The research aimed to assess better P fertilization method for wetland rice which used quickly dissolving P fertilizer given in split application. The research concluded that the application of quickly dissolving P fertilizer to Alfisol and Oxisol applied in split application twice (0 and 30 days after planting) and three times (0, 15 and 30 days after planting) increased the efficiency of P fertilization in wetland rice. The split application of 75 kg ha\(^{-1}\) (50% of recommended dose) in Alfisol yielded dry seed as high as 6,374 kg ha\(^{-1}\) (at twice application), 6,280 kg ha\(^{-1}\) (at three-time application), while the control treatment yielded as high as 6,027 kg ha\(^{-1}\). In Oxisol the yield of rice was 8,200 kg ha\(^{-1}\) for the control treatment, 8,027 kg ha\(^{-1}\) for the twice application and 8,440 kg ha\(^{-1}\) for the three time applications.

Keywords: fertilizer, phosphate, alfisol, oxisol, split application

INTRODUCTION

The use of synthetic mineral fertilizers, including phosphates has continued to increase. According to data, consumption of phosphate fertilizers in Indonesia increased from 178,130 tonnes per year in 2000 to 582,071 tonnes per year in 2008; and NPK fertilizer increased from 19,638 tonnes per year in 2000 to 1,175,027 tonnes per year in 2009 (Association of Indonesian Fertilizer Producers, 2009).

According to Adiningish and Rochayati (1990) an increase in fertilizer consumption is primarily due to the increased use of the fertilizers for rice fields in Java.

The purpose of this study was to improve application method of P fertilizer to wetland rice.

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MATERIALS AND METHODS

The research was conducted in two years, from April 2010 to August 2011. Soils used in this research were obtained from the paddy fields of Alfisol of Jati Karanganyar and Oxisol of Klepu Ungaran. The properties of Alfisol were as follows: H₂O-pH of 6.4, KCl-pH of 5.73, P-fraction (Method of Hesse) extracted-P of 3.14 mg kg⁻¹, Ca-P of 11.98 mg kg⁻¹, Al-P of 9.75 mg kg⁻¹, Fe-P of 49.71 mg kg⁻¹, Occluded-P of 129.99 mg kg⁻¹, while the properties of Oxisol were H₂O-pH of 5.4, KCl-pH of 5.13, P-fraction (Method of Hesse) extracted-P of 2.32 mg kg⁻¹, Ca-P of 8.70 mg kg⁻¹, Al-P of 12.74 mg kg⁻¹, Fe-P of 51.11 mg kg⁻¹, Occluded-P of 124.60 mg kg⁻¹.

The first year study was pot experiment using a factorial completely randomised design with three replications. As many as 36 pots were used in this experiment. A 20 kg of soil was filled into each pot, where 18 pots were filled with Alfisol and the other 18 pots were filled with Oxisol. The treatments tested in this study included two factors: (1). The method of P application including P₀ = 150 kg ha⁻¹ of SP36 given when planting (control), P₁ = 75 kg ha⁻¹ of mashed SP36 given twice (at 0 and 30 dap); P₂ = 75 kg ha⁻¹ of mashed SP36 given three times (at 0, 15, 30 dap); P₃ = 75 kg ha⁻¹ SP36 dissolved in water and sprayed four times; P₄ = 75 kg ha⁻¹ of SP36 given in two methods: one half dose was given in mashed SP36 at planting and the rest was given as sprayed SP36 (30 and 45 dap); P₅ = 75 kg ha⁻¹ of SP36 given in two methods: one half dose given in mashed SP36 (at 0 and at 15 DAP) and the rest given as sprayed SP36 (30 and 45 DAP). (2). Soil types which were Alfisol and Oxisol. All pots were applied with N and K fertilizers at the doses of 150 kg ha⁻¹ of urea, 150 kg ha⁻¹ of KCl, and 100 kg ha⁻¹ of ZA. Two rice seedlings were grown in each pot under the above treatment and were maintained until harvest. The data measurements included: plant height, weight of wet and dry stover, number of productive tillers, panicle length, panicle number per plant, number of filled grain per plant, weight of 100 seeds and grain dry weight per plant. The data obtained were analyzed using Analysis of Variance and Honesty Significant Difference Test of 5%.

The second year study was conducted in the field using factorial randomized block design with five replications. A number of 30 plots, 3 m x 3 m each plot, were used in this study. The rice was grown under a planting space of 20 cm x 25 cm. The treatments tested in this study included two factors (1). The application method including P₀ = 150 kg ha⁻¹ of SP36 given when planting (control), P₁ = 75 kg ha⁻¹ of mashed SP36 given 2 times (at 0 and 30 dap); P₂ = 75 kg ha⁻¹ of mashed SP36 given 3 times (at 0, 15, 30 dap). (2) Soil type, consisting of Alfisol and Oxisol. Data measurements included plant height, weight of wet and dry stover, number of productive tillers, panicle length, panicle number per plant, number of filled grain per plant, 1000 seed weight, harvest age, weight of dry grain per plot, dry grain yields per hectare. The data obtained were analyzed using Analysis of Variance and Honesty Significant Difference Test of 5%.

RESULTS AND DISCUSSION

Phosphate fertilizer (P) in the form of fast dissolving fertilizer (mashed SP36) can accelerate the supply of P available. Preliminary study indicated that application of 150 kg SP36 in the soil quickly dissolved within one week after application, available P increased not significantly in Alfisol (from 3.14 to 6.18 mg kg⁻¹), and Oxisol (from 2.32 to 3.8 mg kg⁻¹). Most P from fertilizers applied to Alfisol and Oxisol formed the Fe-P bond, which reached 35.35 and 44.54 kg ha⁻¹ respectively. The study also recommended that the use of fast dissolving P fertilizer in soils rich in Fe (Alfisol and Oxisol) was more effective given in split, 2 or 3 times the applications, because it reduced significantly the formation of Fe-P bond (Cahyono, 2009).

Pot Experiment

This study examined the use of fast dissolve P fertilizer in rice through a variety of application methods. The result of observation of growth and yield of rice was presented in Table 1.
Data in Table 1 shows that the effect of P fertilization on wet and dry weight of stover was significant. One half dose of fast dissolving P fertilizer which was given in split application of twice (0 and 30 dap) or three times (0, 15 and 30 dap) was not significant with the control treatment (SP36 dose of 150 kg ha\(^{-1}\)) on Alfisol and Oxisol. While P fertilizer given through foliar application, either P\(_3\) treatment (75 kg ha\(^{-1}\) as a foliar spray). P\(_4\) (37.5 kg ha\(^{-1}\) as a foliar spray + 37.5 kg ha\(^{-1}\) mashed SP36 given at planting time). as well as P\(_5\) (37.5 kg ha\(^{-1}\) as a foliar spray + 37.5 kg ha\(^{-1}\) mashed SP36 given at 0 and 15 dap) produced lower grain yield compared with control treatment.

The pattern of P fertilization effect on wet and dry weight of stover differed from that on plant height. The use of quickly dissolving P produced lower weight of stover than in the control treatment. The interaction effect of the P fertilization method and type of soil on stover weight showed a significant difference. This indicates that the method of P fertilization on stover weight depended on soil type. This study has proven that the increase in plant growth is largely determined by the availability of P in the soil. because P is indispensable in the production of biomass crops.

The result of this study also indicated that the effect of P fertilization method on rice yield was significant, while the interaction effect of the treatments showed no significant difference. This means that the influence of P fertilization method on dry grain weight did not depend on soil type. It can be seen from the pattern reflecting the influence of the graph in Figure 1.

The interaction effect of both treatments on dry grain weight (Figure 1) showed that the split application of a half dose of quickly dissolving P fertilizer (75 kg ha\(^{-1}\)) produced no significant dry grain weight compared with the control treatment (150 kg ha\(^{-1}\) of SP36). The pattern of treatment effect did not differ between the two types of soil Alfisol and Oxisol. In the Alfisol, dry weight of grain increased slightly in the treatment of split application of two times (47.68 g) compared with the control treatment (45.82 g). Similarly three-time split application of quickly dissolving P yielded grain slightly higher than that of the control treatment (47.21 g). The same pattern also occurred in Oxisol soil. The split application of a half dose of quickly dissolving P (75 kg P ha\(^{-1}\)) increased dry weight of grain not significantly, which increased from 41.56 g (control treatment) to 44.2 g (twice application) and 44.33 (three-time application).

P fertilizer which was applied as foliar application, either entirely foliar spray (P\(_3\) treatment) or combinations of foliar spray and through-soil application (P\(_4\) and P\(_5\) treatments) yielded lower grain per plant compared with the control treatment. Effect of method of P fertilizer treatments on rice yield had the same pattern with the pattern of treatment effect on the yield component. i.e., panicle length, panicle number, number of grain pithy, number of productive tillers and 100 seed weight.
The process of flowering, panicle initiation and grain filling is largely determined by the availability of P in soil nutrients. In a plant cell, there are elements of Phosphorous as: (1) phospholipid, which is a component of cytoplasmic membranes and chloroplast. (2) phytin, which is the phosphate deposits in the seed. (3) sugar phosphate, which is an intermediate in various metabolic processes of plants (4) the nucleoprotein, the major components of DNA and RNA. (5) ATP, ADP, AMP and similar compounds, as a high-energy compounds to metabolism, (6) of NAD and NADP, both of which are important coenzyme in the process of reduction and oxidation and (7) FAD and various other compounds, which serves as a complement to the plant enzyme (Havlín et al. 1990). Adenosine triphosphate (ATP) is formed through a process of oxidative phosphorylation in phosphate assimilation by plants. P is assimilated into ATP, rapidly transferred through subsequent metabolic reactions into various forms of phosphates in plants, such as sugar phosphates and nucleotides fosfolipida. ATP also plays a role in the process of active transport. Deoxyribonucleic acid (DNA) is composed of Purine and pirimidine base, pentose sugar and phosphate, serves as a carrier of genetic information, whereas the RNA as a translator of information and other involvement in the synthesis of proteins. NAD, NADP and FAD act as a reductant in the synthesis of organic compounds of plants. P is also a constituent of phytin, which is the main form of P stored in the seeds. While phospholipid is a material important role in regulating cell membrane permeability and ion transport (Tisdale et al., 1985; Singer and Munns, 1985).

Field Experiment

The treatment of half dose quickly dissolving P fertilizer produced dry grain the same weight (not significantly different at 5% level) with the control treatment. The treatment resulted in dry grain yields per hectare of 7,200.5 kg (twice application) and 7,360 kg (three times application), whereas the control treatment produced 7113.5 kg of dry grain yield per hectare (Table 2). The results of this study suggested that P fertilizer for rice crop was more efficient when given in quickly dissolving form of twice or three-time split application methods. The pattern of treatment effect of the rice fertilization method on Alfisol and Oxisol soil is presented in Figure 2.
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Figure 2. Effect of P application method and soil types on weight of dry grain per hectare

![Graph showing effect of P application method and soil types on weight of dry grain per hectare.](image)

Table 2. Growth and yield components of rice on treated soil

<table>
<thead>
<tr>
<th>Components</th>
<th>P Application Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td>Plant height (cm)</td>
<td>93.87a</td>
</tr>
<tr>
<td>Wet weight of stover (g)</td>
<td>187.30a</td>
</tr>
<tr>
<td>Dry weight of stover (g)</td>
<td>99.90a</td>
</tr>
<tr>
<td>Length of panicle (cm)</td>
<td>18.42a</td>
</tr>
<tr>
<td>Number of panicle/plant</td>
<td>14.00a</td>
</tr>
<tr>
<td>Number of pithy grain/plant</td>
<td>982.60a</td>
</tr>
<tr>
<td>Number of not filled grain/plant</td>
<td>104.50a</td>
</tr>
<tr>
<td>Number of productive tiller</td>
<td>11.75a</td>
</tr>
<tr>
<td>Number of tiller</td>
<td>15.50a</td>
</tr>
<tr>
<td>Weight of 1000 seeds (g)</td>
<td>252.00a</td>
</tr>
<tr>
<td>Harvesting age (days)</td>
<td>118.00a</td>
</tr>
<tr>
<td>Weight of grain per plot (kg)</td>
<td>5.30a</td>
</tr>
<tr>
<td>Weight of grain per hectare (kg)</td>
<td>7,113.50a</td>
</tr>
</tbody>
</table>

Remarks: Data followed by same letter in the same row indicates not significantly different (at the level of 5%).

P fertilizer used by rice growers in Indonesia is SP36 which has a low solubility rate. Consequently, short-life crops such as rice are often harvested far before all of the added fertilizer was dissolved. Therefore, the efficiency of P fertilizer on rice is very low. Increasing the solubility of P fertilizer will accelerate the availability of elements of P for plants. However, the quickly dissolving P fertilizer should be given gradually. This is because when it is given all at once in the soil having high content of Fe, Al and Mn, most of fertilizer P will be bound into unavailable form. Therefore the use of rapidly dissolving P fertilizer on soils rich in P-binding ions must be applied gradually (split application). With this method, it is expected that dissolved P from fertilizer can be absorbed by plants efficiently.

The study showed that the quickly dissolving P fertilizers given in split application produced more effective photosynthesis. This was proven from the observations on the parameters of wet and dry weight of stover which was found higher in the treatment than in the control treatment. Similarly, this treatment also caused the plants to be able to set up
longer and more numerous panicles, so more filled grains were obtained. The effectiveness of phosphate fertilizers depends on the nature of the fertilizer used and soil conditions. According to Tisdale et al. (1985), the nature of fertilizer and soil conditions that influences its effectiveness include: (1) the size and type of grain, (2) soil moisture, (3) the distribution of grains, (4) the level of usage and the residual phosphorus in the soil. The size of phosphate fertilizer granules determine the degree of solubility of fertilizer, so that the finer grain size, the better to supply P to the plants, especially for plants that require P element immediately. Granules have advantages in applications compared to fine grains. Although the form of powder gives more possibilities to allow for the binding, this can be overcome with proper fertilization time (Syers and Myers, 1996).

CONCLUSIONS AND SUGGESTION

CONCLUSIONS

This study concluded that the use of quickly dissolving P fertilizer in the Alfisol and Oxisol given in a split application method twice and three times increased the efficiency of P fertilizer in rice crop by 50%. With a dose of 75 kg ha⁻¹ (50% of recommended dose), quickly dissolving P fertilizer increased yield of rice compared with the yield of the control treatment (150 kg ha⁻¹ of SP36).

The grain yield of rice was found highest in Alfisol when P was applied twice. Meanwhile, in the Oxisol, rice grain yield was seen significant at three-time split application.

SUGGESTION

The results of this study can be used as an input for fertilizer factory to manufacture quickly dissolving P fertilizers.

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