Effect of reactive phosphate rock to corn on acid sulphate soil in South Kalimantan

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Abstract. In South Kalimantan, acid sulphate soil rich in total phosphorus (P), but poor in available P, because of fixing. Most of the crops on the soil have a symptom of P deficiency. Reactive Phosphate Rock (phosphateR) was a slow-release P fertilizer and has a longer residual effect. This is to research on the effect of phosphateR to corn on acid sulphate soil in South Kalimantan. This research was carried out to determine the effects of reactive rock phosphate and planting method of corn on acid sulphate soil. This study used a factorial randomized block design with two factors. The first factor of P fertilizer, namely: P Fertilizer (SP 36), farmer practice, phosphate rock, phosphate rock + Manure, phosphate rock+ organic fertilizer+ phosphate rock+compost. The second factor is the planting method i.e: existing planting method (70x25 cm), Zig Zag Method (70x12.5 cm). The N and K doses are determined based on soil nutrient status. The results showed that phosphate treatment gave the weight of corncob where phosphate treatment with zig zag method reached 21% compared SP-36 with zig zag method treatment. And the lowest results are shown in the treatment of farmer practice with existing methods reached 10.07 t/ha corncob of weight.

1. Introduction
The existing condition of suboptimal land becomes a limiting factor in the implementation of various innovations and technologies in achieving high productivity including fertilizer and fertilizer technology. One of the most extensive suboptimal lands is the tidal swampland. Based on the results of spatial calculations using a land map, it is observed that the area of swamps in Indonesia is ± 33.42 million ha or 18.28% of the total land area of Indonesia. Of this area, around 19.99 million ha is potential land to be developed into agricultural land. Acidity is the main characteristic of the soil in swamps with acidic to extraordinary acid reactions ranging from pH <4, only a few plants can adapt to high acidity conditions. Acid sulphate soil is a type of soil found in swampy areas and classified as problematic soils because this soil has a dakhil (internal) nature of unfavorable soils with low fertility.

Pyrite has unique properties and depends on the state of the water. Problems arise when pyrite is exposed to oxygen due to prolonged drought or after drainage or excavation of the channel which causes pyrite to oxidize. One mole of oxidized pyrite will produce 4 moles of sulfuric acid resulting in soil acidification [6]. Distinctive tidal swampland characteristics such as high soil acidity, low P content and the presence of toxic elements result in the low contribution of tidal land to national food production. Phosphorus (P) is an important plant nutrient after nitrogen. P availability is low in soils because of its fixation as insoluble phosphates of iron, aluminium, and calcium (especially in calcareous soil) [9].

In tidal swampland, phosphate deficiency is the main obstacle because the level is low in the soil and the soil absorbs phosphate is very strong. Therefore, the application of phosphate with the use of high-
dose slow release fertilizers is important in an effort to increase crop production. One source of phosphate that has the desired properties is Morocco Natural Phosphate which is a mineral mining material with P$_2$O$_5$ content between 28-32% [13]; Mnkeni [10] reports that other nutrients present in natural phosphates such as Ca, Mg and S and other elements have other advantages, namely to improve the chemical and physical properties of the soil so that it supports plant growth better.

The use of natural phosphate fertilizer which has high reactivity, has a residual effect, and is slow release is one of the effective and economic solutions in overcoming the problem of P on acid soils [16]. To achieve the target of ever increasing productivity, the use of Natural Phosphate must be integrated with the application of soil enhancers, the application of macro N, K nutrient fertilizers and the use of high yielding varieties. Natural phosphate used directly is far more effective for acidic land than non-acidic land. Long-term research results in Indonesia on food crops (1990-2013), the use of Moroccan reactive phosphate rock (phosphate rock) with a dose of 1 ton/ha given 1 time in 5 growing seasons can increase corn crop productivity by at least 30% to 4 planting seasons with cost efficiency up to 25% [1; 8].

2. Materials and Methods

The trial for corn is decided to set at farmer farm under acid sulphate soil in the tidal swamp, Barambai village, South Kalimantan. The treatments are comparing three types of Moroccan phosphate rock at two levels of application with soluble P and control. The detail treatment is shown in Table 2. Monitoring parameters include agronomic parameters (yield and yield components), soil properties before and after and its change

| No | Treatment | Source of P | Application rate |
|----|-----------|-------------|-----------------|
| 1  | Control   | 0           | 0               |
| 2  | Farmer practice | NPK     | varied          |
| 3  | Soluble P | SP-36 (36% P$_2$O$_5$) | Soil test based on recommendation dosage (RD) |
| 4  | PR A      | Moroccan PR type A+ manure | 1 ton ha$^{-1}$ phosphateR + 2 ton ha$^{-1}$ Manure |
| 5  | PR A      | Moroccan PR type A+organic fertilizer | 1 ton ha$^{-1}$ phosphateR + 25 kg ha$^{-1}$ organic fertilizer |
| 6  | PR A      | Moroccan PR type A+Compost | 1 ton ha$^{-1}$ phosphateR + 1 ton ha$^{-1}$ compost |

The planting method uses the zigzag method, which is planting by forming a triangle, where each side is twelve point five centimetres away. While the distance between one plant triangle with another plant triangle is 75 centimetres. This method only requires one seed for each planting related to the level of competition between plants in obtaining light, water, space, and nutrients. Plant density can be regulated by using the right amount of seeds. While the conventional method uses a spacing of 70 cm x 25 cm (Figure 1)
Phosphate rock and dolomite are applied at the time of land preparation. Phosphate rock is a phosphate source fertilizer with slow-release, so that it has residues in the soil until the next planting season.

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 area which categorized as tidal type B (flooded only at high tide which occurred twice a month). Based on Soil Survey Staff [14], this site is categorized as Typic Sulfaquent subgroup referring to its soil characteristic such as soil pH >3.5 at every soil depth but after oxidizing process occurred it decrease to < 3.5. This condition might be due to pyrite oxidation that produces Fe^{2+}, SO_{4}^{2-} and H^{+} Therefore soil pH will decrease shaphosphately. This process could be explained in this equation [12]:

\[
2 \text{Fe}^{2+} + 2\text{SO}_{4}^{2-} + 2\text{H}^+ + 6 \text{H}_2\text{O} \quad (R_1)
\]

Soil initial analysis showed that top soil (0-20 cm soil depth) had soil pH 4.01(very acid). As listed in Table 16, showed that as soil depth increase there was an increment on electric conductivity (EC), Fe^{2+} and SO_{4}^{2-}. Increasing on DHL could be due to flooding condition therefore sodium from top soil could infiltrate to sub soil. Al saturation at root zone was high as 15.7%. The soil has high concentration of pyrite (FeS_2). Based on soil characterization, this research site has low soil pH categorized as very acid soil followed with high Al saturation, FeS_2 and SO_4. The low availability of phosphorus is due to it readily forms insoluble complexes with cation such as aluminium and iron under acidic soil condition and with calcium and magnesium under alkaline soil conditions whereas the poor phosphorus fertilizer recovery is due to the fact that the phosphorus applied in the form of fertilizers is mainly absorbed by the soil and is not available for plants up-take [5].

Every cultivated soil has its own ecological equilibrium; the addition of industrial fertilizers will lead to many chemical and mineralogical changes which will disturb this ecological equilibrium [8]. To evaluate the best combination of phosphate rock (phosphate), sulphur (S), organic manure, and phosphate-dissolving bacteria (PDB) inoculation to enhance the availability of phosphorus from phosphate rock and their effects on yield of broad bean plants [10]
3.2. Effect of Direct Application of Phosphate on corn at Barambai, South Kalimantan

The study site in Barambai, South Kalimantan was very interesting. As the land was newly opened land. Our study site is the first time cultivation conducted in this land. The soil is under actual acid sulphate soil that very marginal and limited in soil fertility and other soil properties in supporting plant growth. However, the plant performance in this site was extremely good. Phosphate rock reactivity is a measure of the rate of dissolution of phosphate rocks under standard laboratory conditions or in a given soil and under given field conditions [12]. The dissolution rate of phosphate rocks is mostly affected by soil properties and plant characters [10]. The release of phosphorus from phosphate rock through composting using organic materials and its effect on corn growth was studied by Badr and Taalab [2]. The concentration of total P was significantly enhanced in the final product with all treatments as organic materials de-creased during composting compared to control where no P was added. Phosphorus from phosphate rock was solubilized and transformed into available forms during composting. The result showed in Figure 2, the plant height at 75 DAP showed increasing plant height under all treatment. The treatment of Rock Phosphate application showed high result showing similar response with SP-36, the fast release P fertilizer that is common used in Indonesia. The plant response under application of phosphate rock and manure or other organic matter even showed higher plant height compared under application of SP-36. Some picture of the performance of the corn plant shown in Figure 3. The effect of reactive phosphate rock for corn on anultisol in Pleihari, South Kalimantan province, was reported by Husnain [9]. They conducted a field experiment to evaluate the direct application of reactive phosphate rock (phosphate rock) for corn and its combination with manure and agronomic effectiveness. Reactive phosphate rock improved soil fertility and corn crop productivity. Moroccan phosphate rocks contained the highest citric acid extractable P2O5 as compared to the phosphate rock tested and were the most effective in in-creasing corn production [9]

![Figure 2. The plant height of corn in Barambai, South Kalimantan](image-url)
Figure 3. The Performance of corn in Barambai, South Kalimantan

Figure 4. Effect of treatment on the weight of corn cob in Berambai, South Kalimantan

Figure 4 showed that there is an increment for corn yield with phosphate treatment. The results showed that phosphate treatment gave the weight of corn cob where phosphate treatment with zig-zag method also gave the highest yield as 20.25 ton/ha and SP-36 treatment had the lowest yield as 16.74 ton/ha. This productivity at first planting season in acid sulphate soil type C. Hellal [10] reported In addition, amendments such as elemental organic fertilizer, compost and organic manure. A similar result was found in acid soil in Akande [2] that Phosphate application significantly enhanced dry matter yields of corn Single super phosphate (SSP) gave higher total biomass than the phosphate rocks. In the
regular application frequency in the first cropping, corn total biomass was increased by single super phosphate from 4.23 g/plant to 8.20, 9.25, and 9.72 with 20, 40, and 60 kg P/ha while it was increased to 6.78, 6.26, and 6.34 g with OPR but to 6.88, 7.60, and 7.15 g with another.

The phosphate treatment gave the weight of corn cob where phosphate treatment with zig zag method reached 21% compared SP-36 with zig zag method treatment. And the lowest results are shown in the treatment of farmer practice with existing methods reached 10.07 t/ha.

4. Conclusion
RP treatment gave the weight of corn cob where RP treatment with zig-zag method reached 21% compared SP-36 with zig-zag method treatment, and the lowest results are shown in the treatment of farmer practice with existing methods reached 10.07 t/ha fresh corn cob weight.

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