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# Effect of Bio-phosphate on Increasing the Phosphorus Availability, the Growth and the Yield of Lowland Rice in Ultisol

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## ABSTRACT

**Effects of Bio-phosphate on Increasing the Phosphorus Availability, the Growth and the Yield of Lowland Rice in Ultisol (Yafizham and M Abubakar):** Ultisol soil is low of macro and micro nutrient, pH and base saturation as well as high toxicity of Al and Fe. To increase productivity of ultisols soils, especially availability of P nutrients, the use of bio-phosphate can increase P solubilizing in the soils. The research was conducted in the green house of Agriculture Faculty, the University of Lampung from January to March 2005. A factorial experiment using two factors in a randomized completely block design with five replications was conducted. The first factor was dosages of bio-phosphate (0; 10; 20 g $L^{-1}$), the second factor was lowland rice cultivar (Ciherang, Sintanur, Cilosari and IR64). The results showed that the availability of N, K and P nutrients in the soil before planting was low. Application of bio-phosphate increased availability of N, K and P in the soil. Application of 10 g $L^{-1}$ and 20 g $L^{-1}$ of bio-phosphate increased root length of lowland rice, there were 13.3% and 36.8%, respectively. Application of 20 g $L^{-1}$ of bio-phosphate increased 100 grain weight of lowland rice which were higher 11.4% compared to without any bio-phosphate.

***Keywords***: Bio-phosphate, lowland rice, P availability, ultisol soil

## INTRODUCTION

Most of soils in Indonesia are generally dominated by soils that have further weathering such as Ultisol (Noor 2008). The distribution of Ultisol in Indonesia is extensive namely 29.9% of the whole arid area (Suwardjo and Sinukaban 1996). This kind of soil spreads out in Sumatera, Kalimantan, Sulawesi, and Irian Jaya. Naturally, the fertility level of Ultisol is low, yet if it is properly managed it will give a great potential for increasing the agricultural production (Soepardi 1983).

There are some constrains of Ultisol, which are (1) high acidity (pH<5), (2) scarcity of Mg and Ca, (3) scarcity and the ease of washable K, and (4) high P-fixation resulting in unavailability of P for the plants (Noor 2008). Among these constraints, the scarcity of P is the most important constrain in acid soils (Widjaja-Adhi 1992). Aisyah (1992) explained that the low level of P concentration and the high P-fixation in Ultisol are resulting in P-deficiency of crops, limits their growth and decreases their yield.

One of alternatives to overcome the low level of available P in Ultisol is by changing the soil biotic environment through exploiting phosphate solubilizing microbes. According to Goenadi and Saraswati (1993), some of the soil microbes have the potential in dissolving soil nutrients, including phosphate. Alexander (1977) stated that phosphate solubilizing microbes are among others of genus *Pseudomonas*, *Micrococus*, *Bacillus*, *Flavobacterium*, *Penicillium*, *Sclerotium*, *Fusarium*, and *Aspergillus*. Some microorganisms such as bacteria, fungi and streptomycetes are known to be able to dissolve P from the natural phosphate fertilizers as well as those fixed in the soil (Subba Rao 1982). Kang *et al*. (2002) reported that *Fomitopsis* sp**.** fungus could also dissolve phosphate. Further, Goenadi *et al*. (1993) reported that fungus

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was more able to dissolve P in form of $AlPO_4$ (in aluminum acid soil) and bacteria is more effective to dissolve P in the form of $Ca_3(PO_4)_2$ in alkaline soil. By molecular methods, Pérez *et al.* (2007) isolated heterotrophic bacteria belong to the genera *Burkholderia*, *Serratia*, *Ralstonia* and *Pantoea* could solubilize $Ca_3(PO_4)_2$ and Vazquez *et al.* (2000) isolated some species phosphate solubilizing bacteria from the rhizosphere of mangrove such as *Bacillus amyloliquefaciens, Bacillus licheniformis, Bacillus atrophaeus, Paenibacillus macerans, Vibrio proteolyticus, Kluyvera cryocrescens, Pseudomonas stutzeri,* and *Chryseomonas luteola.* While Sandeep *et al.* (2008) reported that addition of phosphate solubilizing microorganism in to P fertilization could increase the yield of soybean.

Based on the facts mentioned above, the usage of phosphate solubilizing fertilizer such as bio-phosphate that can increase the P-solubility appears to be an alternative that economically cheap for the solution of P-fertilizer efficiency, especially in marginal soils such as Ultisol. Lampung Province appears to be one of rice producing area in Sumatera. Rice varieties that are grown at the most by the farmers are Ciherang, IR 64, Sintanur, dan Cilosari, but the yield of the four varieties are now below the production potential as part of the land used is the marginal soil such as Ultisol.

The objective of this study is to find out the effect of bio-phosphate on the P-availability, the growth and the yield of lowland rice in Ultisol.

## MATERIALS AND METHODS

### Design of the Study

The study was conducted from January to March 2005 at the green house of Agronomy Department and soil analysis was conducted at Soil Science Laboratory the Faculty of Agriculture, University of Lampung. A factorial experiment design with two factors was used in the randomized complete block design with five replications. The first factor was dosages of bio-phosphate (0, 10, 20 g $L^{-1}$), the second factor was the lowland rice cultifars (Ciherang, Sintanur, Cilosari, and IR 64). Each of the treatments combination was replicated five times.

### The Implementation of the Study

Ultisol soil used as planting medium was taken at the depth of 0-20 cm fromTamanbogo Experimental Station East Lampung with some characteristics were described in Table 1. The soil was put into a bucket in which a 20 kg soil for each bucket. The planting medium was later mixed with 100 g manure per bucket as a basic treatment, poured with water and the medium was kept until resembles rice field soil. Bio-phosphate with bacterial population of $10^8$ cells m $L^{-1}$ was applied at the time of planting, by dissolving 10 g of bio-phosphate into 1 liter of water for the 10 g $L^{-1}$ dosage and 20 g of bio-phosphate into 1 liter water for the 20 g $L^{-1}$ dosage. Before planting the roots of rice seedling were immersed into Bio-phosphate solution in accordance with each treatment dosages for 2 hours and for the control (without bio-phosphate) the roots was immersed into distilled water. Three seedlings were planted in each bucket. During the study, the plants was maintained by adding water, weeding, and pest and disease control. Observed variables included plant height, root length at the time of harvesting, the number of tillers per cluster, the number of panicle per cluster, the number of fertile grains per panicle, and the weight of 100 grains. Soil chemical characteristics before and after harvesting were also examined.

### Data Analyses

To test the homogenity of variance between treatment, the resulting data was tested using a Bartlett test and the model additivity was tested using a Tukey test, analysis of variance of the data was further carried out at 1% and 5% level. To compare the treatment means, Least Significant Difference (LSD) was applied at 5% level.

## RESULTS AND DISCUSSION

### Soil Chemical Characteristics Before and After Harvesting

Table 1 indicated that the nutrient level of N, K, and P (Bray I) before planting were very low, namely 0.10%, 0.06 cmol $kg^{-1}$, and 1.69 mg $kg^{-1}$ respectively. The application of bio-phosphate increased the availability of N, K and especially P nutrients in the soil. The availability of N, K, and P nutrients increased to 0.09%, 0.56 cmol $kg^{-1}$ and 28.56 mg $kg^{-1}$, respectively, compared to before planting/application of bio-phosphate. According to Subba Rao (1982), the application of bio-phosphate would increase the population of phosphate dissolving microorganisms

Table 1. Soil chemical characteristics before and after harvesting with bio-phosphate treatment at a green house.

| Soil Characteristics | Before | After |
|---|---|---|
| pH $H_2O$ | 4.57 | 6.21 |
| N (%) Kjeldahl | 0.10 | 0.19 |
| Available-P Bray I (mg $kg^{-1}$) | 1.69 | 30.25 |
| Total-P (mg $kg^{-1}$) | 138.10 | 387.34 |
| K (cmol(+) $kg^{-1}$) | 0.06 | 0.62 |
| CEC (cmol(+) $kg^{-1}$) | 6.90 | 6.21 |
| Al-dd 1.0 *N* KCl (cmol(+) $kg^{-1}$) | 0.10 | 0.15 |
| H-dd 1.0 *N* KCl (cmol(+) $kg^{-1}$) | 0.10 | 1.00 |

surrounding the roots, that the high density would increase the P-solubility until it becames available to the plants. This condition confirmed by Harley and Smith (1983) who stated that addition of phosphate dissolving microorganisms can increase the P-availability in the soil that increased the absorption of P. Further, it was said that addition of bio-phosphate or phosphate solubilizing micro-organisms into the soil could improve the soil productivity because (1) bio-phosphate appears to be soil microbes that capable to solubilize phosphate which is difficult to solubilize in the soil, both the one originated from held parent material and those originated from donation from phosphorus fertilizers and (2) phosphate solubilizing microbes excreted organic acid such as: sulphuric acid, citric acid, formic acid, succinic acid, asetic acid, propionic acid, butyric acid and oxallic acid (Setiawati and Miharja 2008).

The presence of these acids evoked dissolving of phosphate compounds both organic acid and inorganics (Alexander 1977; Subba Rao 1982). Organic acids capable of dissolving Ca-P, Al-P and Fe-P by supplying protons and complexing cation (Rajan *et al*. 1996). Organic compounds excreted by phosphate solubilizing microbes formed complex compounds (chelates) that was difficult to dissolve by Al and Fe in the soil so that fertilizer originating phosphorous that is usually fixed by Al and Fe become available for the plants.

**Plant Growth**

Statistical analysis showed that application of bio-phosphate significantly affected the growth of lowland rice which was reflected from plant height, length of roots, and the number of tillers per cluster (Table 2). Dosage 10 g $L^{-1}$ of bio-phosphate application increased the height of lowland rice of 30 days after planting (dap) and 60 dap in which 9.0% and 5.8%, respectively, compared to without bio-phosphate.

While, bio-phosphate application up to 20 g $L^{-1}$ was capable to increase plant height of 30 dap and 60 dap in which 21.5% and 11.0%, respectively compared to without bio-phosphate application.

The 10 g $L^{-1}$ dosage and 20 g $L^{-1}$ dosage of bio-phosphate applications increased the root length of lowland plant in which 13.3% and 36.8%, respectively, higher than plants without bio-phosphate application. Bio-phosphate dosage of 10 g $L^{-1}$

Table 2. The effect of bio-phosphate and the varieties on the growth of lowland rice

| Treatments | Plant height (30 dap) | Plant height (60 dap) | Root length (cm) | The number of tillers per cluster (30 dap) | The number of tillers per cluster (60 dap) |
|---|---|---|---|---|---|
| | ----------cm---------- | | | | |
| Bio-phosphate | | | | | |
| - Without bio-phosphate | 34.21 c | 72.39 c | 13.98 c | 1.45 b | 8.50 c |
| - 10 bio-phosphate g $L^{-1}$ | 37.28 b | 76.59 b | 15.84 b | 1.50 b | 10.50 b |
| - 20 bio-phosphate g $L^{-1}$ | 41.56 a | 80.38 a | 19.12 a | 2.15 a | 12.75 a |
| Varieties | | | | | |
| - Ciherang | 38.29 a | 77.20 a | 15.80 a | 1.60 a | 10.87 a |
| - Sintanur | 37.72 a | 76.19 a | 16.58 a | 1.53 a | 10.53 a |
| - Cilosari | 36.30 a | 75.89 a | 17.11 a | 1.67 a | 9.93 a |
| - IR64 | 38.41 a | 76.53 a | 15.75 a | 2.00 a | 11.00 a |

Note: Vertically means followed by a similar letter were not significantly different at the level of 5% according to LSD test. dap = days after planting.

Table 3. The effect of bio-phosphate application and varieties on the yield of lowland rice.

| Treatments | The number of panicle per cluster | The number of filled out grains per panicle | Weight of 100 grains (g) |
|---|---|---|---|
| Bio-phosphate | | | |
| -Without bio-phosphate | 30.60 c | 138.50 a | 2.36 b |
| - 10 bio-phosphate g $L^{-1}$ | 35.45 b | 137.00 a | 2.41 b |
| - 20 bio-phosphate g $L^{-1}$ | 42.90 a | 150.95 a | 2.63 a |
| Varieties | | | |
| - Ciherang | 34.53 a | 153.67 a | 2.38 a |
| - Sintanur | 37.13 a | 129.33 b | 2.47 a |
| - Cilosari | 35.87 a | 151.27 a | 2.57 a |
| - IR64 | 37.73 a | 134.33 ab | 2.44 a |

Note: Vertically means followed by a similar letter were not significantly different at the level of 5% according to LSD test.

application increased the number of tillers per cluster of lowland rice of 30 dap and 60 dap in which 3.4% and 23.5%, respectively, higher than without bio-phosphate applications. While application of bio-phosphate up to 20 g $L^{-1}$ dosage increased the number of tillers per cluster of lowland rice of 30 dap and 60 dap in which 48.3% and 50.0%, respectively, more than the plants without bio-phosphate application.

The increasing of plant height and the number of tillers per cluster were due to the increasing of nutrients absorbtion as the results of bio-phosphate application. especially the increasing of availability P in the soil that could be absorb by the plant.

The increasing in length of the plant roots of the lowland rice was in turn increased the absorption of P by the plants. The longer the length of the plant roots, the more the absorption of nutrients from the soil especially absorption of P nutrient which was difficult to be available for the plants. According to Whitelaw (2000) and Gardner *et al*. (1991) the availability of P which cames from phosphate solubilizing fungus increased the plant growth which starting from the increase of photosynthesis and further the increase of root growth. Adequate phosphorous will increase the root growth (Leiwakabessy 1988).

The type of lowland rice varieties did not have a significant difference on plant growth (Table 2). Yet, from the average values of plant height, root lenght, and the number of tillers per cluster, it were shown that there were differences among varieties. The highest plant height at 30 dap and 60 dap was shown by IR64 and Ciherang varieties, respectively. The highest root length at the time of harvesting was shown by Cilosari variety. While the most number of tillers per cluster at the age of 30 dap and 60 dap was shown by IR64 variety.

## Plant Yield

Aplication of bio-phosphate significantly affected the number of panicle per cluster and weight of 100 grains of lowland rice (Table 3). Application of bio-phosphate at the dosage of 10 g $L^{-1}$ and 20 g $L^{-1}$ dosages increased the number of panicle per cluster of lowland rice by 15.8% and 40.2%, respectively. higher than without bio-phosphate application. However, bio-phosphate application did not significantly affected the number of filled out grains per panicle. Yet, the number of filled out grains increased on the bio-phosphate 20 g $L^{-1}$ treatment, namely 9.0% higher than without bio-phosphate application. Bio-phosphate applications at the 10 g $L^{-1}$ and 20 g $L^{-1}$ dosages also significantly affected the weight of 100 grains of lowland rice by 2.1% and 11.4%, respectively higher than without bio-phosphate application.

Increasing of lowland rice yield as the results of bio-phosphate application was due to the improvement of plant growing environment such as the increase of P availability in the soil (Khan *et al.* 2007). This indicates the importance of P nutrient in the effort of increasing lowland rice yield.

Study by Saraswati *et al.* (1999) also indicated that application of bio-phosphate without P fertilizer treatment increased dry grain yield of pady 5.1%. When bio-phosphate application was combined by averages of P ¼, ½, and 1 times recommendation dosage (75 kg SP36 $ha^{-1}$) indicated the increase of dry grain yield 33.6%, 52.2%, and 55.3%, respectively. Combination of bio-phosphate application (200 g $ha^{-1}$) with P fertilizer of ½ recommended dosage (75 kg SP36 $ha^{-1}$) increased dry grain of lowland rice 21.6% compared to without bio-phosphate application (P fertilizer of ½ recommended dosage only).

The type of varieties significantly affected the number of filled out grain per panicle (Tabel 3). The highest number of filled out grain per cluster was showen by Ciherang variety namely higher than Cilosari, IR64, and Sintanur varieties, each of 1.6%. 14.4% and 18.8%, respectively. The type of varieties did not show a significant difference on the number of panicle per cluster and the weight of 100 grains (Table 3). However, the number of panicle per cluster and weight of 100 grains were clearly a different among each varieties. The highest number of panicle per cluster was produced by IR64 variety and followed by Sintanur and Cilosari varieties. The highest weight of 100 grains was produced by Cilosari variety and followed by Sintanur and IR64 varieties.

## CONCLUSIONS

Based on the results of the study, it can be concluded the application of bio-phosphate was able to increase the P-availability in Ultisol. Bio-phosphate application of 10 g $L^{-1}$ and 20 g $L^{-1}$ were capable to increase lowland rice root length by 13.3% and 36.8%, respectively, higher than without bio-phosphate. While application of bio-phosphate up to 20 g $L^{-1}$ dosage was capable of increasing weight of 100 grain of lowland rice 11.4% higher than without bio-phosphate application. The type of varieties significantly affected the number of filled out grain per panicle. The highest number of filled out grain per panicle was produced by Ciherang variety.

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