Effects of pre-seed and seedling treatment by phosphorus fertilizer on growth and grain yield of lowland rice

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INTRODUCTION

Rapidly increasing costs of fertilizers and lack of purchasing credit for farmers have led to the inability to access sufficient quantity of fertilizers, particularly in developing countries, resulting in low crop production. In addition, the loss and low use efficiency of fertilizers can be noted in common fertilizer application methods such as spreading fertilizer over the field. Hence, reducing the loss of fertilizer per planting area and increasing fertilizer use efficiency are necessary. Fertilizer seed coating and seedling soaking methods have long been considered as the options to reduce the quantity of fertilizer use in agriculture; however, the information regarding these methods is still lacking. This study aimed to investigate the potential of using small quantity of chemical fertilizer to improve the early growth of rice seedlings in a lowland system.

MATERIALS AND METHODS

In a pot experiment, the shoot dry matter (DM) of *indica* rice (*Oryza sativa* L. cv. IR74) after seedling soaking and seed coating with small quantity of P fertilizers was determined on acidic low P soil for three replications. For seedling soaking trial, a 6–7 leaf seedling was soaked in 1 % and 5 % (w/v) NPK (14-14-14) or potassium dihydrogen phosphate (KH_2PO_4-KP) for 30 and 60 min, transplanted, and grown for 75 days on zero basal P fertilizer applied- and applied- soils (331.4 mg $Ca(H_2PO_4)_2$ / 3 kg soil). Other basal fertilizers were applied regarding Ros *et al*. (2000). For seed coating trial, rice seeds were coated with ground Burkina Faso phosphate rock (BPR), NPK, and KP at the rate 1.2 and 2.4 mg fertilizer per seed, directly sowed, and grown for 40 days in a pot experiment. Both studies were conducted at the Tropical Agriculture Research Front (TARF) in Ishigaki, Japan.

Another seed coating experiment was conducted at the on-station field of the University for Development Studies, Tamale, Ghana. For this, triple superphosphate (TSP)-coated seeds were prepared by mixing the seeds (GR18), soil, and TSP at a ratio of 10:10:1 with some water and air-dried before use (Photo 1). The coated seeds were cultivated on low P soil and fertilized with three rates of P fertilizers (0 P, 135 kg $P_2O_5 \cdot ha^{-1}$ as BPR and as TSP, respectively), and three rates of organic residues: control without organic residue application (NoR); 2 $t \cdot ha^{-1}$ rice straw, RS; and 1.5 $t \cdot ha^{-1}$ cattle manure, CM, for 6 replications. The experimental design was randomized complete block design. The grain yield was observed after cultivation.

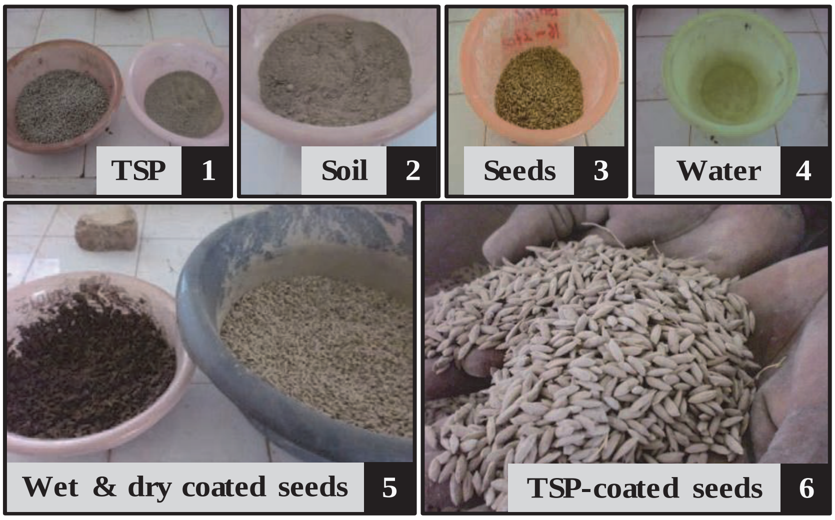

Photo 1 Materials used for fertilizer seed coating conducted in the field trial; (1) Ground TSP, (2) Soil, (3) Rice seeds, (4) Water, (5) Coated seeds during wet and air-dried conditions, and (6) TSP-coated seeds ready for use.

RESULTS AND DISCUSSION

In the pot experiment, coating seeds with KP and 30-min soaking the seedlings in KP significantly increased DM (Figures 1 and 2). From Tables 1 and 2, agronomic efficiency of P of KP-coating and soaking were higher than those of P fertilizers used for seed and seedling pre-treatment. By using KP-coating and soaking could reduce amount of P fertilizers for rice growth. Estimated P fertilizer saving rate of the seedling soaking technique was 40 % relative to that of chemical fertilizer (Fukuda *et al*., 2013). Both methods improved the early growth of rice seedlings and were expected to reduce the loss of fertilizer per planting area and to save farmers' credit for fertilizer purchasing at the early cropping season (Fukuda *et al*., 2012).

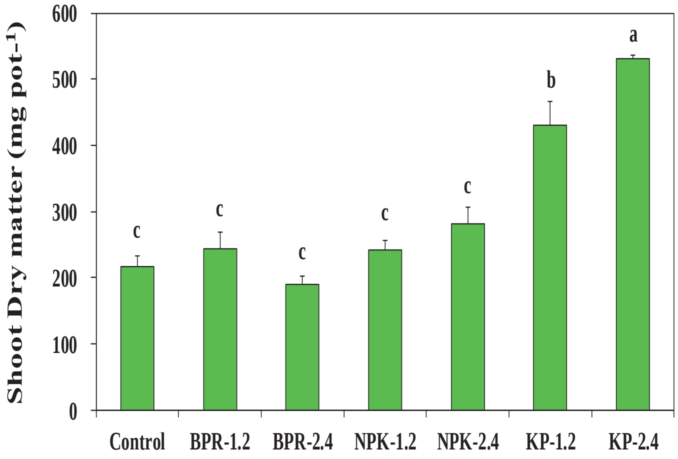

Figure 1 Shoot dry matter or rice plant (IR74) as affected by fertilizer seed coating at 40 days after sowing. Fertilizer application rates were 1.2 and 2.4 mg fertilizer seed^{-1})

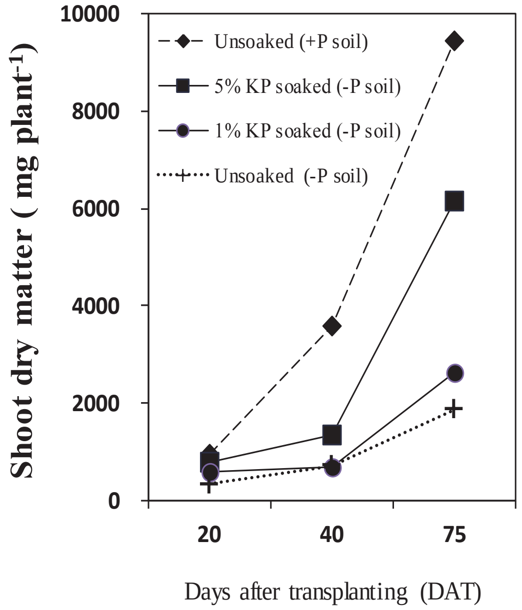

Figure 2 Shoot dry matter of rice (IR74) after soaking seedlings in 1 % and 5 % KH_2PO_4 (KP) for 30 min before transplanting compared with un-soaked seedlings grown on non P (-P) and P (+P) applied soils obtained at 20, 40, and 75 days after transplanting (DAT).

Table 1 Agronomic efficiency of P of the rice plants obtained at 20 and 40 days after sowing as affected by fertilizer seed coating (Pot experiment)

Coating fertilizer	Applied P (mg/seed)	Agronomic efficiency of P (AEP) † Days after sowing (DAS)	
		20	40
BPR-1	0.18	32	151
BPR-2	0.36	(nil)	(nil)
NPK-1	0.07	(nil)	349
NPK-2	0.15	(nil)	434
KP-1	0.27	64	781
KP-2	0.55	24	575

†Agronomic efficiency of P = ($DM_{amended}$ - $DM_{control}$)/(Total P added)

Table 2 Agronomic efficiency of P of rice plants obtained at 75 days after transplanting as affected by seedling soaking for 30 min before transplanting (Pot experiment)

Soaking solution	Applied P/seedling† (mg)	Shoot DM (mg)	Agronomic efficiency of P (AEP)††
Non-soaked (-P soil)	0.0	1,854	-
1% KP	452	2,622	1.71
5% KP	2261	6,142	1.90
1% NPK	122	1,602	-2.10
5% NPK	612	1,759	-0.16
Non-soaked (+P soil)	17.5	9,442	433

†Fertilizer solution 3 L per 15 seedlings, ††Agronomic efficiency of P = (DM amended - DM control)/(Total P added)

In the on-station trial, TSP-coated seeds showed increased rice grain yield, particularly in BPR and RS co-applied soils (Figure 3). The increased grain yields were 449 and 481 kg·ha^{-1} in BPR and TSP fertilized soils without OR application, respectively. Under RS application, increased yields were 657 and 797 kg·ha^{-1} in P0 and BPR application, respectively. Under CM application, the increased grain yield was 263 kg·ha^{-1} in non-P treatment (Table 3). This implied the positive results of using the seed coating technique to improve the rice grain yield. Moreover, the seed coating could be used either when inorganic and organic fertilizers are being solely- or co-supplied to the soils.

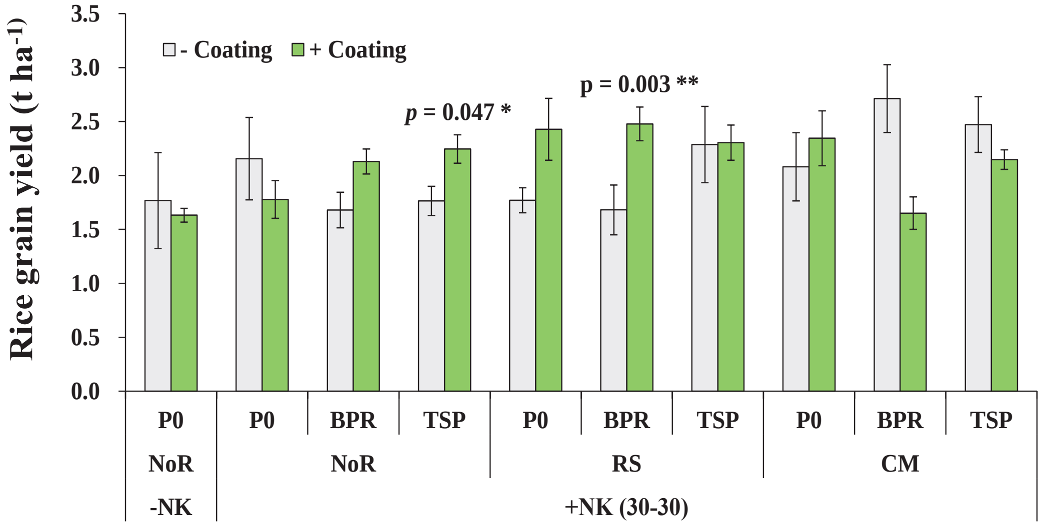

Figure 3 Grain yield of rice (GR18) as affected by seed coating under various co-applications of inorganic fertilizer and organic residue at the on-station experiment. Bars indicate SE (n = 4).

Table 3 Increased rice (GR18) grain yield as affected by triple superphosphate (TSP) seed coating compared to that of uncoated seeds at the on-station experiment

Basal fertilizer	Organic residue	P Fertilizer	Increased grain yield (kg ha^{-1})	Significance
-NK	NoR	P0	-	
+NK	NoR	P0	-	
		BPR	449	*
		TSP	481	*n.s*
	RS	P0	657	*n.s*
		BPR	797	**
		TSP	19	*n.s*
	CM	P0	263	*n.s*
		BPR	-	
		TSP	-	

*, ** Significance at $p < 0.05$ and 0.01, respectively and *n.s.* = non-significance (Student's t-test)

According to our on-station experiments, coating rice seeds with small amount of TSP increased rice grain yield. Other benefits of the method, such as reducing the amount of used fertilizer and labor, saving money for purchasing fertilizer, easy handling, and adding P elements and other nutrient compounds to soil, have been also expected.

The fertilizer seedling soaking method has been tested only in a pot experiment. The results indicated positive effects on the early growth of plants and improved the agronomic efficiency of P; however, further investigations conducted in fields are necessary. Similarly, the beneficial effects of soaking method are expected through the returning of fertilizer-soaking solution to the field and strengthening young rice seedlings to cope with low P in soils. From our calculation, 3 L of 5% KP could be used for 500 seedlings of rice plant.

In Ghana, very low rate of P fertilizer application and zero-fertilization are common and become typical constraints of rice production under the ordinary rice cultivation system. Although, the utilization of locally available organic resources has been well documented for improving soil and crop productivity (Issaka *et al*., 2012; FAO 2006; Buri *et al*., 2005). In Guinea Savanna agro-ecological zone, where seed direct sowing is a major system of rice cultivation, the fertilizer seed coating technique should be useful. Conversely, seedling soaking can be adopted under the transplanting system that is practiced in the lowlands of the equatorial forest zones.

The advantages of utilizing small amount of chemical fertilizer in lowland rice cultivation system included facilitation of small-scale farmers to maintain desired crop production in a short term when fertilizer sources and labor are limited and helping farmers in delayed fertilizer application until they can obtain all the fertilizers needed for the crops. Moreover, the costs for handling of seed coating and seedling soaking techniques are relatively lower than those for the complete doses of chemical fertilizer for crops. Therefore, appropriate selection of the types or forms of accessible fertilizers and addition of seed and seedling treatment options such as soaking or coating might facilitate farmers to obtain more yield production while lowering the expenditure for rice production.

CONCLUSIONS

The utilization of small quantity of fertilizer could increase the early growth of plant and crop productivity, reduce losses, and increase the efficiency of fertilizer P. Applying small quantity of fertilizer directly to the seeds or seedlings might benefit farmers in managing fertilizer sources and the time of application when sufficient amount of fertilizers are not easily available.

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