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Urea Berlapis Bakteri Untuk Mengurangi Dosis Pupuk Urea Pada Budidaya Kentang

Bacterial-Coated Urea To Reduce The Use Of Urea Fertilizer In Potato Cultivation

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ABSTRACT

Urea fertilizers and biofertilizers play an important role in potato (Solanum tuberosum L.) cultivation, but urea fertilizers are volatile and leach out easily that reduce their effectiveness. Urea coated with beneficial bacteria-enriched organic matter is expected to increase nitrogen used efficiency. The purpose of the experiment was to determine the ability of bacterial-coated urea (BCU) included Bacillus and Azotobacter to improve the growth, nutrient status and yields of potatoes grown in field; as well as to reduce urea dose. The experiment was setup in randomized block design with five treatments and six replications. The treatments were four combinations of the dose and formulation of BCU; and conventional urea fertilizer as control treatment. Application of both BCU formulation increased plant height as well as N and P uptake particularly when the recommended dose was used. In contrast, the doses and formulation of BCU did not affect chlorophyll content. Application of BCU-A or BCU-B at the rate of 200 kg/ha increased tuber weight by 59% and 81% respectively. Both high and low dose of BCU did not reduce the vegetative growth and yield compared to the plants fertilized with conventional urea. This experiment showed that BCU is considered to reduce the rate of Urea in potatoes cultivation.

Keywords: *Azotobacter sp.; Bacillus sp.; crop yield; vegetative growth.*

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INTRODUCTION

Potato (Solanum tuberosum L.) is a horticultural commodity which is currently consumed elsewhere as a carbohydrate in human diet other than rice, wheat and corn. The nutritional content of potatoes in 100 grams tuber is 2 g protein, 0.1 g fat, 19.1 g carbohydrate, 11 mg calcium, 50 mg phosphorus, 0.7 mg iron, 0.3 g fiber, 0.09 mg vitamin B1, 16 mg vitamin C and 83 calories (Wulandari et al., 2014). Potato productivity in Indonesia in 2019 was 19.27 tons/ha and showed an increase compared to 2018 of 18.71 tons/ha (BPS, 2019). However, potato productivity in Indonesia is still relatively low and unstable compared to that of certain countries.

Methods of increasing potato productivity in Indonesia include nitrogen (N) fertilization in rational dose because Indonesian soils generally contain low total-N, 0.2% (Yanai et al., 2014). Nitrogen is needed in every phase of plant growth, especially the vegetative phase so that Urea is the most widely used fertilizer during the cultivation of food crops. Urea is reported has a role to promote plant growth promoter in the vegetative phase, it is also a prominent nutrient in the formation of potatoes tuber during the generative phase (reference). In the tropics, N ions (NH4 and NO3) from urea are easily lost due to washing and evaporation (Tando et al., 2018). The efficiency of using urea fertilizer is low, even 50% depend on climate and soil (Afshar et al., 2018; Panday et al., 2020).

In sustainable agriculture that supports a green economy, part of N fertilizer dose can be replaced by N2-fixing biofertilizers. Reduction of N fertilizer level by N2-fixing bacteria has been shown in vegetable and food crops (Hindersah et al., 2020; Schütz et al., 2018). However, farmers are not adapted to biofertilizers due to limited information and availability of these fertilizers in the market. This problem can be solved, among others, by coating inorganic fertilizers with biofertilizers. The study of microbial-coated inorganic fertilizer technology is limited. The benefits of organic and inorganic materials in Urea coating technology have shown to reduce loss of available N from the root zone and increase the efficiency of urea fertilizer (Zulaehah & Sukarjo, 2017; Zvomuya et al., 2003). In relation to the intensification of biofertilizer used for growing food crops, the use of microbial-coated Urea might also increase the application of biofertilizers in the field.

Resistance to drought stress is one of the prerequisites for microbial biofertilizers in tropics since arable lands in tropics usually are not irrigated. Phosphate (P) solubilizing and N-fixers Azotobacter are two important beneficial bacteria that commonly colonize the plant rhizosphere. Both genus of bacteria are also well known to produce phytohormones (Fahad et al., 2015; Kukreja et al., 2004). Under drought stress, Bacillus and Azotobacter form spores and cysts, respectively(Inamdar et al., 2000; Toyota, 2015). The bacterial used in coating the urea must be drought resistant because the water content of urea is only 0.5%.

Soil Biology Laboratory of Universitas Padjadjaran has developed two formulas of bacteria-coated urea (BCU); the bacterial consortia were formulated in liquid inoculant before coating process. The biofertilizer comprised of Bacillus subtilis, B. megaterium, Azotobacter chroococcum and A. vinelandii. The preliminary study verified that molasses-based media supported bacterial growth; and initial balance ratio of bacteria (1:1:1:1) in liquid inoculant was better to increase bacterial growth (Hindersah et al., 2020). Balance composition of all bacterial species in organic-based solid inoculant induce the population increment after coating process (Hindersah et al., 2021). Moreover, application of urea coated with Bacillus-Azotobacter consortia in strawberry seedlings increased root dry weight, root volume, SPAD value, and N uptake (Hindersah et al., 2021).

Based on previous research described above, two BCU formulas were obtained which were differentiated based on zeolite content and bacterial cell density (Hindersah et al., 2021). The purpose of the experiment was to observe the ability of BCU to induce the growth of potato plants, their N and P status, and tuber yields of potatoes grown in field. The objective of the experiment was also to verify the possibility of BCU to reduce the dose of urea in potato production.

RESEARCH METHOD

The experiment was carried out in Cimenyan Village, Cimenyan District, Bandung Regency, West Java at an altitude of 920 m above sea level. Chemical and microbiological analyses were carried out at the Laboratory of Soil Biology and the Laboratory of Soil Fertility and Plant Nutrition, Department of Soil Science and Land Resources, Universitas Padjadjaran. The soil was fertile Silty Loam Inceptisols, with pH 5.84, organic-C 2.9%, total-N 0,2, C/N 14.5, potential P2O5 72.89 mg/100 g, potential K2O 32.62 mg/100 g, Cation Exchange capacity C 37.41, and base saturation 27.62%. Bacterial-coated urea has been developed by Soil Biology Laboratory by using solid inoculant consortium of bacteria composed of *B. subtilis, B. megaterium, A. chroococcum* and *A. vinelandii*.

Experimental Establishment. The field experiment design was a randomized block design with 5 treatments and 5 replications. The experimental treatments were a combination of two doses and two formulations of BCU; the control treatment was conventional Urea. The BCU application dose is one and half dose of the recommended dose of Urea for growing the potato plants, which is 200 kg/ha. Therefore, the treatments tested in the experiment were A: Uncoated Urea, B: 200 kg/ha of BCU-A; C: 200 kg/ha of BCU-B, D: 100 kg/ha BCU-A, and E: 100 kg/ha of BCU-B.

Tillage was conducted by hoeing the soil as deep as 30 cm until it became loose; the experimental area then is left for 15 days prior to create plots of 550 cm long to 70 cm wide; with 50-cm distance between plots. A total of 20 t/ha of cow manure were mixed thoroughly with soil in plots, then incubated for 3 days. A single F1 potato tuber var. Granola with the diameter of 2 cm was placed in a 5 cm-deep planting hole with a distance of 40 cm between the holes in a bed. Seedlings are planted at a distance of 15 cm from the side of the plot. After planting the beds were mounding up to 15 cm.

The SP-36 and KCl fertilizers were applied to all plants, while Urea and BCU was given based on the treatment. Based on the recommended doses, the SP-36 and KCL fertilizers were amended as much as 10 g/plant and 5 g/plant respectively. Control plants received 10 g/plant of Urea while treated plants received 10 g or 5 g of BCU. All fertilizer were applied at 14 and 35 days after planting in holes around the plant stem. The dose of any urea was halved in each application. Mounding the beds and weeding were done twice at the same time as fertilization. During the experiment, pests or disease attacks were not significant; therefore, pesticides were not used.

Parameters and Statistical Analysis. Experimental parameters measured in the vegetative phase consisted of: 1. Plant height once a week until week four; 2. chlorophyll content using spectrophotometry at day 50; 3. The N and P uptake plant shoot at 50 days after planting and 4. Population of *Bacillus* sp. and *Azotobacter* sp. in the potato rhizosphere at day 50. Yield parameters observed at harvest (115 days after planting) were the weight and number of potato tuber per plot, and the degree Brix to determine tuber sweetness by using a refractometer after storing the tuber for 2 and 4 weeks. All data were subjected to Analysis of Variance (ANOVA) at $p < 0.05$). If there was a significant effect of treatment on the parameters, the data were analyzed by Duncan's multiple range test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Application of BCU affected the plant height on 3rd and 4th week after planting. However, the urea fertilizer treatment but had not a significant effect on chlorophyll index. In general BCU increased plant height at week three but half dose of BCU-B did not enhanced the plant height at week three and four compared to the plants treated by conventional urea (Table 1). Plants treated with BCU-A at the rate of 200 kg/ha enhanced the plant height by 11.1 % higher than control at 4th week after planting. Application of 200 kg/ha of BCU-B resulted in 25% higher chlorophyll a and 17.1% higher chlorophyll b index but the increment did not significant compared to the control and other treatments (Table 1).

Table 1. Effect of various dose and formulation of bacterial-coated urea on plant height of three- and four-days old potatoes plants

Coated Urea Fertilizer	Plant height (cm) at		Chlorophyll content	
	3^{rd} week	4^{th} week	Chlorophyll a	Chlorophyll b
A: Urea 200 kg/ha	30.8 a	45.0 a	20.1 a	4.4 a
B: BCU-A[1] 200 kg/ha	41.3 b	50.3 b	23.6 a	5.1 a
C: BCU-B[2] 200 kg/ha	38.0 b	47.8 ab	25.1 a	5.1 a
D: BCU-A 100 kg/ha	39.3 b	49.7 ab	20.5 a	2.4 a
E: BCU-B 100 kg/ha	35.0 a	46.5 a	21.5 a	2.8 a

Values followed by the same letters are not significantly different based on Duncan Multiple Range Test at $p \leq 0.05$. 1Formula A of bacterial-coated Urea; 2Formula B of bacterial-coated Urea.

The treatment has a significant effect in N as well as P uptake based on ANOVA. Potatoes plant treated with BCU-A at 200 kg/ha consistently have higher N and P uptake (Table 2). A dose and half dose of BCU-A resulted in 27% higher N uptake and 148% higher P uptake. Another BCU treatment produced plant shoot with similar N and P uptake with the control plants.

Table 2. Effect of various dose and formulation of bacterial-coated urea on phosphorus dan Nitrogen uptake of 35-day old potatoes plants

Coated Urea Fertilizer	N uptake (mg/plant)	P uptake (mg/plant)
A: Urea 200 kg/ha, control	0.189 a	0.039 a
B: BCU-A[1] 200 kg/ha	0.241 b	0.097 b
C: BCU-B[2] 200 kg/ha	0.186 a	0.041 a
D: BCU-A 100 kg/ha	0.204 a	0.051 a
E: BCU-B 100 kg/ha	0.174 a	0.052 a

Values followed by the same letters are not significantly different based on Duncan Multiple Range Test at $p \leq 0.05$. [1]Formula A of bacterial-coated Urea; [2]Formula B of bacterial-coated Urea

Analysis of variance verified that BCU application in any dose and formulation have a significant effect on the population of Bacillus dan Azotobacter in the rhizosphere of Potatoes. Both Bacillus counts was higher in the rhizosphere of potatoes plant grown with 100 kg/ha of BCU-A and BCU-B than the control (Table 3). Nonetheless, the population of Azotobacter in the rhizosphere of plant treated with 100 kg/ha BCU-A was surpass the population of other treatments. In general, we found that no even one coated urea treatment resulted in bacterial population lower than the control.

Table 3. Effect of various dose and formulation of bacterial-coated urea on the population of total Bacillus and Azotobacter in the rhizosphere of 35-day old potatoes plants.

Coated Urea Fertilizer	Bacterial population 10^7 CFU/mL)	
	Bacillus	Azotobacter
A: Urea 200 kg/ha, control	68.2 a	2.59 a
B: BCU-A[1] 200 kg/ha	85.4 a	2.43 a
C: BCU-B[2] 200 kg/ha	80.2 a	2.41 a
D: BCU-A 100 kg/ha	116.4 b	2.89 b
E: BCU-B 100 kg/ha	95.6 ab	2.33 a

Values followed by the same letters are not significantly different based on Duncan Multiple Range Test at $p \leq 0.05$. [1]Formula A of bacterial-coated Urea; [2]Formula B of bacterial-coated Urea

The potatoes yield might be increased following 200 kg/ha BCU application (Table 4). The tuber weight in plots with 200 kg/ha BCU-A as well as BCU-B. The tuber weight increment after application of 200 kg/ha BCU was approximately 59-81%; but the increment was 10-25% in plots with lower dose of BCU. In general, the tuber number of control plants was similar with that of plants treated with BCU except plants received 100 kg/ha of BCU-A.

Table 4. Effect of various dose and formulation of bacterial-coated urea on the weight and number of potatoes tuber

Coated Urea Fertilizer	Tuber weight (g/plot)	Tuber number per plot
A: Urea 200 kg/ha, control	93.8 a	22.2 b
B: BCU-A[1] 200 kg/ha	149.4 b	24.8 b
C: BCU-B[2] 200 kg/ha	169.8 b	21.4 b
D: BCU-A 100 kg/ha	104.1 c	14.4 a
E: BCU-B 100 kg/ha	117.4 ab	20.4 ab

Values followed by the same letters are not significantly different based on Duncan Multiple Range Test at $p \leq 0.05$. [1]Formula A of bacterial-coated Urea; [2]Formula B of bacterial-coated Urea

In order to determine the sweetness of tuber after two- and four-weeks storage in room temperature, the degree Brix was measured. Based on ANOVA, the application of coated urea only influenced degree Brix of tuber after four weeks (Figure 1). In general, the degree Brix was about 5.2-6.2; that range is average for potato. After four-weeks storage, the highest degree brix was shown by tuber from plants treated with 100 kg/ha of BCU-B. Degrees Brix measured by refractometer represented the dissolved solids in a liquid. It is used elsewhere to determine dissolved sugar content. One degree Brix is 1 g of sucrose in 100 gr of solution.

This current experiment verified that at some parameters, application of BCU benefice the growth and production of potatoes in field. Bacillus and Azotobacter not only fix nitrogen but their ability to mobilize inorganic P in soil is reported (Prabha, 2016; Saeid et al., 2018). This enzymatic ability combined with their capacity to produce and secrete phytohormone to soil are the natural mechanisms to induce plant growth. Moreover, In the rhizosphere (Table 4), the population of Bacillus of plant treated with any dose of BCU-A was relatively higher than plant with BCU-B. However, all plant rhizosphere has similar count of Azotobacter. This showed that Bacillus proliferate more in the rhizosphere than Azotobacter. The Bacillus is important rhizobacteria in food crops, they are cosmopolitan and form endospore to survive in harsh condition. Even though Azotobacter can adapt abiotic stress, the-heat resistance spores is likely more important.

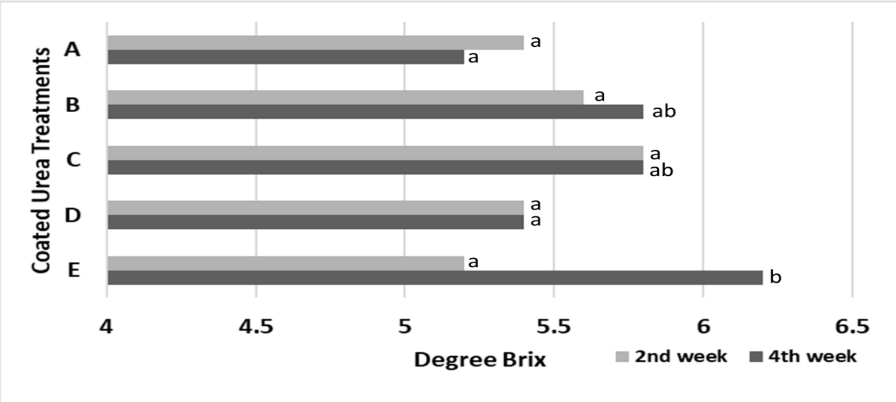

Figure 1. Effect of various dose and formulation of bacterial-coated urea on the Brix degree of potatoes tuber at two and four weeks after harvest. A: Urea 200 kg/ha, control; B: BCU-A 200 kg/ha; C: BCU-B2 200 kg/ha; D: BCU-A 100 kg/ha and E: BCU-B 100 kg/ha

The BCU formula A was likely more adapted in potatoes cultivation. This formula contained only 1% of bacterial inoculant in the beginning of coating process compared to 5% of BCU formula B. Surprisingly, in our experiment the BCU-A was more prominent to increase plant height as well as N and P uptake; even though the ability of both BCU formulation to increase tuber weight was similar. Low population density in BCU-A might cause the synergistic effect among the species. These circumstances allow the bacterial cell of each species to proliferate without significant inhibition by other species. Moreover, the nutrient and space competition between species is supposed lower.

This experiment demonstrated the ability of BCU to reduce the level of Urea fertilizer. Application of 200 kg/ha of BCU-A or BCU-B enhanced tuber weight by 59% and 81% respectively and consistency low dose of both BCU caused lower increment of tuber weight. None BCU treatment decreased vegetative growth and yield compared to the control plants with conventional urea fertilizer. The results showed that lower dose of BCU (equal to 50% of Urea recommended dose) is considered to be applied for potato plants. The experiment demonstrated that BCU can reduce the dose of Urea in potatoes cultivation. Our results agree with the previous application of BCU in strawberry seedlings (Hindersah *et al.*, 2021). Nowadays, bacterial -coated fertilizer development and used is still limited but the impact of this new fertilizer technology is promising technology. Nonetheless, the results agree with the urea coating with *Bacillus* sp strain KAP6 and compost that improved grain yield of wheat up to 20% (Ahmad *et al.*, 2017). A study with micronutrient fertilizer revealed that ZnO coated with *Bacillus* sp. AZ6 improve the yield of wheat (Ain *et al.,* 2020). All studies related to the application of bacterial-coated fertilizer is suggested for enhancing the productivity effectively.

CONCLUSION

The results showed that application of any formulation of BCU increased plant height as well as N and P uptake particularly when the dose of BCU was similar with that of recommendation dose of Urea. However, the doses and formulation of BCU did not affect chlorophyll content in leaves. The results verified the ability of BCU to minimize Urea fertilizer dose. Application of 200 kg/ha of BCU-A or BCU-B enhanced tuber weight by 59% and 81% respectively. We observe that all high and low dose of BCU did not decrease the vegetative growth and yield compared to the control pants that received conventional urea fertilizer. The field experiments confirmed that BCU has the ability to decrease the dose of Urea in potatoes cultivation.

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