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IMPROVEMENT OF PHOSPHATE FERTILIZATION METHOD IN WETLAND RICE

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ABSTRACT

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 eficiency 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 2008 (Association of Indonesian Fertilizer Producers, 2009).

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

The increase in the consumption of synthetic fertilizers is not only due to the extension of planting area, but also due to increase in dose per unit area. According to the observation, the range of P fertilizer used by most farmers in Indonesia is 0-300 kg ha^{-1} (Irsal *et al*. 2006). Compared to some rice-producing countries in Asia, the use of P fertilizer in Indonesia is relatively higher. In Malaysia it was at an average of 40 kg ha^{-1}, in Thailand was 33 kg ha^{-1} and in the Philippines was 15 kg ha^{-1} (Karsyno, 2006). Whereas the efficiency of P fertilizers is generally very low (Suwandi, 1988; Ball-Coelho *et al.,* 1993; Hilman and Suwandi,1989).

Most of the rice growing farmers in Jati Karanganyar and Klepu Ungaran generally applied as much as 150 kg ha^{-1} of SP36 which were applied at the time of planting. This method was performed because P fertilizer dissolves slowly (SP36 and TSP). Owing to the low solubility of the P fertilizer, the plant could not take the whole P content from soil due to the fact that most P minerals in paddy soils were found in the form of fixed P (De datta *at al.,* 1990). Moreover, Cahyono (2009) reported that in paddy soil with high level of iron and manganese solution, residual P fertilizer that remains in the soil could potentially form the occluded-P, form of P mineral most stably bound.

Improve the efficiency of P fertilizer can be reached by providing a quickly dissolving phosphate fertilizer. However, as phosphate will form a reaction with other compounds soon after released from the fertilizer, a proper method of P application, split application, should be applied.

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: H_2O-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 H_2O-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 P_0 = 150 kg ha^{-1} of SP36 given when planting (control), P_1 = 75 kg ha^{-1} of mashed SP36 given twice (at 0 and 30 dap); P_2 = 75 kg ha^{-1} of mashed SP36 given 3 times (at 0 , 15, 30 dap), P_3 = 75 kg ha^{-1} SP36 dissolved in water and sprayed four times; P_4 = 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); P_5 = 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 P_0 = 150 kg ha^{-1} of SP36 given when planting (control), P_1 = 75 kg ha^{-1} of mashed SP36 given 2 times (at 0 and 30 dap); P_2 = 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.

Table 1. 5% HSD Analysis of Growth Components of Rice

Treatments		**Growth Component**		
Soil	**Method**	**Plant Height (cm)**	**Wet Weight of Stover (g)**	**Dry Weight of Stover (g)**
Alfisol	P0	97.67a	209.67a	90.66a
	P1	98.50a	167.50e	85.29b
	P2	96.50a	150.50f	68.05d
	P3	91.50b	127.42gh	67.03e
	P4	92.00b	125.30hi	71.12d
	P5	92.30b	132.50gh	72.90d
Oxisol	P0	96.75a	165.00e	79.25c
	P1	98.25a	177.50c	67.22e
	P2	97.00a	190.00b	88.52ab
	P3	90.50b	116.47i	58.42f
	P4	92.20b	124.71hi	70.32de
	P5	91.80b	134.60gh	73.00d
	Interaction	ns)	*)	*)

Remarks: [1)] Data followed by same letter in the column indicates not significantly different (at the level of 5%). [2)] Interaction: ns) = not significant *) = significant different (at the level of 5%)

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 Alfsiol 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.

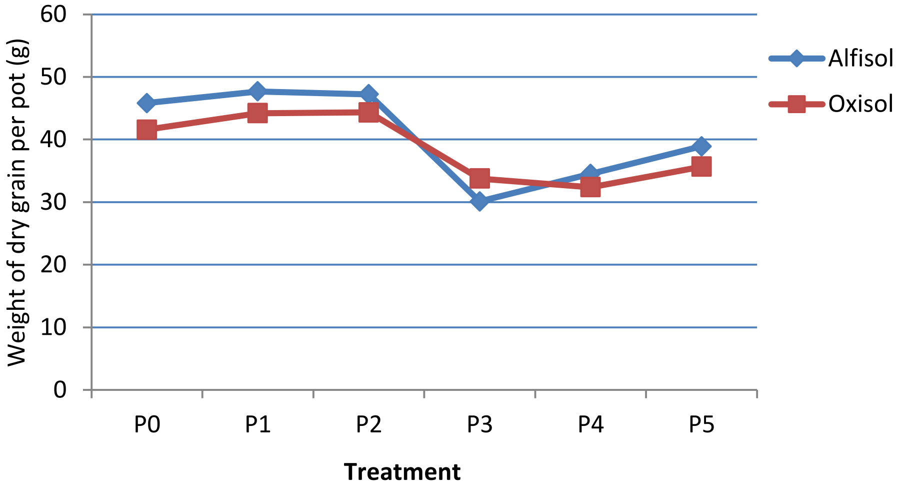

Figure 1. Effect of P application method and soil types on weight of dry grain per pot

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. the cell nucleus. (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 (Havlin *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.

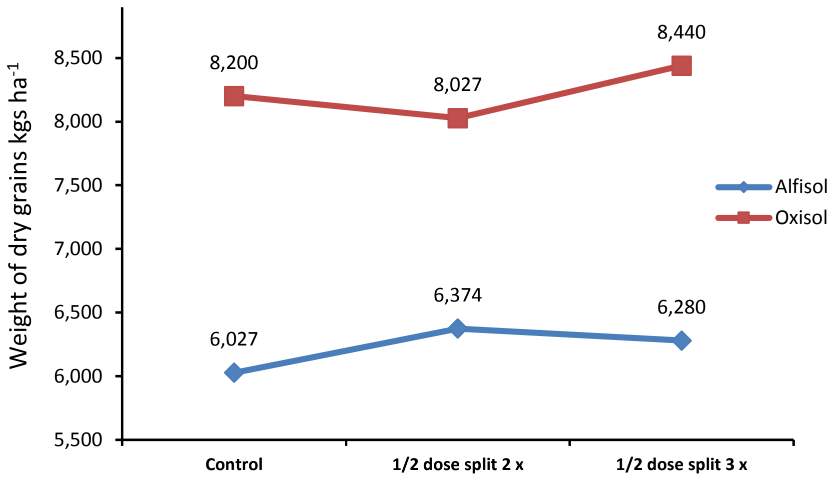

Figure 2. Effect of P application method and soil types on weight of dry grain per hectare

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

Components	P Application Methods		
	Control	½ Dose applied twice	½ Dose applied three times
Plant height (cm)	93.87a	94.82a	93.80a
Wet weight of stover (g)	187.30a	205.90b	201.60b
Dry weight of stover (g)	99.90a	113.30b	113.50b
Length of panicle (cm)	18.42a	20.88b	18.61a
Number of panicle/plant	14.00a	15.50b	16.00b
Number of pithy grain/plant	982.60a	995.40b	999.00b
Number of not filled grain/plant	104.50a	102.60a	103.00a
Number of productive tiller	11.75a	13.00a	12.00a
Number of tiller	15.50a	17.50a	17.00a
Weight of 1000 seeds (g)	252.00a	256.00a	255.50a
Harvesting age (days)	118.00a	118.00a	118.00a
Weight of grain per plot (kg)	5.30a	5.40a	5.50a
Weight of grain per hectare (kg)	7,113.50a	7,200.50a	7,360.00a

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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