, bran, agricultural shrimp paste), chicken manure fertilizer, phosphate solubilizing bacteria (*Bacillus cereus, B. pseudomycoides*, and *B. amyloliquefaciens)*, SS. - Ammophos, ZA, TSP, Paten kali Butir and other materials. The research design used a factorial randomized block design with four replications. The first factor was the type of organic fertilizer (liquid organic fertilizer and chicken manure), and the second factor was phosphate solubilizing bacteria (PSB) {without PSB (control), *B. cereus, B. pseudomycoides* dan *B. amyloliquefaciens*}.

Liquid organic fertilizer was made using the modified research results of Marpaung *et al.*, (2018). The materials used for making liquid organic fertilizer were: 4.5 L of rabbit urine; 5 liters of coconut water; bran 0.5 kg; of pineapple 0.5 kg; of shrimp paste 0.25 kg; of 1 kg of brown sugar, 0.5 kg of fish fertilizer, 0.3 L of pure milk and 0.25 kg of chicken manure (derived from the small intestine of chickens). The process of making liquid organic fertilizer was all ingredients (except milk and chicken manure) cooked, then cooled to a temperature of 27^0C then added to pure cow's milk and chicken manure (derived from the small intestine of a chicken). Then the fertilizer is fermented for 1 month. Furthermore, the liquid organic fertilizer is filtered and can be applied. Phosphate solubilizing bacteria used are collections from the Berastagi Experimental Farm.

The land was processed by tractor and cleaned, then an experimental plot was made with a size of 2.2 m x 2.4 m consisting of 2 beds, with a bed size of 0.9 m x 2.2 m, and the distance between beds was 0.4 m. The distance between treatments was 1 m and the distance between replications was 2 m. Then given organic fertilizer chicken manure 20 t/ha (according to the treatment tested) and chemical fertilizer 250 kg Ha^{-1} N, 175 kg Ha^{-1} P_2O_5, and 225 kg Ha^{-1} K_2O. Chemical fertilizers were given 1 time, which is given by spreading it on the bed and then covering it with soil to a height of 30 cm, then mulch is installed. The tubers were planted in 2 rows (with a spacing of 60 cm x 40 cm), so the number of plants per experimental plot was 24 plants. The application of liquid organic fertilizer (according to the treatment tested) was conducted at planting, 2, 4, and 6 weeks after planting (WAP) with a concentration of 120 ml l^{-1} water and given as much as 200 ml/planting hole per application (Marpaung *et al.*, 2018) with watering (Milala 2018). Phosphate solubilizing bacteria was given when the plants were 2 weeks old after planting at a dose of 30 ml/plant with a density of 10^9 CFU ml^{-1} (Sembiring *et al.* 2016). Maintenance has conducted the form of weeding once every 2 weeks and watering if it does not rain. To prevent pest and disease attacks, insecticides with the active ingredients of cypermethrin 50 g/l (2 cc L^{-1} water), profenofos, chlorantraniliprole 50 g L^{-1}, imidacloprid, summit (1 cc L^{-1} water) and emamectin benzoate (0.5–1.0 cc L^{-1} water), fungicide mancozeb or difenoconazole 250 g (2 g L^{-1} water). Spraying was conducted every for 4 days or depending on the level of pest/plant disease attack in the field. Harvesting was conducted when the plant is 90 days after planting.

Parameters observed were the height and diameter of plants aged 4, 6, and 8 WAP, number of stems aged 8 WAP, tuber weight per plant, number of tubers per plant, percentage of tuber grade per plant according to SNI No: 01-3175-1992, (large = > 100 g per tuber, medium = 60 – 100 g per tuber, small = < 60 g per tuber) and yield. The mean data were analyzed by ANOVA and continued with Tukey's HSD test at a 5%.

ISSN: 1412-4718, eISSN: 2581-138x

Result and Discussion

Plant Height. The results of data analysis showed that potato plant height at the age of 4 WAP with organic fertilizer type treatment gave a significant effect, while the PSB type treatment and the interaction of the two treatments had no significant effect, while at the age of 6 WAP the two treatments and their interactions had no significant effect (Table 1). At the age of 8 WAP, the interaction of both treatments had a significant effect (Table 2).

Table 1. Effect of organic fertilizer and PSB on plant height at 4 and 6 WAP

Treatment	Plant Height (cm)	
	4 WAP	6 WAP
Organic Fertilizer Type		
Liquid Organic Fertilizer	15.83 a	35.00 a
Chicken Manure	11.96 b	33.54 a
PSB Type		
Without PSB	13.92 a	33.08 a
Bacillus cereus	13.04 a	32.00 a
Bacillus pseudomycoides	13.96 a	35.92 a
Bacillus amyloliquefaciens	14.67 a	36.08 a
CV (%)	**11.94**	**12.24**

The mean followed by the same letter in the same column and factor is not significantly different according to the Tukey's HSD test at 0.05.
WAP = Week After Planting; PSB = Phosphate Solubilizing Bacteria; CV = Coefficient of Variation

Table 2. Effect of organic fertilizer and PSB on plant height at 8 WAP

Treatment	Plant Height (cm)				M
	C	BC	BP	BA	
Liquid Organic Fertilizer	47.00 abc	40.00 c	49.00 abc	50.67 ab	**46.67**
Chicken Manure	42.83 bc	56.67 a	51.67 ab	46.00 bc	**49.29**
M	**44.92**	**48.33**	**50.33**	**48.33**	
CV (%)		**8.21**			

The same letter below the mean is not significantly different according to the Tukey's HSD test at 0.05.
C = control; BC = *Bacillus cereus* ; BP = *Bacillus pseudomycoides* BA = *Bacillus amyloliquefaciens*; WAP = Week After Planting PSB = Phosphate Solubilizing Bacteria; M = Mean; CV = Coefficient of Variation

The application of liquid organic fertilizer at the age of 4 WAP resulted in the highest plant yield, which was an increase of 24.45%, while at the age of 6 WAP it had no significant effect. It is suspected that liquid organic fertilizer is absorbed by plants more quickly for growth. This is according to research (Bahua and Gubali, 2020), the application of liquid fertilizer can increase the growth of rice plants. PSB treatment had no significant effect at 4 and 6 WAP, however *B. amyloliquefaciens* and *B. pseudomycoides* tend to higher plant height than without PSB treatment.

At the age of 8 WAP, the application of liquid organic fertilizer resulted in the highest plant height accompanied by the application of *B. amyloliquefaciens* (50.67 cm) although it was not significantly different from the application of *B. pseudomycoides* and without PSB. The application of organic chicken manure accompanied by the application of B. cereus and *B. pseudomycoides* resulted in plant height growth which was not significantly different to without PSB treatment. The interaction of the two treatments gave the highest significant effect on plant growth obtained in the interaction of chicken manure and *B. cereus* (56.67 cm). This showed that chicken manure can be absorbed by plants and its availability is longer available in the soil than liquid fertilizer. Giving PSB in general also affects plant height. This is to the role of PSB which can dissolve phosphate in the soil so that it is available and can be absorbed by plants for growth. This is supported by the results of research by Othaman *et al*., (2014), that phosphate solubilizing microbes have special qualities to secrete enzymes such as phosphatase, phytase, and C–P lypase that help in organic P mineralization. The results of research by Zhu *et al*., (2018) stated that phosphate plays a role in plant growth and development.

Plant Diameter. Data from analysis of variance showed that potato plant diameter at the age of 4 and 6 WAP was significantly affected by the type of organic fertilizer and PSB treatment, while the interaction of the two treatments had no significant effect (Table 3). At the age of 8 WAP, the interaction of the two treatments had a significant impact on plant diameter (Table 4).

Likewise, with plant diameter, the application of liquid organic fertilizer at the age of 4 WAP resulted in the highest plant diameter compared to organic chicken manure, which was 29.16 cm, but with increasing age (6 WAP) an increase in plant diameter was found in the application of chicken manure, although it has no real effect. This shows that the form of organic fertilizer affects the initial growth of plants, where liquid organic fertilizer is absorbed by plants more quickly than solid. The PSB treatment had a significant effect at the ages of 4 and 6 WAP, where the application of *B. pseudomycoides* and *B. amyloliquefaciens* resulted in higher plant diameters than those without PSB, which were 28.29 cm and 28.25 cm, and 57.38 cm and 55.54 cm. The results of research by Marpaung *et al.* (2021) also resulted that the highest potato plant diameter was found in the application of phosphate-solubilizing bacteria *B. pseudomycoides*. However, it was not significantly different from other treatments.

Table 3. Effect of type of organic fertilizer and PSB on diameter of plants aged 4 and 6 WAP

Treatment	Plant Diameter (cm)	
	4 WAP	6 WAP
Organic Fertilizer Type		
Liquid Organic Fertilizer	29.16 a	53.92 a
Chicken Manure	24.24 b	55.94 a
PSB Type		
Without PSB	25.90 b	52.00 b
Bacillus cereus	24.35 b	54.79 ab
Bacillus pseudomycoides	28.29 a	57.38 a
Bacillus amyloliquefaciens	28.25 a	55.54 ab
CV (%)	**11.07**	**5.60**

The mean followed by the same letter in the same column and factor is not significantly different according to the Tukey's HSD test at 0.05
WAP = Week After Planting; PSB = Phosphate Solubilizing Bacteria; CV = Coefficient of Variation

Table 4. Effect of organic fertilizer and PSB on plant diameter at 8 WAP

Treatment	Plant Diameter (cm)				M
	C	BC	BP	BA	
Liquid Organic Fertilizer	62.33 abc	54.92 c	66.25 ab	62.58 abc	**61.5 b**
Chicken Manure	60.08 abc	69.58 a	68.50 a	62.67 abc	**65.2 a**
M	**61.21 b**	**62.25 b**	**67.38 a**	**62.63 ab**	
CV (%)	**5.58**				

The same letter below the mean is not significantly different according to the Tukey's HSD test at 0.05.
C = control; BC = *Bacillus cereus* ; BP = *Bacillus pseudomycoides* BA = *Bacillus amyloliquefaciens*; WAP = Week After Planting PSB = Phosphate Solubilizing Bacteria; M = Mean; CV = Coefficient of Variation

The liquid organic fertilizer treatment resulted in the highest plant diameter accompanied by the application of *B. pseudomycoides* (66.25 cm) and was not significantly different from the application of *B. amyloliquefaciens* and without PSB. The application of organic chicken manure accompanied by *B. cereus* and *B. pseudomycoides* resulted in plant height growth which was significantly higher than the treatment without PSB (69.58 cm and 68.50 cm). The interaction of chicken manure and *B. cereus* gave the highest significant effect on plant diameter (69.58 cm). This shows that the nutrient content in organic fertilizers plays a role in plant growth, although the amount is small. This is following the results of research (Amara and Mourad, 2013; El-Sayed *et al.*, 2015) which states that the application of organic fertilizer can increase potato growth.

Number of Stems per Plant. The results of data analysis showed that the type of organic fertilizer treatment had a significant effect on the number of potato stems. In contrast, the type of PSB treatment and the interaction of the two treatments had no significant effect (Table 5).

Table 5. Effect of type of organic fertilizer and PSB on the number of stems per plant at 8 WAP

Treatment	Stems Number (Stems)
Organic Fertilizer Type	
Liquid Organic Fertilizer	2.46 b
Chicken Manure	3.21 a
PSB Type	
Without PSB	2.92 a
Bacillus cereus	2.92 a
Bacillus pseudomycoides	3.00 a
Bacillus amyloliquefaciens	2.50 a
CV (%)	**23.97**

The mean followed by the same letter in the same column and factor is not significantly different according to the Tukey's HSD test at 0.05
WAP = Week After Planting; PSB = Phosphate Solubilizing Bacteria; CV = Coefficient of Variation

The highest number of stems was obtained by giving chicken manure (3.21 stems). This shows that chicken manure can provide nutrients for a long time (8 WAP) compared to liquid organic fertilizers needed by plants for vegetative growth, namely forming stems. Supported by the research results of Anastasia *et al.*, (2014), which stated that the growth of vegetable crops with solid organic fertilizer was significantly higher than with liquid organic fertilizer.

Tubers Weight and Number per Plant. The data from the analysis of variance showed that the interaction of treatment types of organic fertilizer and PSB had a significant effect on the weight and number of tubers per plant (Table 6 - 7). The application of organic fertilizer and phosphate solubilizing bacteria generally resulted in higher tuber weight than the treatment without phosphate solubilizing bacteria.

Table 6. Effect of type of organic fertilizer and PSB on tuber weight per plant

Treatment	Tuber Weight per Plant (kg)				M
	C	BC	BP	BA	
Liquid Organic Fertilizer	0.86 abc	0.83 bc	1.14 a	1.12 a	**0.98**
Chicken Manure	0.57 c	1.04 ab	1.29 a	0.66 bc	**0.89**
M	**0.71 b**	**0.93 b**	**1.21 a**	**0.89 b**	
CV (%)	**19.73**				

The same letter below the mean is not significantly different according to the Tukey's HSD test at 0.05.
C = control; BC = *Bacillus cereus* ; BP = *Bacillus pseudomycoides* BA = *Bacillus amyloliquefaciens*; WAP = Week After Planting PSB = Phosphate Solubilizing Bacteria; M = Mean; CV = Coefficient of Variation

The highest tuber weight per plant was obtained in the treatment of chicken and *B. pseudomycoides* organic fertilizer, which was 1.29 kg (Table 6), although it was not significantly different from the application of liquid organic fertilizer and *B. pseudomycoides* and *B. amyloliquefaciens*. This indicates that solid and liquid organic fertilizers and phosphate solubilizing bacteria play a role in the formation of potato tubers. Organic fertilizers have a role in improving the physical properties of the soil, one of which is to help improve the porosity of the soil for the better so that the soil with good porosity will help the development of roots which will later become a place for tuber formation. This is supported by the results of research by Anastasia *et al.*, (2014) which stated that the application of organic fertilizers, especially solids, resulted in higher soil porosity than without organic fertilizers.

The provision of phosphate solubilizing bacteria plays a role in potato crop yields due to the function of PSB which can provide available P nutrients to plants so that they can be absorbed and utilized for tuber enlargement. According to the research results of Ulfyati and Zulaika, (2015) the genus *Bacillus* can dissolve phosphate qualitatively.

The application of liquid organic fertilizer with PSB resulted in a higher number of tubers than without PSB, where the highest number of tubers was obtained with giving *B. amyloliquefaciens* (11.28 tubers). In contrast to the application of organic chicken manure, the highest amount was obtained without PSB (9.83 tubers). The occurrence of the highest treatment differences in tuber weight and the number of tubers indicated that there were differences in tuber size per plant. Where if the weight of the tubers produced is high while the number of tubers is low, it is suspected that the size of the tubers is dominated by large sizes. This is in accordance with the treatment of manure and B. amyloliquefaciens.

Table 7. Effect of type of organic fertilizer and PSB on the number of tubers per plant

Treatment	Tuber Number (Tuber)				M
	C	BC	BP	BA	
Liquid Organic Fertilizer	8.17 ab	9.17 ab	10.17 ab	11.28 a	**9.69 a**
Chicken Manure	9.83 ab	9.00 ab	7.33 ab	5.83 b	**8.00 b**
M	**9.00**	**9.08**	**8.75**	**8.56**	
CV (%)	**22.89**				

The same letter below the mean is not significantly different according to the Tukey's HSD test at 0.05.
C = control; BC = *Bacillus cereus* ; BP = *Bacillus pseudomycoides* BA = *Bacillus amyloliquefaciens*; WAP = Week After Planting PSB = Phosphate Solubilizing Bacteria; M = Mean; CV = Coefficient of Variation

Tuber Grade Percentage. The results of the analysis of variance showed that the interaction of organic fertilizer and PSB treatments had a significant effect on the percentage of large and small tuber grades. In contrast, for medium tuber grade, the two treatments had no significant effect (Table 8 -10).

Table 8. The effect of the type of organic fertilizer and PSB on the percentage of big tuber grade

Treatment	Big Tuber Grade (%)				M
	C	BC	BP	BA	
Liquid Organic Fertilizer	44.40 ab	47.97 ab	50.44 a	50.18 a	**48.25**
Chicken Manure	19.60 b	45.90 ab	65.88 A	46.87 ab	**44.56**
M	**9.00**	**9.08**	**8.75**	**8.56**	
CV (%)	**27.09**				

The same letter below the mean is not significantly different according to the Tukey's HSD test at 0.05.
C = control; BC = *Bacillus cereus* ; BP = *Bacillus pseudomycoides* BA = *Bacillus amyloliquefaciens*; WAP = Week After Planting PSB = Phosphate Solubilizing Bacteria; M = Mean; CV = Coefficient of Variation

The highest percentage of large tubers per plant was found with the application of organic chicken manure and PSB *B. pseudomycoides*, which was 65.88%. This indicated that the application of chicken manure and *B. pseudomycoides* was able to provide the nutrients needed by plants for tuber enlargement, increasing by 32.60% - 70.23% from the treatment without PSB. This also showed that although the number of tubers in the treatment was small, the tuber weight per plant was high because the grade of tuber was high. The application of organic fertilizers also affects the porosity of the soil, where if the soil porosity is good it will affect the formation and enlargement of tubers. This is following the research results of Anastasia *et al*., (2014), which stated that organic fertilizer application was able to increase soil porosity compared to no organic fertilizer application. In general, each treatment produced a medium tuber grade that did not differ from one another.

Table 9. Effect of organic fertilizer and PSB on the percentage of medium tuber grade

Treatment	Medium Grade (%)
Organic Fertilizer Type	
Liquid Organic Fertilizer	19.96 a
Chicken Manure	19.53 a
PSB Type	
Without PSB	24.86 a
Bacillus cereus	17.73 a
Bacillus pseudomycoides	16.98 a
Bacillus amyloliquefaciens	19.42 a
CV (%)	**39.81**

The mean followed by the same letter in the same column and factor is not significantly different according to the the Tukey's HSD test at 0.05.

Table 10. Effect of organic fertilizer and PSB on the percentage of small tuber grade

Treatment	Small Tuber Grade (%)				M
	C	BC	BP	BA	
Liquid Organic Fertilizer	28.41 b	34.37 ab	33.69 ab	30.70 b	**31.79**
Chicken Manure	57.88 a	36.31 ab	16.02 b	33.42 ab	**35.90**
M	**43.14 a**	**35.34 ab**	**24.86 b**	**32.06 ab**	
CV (%)	**31.77**				

The same letter below the mean is not significantly different according to the Tukey's HSD test at 0.05.
C = control; BC = *Bacillus cereus* ; BP = *Bacillus pseudomycoides*
BA = *Bacillus amyloliquefaciens*; WAP = Week After Planting
PSB = Phosphate Solubilizing Bacteria; M = Mean; CV = Coefficient of Variation

The highest percentage of small tubers was produced in the treatment of giving chicken manure without PSB, with the percentage 57.88%, while the lowest was obtained in the treatment of giving chicken manure and PSB *B. pseudomycoides*, which was 16.02%. This shows that the interaction treatment was able to reduce small tubers by 43.61% - 72.32% compared to the treatment without PSB. This is showed that the role of organic fertilizers can increase soil organic matter and nutrient availability, and also increase soil biological activity (Jiangzhou *et al.* 2019) so that the soil becomes better as a medium for growing plants which will later affect the yield.

Yield. The data from the analysis of variance showed that the interaction of treatment types of organic fertilizer and PSB had a significant effect on yield (Table 11). The application of chicken manure and PSB *B. pseudomycoides* significantly resulted in the highest yield compared to other treatments, which was 31.00 kg.

Table 11. Effect of type of organic fertilizer and PSB on potato yield

Treatment	Yield (ton ha^{-1})				M
	C	BC	BP	BA	
Liquid Organic Fertilizer	21.38 bcd	20.79 bcd	23.29 abcd	27.92 ab	**23.34**
Chicken Manure	14.13 d	25.88 abc	32.29 a	16.54 cd	**22.21**
M	**17.75 c**	**23.33 ab**	**27.79 a**	**22.23 bc**	
CV (%)	**17.56**				

The same letter below the mean is not significantly different according to the Tukey's HSD test at 0.05.
C = control
BC = *Bacillus cereus*
BP = *Bacillus pseudomycoides*
BA = *Bacillus amyloliquefaciens*
WAP = Week After Planting
PSB = Phosphate Solubilizing Bacteria
M = Mean
CV = Coefficient of Variation

The interaction of both factors can increase yield in the range of 33.81% - 56.26% of the treatment without PSB. It is suspected that the interaction of the two treatments was suitable for the growth of PSB and provided the nutrients needed by plants, especially available P nutrients which were very low in Andisol so the formation of potato tubers, as a result, could be maximized. According to (Amara and Mourad, 2013; El-Sayed *et al*., 2015) the application of organic fertilizer can increase potato production. In addition to the nutrient content in organic fertilizers, the porosity of the soil will also be good (Anastasia *et al*., 2014), therefore the process of formation and enlargement of tubers will be good.

Conclusion

The treatment of organic chicken manure (solid fertilizer) was able to increase the growth and production of potato plants. Phosphate solubilizing bacteria *B. pseudomycoides* was able to increase potato production. The interaction of organic chicken manure and phosphate solubilizing bacteria *B. pseudomycoides* was able to increase potato yield by 33.79% - 56.24% and large tuber grade by 32.60% - 70.23% and reduce small tuber grade by 43.61% - 72.32% from treatment without PSB. Phosphate solubilizing bacteria *B. pseudomycoides* and chicken manure fertilization have the potential to be applied to Andisol to increase potato production.

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