Production of stringbean (*Phaseolus vulgaris* L.) using phosphate solubizing bacteria and natural phosphate fertilizer on acid soil

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Abstract. Acid soil can be used for land extensification, but need input technology in order its for maximum crop growth support. The aim of the research was to know the effect of Phosphate Solubilizing Bacteria and Natural Phosphate Fertilizer on the production of Stringbean (*Phaseolus vulgaris* L.). A field trial at Universitas Padjadjaran research station 768 m above sea level had been carried out using randomized block design two factors with factorial pattern and three replications. The first factor was concentration of Phosphate Solubilizing Bacteria (0 ml, 10 ml, 20 ml, 30 ml), while the second factor was the type of natural phosphate fertilizer (120 g of guano polybag⁻¹, 120 g of rock phosphate polybag⁻¹ and 120 g of swimmer crab flour polybag⁻¹). The results showed there was no interaction effect of Phosphate Solubilizing Bacteria and Natural Phosphate Fertilizer on harvest index. The type of natural phosphate fertilizer has an independent effect on leaf area and pod dry weight but the value is still below its potential production.

1. Introduction

Stringbean (*Phaseolus vulgaris* L.) cultivation on acid soil produces low production. On the acid soil P is converted into insoluble complexes due to precipitation reactions with Al³⁺ and Fe³⁺ in acidic soil cause low available phosphorus [1,2].

Indonesia has a range of potential natural phosphate fertilizer that can be used as a source of P with high P content, but low availability. Rock phosphate has high phosphate content but slow release [3]. Bat guano also has high phosphorus and can enhance plant growth with organic matter by 23.0%-79.0% [4,5]. Swimmer crab flour has high calcium content and potential to increase pH thus phosphate can be released [6].

Phosphate Solubilizing Bacteria (PSB) is considered among the most effective plant assistant to supply phosphorus at a favorable level [7]. PSB play a vital role in P solubilization by producing organic acids [8]. Organic acids were found to be responsible for rock phosphate solubilization [9]. PSB is important in increasing the P efficiency of both native and applied P and improving the growth and yield various crops [2].

Phosphorus native sources and bacterial inoculation are considered beneficial for improving the P supply [10,11]. In this study, source of P not only from natural phosphate, but using waste product namely swimmer crab flour.
The aim of the research was to know the effect of Phosphate Solubilizing Bacteria and Natural Phosphate Fertilizers on improving the production of Stringbean (*Phaseolus vulgaris.*L) on acid soil.

2. Methods
A field trial at Unpad research station 768 m above sea level had been carried out using randomized block design two factors with factorial pattern and three replications. The first factor was concentration of Phosphate Solubilizing Bacteria concentration (0 ml, 10 ml, 20 ml, 30 ml) while the second factor was the type of natural phosphate fertilizer (120 g of guano polybag⁵, 120 g of rock phosphate polybag¹, and 120 g of swimmer crab flour polybag¹). Parameters evaluated were leaf area, harvest index and pod dry weight measured at the time of harvest. To analyze the data, F test at 5 % level was used and continued with Duncan’s Multi Range Test at 5 % level.

Acid soil inserted in 30x30 cm polybags and applied with manure 120 g polybag⁻¹, rock phosphate 120 g polybag⁻¹, guano polybag¹, and crab swimmer flour 120 g polybag⁻¹ and incubated within 1 week, then treated by PSB (Pseudomonas cepaceae) inoculum appropriate with the treatment 10 ml crop¹, 20 ml crop¹ and 30 ml crop¹ at 3 days before planting. Two weeks old seedling with 3-4 fresh green leaves was planted 3-5 cm deep in polybag and covered by soil. Maintenance included replacing abnormal plant at maximum 7 days after planting (DAP), watering in the morning and in the afternoon when there was no rain. Continued fertilization was given at 14 DAP using urea 1,66 g polybag⁻¹, SP36 0,86 g polybag⁻¹, KCl 1,04 g polybag⁻¹ in a manner to be immersed as deep as 5 cm. Pest and disease control was done by mechanical method and pesticide as last alternative and harvesting at 45 DAP.

3. Result and discussion
3.1. Leaf width
Application of PSB and natural phosphate ferilizer showed no interaction effect on leaf width. PSB and natural phosphate fertilizer each increased leaf width significantly. Application 30 ml of PSB reached the highest width leaf and all of the natural phosphate fertilizers which were used in this experiment increased leaf width significantly (table 1).

| Treatments | Leaf Width (cm²) |
|------------|-----------------|
| PSB concentration | Total |
| b₀ | 224.96 a |
| b₁ | 273.05 ab |
| b₂ | 276.96 ab |
| b₃ | 321.20 b |
| natural phosphate fertilizers | |
| p₀ | 198.01 a |
| p₁ | 306.58 b |
| p₂ | 306.58 b |
| p₃ | 309.02 b |

Remarks: Numbers followed by same letter are not significantly different based on Duncan’s Multiple Range Test at 5% level.

Phosphate solubilizing bacteria and natural phosphate fertilizer increased leaf width. The PSB released phosphatase enzyme that accelerates the P availability process. The treatment of plants with PSB...
increased soil available P and P uptake in leaves of *Aloe barbadensis*, and consequently elevated all parameters of *A. barbadensis*, including leaf length and total number of leaves [11].

Natural phosphate fertilizers provide P which was needed by plant in the storage and transfer of energy in the plant. Phosphorus is an essential part in the process of photosynthesis and carbohydrate metabolism, the formation of cell nuclei, cell division and cell duplication. Finally it would affect organ vegetative development including leaves.

3.2. Harvest Index
There was no interaction effect or simple effect of Phosphate solubilizing bacteria and natural phosphate fertilizer on harvest index. The treatments did not improve harvest index value (table 2).

| Treatments                      | Harvest index |
|--------------------------------|---------------|
|                                | Total         |
| PSB concentration              |               |
| b₀                             | 0.34 a        |
| b₁                             | 0.34 a        |
| b₂                             | 0.33 a        |
| b₃                             | 0.31 a        |
| natural phosphate fertilizers  |               |
| p₀                             | 0.34 a        |
| p₁                             | 0.33 a        |
| p₂                             | 0.34 a        |
| p₃                             | 0.33 a        |

Remarks: Numbers followed by same letter are not significantly different based on Duncan’s Multiple Range Test at 5% level.

Phosphate solubilizing bacteria and natural phosphate fertilizer increased leaf width (table 1) and pod dry weight (table 3) but not yet for harvest index. Apparently the PSB provided insufficient P for harvest index due to soil C organic content was very low. With very low soil C organic content the number of PSB is not high enough therefore did not work maximum in phosphate solubilization process. Bat guano and rock phosphate contain high phosphate, but in the insoluble form which was needed microbe help to solubilize insoluble inorganic phosphate from native P source. Whereas swimmer crab flour increased pH below 5 so the P release being limited. Limitations of P supply cause photosynthate partition to the harvesting organ being reduced. The adequate supply of P could have increased the number of branches per plant, and leaf area which in turn increased photosynthetic area resulting in higher dry matter accumulation [12].

3.3. Pod dry weight
Application of PSB and natural phosphate fertilizer gave no interaction effect on pod dry weight. PSB and natural phosphate fertilizers each increased pod dry weight. Increasing of pod dry weight significantly. Increasing of pod dry weight by PSB was started from concentration 10 ml and all of the natural phosphate fertilizers increased pod dry weight (Table 3).

PSB inoculation increased pod dry weight. PSB increase pod dry weight through increasing P uptake. *Pseudomonas cepaceae* as PSB used in this study is capable of increasing the nutrient elements P by utilizing the total soil P (24.77%) where P element is required in the pods formation. PSB treatment had the maximum stimulatory effect on shoot dry weight [13]. That P content in the soil promoted root growth, resulting in root expansion into more soil space for assimilating nutrient uptake [14]. A developed root system is beneficial to the development of aboveground parts. The increase in
above ground dry biomass yield might be attributed to the enhanced availability of P for vegetative
growth of the plants (Table 1) [12].

Application of natural phosphate fertilizers increased also pod dry weight. This means that P element
contained in guano, rock phosphate, and smimmer crab flour were adequate to support crop yield. Seen
the influence of P on pod dry weight, although showed improvement, but the value is still below the
potential crop yield.

**Table 3.** The Effect of Phosphate Solubilizing Bacteria BPF concentration and natural
phosphate fertilizer on pod dry weight.

| Treatments          | Pod dry weight Total |
|---------------------|----------------------|
| PSB Concentration   |                      |
| b₀                  | 3.65 a               |
| b₁                  | 4.99 b               |
| b₂                  | 5.28 b               |
| b₃                  | 5.33 b               |
| natural phosphate fertilizer |            |
| p₀                  | 3.32 a               |
| p₁                  | 4.92 b               |
| p₂                  | 5.25 b               |
| p₃                  | 5.77 b               |

Remarks: Numbers followed by same letter are not significantly different based on Duncan’s Multiple
Range Test at 5% level.

4. Conclusion
Application of Phosphate solubilizing bacteria and natural phosphate fertilizer independently increased
leaf width and crop yield, but the value is still below its potential production.

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