Residual effects of rock phosphate on soybean growth at tidal swampland South Kalimantan

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Abstract. Phosphorus fertilizer application could be an option to improve soybean yield in Indonesia. As in tidal swampland, phosphate deficiency is one of the main obstacles in the soil because it fixates ferro as insoluble phosphates. This experiment aimed was to determine the residual effects of Reactive Phosphate Rock (RPR) in the second cropping season on soybean growth in tidal swampland of South Kalimantan. The experiment was conducted at Barambai Village, South Kalimantan. This study was set in a factorial randomized block design with six treatments and three replications. The treatments were farmer practice, P Fertilizer (SP 36), residual of RPR, residual of RPR with soluble P Bacteria, residual of RPR with mycorrhiza, residual of RPR with Rhizobium and Soluble P Bacteria. The residual effect of RPR treatments with rhizobium and soluble P bacteria in the second planting season gave higher plant height of soybean compared to farmer practice and SP 36 treatment. The residual effect RPR treatment with rhizobium increased soybean yield up to 40.9% compared to without RPR and microbe in second cropping season. The released soluble P derived from RPR is relatively slow, therefore the application of high-dose RPR increases crop production.

1. Introduction

Soybean (Glycine max (L.) Merrill) a leguminous crop is one a source of vegetable protein that is widely consumed in various processed forms. Soybean is the main food plant after rice and is also known as Gold from the Soil, or as World’s Miracle, considering the high quality of protein amino acids, which is balanced and complete. The results of the analysis conclude that production up to 2020 has increased by an average of 6.80% per year and consumption has increased by an average of 2.10% per year [1]. Therefore, various efforts are needed to increase soybean production, one of which is through amelioration.

Tidal swamplands are sub-optimal land which can play an important role in soybean production. Indonesia has the largest swamplands in the tropics with sedimentary materials consisting of mineral soils, peat soils, or a combination of both. The main problem in swamps is the presence of peat and acid sulphate, both of which are stable in a reductive environment (natural conditions of swamp forest). The conversion of swamps for the production of cultivated biomass through land clearing and making drainage channels can lead to a change in the reductive atmosphere towards an oxidative...
direction accompanied by soil acidification [2]. Acidity is the main characteristic of swampy soils with acid to extremely acidic soil reactions ranging from pH 4 (Sulfuquests) and pH <3.5 (Sulfufabs), only a few plants can adapt to high acidity conditions [3]. Soybean is one of the most important legume crops for human nutrition and has been cultivated in tidal swampland soils with Type B or Type C.

Triple superphosphate (TSP) is an excellent soluble phosphorus (P) source. However, its high cost of production makes the long-term use of crude rock phosphate (RP) a more attractive alternative in developing countries [4]. Rock phosphate is a complex of tri-calcium phosphate \( \text{Ca}_3(\text{PO}_4)_2 \cdot \text{CaCO}_3 \) which is insoluble in water and hence unavailable to plants [5]. The dissolution of RP to release plant-available P is governed by many factors including soil and climatic conditions, granular size, moisture content and time and application techniques [6]. Although RP has a lower reactivity than commercial fertilizers for direct application on the soil, P availability from these rocks can be increased over the years of cultivation, for instance, due to the action of the soil micro biota [7]. The direct use of PR generally requires P-deficient acidic soils with a pH less than 5.5 [8,9].

Acidic soils cause poor plant growth resulting from iron and iron toxicity or deficiency of essential nutrients like phosphorus, calcium and magnesium. In legumes such as soybean plants, phosphorus plays an important role in the processes of photosynthesis, respiration, energy storage and transfer, cell division, and soybean yields. Silva et al. [4] reported that phosphate from rock phosphate may favourably alter microbial communities to improve P availability. Soil microbes also produce organic acids, which are involved in P solubilization [10]. Additional metabolic reactions such as cellular respiration by soil microbes also contribute to P solubilization [11]. Lastly, microbes help supply P by hydrolysis of organic P through the action of phosphatases, especially phytases [12].

Phosphate availability from rock phosphate can be increased over the years of cultivation due to the action of soil microbiota. Long-term effects of rock phosphate on the maize rhizosphere on Nigeria soil were studied by [4]. Naseer & Muhammad [13] reported the residual effects of rock phosphate during 2 consecutive seasons in calcareous soil with crop rotation wheat then maize. Compared to control, water-soluble phosphate concentration in soil was significantly higher from rock phosphate treatments during season 1, post-harvest and throughout season 2 of the study. The uptake of phosphorus was also higher during both seasons. Significantly higher grain and biomass yield were observed after both seasons from rock phosphate compared to a control treatment. This experiment aimed to determine the residual effects of Reactive Phosphate Rock (RPR) in the second cropping season on soybean growth in tidal swampland of South Kalimantan.

2. Materials and methods
The research was conducted from July to November 2018 at at farmer farm under acid sulfate soil in the tidal swamp land, Barambai village, South Kalimantan. The treatments are studying the residual effect of rock phosphate from Moroccan with the application of microorganisms at fourth levels of application with control (triple super phosphate and farmer practice). The detail treatment is shown in table 1.

Rock phosphate and dolomite are applied at the time of land preparation at first cropping season, namely when ploughing (tillage I) with rotary (tillage II). Rock phosphate is a phosphate source fertilizer or equivalent to 300 kg \( \text{P}_2\text{O}_5 \) ha\(^{-1}\) with a pattern of providing P elements in a long time (slow P is available, slow-release) so that it has residues in the soil until 4-6 subsequent planting seasons. Soybean production and plant height were analyzed using one-way analysis of variance (ANOVA and mean separation, where necessary using Duncan’s Multiple Range Test (DMRT) procedures at P <0.01. Regression analysis was carried out to estimate the relationship between the variables.
Table 1. Treatment of field trial residual effect of Moroccan reactive phosphate rock.

| No. | Treatment          | Source of P                                      | Application rate                      |
|-----|--------------------|--------------------------------------------------|---------------------------------------|
| 1.  | Farmer practice (P0) | NPK                                              | NPK varied                            |
| 2.  | Fertilizer P (P1)   | Super Phosphate (SP-36)                          | Soil test based on recommendation dosage (RD) |
| 3.  | Soluble P Bacteria (P2) | Rock phosphate type A from Moroccan in the first cropping season | 1 t ha⁻¹ rock phosphate at cropping first season |
| 4.  | Rhizobium (P3)      | Rock phosphate type A from Moroccan in the first cropping season | 1 t ha⁻¹ rock phosphate first cropping season |
| 5.  | Mycorrhiza (P4)     | Rock phosphate type A from Moroccan in the first cropping season | 1 t ha⁻¹ rock phosphate first cropping season |
| 6.  | Rhizobium+ Soluble P (P5) | Rock phosphate type A from Moroccan in the first cropping season | 1 t ha⁻¹ rock phosphate first cropping season |

Note: RPR = Reactive Phosphate Rock.

3. Results and discussion

3.1. Site characterization

This experiment was conducted in sulphate acid soil at Barambai Village, Barito Kuala Regency, South Kalimantan Province. This site is the tidal swamp which categorized as tidal type C (no flooded but ground water level <50 cm). Based on Soil Survey Staff, 2014 [14] the actual sulfate soil is categorized in this site. The characteristic actual acid sulfate soils have already undergone oxidation to produce acid, resulting in a soil pH of less than 4. They also often exhibit yellow and/or red mottling in the soil profile. If these soils still contain sulfides, they have the potential to produce more acid. The soil was classified as a Typic Sulfaquept, Sulfuric soil in the Australian ASS classification key [15].

The highest peak of rainfall in Barito Kuala District in 2018 was defined in December with 606 mm. The rainfall data during the crop period from July to October 2018 ranged from 56.3 to 113 mm per month (figure 1). Soybeans can be grown throughout the year in the tropics and subtropics, if the water is available and depending on soil type and stored soil moisture, Soybean can grow and yield with as little as 180 mm of in-crop rain, but yield could expect at a 40-60 percent decline compared to optimal conditions. The ideal rainfall range is between 500 and 1,000 mm.

![Rainfall distribution at Barito Kuala District, South Kalimantan from January to December 2018 (mm).](image)
3.2. Plant height

Plant height is an important character in supporting soybean yields. Tidal swamp land in this study was classified as acidic land (pH 4.30) with a high exchangeable Al. In Figure 2, the average plant height of 6 treatments at 90 DAP was 82.72 cm, where the highest plant height was achieved by residual RPR with Rhizobium and soluble P bacteria (92.1 cm) and the lowest without RPR with super phosphate (70.7 cm). Kuswantoro et al. [16] reported on tidal swampland with pH 4.30 and a high exchangeable Al up to 10.90 me 100 g−1, soybean with a variety of “Menyapa” can achieve plant height 85.4 cm. Aluminum excess on acid soils can cause soybean growth disruption and resulting low grain yield. In this study, although the soil included as an acid with high exchangeable Al, the plant height of the tested soybeans was relatively normal because rock phosphate fertilizer at first cropping season and microbial [17].

Phosphorus is frequently deficient for crop production and is required by soybean. Phosphorus deficiency affects the major functions in energy storage and transfer of rice plants which include tillering, root development, early flowering, and ripening. Soluble phosphorus from fertilizer or natural weathering, reacts with clay, iron, and aluminium compounds in the soil, and is converted readily to less available forms by the process of phosphorus fixation. This fixed, residual phosphorus remains in the rooting zone and will be slowly available to crops. Adequate supplies of other plant nutrients and plant promoting regulators hormones) tend to increase the absorption of phosphorus from the soil.

Table 2. Plant height of soybean with reactive rock phosphate and organic fertilizer in acid sulphate soil.

| Treatments                  | Plant height 30 DAP | Plant height 90 DAP |
|----------------------------|---------------------|---------------------|
| Farmer practice (P0)       | 46.57 ± 1.14 bc     | 74.97 ± 2.22 b      |
| Fertilizer SP 36 (P1)      | 43.90 ± 5.46 c      | 70.67 ± 7.15 b      |
| Soluble P Bacteria (P2)    | 48.43 ± 1.80 abc    | 85.03 ± 1.65 a      |
| Rhizobium (P3)             | 47.57 ± 3.45 abc    | 84.90 ± 6.68 a      |
| Mycorrhiza (P4)            | 50.50 ± 1.57 ab     | 88.67 ± 3.96 a      |
| Rhizobium+ Soluble P (P5)  | 52.50 ± 1.32 a      | 92.10 ± 2.25 a      |
| CV                         | 5.99                | 4.91                |

Note: Means followed by the same letter in each column are not significantly different (p <0.05).

3.3. Yield

The yield of soybean in tidal swamp land can be seen in figure 2. Grain yield is a complex character that supported by other agronomical characters. In figure 2, the average yield of 6 treatments was 2.07 t ha⁻¹, where the highest yield was achieved by residual RPR with Rhizobium (2.27 t ha⁻¹) and the lowest without RPR with super phosphate (1.61 t ha⁻¹) because the Inoculation of Rhizobium sp. make root nodules more active in nitrogen fixation, resulting in more root nodules and a larger size which affects plant growth for the better. Soybeans one of the kind legumes can able to form novel root organs known as nodules, within which biological nitrogen fixation is facilitated through a symbiotic interaction with soil-dwelling bacteria called rhizobium [18].
Figure 2. Soybean yield under residual effect of RPR and application microbial at Barito Kuala District, South Kalimantan.

4. Conclusions
The experimental results showed that the residual effect of RPR treatments with rhizobium and soluble P bacteria in the second planting season gave higher plant height of soybean compared to farmer practice and SP 36, and the yield increased up to 40.9% compared to without RPR and microbe. Phosphate rock is relatively slow to release soluble P, therefore the effect of application of RPR on improving crop production could be seen in the next planting season.

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The authors stated that the positions of all authors are equal to this manuscript.

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