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# EFFECT OF ROCK PHOSPHATE ENRICHED WITH SP36 TO SOYBEAN YIELD ON ULTISOL LAMPUNG

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## ABSTRACT

Research to study the effect of application of rock phosphate (RP) enriched with SP36 to soybean on Ultisol was conducted at ILETRIs' green house from July to October 2008. Treatment consisted of combination of rock phosphate from Lamongan and Bojonegoro at rates of 162 kg $P_2O_5$/ha with three rates of SP36 (0, 9, 18 and 27 kg $P_2O_5$/ha). The treatments were arranged in randomized complete block design and replicated three times. The result showed that application of RP from Lamongan and Bojonegoro to Ultisol Lampung at rates of 162 kg $P_2O_5$/ha increased soil pH by 0.3 and 0.5, available P (Bray 1) by 400% and 823% respectively compared to check. Highest soybean yield was attained by application of RP from Lamongan combined with SP36 at rates of 18 kg $P_2O_5$/ha or RP from Bojonegoro combined with SP36 at rates of 9 kg $P_2O_5$/ha which yielded 4.98 and 5.21 g/pot respectively. This result indicated that RP from Lamongan and Bojonegoro can be applied directly as P fertilizer for soybean in acid soil, and combining them with SP36 will increase their effectiveness.

Keywords: rock phosphate, SP36, soybean, ultisol

## INTRODUCTION

Phosphorus (P) is one of an essential element for plant. P is needed to synthesize ATP that is an energy source for growth and development process (Foth, 1994). Phosphorus in soil occurs in the form of organic-P ($\triangle^{H}{}_{2}{}^{PO}{}_{4}$) and inorganic-P ($H_2PO_4^-$ and $HPO_4^{2-}$) (Tisdale *et al*., 1985).

Phosphorus concentration in the soil solution is influenced by biological immobilization and reaction with soil mineral fraction. Phosphorus fixation can occurs in soil which have low activity clay, especially when clay mineral is dominated by 1:1 type and high hidroxy Al or Fe content, and it causes P unavailable to plant (Tisdale *et al*., 1985). Phosphorus availability in acid soil is influenced by soil pH, Al and Fe oxide/hydroxide, and soil organic matter. The free form of Al and Fe in acid soil can fix P to perform Al-P and Fe-P which have low solubility and finally become insoluble and hence unavailable to plant (Iyamuremye *et al*., 1996; Tan, 1998).

Single Super Phosphate (SP) and Triple Super Phosphate (TSP) are water soluble fertilizers widely use by farmer. The advantage of using water soluble P fertilizer is that P can be rapidly absorbed by plant and therefore give rapid response. However, if thus fertilizer applies on acid soil containing high hydrous oxide of Al and Fe, P released from fertilizer will be fixed and become unavailable to plant. On the other hand, the price of SP and TSP fertilizer are expensive. Rock phosphate (RP) is P source which low water solubility, and hence suitable to be used on acid soil. The RP deposits in Indonesia is around 7 to 8 million tone with $P_2O_5$ content vary from 1 to 38% (Moersidi, 1999), and some RP can directly apply as P fertilizer (Kpomblekou and Tabatabai, 2003).

Many researches on RP usage as fertilizer had been done. The advantage of using RP were it had similar effectiveness with TSP but better residual effect, cheaper than TSP, could be applied once at high rate and therefore did not need to apply every planting season and hence reduced labor cost (Idris 1995). Adiningsih *et al*., (1998) reported that effectiveness of TSP combining with lime to soybean was better than RP in the first season, but residual effect of RP was better than TSP+lime. This result indicated that the RP has a good prospect to develop as P

source on acid soil. The RP has low solubility hence first season plant often showing P deficiency.

Objective of the research was to study response of soybean to rock phosphate enriched with SP36 on Ultisol from Lampung.

## MATERIALS AND METHODS

The research was conducted at ILETRIs' green house in Malang from July to October 2008. Soil sample at depth of 0-20 cm was taken from Sari Bakti 2 village, Seputih Banyak Subdistrict, Central Lampung District, Lampung Province. Rock Phosphate (RP) from Bojonegoro and Lamongan, East Java was used in this research. Chemical characteristic of RP and soil presented in Table 1 and Table 2.

Treatment consisted of combination between SP36 and Rock Phosphate (RP). Rate of P fertilizer was calculated based on external P concentration of 0.02 ppm P. To attain external P concentration of 0.002 ppm P on soil used in this research needed application of 162 kg $P_2O_5$/ha (Wijanarko and Sudaryono 2007). The treatment laid out in randomized complete block design with three replications. The treatment constructed as follow:

1. Check.
2. SP36 (SP) at rate of 162 kg $P_2O_5$/ha.
3. RP-Lamongan (RP-L) at rate of 162 kg $P_2O_5$/ha.
4. RP-L at rate of 162 kg $P_2O_5$/ha + SP at rate of 9 kg $P_2O_5$/ha.
5. RP-L at rate of 162 kg $P_2O_5$/ha + SP at rate of 18 kg $P_2O_5$/ha.
6. RP-L at rate of 162 kg $P_2O_5$/ha + SP at rate of 27 kg $P_2O_5$/ha.
7. RP-Bojonegoro (RP-B) at rate of 162 kg $P_2O_5$/ha.
8. RP-B at rate of 162 kg $P_2O_5$/ha + SP at rate of 9 kg $P_2O_5$/ha.
9. RP- B at rate of 162 kg $P_2O_5$/ha + SP at rate of 18 kg $P_2O_5$/ha.
10. RP- B at rate of 162 kg $P_2O_5$/ha + SP at rate of 27 kg $P_2O_5$/ha.

Phosphate fertilizer according to the treatment was mixed with 5 kg of air dried soil and poured into polybag. After two weeks incubation, soybean (Sinabung variety) seed was planted in each polybag, and tinning to two plants per polybag at 10 days after planting. Urea (46% N) and KCl (60% $K_2O$) at rates of 75 kg/ha and 100 kg KCl/ha respectively were applied as basal fertilizer. Water content in polybag maintained at field capacity level by addition of distilled water. The plant was harvested at physiological maturity.

Parameter observed consisting of plant height at 45 days after planting and at harvesting, number of filled pod, number of unfilled pod, 100 seed weight, and seed yield, soil pH and available P (Bray-1) at harvesting, and relative agronomic effectiveness (RAE). RAE calcúlate as follows:

RAE = [(Y1 - Yo)/(Y2 - Yo)]x 100
Y1= yield on Rock Phosphate treatment
Y2= yield on SP36 treatment
Yo= yield on check

Variance analysis was used to detect effect of the treatment, and mean comparation using Least Significant Different (LSD) at 5% level to detect difference among the treatment.

Table 1. Chemical characteristic of Rock Phosphate (RP) from Bojonegoro and Lamongan

| Characteristics | RP from Bojonegoro | RP from Lamongan |
|---|---|---|
| $P_2O_5$ - Citric acid (%) | 13.74 | 5.08 |
| $P_2O_5$ - Total (%) | 24.07 | 14.30 |
| CaO (%) | 25.74 | 21.03 |
| K-Total (%) | 1.09 | 0.78 |
| Na (%) | 0.97 | 0.34 |
| MgO (%) | 0.39 | 1.56 |
| Fe (ppm) | 7,99 | n.a |
| Mn (ppm) | 56 | n.a |
| Cu (ppm) | 23 | n.a |
| Zn (ppm) | 392 | n.a |

Remarks= n.a = not analyzed

Table 2. Chemical characteristic of Ultisol from Lampung.

| Variables | Methods/Extractant | Value |
|---|---|---|
| pH-$H_2O$ | pH meter | 5.15 |
| pH-KCl | pH meter | 3.90 |
| Available P (ppm $P_2O_5$) | Bray I | 4.28 |
| C-organic (%) | Kurmies | 1.07 |
| Total N (%) | Kjedahl | 0.05 |
| Exchangeable K (me/100g) | $NH_4OAc$ pH 7 | 0.03 |
| Exchangeable Ca (me/100g) | $NH_4OAc$ pH 7 | 0.77 |
| Exchangeable Mg (me/100g) | $NH_4OAc$ pH 7 | 0.54 |
| Exchangeable Na (me/100g) | $NH_4OAc$ pH 7 | 0.05 |
| Fe (ppm) | DTPA | 26.5 |
| Exchangeable Al (me/100g) | KCl 1N | 2.17 |
| Exchangeable H (me/100g) | KCl 1N | 0.11 |
| CEC (me/100g) | $NH_4OAc$ pH 7 | 19.20 |
| Al saturation (%) | | 59.13 |

## RESULTS AND DISCUSSION

### Soil Chemical Characteristic

Soil analysis showed that soil pH categorized as acid; organic-C, total-N, available P, basic cations, and CEC were low; Al saturation was very high (Table 2). The analysis result indicated that the soil had low fertility and high potential to aluminum toxicity. Ultisol is a weathered soil and hence this soil has low macro as well as micro nutrient content (Hardjowigeno, 1993), high Al content that can be toxic to plant and also potentially fixed phosphorus (Tan, 1998). Related to soybean growth requirement, this soil needs high fertilizer input and soil amelioration. Critical level of soil pH for soybean is 4 to 5.5 (Follet *et al*., 1981), but optimum ranged from 5.5 to 6.0 (Ismail and Effendi, 1985). Soybean is sensitive to high aluminum content with critical aluminum saturation is 30% (Hartatik and Adiningsih, 1987). Critical level of phosphorus for soybean is 7 ppm P (Tandon and Kimmo, 1993), 6-10 ppm P (Franzen, 2003).

### Phosphorus Availability

Application of P fertilizer increased P availability in soil. Application of SP36 at rates of 162 kg $P_2O_5$/ha increased available-P up to 245% compared to check (14.3 ppm $P_2O_5$). Application of RP enriched with SP36 increased available P more than SP36 at rates of 162 kg $P_2O_5$/ha. Application RP from Lamongan and Bojonegoro at rates of 162 kg $P_2O_5$/ha increased available-P by 400% and 823% respectively compared to check. Highest level of available P attained on application of RP from Lamongan and Bojonegoro at rates of 162 kg $P_2O_5$/ha combined with SP36 at rates of 27 and 18 kg $P_2O_5$/ha which increased by 739% and 955% respectively (Figure 1). The result indicated that enrichment of RP with SP36 as such increase available P. Better RP quality will be higher available P gained. Chien (1992) showed that there is correlation between Bray 1 extractable-P with RP solubility in 2% citric acid.

At certain level of RP applied, available P increased according to increasing rate of SP36 added (Figure 1). Application of RP from Bojonegoro gave higher available P than RP from Lamongan at various rates of SP36 added. It may be due to higher P content in RP from Bojonegoro than from Lamongan (Table 1). However, soybean yield did not linearly increased as available P increased. There was weak quadratic relationship between soybean yield and available P content with equation of $Y = -0.0002\ X^2 + 0.0485\ X + 1.8041$; $R^2 = 0.48$ (Figure 2).

### Soil pH

RP application increased soil pH, while application of SP36 reduced soil pH by 0.1 unit compared to check (pH=5.1). The soil pH increment varied between 0.1 to 0.5 units depending on the origin of RP and rate of SP36 added (Figure 3). Application of RP from Lamongan that contain 21% CaO increased soil pH by 0.3 unit, while application of RP from Bojonegoro that contain 25.7% CaO increased

soil pH by 0.5 unit. Reduction of soil pH increment occurred when they were combined with SP36. Combination of the RP from Lamongan with SP36 at rate of 9, 18 and 27 kg $P_2O_5$/ha increased soil pH by 0.2, 0.2 and 0.1 unit respectively compared to check. Combination of the RP from Bojonegoro with SP36 at rate of 9, 18 and 27 kg $P_2O_5$/ha increased soil pH by 0.3, 0.4 and 0.1 unit respectively compared to check. According to national standard of Indonesia No 02-3769-1995, SP36 fertilizer contain total P minimum 36% $P_2O_5$, maximum 5% S and 6% free $H_3PO_4$. Reducing pH due to SP36 application might because of Sulphur and free Phosphoric acid content in the SP36 fertilizer.

Idris (1995) reported that application of RP from Lamongan and Bogor on acid soil from Jasinga and Sitiung IV increased soil pH. Chien (1992) also reported that application of RP from Sechura at rates of 400 mg P/g soil increased soil pH of Oxisol from Columbia by 8%.

**Response of Soybean**

Application of Rock Phosphate enriched with SP36 (RP+SP) significantly affected plant height at 45 days after planting (DAP) but not at harvest (Table 3). The RP+SP treatment significantly increased plant height at 45 DAP compared to check and even with SP36 (SP) treatment. The best plant height attained on RP-L treatment combined with SP at rate of 27 kg $P_2O_5$/ha which was increased by 24.8% and 12.6% compared to check and SP treatment respectively. RP it self, also significantly increased plant height even thought without enriched with SP. Application of RP on acid soil increased available P and soil pH and hence give positive effect on plant growth.

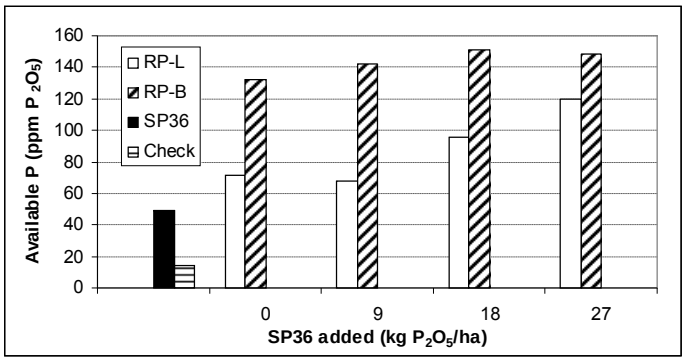


Figure 1. Effect of rock phosphate enrichment with SP-36 on Phosphorus availability (RP-L and RP-B: rock phosphate from Lamongan and Bojonegoro; SP36 at rate of 162 kg $P_2O_5$/ha)

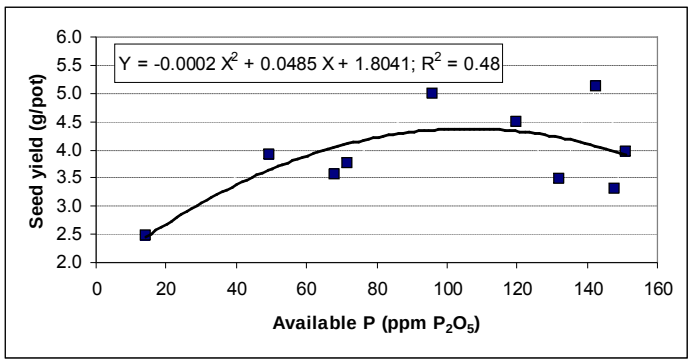


Figure 2. Relationship between soybean seed yield and available P content on Ultisol from Lampung.

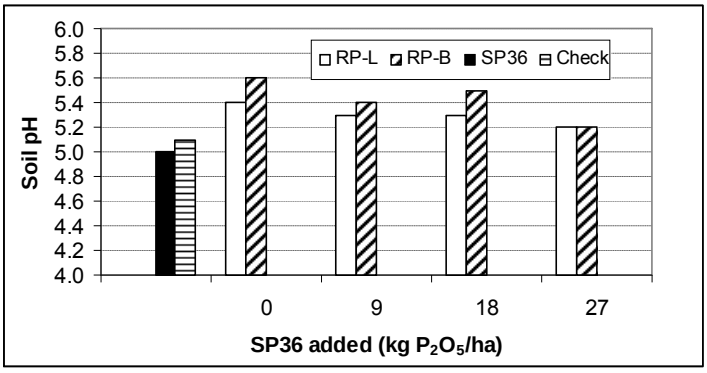


Figure 3. Effect of rock phosphate, SP36 and their combination on soil pH of Ultisol from Lampung.

The RP+SP treatment significantly increased filled pod and seed weight, but did not affect unfilled pod and 100 seed weight. The RP from Lamongan enriched with SP36 at rate of 18 kg $P_2O_5$/ha increased seed yield by 100.8% and 27.4% compared to check and SP36 treatment respectively. The RP from Bojonegoro enriched with SP36 at rate of 9 kg $P_2O_5$/ha increased seed yield by 110% and 33.2% compared to check and SP36 treatment respectively (Table 3). The higher SP36 added to RP from Lamongan than from Bojonegoro was because RP from Bojonegoro had higher total P and citric acid soluble-P content (Table 1). Highest soybean yield was gained from thus two treatments.

Total P and 2% citric acid soluble-P content are two parameters to measure quality of RP. Adiningsih *et al.* (1998) stated that plant root excrete weak acid to root zone to solubilize nutrient from soil, and hence the quality of RP should be measured from the phosphorus contain extracted with weak acid and not based on the total P. There is positive correlation between RP solubility and relative agronomic effectiveness (RAE) with phosphorus content that is extracted with 2% citric acid or formic acid (Rajan *et al.,* 1996).

McClelland and van Kauwenvergh (1992) divided the quality of RP into three categories based on its' phosphorus content in citric acid 2% extraction, i.e. low (<6.0% $P_2O_5$), medium (6.7-8.4% $P_2O_5$) and high (>9.4% $P_2O_5$). Based on this criteria, RP from Lamongan and Bojonegoro were belongs to low and high quality respectively (Table 1).

The RP quality also can be measured based on RAE (Relative Agronomic Effectiveness). The RAE value calculates by comparing effect of RP treatment with standard P fertilizer (SP36). Based on the RAE value, McClelland and Van Kauwenvergh (1992) grouped solubility of RP into four, i.e. high (RAE>90), medium (RAE 90-70), low (RAE 70-30), and very low (RAE<30).

Based on RAE value (Figure 4) indicated that RP from Lamongan and Bojonegoro has medium and low RAE value and they can be increased to high RAE by combining it with SP36 at rates of 18 and 27 kg $P_2O_5$/ha and 9 and 18 kg $P_2O_5$/ha respectively. This combinations have RAE value more than SP36 at rates of 162 kg $P_2O_5$/ha.

This result indicated that RP from Lamongan and Bojonegoro can be directly applied as P source fertilizer. To improve RAE value, RP from Lamongan can be mixed with SP36 at concentration of 0.66-0.96% and RP from Bojonegoro with SP36 at concentration of 3.71-7.43% (calculated based on total P content in RP as presented in Table 2).

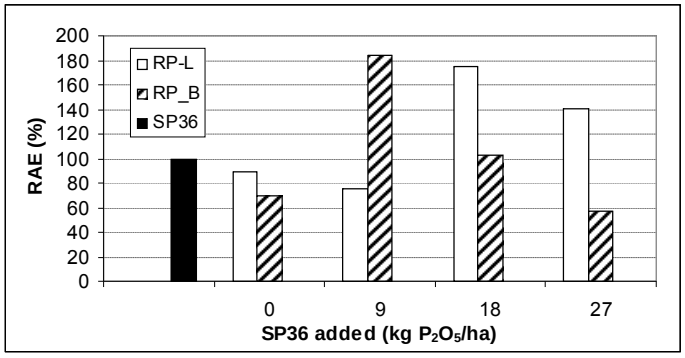


Figure 4. Relative Agronomic Effectiveness (%) of rock phosphate (RP) combined with SP36 at various rates (RP-L and RP-B: rock phosphate from Lamongan and Bojonegoro; SP36 at rate of 162 kg $P_2O_5$/ha)

Table 3. Effect of rock phosphate (RP) enriched with SP36 on soybean growth and yield on Ultisol Lampung. Malang 2008.

| Treatment | | Plant height at 45 DAS[2)] (cm) | Plant height at harvest (cm) | Number of filled pod | Number of empty pod | Seed weight (g/pot) | A 100 seed weight (g) |
|---|---|---|---|---|---|---|---|
| Origin of RP[1)] | SP36 (kg $P_2O_5$/ha) | | | | | | |
| – | 0 | 32.2 c | 47.3 a | 6.9 d | 2.8 a | 2.48 e | 6.25 a |
| – | 162 | 35.7 bc | 51.8 a | 14.5 ab | 1.5 a | 3.91 bcd | 6.33 a |
| Lamongan | 0 | 36.7 ab | 51.7 a | 11.7 bc | 1.7 a | 3.77 cd | 6.42 a |
| Lamongan | 9 | 36.7 ab | 49.0 a | 10.2 cd | 2.2 a | 3.57 cde | 6.02 a |
| Lamongan | 18 | 38.0 ab | 53.2 a | 15.8 a | 1.5 a | 4.98 ab | 6.81 a |
| Lamongan | 27 | 40.2 a | 57.3 a | 12.8 abc | 1.2 a | 4.50 abc | 7.01 a |
| Bojonegoro | 0 | 36.7 ab | 49.7 a | 11.8 abc | 2.3 a | 3.48 cde | 5.85 a |
| Bojonegoro | 9 | 39.0 ab | 55.7 a | 15.5 ab | 2.0 a | 5.21 a | 6.73 a |
| Bojonegoro | 18 | 38.8 ab | 53.7 a | 14.5 ab | 2.2 a | 3.95 bcd | 5.82 a |
| Bojonegoro | 27 | 36.8 ab | 54.5 a | 12.0 abc | 2.5 a | 3.31 de | 5.92 a |
| | KK (%) | 5.8 | 9.4 | 18.9 | 36.6 | 16.4 | 10.9 |

Remarks= The numbers in one column followed by the same letter are not significantly different according to LSD at 5% level.
1) RP applied at rate of 162 kg $P_2O_5$/ha
2) DAS=days after sowing

## CONCLUSIONS

According to Relative Agronomic Effectiveness (RAE) value, quality of rock phosphate (RP) from Lamongan and Bojonegoro is medium and low respectively. Thus quality can be improved by addition of SP36 fertilizer at concentration of 0.66-0.96% and 3.71-7.43% for RP from Lamongan and Bojonegoro consecutively.

Application of RP from Lamongan and Bojonegoro to Ultisol Lampung at rates of 162 kg $P_2O_5$/ha increased soil pH by 0.3 and 0.5, available P (Bray 1) by 400% and 823% respectively compared to check. Mixing of RP with SP36 at rates of 9 to 27 kg $P_2O_5$/ha increased available P more than RP alone.

Application of RP from Lamongan mixed with SP36 at rates of 18 kg $P_2O_5$/ha increased soybean seed yield by 100.8% compared to check (3.28 g/pot) and by 27.4% compared to SP36 only. Application of RP from Bojonegoro mixed with SP36 at rates of 9 kg $P_2O_5$/ha increased soybean seed yield by 110% compared to check and by 33.2% compared to SP36 only.

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