Alternative Fertilizer Utilizing Methods for Sustaining Low Input Agriculture

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/53578

1. Introduction

1.1. Declining soil fertility in low input agriculture

Improvement of soil fertility and plant nutrition to sustain adequate yield of crop is essential since soil degradation has been identified as a major constraint and a root cause of declining crop productivity in many developing countries *e.g.* Sub-Saharan Africa (SSA). Sanchez [1] reported very high rate of annual depletion for 22 kg nitrogen (N), 2.5 kg phosphorus (P), and 15 kg potassium (K) per hectare of cultivated land or an annual loss equivalent to 4 billion U.S. dollar in fertilizer in 37 African countries over three decades. Due to large quantities of nutrients are removed from soil through crop harvest without sufficient supply of fertilizers and manure causing low input agriculture has been unfortunately implemented by farmers and the consequences of low crop productivity would increase food insecurity. In many regions, local farmers lack of sufficient fertilizer, money for purchase, access to the credit, and transportation resulting to low in fertilizer input and a gradual decrease of soil fertility [2]

1.2. Limitation on replenishing soil fertility and increasing crop yield

Numbers of strategies have been used to restore soil fertility including traditional application of inorganic fertilizers or use of organic fertilizing materials such as plant residues (*i.e.* rice straw and husk), green manure, and animal manure [3]. Uses of crop management system such as cover crops, legumes, mulching, fallow, and agroforestry are well documented [4]. Moreover, adoption of high yielding and genetically improved crop varieties is a good option for increasing yield productivity.

Amongst ways of soil fertilization, increasing use and continuous application of inorganic fertilizers seemed to be limited because fertilizers in Africa are 2 – 6 times more expensive than that of in Europe, North America, and Asia [1]. Applying plant residue or organic biomass to soil has influenced on soil nutrients, soil physical condition, soil biological activity, and crop performance. However, applying these organic fertilizing materials such as rice straw and husk, green manure or organic biomass (*i.e.* leaf biomass) to soil are not attractive to farmers compared to straw burning due to short term effects of organic materials on crop yield are often small. Cutting and carrying biomass to the field also require high labor and cost. On other hands, crop residues have high economic value and have been used as livestock feed and fuel so leaving crop residues in the field is seldom. Even though, incorporation of rice straw which is abundant and widely spread in the rice field can return and reserve most of nutrients to soil particularly N, P, K, S, and Si in long term [5]. Tobita et al. [6] and Issaka et al. [3] reported that adding rice straw to rice system could gain approximately 20 percent of N and P, and most K relative to the needs of applied chemical fertilizers in the Northern region of Ghana where rice cultivation is the most prominent.

Crop management such as tree fallow system is not attractive for farmer because they prefer better land use alternative owing to population pressure particularly in the humid and tropical regions. Besides, improved fallows have not been proved yet on their benefits in semiarid tropics of Africa. The potential of fallow system on shallow and poorly drained soil is poor [1]. Growing leguminous plants as fallows before cropping season or intercropping with crop is effective crop management to accumulate N for consecutive crops. However, it should be noted that effects of plant residues on soils and crops depend on the quality (*i.e.* carbon/nitrogen ratio, lignin, and polyphenol contents) and the decomposition rates of residues which in turn control the nutrient release rates. Tian et al. [7] found that the contribution of low quality plant residues as mulching on maize grain yield and protein concentration was lowest in comparison to intermediate or high quality residues on Oxic Paleustalf soil in Nigeria.

Animal manures from poultry, pig, cow, goat, and sheep contain all the major nutrients. These manures are very good materials for improving soil fertility and crop productivity [8,3]. Tobita et al. [6] reported that if only 20 percent of total livestock organic resource estimated in Ghana was utilized, so it could replace the requirement for chemical fertilizer in rice cultivation system entire the Northern region. However, gathering bulky dung of livestocks or excreta (dung and urine) from grazing livestock was difficult particularly in rural area where these manures are not sold and scarce [9]. Unlikely, poultry manure may be valid in urban center where intensive production of poultry has being implemented. In present, poultry manure is on high demand but its quantity is not enough for farmer’s need resulting farmers have to pay in advance before manure will be delivered to the field [3,10].

1.3. Alternative P fertilizer utilizing methods

Many soils in sub-humid and humid tropics including SSA have very low levels of natural P, thus P fertilization is essential for maintaining desired level of crop yield. Buresh et al. [2] indicates that input of P fertilizers is required to replenish P stock in highly P deficient soils rather than only dependence on P cycling through organic-based system. However, P fertilizer management became more difficult because the only natural P source *i.e.* phosphate rock (PR) for manufacturing P chemical fertilizers is non-renewable and finite resource. Though, ground PR can be directly used as P fertilizer but it slowly releases P in acid soils resulting in gradual build up P in numbers of cropping season.

Phosphate rock, a natural form of mineral apatite contains not readily phosphate content for plant. Phosphate rock must be treated to convert phosphate to water soluble of plant available forms [11]. Major solid water soluble P fertilizers are single superphosphate (SSP), triple superphosphate (TSP), monoammonium phosphate (MAP), and diammonium phosphate (DAP). In fully acidulated commercial grade P fertilizers, SSP is made by adding sulfuric acid to PR. Triple superphosphate containing about 2 times of P concentration as SSP, is made by adding phosphoric acid to PR. Ammonium phosphate fertilizers are produced by passing amnonia through phosphoric acid. The compounds of P within water soluble fraction are mainly in the forms of monocalcium phosphate or MCP [$Ca(H_2PO_4)_2.2H_2O$] in SSP and TSP, $NH_4H_2PO_4$ in MAP, and $(NH_4)_2HPO_4$ in DAP in which over 90% of total P concentrations are water soluble P [12,13]. Diammonium phosphate, MCP, and TSP can be accounted as a half of phosphate-based fertilizer applications worldwide [11].

Continuous mining PR and increasing use of P chemical fertilizers might not be responsible management of resource use. More efficient uses of P fertilizers in agriculture have been paid intention. Phosphorus efficient plants are recently developed through plant breeding or genetic modification, but more P efficient plants which are modified root growth and architecture, manipulated root exudates, or managed plant-microbial association such arbuscular mycorrhizal fungi and microbial inoculants are not common, and still have less potential trade-off [14]. So far, fertilizer management still has a significant contribution to overall agricultural crop production, household's farming system, farmers, and the rural poor [4]. In addition, the potential of genetically improved crops cannot be achieved when soils are depleted of nutrients. Sanchez [1] stated that improved crop varieties have responsible for only 28% yield increases in Africa, but 66-88% in Asia, Latin America, and the Middle East when rates of adoption for new improved varieties have been similar during the last four decades. Therefore, it is necessity to find alternative fertilizer utilizing methods to increase and sustain crop yield in low input agriculture and these methods should be affordable for local farmer.

2. Materials and methods

This work gathered information from published papers (secondary data) focusing on the utilization of small quantity of fertilizer to boost crop productivity in wide-range of climates and soil conditions. The effective methods have been revealed including 1) fertilizer microdose application, 2) addition of small amount of fertilizer to the seed by coating, 3) increase of nutrient concentration in seedling by soaking in, or dipping seedling in the nutrient slurry. Moreover, two experiments were conducted to investigate the effects of fertilizer seed coating and fertilizer seedling soaking on the early growth of rice (*Oryza sativa* cv. IR74) grown on acidic P deficit soil.

2.1. Fertilizer seed coating method

Treatments were triplicated and comprised of 1) control_uncoated; 2) control_oil; 3) Burkina Faso phosphate rock (BPR); 4) Potassium dihydrogenphosphate (KH_2PO_4) and 5) NPK (14-14-14). The 15 seeds of IR74 rice were coated by 2 levels of ground fertilizer (18 or 36 mg) using vegetable oil as adhesive material. By this method, ground fertilizers were mixed with seeds at approximately 1.2 and 2.4 mg per seed. Coated seeds were sowing directly into moistened soil. Soil used in this experiment was collected from Tropical Agriculture Research Front (TARF). Massive amount of soil was collected, air dried, and sieved to 2 mm. Five hundred gram of air dry soil was weighed into bag. Soil properties were $pH_{H2O,}$ 4.83; EC, 6.03 mS m^{-1}, and Bray 1-P, 1.66 mg kg^{-1}. The basal nutrients were mixed to each soil (mg kg^{-1} soil); $Na_2MoO_4.2H_2O$; 0.36; H_3BO_3, 0.71; $CuSO_4.5H_2O$, 5; $ZnSO_4.7H_2O$, 10; $MnSO_4.H_2O$, 15; $MgSO_4.7H_2O$, 21; $CaCl_2.2H_2O$, 71; K_2SO_4, 142; NH_4NO_3, 200, respectively. Percentage of plant emergence was monitored at 5, 10, and 15 day after sowing (DAS), and then thinned to 4 seedlings. Watering was done daily. Plant height, tiller number, and leaf age were measured at 20 and 40 DAS. Two rice plants were sampled for shoots and roots from each treatment at 20 and 40 DAS, oven-dried to obtain dry matter, and ground prior to further chemical analysis. Total P in plant organs was determined after dry-ashing procedure.

2.2. Fertilizer seedling soaking

Treatments were triplicated and comprised of 1) control (+P soil); added P soil [adding $Ca(H_2PO_4)_2$; 331.4 mg] with non-fertilizer soaked rice (conventional method by farmers); 2) control (-P soil); non P added soil with non-fertilizer soaked rice, and other treatments were conducted on non added P soil with soaked rice by 3) Potassium dihydrogenphosphate (KH_2PO_4) solution; 4) NPK (14-14-14) solution. Five seedlings of 6-7 leaf age rice were soaked in 1 % and 5% (w/v) of each fertilizer solution with 2 soaking periods (30 min or 60 min). Freshly soaked seedlings were transplanted directly into flooded soil. Rice seedlings were thinned to 3 seedlings at 7 days after transplanting (DAT). Rice seedlings used in this experiment were grown on fully fertilized soil for 3 weeks before soaking and transplanting into pots. Three kilogram of 2 mm sieved soil was weighed into 1/5,000 are-pot. The basal nutrients were mixed to soil at the same rate of previous experiment described above. Water was added daily to maintain submerged/flooded condition. Tiller number and leaf age were monitored at 20 and 40 DAT. Plant height was measured at 20, 40, and 75 DAT, and then a rice plant was harvested for shoot and root at 20 and 40, and 75 DAT, then oven-dried to obtain dry matter, and ground prior to further analysis for total P concentration after dry ashing procedure.

2.3. Data and statistical analysis

The JMP 9.0.0 (SAS Institute Inc., USA) was used to perform ANOVA and compare the means by the Tukey Kramer HSD for plant growth (height, tiller number, leaf age), shoot and root DM, P concentration, P uptake.

3. Results and discussion

3.1. Fertilizer microdosing

Fertilizer microdosing or known as microdose fertilizer application or point application is an application method of small, affordable quantity of fertilizer with the seed at planting time or as top dressing 3-4 weeks after emergence [15]. This application method has been developed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and its partners to improve inorganic fertilizer use of farmers in Sahel region, Africa. This method is documented to enhance fertilizer use efficiency, high probability of yield response, crop productivity with favorable fertilizer per grain price ratio rather than spreading fertilizer over the field, root systems, and soil water capture [15,16].

Microdosing soil with fertilizer uses about one-twentieth of the amount of fertilizer used on corn, and one-tenth of the amount used on wheat in America. Particularly, this pity amount often doubles crop yields on African soils due to they are starved of macronutrients such as N, P, and K. Small doses of fertilizers, about a full bottle cap or a three-finger pinch per a hole of planting are required and this amount equals to 6 gram of fertilizer or about 67 pound of fertilizer for every 2.5 acres or 30 kg fertilizer per hectare. Farmers just prepare small holes before the rain starts when soils are still hard. Later, fertilizers and seeds shall be put in the hole when the rain begins and the soils provide enough moist condition, encouraging root growth [15].

Successful works have been showed through Tabo et al. [17] who reported the yields of sorghum and millet were increased from 44 to 120% after adoption of fertilizer microdosing in harsh semi-arid climate of Mali, Burkina Faso, and Niger, the western Africa where soils were sandy and low in fertility with 500-800 mm annual rainfall. Farmers, themselves, selected plant varieties and types of fertilizer which were differed among countries and availability of fertilizer on the local markets. Rates of fertilizer micro-dose per hill of planting were 4 g of NPK (15-25-15) in Burkina Faso, 4 g of NPK (17-17-17) in Mali, and 6 g of NPK (15-15-15), 2 g DAP (18-46-0), and 2 g DAP + 1 g Urea (46-0-0) in Niger.

Bagayoko et al. [16] compared the effectiveness of fertilizer microdosing among no fertilizer microdosing check (farmer's practice), blank (zero fertilizer application), microdosing only, microdosing plus 20 kg P_2O_5 ha^{-1} and 30 kg N ha^{-1} in wide range of climates and soils in Burkina Faso, Mali, and Niger. It was found that microdose fertilizer application increased yields of grain and stover of pearl millet across wide range of climates and soils in Burkina Faso, Mali, and Niger. Additional supply of 20 kg P_2O_5 ha^{-1} and 30 kg N ha^{-1} had much increased grain and stover yields of pearl millet. Fertilizer microdose rates were 4 g of NPK (15-15-15) or equivalent to 62.5 kg ha^{-1} in Burkina Faso, 2 g of DAP (18-46-0) or equivalent to 33.2 kg ha^{-1} in Mali, and 4 g of NPK (15-15-15) or equivalent to 62.5 kg ha^{-1} in Niger. Nutrient sources of N as urea (46-0-0) and P as 0-46-0 were additionally supplied.

Hayashi et al. [18] demonstrated that millet farmers could delay inorganic fertilizer application or timing of using the micro-dosing technology from 10 to 60 days after sowing without the reduction of profits and their economic returns relative to the non-fertilizer applied treatment. Fertilizer microdose rate was applied 6 g of NPK (15-15-15) per millet hill or 60 kg NPK per hectare for an on-station trial, and 2 g of DAP (18-46-0) per millet hill or 7.24 kg of DAP per hectare for an on-farm field trial. The results stressed that local farmers had more options of fertilizer utilization timing. Delayed fertilizer microdosing still increased millet production and helped farmers who were not able to supply fertilizer at sowing or suffered from shortage of labors and fertilizers. The outcome of this work showed more flexibility in managing money and labor resources for purchasing fertilizer. Microdosing technique was more advantage than other methods to increase crop productivity for subsistence farmer in harsh Sahel region.

3.2. Fertilizer seed coating

According to the survey on inorganic fertilizer application practices by farmers in Fakara, Niger, West Africa [18], it showed that every farmer's household applied fertilizer by mixing fertilizer with seed before planting. Although, mixing rate of fertilizer and seed was very low (fertilizer/seed = 0.2) or equivalent to 0.9-1.8 kg of fertilizer per hectare indicating that farmers have attempted to mix very little fertilizer which they could afford with seeds in order to plant as vast an area as possible. Farmers were aware of fertilizing soil but they were not able to purchase sufficient amount of fertilizer due to some credit and financial problems. Amount of applied fertilizer at 0.9-1.8 kg by farmer's practicing was less than that of recommended level at 9 kg P_2O_5 per hectare by microdosing method which was essential to obtain the optimal improvement of millet production. Therefore, farmers could not achieve desired levels of crop, but some residual effects on P in soil could be expected after this kind of practices. From this view point, it should be noted that farmers really lacked of adequate amount of fertilizer to be used although an effective fertilizer utilizing method such as microdosing has been introduced, but it still consumes quantity of fertilizer and labor. Therefore, another fertilizer utilizing method should be considered in order to reduce much quantity of fertilizer and even labor requirement.

Up-to date, a method such fertilizer seed coating with use of very pity quantity of fertilizer has been interested as an alternative method [15] This method applies ground fertilizer on seed using sticky adhesive materials to firmly attach fertilizer on seed. Fertilizer seed coating may have advantage over mixing fertilizer with seed due to lower labor requirement and high concentration of seed nutrients may be easily raised after firmly coating seed. The release of nutrients from fertilizer coated seed is expected to be much closure to plant root rather than mixing fertilizer and seed before planting. Besides, high concentration of seed nutrients are important for plant establishment in soil which low in nutrient availability, as a massive root system is needed before soil can supply sufficient nutrients to meet the needs of plant [19].

Ros et al. [19] pointed out that the effective of P fertilizer on early plant growth was enhanced by coating rice seed (*Oryza sativa* cv. IR66) with various P fertilizers. Inorganic P fertilizers used for seed coating included single superphosphate (SSP), phosphate rock (PR), monoammonium phosphate (MAP), and potassium phosphate (KH_2PO_4; PP). The rates of applied P fertilizer in mg P per seed were 3.8 coating-SSP; 1.2 coating-PR; 3.4 coating-MAP;

3.7 coating-PP and methyl cellulose glue at the rate of 5% (w/v) was used as adhesive material. The results revealed that coating rice seed increased shoot dry matter (DM) but decreased root DM at 20 days after sowing (DAS) and the effect of coating persisted to 40 (DAS), root length and DM also increased, moreover shoot DM increased 400-870% at this stage. Coating rice seed with PR was more promising for stimulating early growth of rice on low P soils. Coating rice seed by 1.2 mg PR per seed or 0.5 kg PR per kg of seed was not harsh to seedling emergence, but increased a fourfold higher shoot and root growth of rice.

From our works [10] attempted to coat rice seed (*Oryza sativa* cv. IR74) by 1.2 or 2.4 mg per seed of ground fertilizers: Burkina Faso phosphate rock (BPR), Potassium Dihydrogenphosphate (KH_2PO_4), NPK (14-14-14) before direct sowing. The results revealed that coating rice seed by powdered KH_2PO_4 for 1.2 or 2.4 mg per seed using vegetable oil as adhesive material could increase plant DM to 174 and 215% (Table 1, Figure 1, and Photo 1), height to 142 and 131%, and leaf age to 118 to 120% (Table 2) at 40 DAS, shoot P concentration to 172 and 226%, P uptake to 136 and 160% at 20 DAS (Table 1), and shoot P concentration to 196 and 168%, and P uptake to 336 and 359% compared to the control (without coating) at 40 DAS (Table 1), respectively. Moreover, plant root DM and P uptake increased to 164 and 199% with 2.4 mg KH_2PO_4 compared to the control (without coating) at 40 DAS, respectively (Table 3).

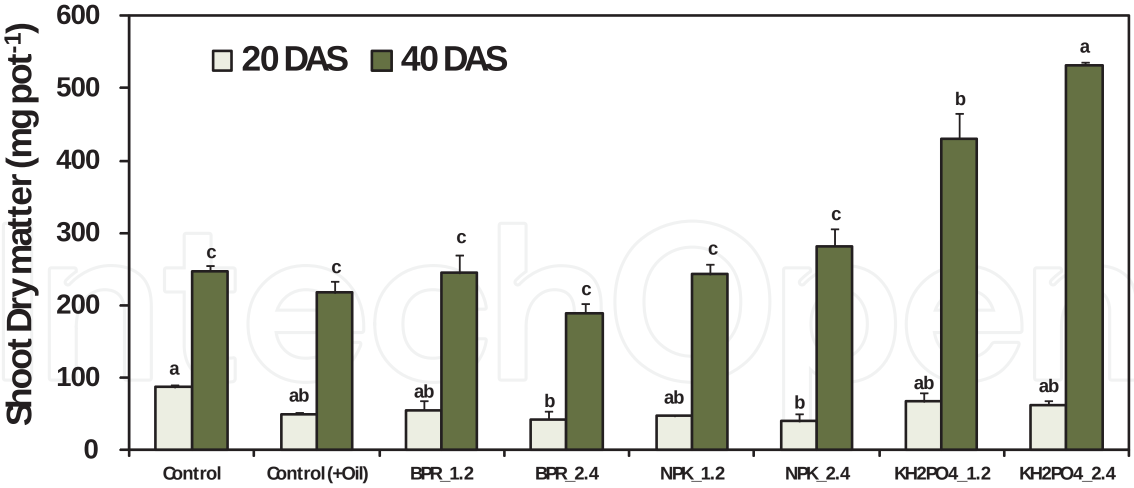
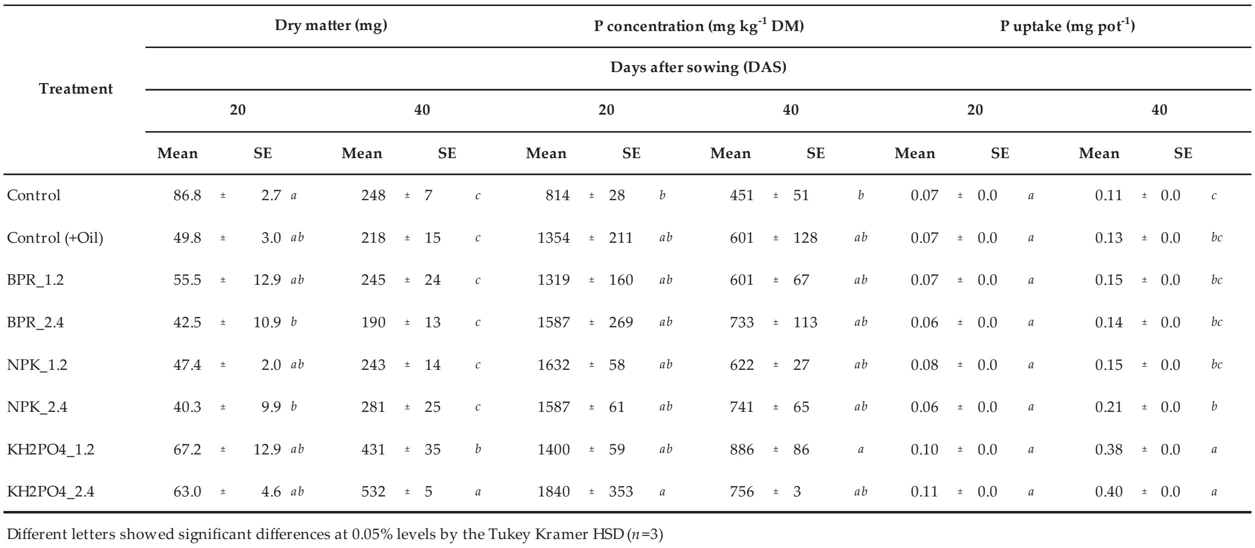


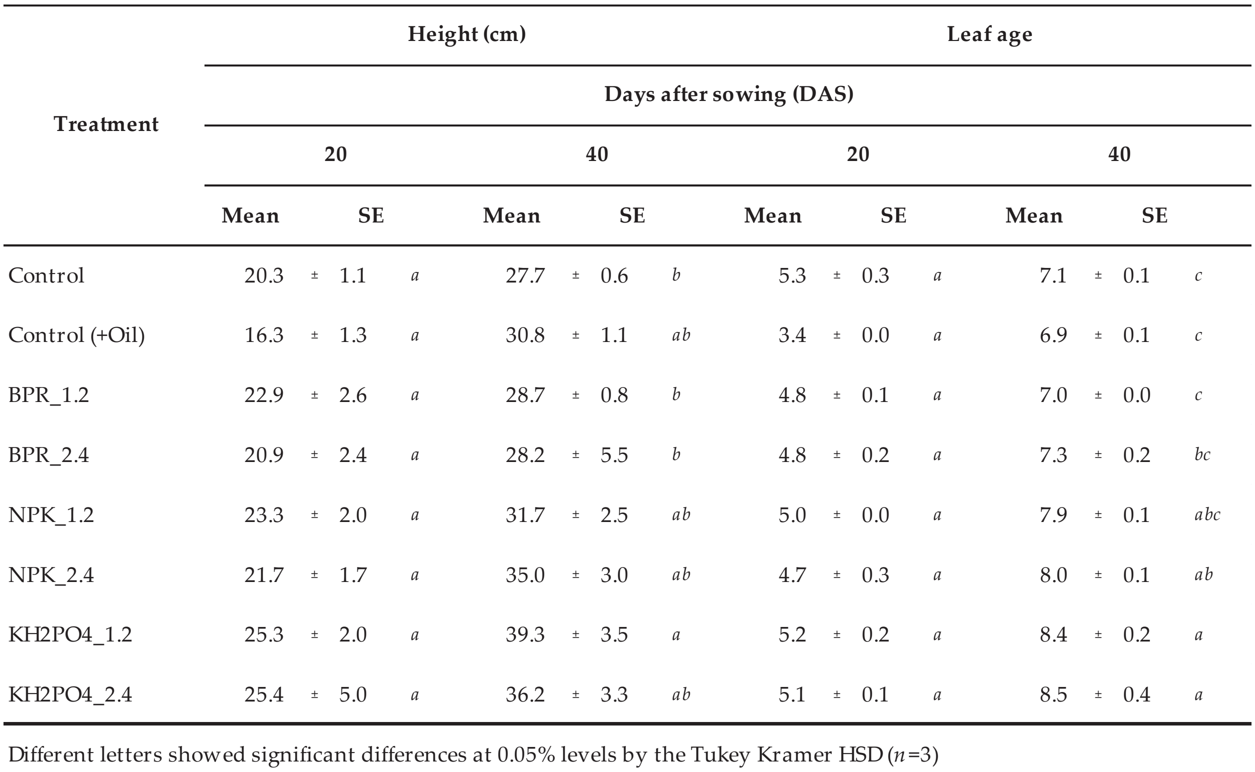
Figure 1. Shoot dry matter of rice after fertilizer seed coating



Treatment	Dry matter (mg)						P concentration (mg kg^{-1} DM)						P uptake (mg pot^{-1})					
	Days after sowing (DAS)																	
	20			40			20			40			20			40		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Control	86.8	± 2.7	*a*	248	± 7	*c*	814	± 28	*b*	451	± 51	*b*	0.07	± 0.0	*a*	0.11	± 0.0	*c*
Control (+Oil)	49.8	± 3.0	*ab*	218	± 15	*c*	1354	± 211	*ab*	601	± 128	*ab*	0.07	± 0.0	*a*	0.13	± 0.0	*bc*
BPR_1.2	55.5	± 12.9	*ab*	245	± 24	*c*	1319	± 160	*ab*	601	± 67	*ab*	0.07	± 0.0	*a*	0.15	± 0.0	*bc*
BPR_2.4	42.5	± 10.9	*b*	190	± 13	*c*	1587	± 269	*ab*	733	± 113	*ab*	0.06	± 0.0	*a*	0.14	± 0.0	*bc*
NPK_1.2	47.4	± 2.0	*ab*	243	± 14	*c*	1632	± 58	*ab*	622	± 27	*ab*	0.08	± 0.0	*a*	0.15	± 0.0	*bc*
NPK_2.4	40.3	± 9.9	*b*	281	± 25	*c*	1587	± 61	*ab*	741	± 65	*ab*	0.06	± 0.0	*a*	0.21	± 0.0	*b*
KH2PO4_1.2	67.2	± 12.9	*ab*	431	± 35	*b*	1400	± 59	*ab*	886	± 86	*a*	0.10	± 0.0	*a*	0.38	± 0.0	*a*
KH2PO4_2.4	63.0	± 4.6	*ab*	532	± 5	*a*	1840	± 353	*a*	756	± 3	*ab*	0.11	± 0.0	*a*	0.40	± 0.0	*a*

Different letters showed significant differences at 0.05% levels by the Tukey Kramer HSD (*n*=3)

Table 1. Shoot dry matter, P concentration, and P uptake of rice plant at 20 and 40 days after sowing as affected by fertilizer seed coating



Treatment	Height (cm)						Leaf age					
	Days after sowing (DAS)											
	20			40			20			40		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Control	20.3	± 1.1	*a*	27.7	± 0.6	*b*	5.3	± 0.3	*a*	7.1	± 0.1	*c*
Control (+Oil)	16.3	± 1.3	*a*	30.8	± 1.1	*ab*	3.4	± 0.0	*a*	6.9	± 0.1	*c*
BPR_1.2	22.9	± 2.6	*a*	28.7	± 0.8	*b*	4.8	± 0.1	*a*	7.0	± 0.0	*c*
BPR_2.4	20.9	± 2.4	*a*	28.2	± 5.5	*b*	4.8	± 0.2	*a*	7.3	± 0.2	*bc*
NPK_1.2	23.3	± 2.0	*a*	31.7	± 2.5	*ab*	5.0	± 0.0	*a*	7.9	± 0.1	*abc*
NPK_2.4	21.7	± 1.7	*a*	35.0	± 3.0	*ab*	4.7	± 0.3	*a*	8.0	± 0.1	*ab*
KH2PO4_1.2	25.3	± 2.0	*a*	39.3	± 3.5	*a*	5.2	± 0.2	*a*	8.4	± 0.2	*a*
KH2PO4_2.4	25.4	± 5.0	*a*	36.2	± 3.3	*ab*	5.1	± 0.1	*a*	8.5	± 0.4	*a*

Different letters showed significant differences at 0.05% levels by the Tukey Kramer HSD (*n*=3)

Table 2. Height and leaf age of rice plant at 20 and 40 days after sowing as affected by fertilizer seed coating

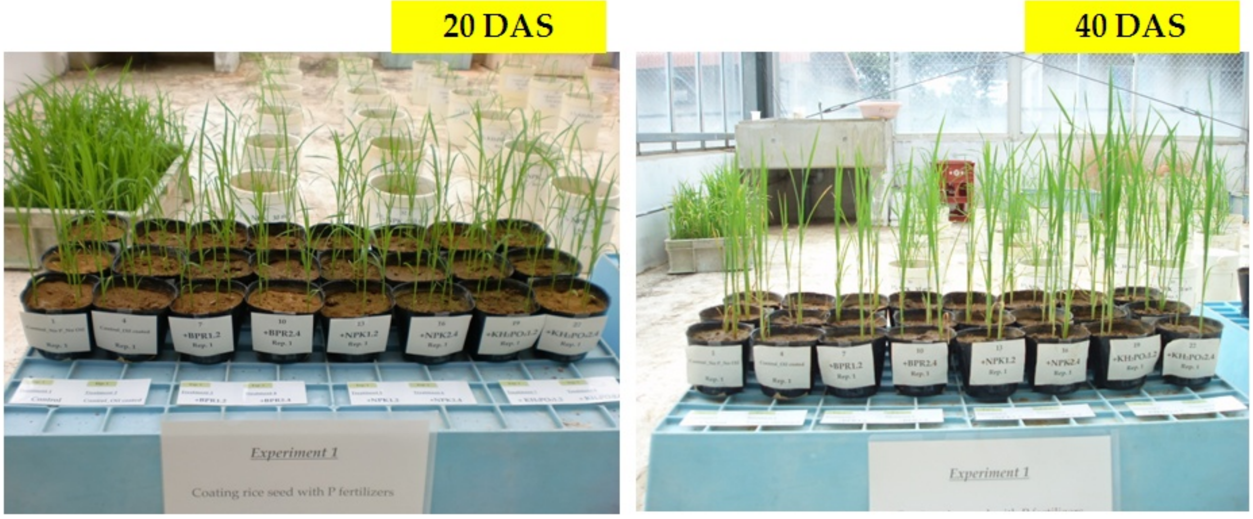


Photo 1. The growth of rice plant after fertilizer seed coating

Treatment	Dry matter (mg)						P concentration (mg kg^{-1} DM)						P uptake (mg pot^{-1})					
	Days after sowing (DAS)																	
	20			40			20			40			20			40		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Control	14.2	± 1.5	a	176	± 14	*b*	790	± 74	*a*	604	± 14	*a*	0.011	± 0.0	*a*	0.11	± 0.0	*bc*
Control (+Oil)	7.0	± 1.1	b	129	± 0.1	*b*	1032	± 52	*a*	714	± 76	*a*	0.007	± 0.0	*a*	0.09	± 0.0	*c*
BPR_1.2	6.2	± 0.9	b	146	± 13	*b*	1059	± 133	*a*	753	± 70	*a*	0.006	± 0.0	*a*	0.11	± 0.0	*bc*
BPR_2.4	6.0	± 1.4	b	148	± 26	*b*	1377	± 921	*a*	808	± 104	*a*	0.014	± 0.0	*a*	0.12	± 0.0	*bc*
NPK_1.2	6.2	± 0.5	b	148	± 23	*b*	1093	± 104	*a*	786	± 70	*a*	0.007	± 0.0	*a*	0.12	± 0.0	*bc*
NPK_2.4	7.1	± 1.6	b	133	± 23	*b*	1441	± 248	*a*	807	± 60	*a*	0.009	± 0.0	*a*	0.11	± 0.0	*bc*
KH2PO4_1.2	9.5	± 1.3	ab	229	± 39	*ab*	1035	± 89	*a*	856	± 63	*a*	0.010	± 0.0	*a*	0.19	± 0.0	*ab*
KH2PO4_2.4	7.8	± 0.9	b	288	± 11	*a*	1259	± 218	*a*	739	± 28	*a*	0.009	± 0.0	*a*	0.21	± 0.0	*a*

Different letters showed significant differences at 0.05% levels by the Tukey Kramer HSD (*n* =3)

Table 3. Root dry matter, P concentration, and P uptake of rice plant at 20 and 40 days after sowing as affected by fertilizer seed coating

Coating dry rice seed by ground/powdered KH_2PO_4 with seed with small volume of vegetable oil extended the growth of seedling up to 40 DAS in soil where none of P fertilizer was applied. Delayed plant emergence could be found at 5 DAS but this problem was overcome after 10 days. The growth of plant was enhanced after 20 days compared to un-coated plant. Coating rice seed by 2.4 mg powdered KH_2PO_4 per seed or 92 g KH_2PO_4 per kg of seed (averaged seed weigh = 26.08 mg) was expected to be low cost and easily handled.

Use of BPR or NPK, some procedures such as pre-germination or dormancy break of rice seed might be required to increase water imbibition, and subsequent emergence, and root growth prior to nutrient released from these P fertilizers could supply adequate amount of P to plant without damaging effect on the growth.

3.3. Fertilizer seedling dipping/soaking

Lowland rice soils in the tropics are P deficient and the management of P fertility in soils depends on P source, timing, and application method. More effective methods for P application are surface broadcasting or incorporation of fertilizer before planting rather than deep placement of P at 10 or 20 cm depth in planting hill or between planting rows. While, the best timing of applying P fertilizer for rice is at transplanting with total dose of a basal P because plant requires more P at early growth stage. Sufficient P supply may increase better root development and tillering. However P fertilizer application may also be delayed, but it should be before the vigorous stage of tillering. Split application method of P is less effective and not necessary due to P mobility from old leaves to new ones. In contrast, applying P fertilizer 2 weeks before panicle initiation of rice plant is as effective as that applied at transplanting. It is considered that 8-20 % of fertilized P to soil is recovery by rice and remaining 80-90% of applied P can benefit to succeeding crops [20].

Methods of P fertilization with use of small quantity such as fertilizer seedling soaking/dipping has drawn attention in some countries [21]. Lu et al. [21] stated that dipping rice seedling in phosphate fertilizer was a traditional method in China. Farmers generally applied P by mixing with fertile soil or compost in a portion of 1:1 or 1:5 and water to make a paste or slurry. Rice seedlings were dipped into this slurry before transplanting however it was necessary to avoid damage of root during dipping. Another work by Katyal [22] cited by [21] showed dipping seedling roots might provide 40-60% saving on P fertilizer for maintaining the same level of yield. Ling [23] cited by [21] showed that P fertilizer recovery has been markedly increased following dipping rice seedling roots by using ^{32}P experiment. The effects of dipping/ soaking seedling in P fertilizer may be attributed to a direct contact of rice roots with P fertilizer resulting in a greater gradient of P concentration was established and would facilitate the diffusion of P to the roots [21]. Since, rice plant during early growth stages required more P, but available P from soil could not meet the needs of plant at this stage. Therefore, enhancing plant's early growth stage by fertilizer seedling soaking/dipping would increase root development and tillering and in turn increased rice grain yield, particularly in P deficit soils [20]. Besides, De Datta et al. [20] reported that dipping rice seedling root in a P-soil slurry reduced fertilizer requirement by 50%. Katyal [22] cited by [20] indicated P fertilizer utilization was reduced to 50% without decreasing yield with this dipping seedling method. Therefore, application of P to root in form of a slurry before transplanting was an economical method.

From our work [10] showed the soaking rice seedling (*Oryza sativa* cv. IR74) in P fertilizer solution before transplanting increased the growth of rice grown on acidic P deficit soil up to 75 DAT. The procedure of fertilizer seedling soaking has been showed in Photo 2.

Under non-P fertilized soil, soaking rice seedling with 5% KH_2PO_4 solution before transplanting for 30 and 60 min increased shoot DM to 246 and 235%, shoot P concentration to 159 and 141%, root P concentration to 155 and 135 %, leaf age to 117 and 119%, and tiller number to 300 and 433 % at 20 days after transplanting (DAT), respectively (Table 4, 5, 8, 11, 12 and Figure 2). At 40 DAT, shoot DM and P uptake, root concentration and P uptake, leaf age, and tiller number increased to 265, 277, 456, 471, and 115, and 375%, respectively with

5% KH_2PO_4 for 60 min (Table 4, 6, 8, 9, 11, and 12). At 75 DAT, shoot DM was increased by soaking with 1 and 5 % KH_2PO_4 to 141 and 331% for 30 min, and 167 and 181 % for 60 min compared to the control (-P) soil, respectively (Figure 2, Table 4). Root DM was increased by soaking with 5% KH_2PO_4 to 299 and 138% for 30 and 60 min soaking, respectively. By soaking with 1% KH_2PO_4 for 30 min increased root DM to 115% (Figure 2, Table 7).

Photo 2. Procedure of fertilizer seedling soaking

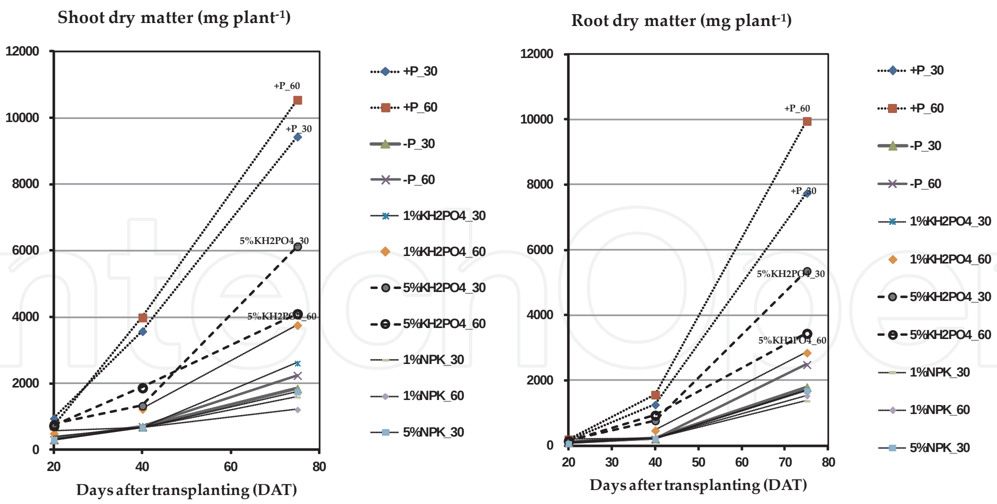


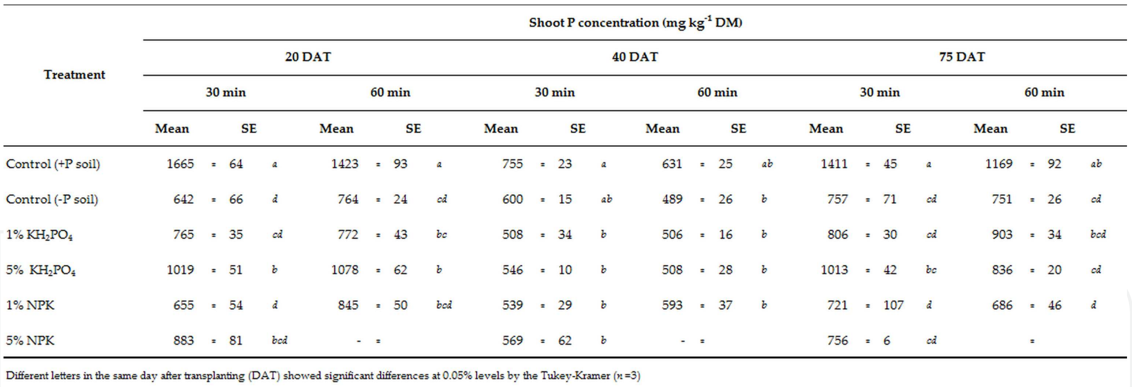
Figure 2. Dry matter of rice's shoot and root after fertilizer seedling soaking

Shoot P uptake was increased after soaking by 1 and 5 % KH_2PO_4 to 147 and 292 % for 30 min, and 204 and 100 % for 60 min, respectively (Table 6). Root P uptake was increased by soaking by 1 and 5% KH_2PO_4 to 130 and 324 % for 30 min, and 131 and 159 % for 60 min, respectively (Table 9). This revealed the seedling soaked by 5% KH_2PO_4 for 30 min has progressive increased shoot and root DM and P uptake from early growth stage to 75 DAT. In contrast, 5 % NPK severe damaged seedling and caused to death of seedling. While, 1 % NPK had no effect on the growth compared to the control. This study concluded that soaking rice seedling with 5% KH_2PO_4 solution before transplanting for 30 min improved the growth of rice up to 75 DAT on lowland acidic P deficit soil without P fertilization. However, it should be noted that the fertilization soil with fertilizer was required to maintain desired level of rice production. Sufficient supplied nutrients support entire crop's life cycle.

Treatment	Shoot Dry matter (mg)																	
	20 DAT						40 DAT						75 DAT					
	30 min			60 min			30 min			60 min			30 min			60 min		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Control (+P soil)	955	± 273	*a*	737	± 45	*abc*	3583	± 973	*a*	3997	± 166	*a*	9442	± 1446	*a*	10552	± 2218	*a*
Control (-P soil)	322	± 11	*c*	315	± 17	*c*	705	± 132	*b*	709	± 80	*b*	1854	± 472	*bc*	2252	± 298	*bc*
1% KH_2PO_4	573	± 26	*abc*	507	± 49	*bc*	666	± 36	*b*	1241	± 156	*b*	2622	± 603	*bc*	3768	± 661	*bc*
5% KH_2PO_4	792	± 42	*ab*	741	± 43	*abc*	1337	± 163	*b*	1880	± 167	*b*	6142	± 648	*ab*	4108	± 230	*bc*
1% NPK	389	± 25	*bc*	329	± 18	*c*	674	± 181	*b*	683	± 63	*b*	1602	± 556	*bc*	1225	± 194	*c*
5% NPK	306	± 21	*c*	-	±		686	± 44	*b*	-	±		1759	± 72	*bc*		±	

Different letters in the same day after incubation (DAT) showed significant differences at 0.05% levels by the Tukey-Kramer (n=3)

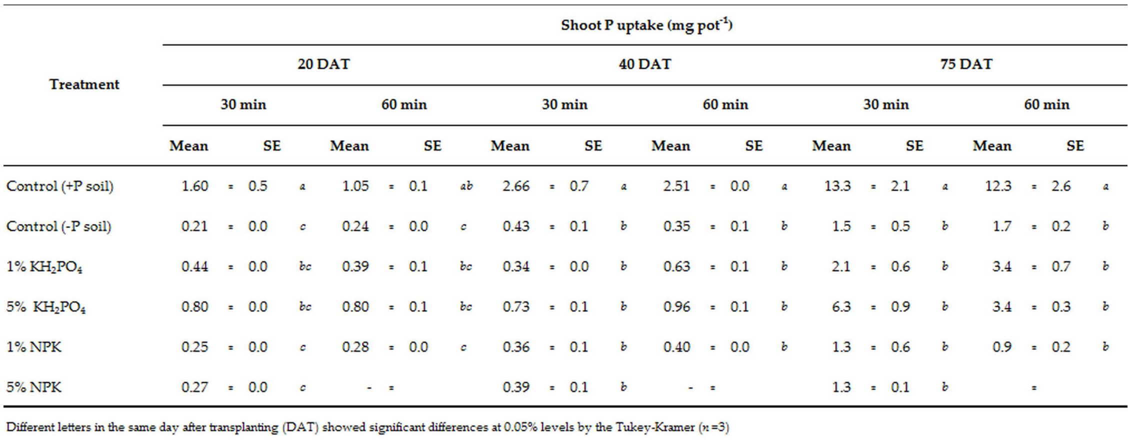
Table 4. Shoot dry matter of rice plant at 20, 40, and 75 days after transplanting as affected by various fertilizers and timing of seedling soaking



Treatment	Shoot P concentration (mg kg^{-1} DM)																	
	20 DAT						40 DAT						75 DAT					
	30 min			60 min			30 min			60 min			30 min			60 min		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Control (+P soil)	1665	= 64	*a*	1423	= 93	*a*	755	= 23	*a*	631	= 25	*ab*	1411	= 45	*a*	1169	= 92	*ab*
Control (-P soil)	642	= 66	*d*	764	= 24	*cd*	600	= 15	*ab*	489	= 26	*b*	757	= 71	*cd*	751	= 26	*cd*
1% KH_2PO_4	765	= 35	*cd*	772	= 43	*bc*	508	= 34	*b*	506	= 16	*b*	806	= 30	*cd*	903	= 34	*bcd*
5% KH_2PO_4	1019	= 51	*b*	1078	= 62	*b*	546	= 10	*b*	508	= 28	*b*	1013	= 42	*bc*	836	= 20	*cd*
1% NPK	655	= 54	*d*	845	= 50	*bcd*	539	= 29	*b*	593	= 37	*b*	721	= 107	*d*	686	= 46	*d*
5% NPK	883	= 81	*bcd*	-	=		569	= 62	*b*	-	=		756	= 6	*cd*		=	

Different letters in the same day after transplanting (DAT) showed significant differences at 0.05% levels by the Tukey-Kramer (*n* =3)

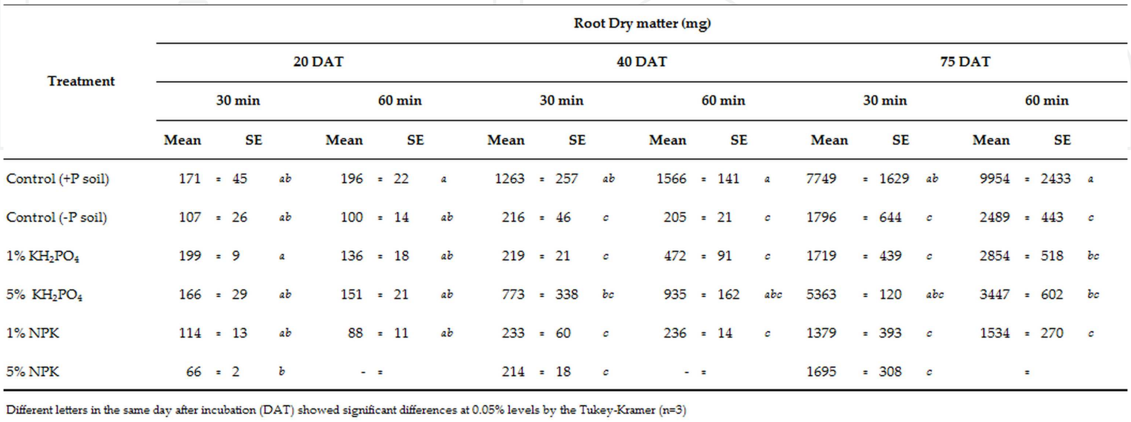
Table 5. Shoot P concentration of rice plant at 20, 40, and 75 days after transplanting as affected by various fertilizers and timing of seedling soaking



Treatment	Shoot P uptake (mg pot^{-1})																	
	20 DAT						40 DAT						75 DAT					
	30 min			60 min			30 min			60 min			30 min			60 min		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Control (+P soil)	1.60	= 0.5	*a*	1.05	= 0.1	*ab*	2.66	= 0.7	*a*	2.51	= 0.0	*a*	13.3	= 2.1	*a*	12.3	= 2.6	*a*
Control (-P soil)	0.21	= 0.0	*c*	0.24	= 0.0	*c*	0.43	= 0.1	*b*	0.35	= 0.1	*b*	1.5	= 0.5	*b*	1.7	= 0.2	*b*
1% KH_2PO_4	0.44	= 0.0	*bc*	0.39	= 0.1	*bc*	0.34	= 0.0	*b*	0.63	= 0.1	*b*	2.1	= 0.6	*b*	3.4	= 0.7	*b*
5% KH_2PO_4	0.80	= 0.0	*bc*	0.80	= 0.1	*bc*	0.73	= 0.1	*b*	0.96	= 0.1	*b*	6.3	= 0.9	*b*	3.4	= 0.3	*b*
1% NPK	0.25	= 0.0	*c*	0.28	= 0.0	*c*	0.36	= 0.1	*b*	0.40	= 0.0	*b*	1.3	= 0.6	*b*	0.9	= 0.2	*b*
5% NPK	0.27	= 0.0	*c*	-	=		0.39	= 0.1	*b*	-	=		1.3	= 0.1	*b*		=	

Different letters in the same day after transplanting (DAT) showed significant differences at 0.05% levels by the Tukey-Kramer (*n* =3)

Table 6. Shoot P uptake of rice plant at 20, 40, and 75 days after transplanting as affected by various fertilizers and timing of seedling soaking



Treatment	Root Dry matter (mg)																	
	20 DAT						40 DAT						75 DAT					
	30 min			60 min			30 min			60 min			30 min			60 min		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Control (+P soil)	171	= 45	*ab*	196	= 22	*a*	1263	= 257	*ab*	1566	= 141	*a*	7749	= 1629	*ab*	9954	= 2433	*a*
Control (-P soil)	107	= 26	*ab*	100	= 14	*ab*	216	= 46	*c*	205	= 21	*c*	1796	= 644	*c*	2489	= 443	*c*
1% KH_2PO_4	199	= 9	*a*	136	= 18	*ab*	219	= 21	*c*	472	= 91	*c*	1719	= 439	*c*	2854	= 518	*bc*
5% KH_2PO_4	166	= 29	*ab*	151	= 21	*ab*	773	= 338	*bc*	935	= 162	*abc*	5363	= 120	*abc*	3447	= 602	*bc*
1% NPK	114	= 13	*ab*	88	= 11	*ab*	233	= 60	*c*	236	= 14	*c*	1379	= 393	*c*	1534	= 270	*c*
5% NPK	66	= 2	*b*	-	=		214	= 18	*c*	-	=		1695	= 308	*c*		=	

Different letters in the same day after incubation (DAT) showed significant differences at 0.05% levels by the Tukey-Kramer (n=3)

Table 7. Root dry matter of rice plant at 20, 40, and 75 days after transplanting as affected by various fertilizers and timing of seedling soaking

Treatment	Root P concentration (mg kg^{-1} DM)																	
	20 DAT						40 DAT						75 DAT					
	30 min			60 min			30 min			60 min			30 min			60 min		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Control (+P soil)	1397	= 36	*a*	1038	= 51	*b*	730	= 80	*a*	521	= 11	*bc*	374	= 16	*a*	335	= 32	*ab*
Control (-P soil)	560	= 3	*e*	739	= 58	*de*	513	= 26	*bc*	501	= 25	*bc*	259	= 45	*abc*	227	= 20	*bc*
1% KH_2PO_4	744	= 53	*de*	771	= 27	*cde*	465	= 18	*c*	456	= 22	*c*	325	= 17	*ab*	255	= 3	*abc*
5% KH_2PO_4	870	= 65	*bcd*	998	= 72	*bc*	498	= 19	*bc*	510	= 30	*bc*	252	= 15	*abc*	258	= 8	*abc*
1% NPK	743	= 29	*de*	692	= 32	*de*	557	= 22	*bc*	588	= 36	*abc*	180	= 38	*c*	157	= 38	*c*
5% NPK	742	= 30	*de*	-	=		652	= 12	*ab*	-	=	-	204	= 35	*bc*		=	

Different letters in the same day after transplanting (DAT) showed significant differences at 0.05% levels by the Tukey-Kramer (*n* =3)

Table 8. Root P concentration of rice plant at 20, 40, and 75 days after transplanting as affected by various fertilizers and timing of seedling soaking

Treatment	Root P uptake (mg pot^{-1})																	
	20 DAT						40 DAT						75 DAT					
	30 min			60 min			30 min			60 min			30 min			60 min		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Control (+P soil)	0.24	= 0.1	*a*	0.20	= 0.0	*ab*	0.9	= 0.1	*a*	0.8	= 0.1	*ab*	2.8	= 0.5	*ab*	3.4	= 0.9	*a*
Control (-P soil)	0.06	= 0.0	*c*	0.08	= 0.0	*c*	0.1	= 0.0	*d*	0.1	= 0.0	*d*	0.4	= 0.1	*c*	0.6	= 0.1	*c*
1% KH_2PO_4	0.15	= 0.0	*abc*	0.11	= 0.0	*bc*	0.1	= 0.0	*d*	0.2	= 0.0	*cd*	0.5	= 0.1	*c*	0.7	= 0.1	*c*
5% KH_2PO_4	0.14	= 0.0	*abc*	0.15	= 0.0	*abc*	0.4	= 0.2	*cd*	0.5	= 0.1	*bc*	1.4	= 0.1	*bc*	0.9	= 0.1	*c*
1% NPK	0.08	= 0.0	*c*	0.06	= 0.0	*c*	0.1	= 0.0	*d*	0.1	= 0.0	*cd*	0.3	= 0.1	*c*	0.2	= 0.0	*c*
5% NPK	0.05	= 0.0	*c*	-	=		0.1	= 0.0	*cd*	-	=		0.3	= 0.0	*c*		=	

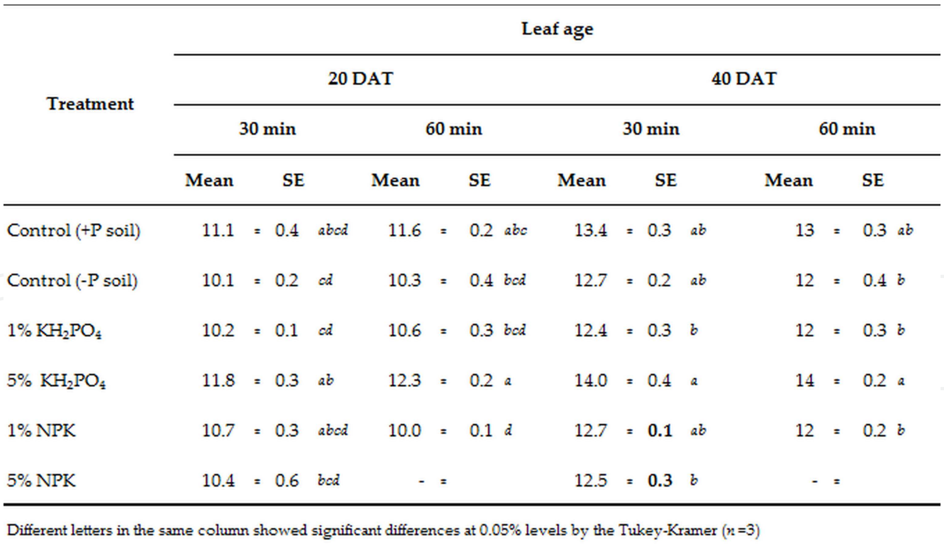
Different letters in the same day after transplanting (DAT) showed significant differences at 0.05% levels by the Tukey-Kramer (*n* =3)

Table 9. Root P uptake of rice plant at 20, 40, and 75 days after transplanting as affected by various fertilizers and timing of seedling soaking

Treatment	Height (cm)																	
	20 DAT						40 DAT						75 DAT					
	30 min			60 min			30 min			60 min			30 min			60 min		
	Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE		Mean	SE	
Control (+P soil)	53.3	= 42	*a*	54.3	= 12	*a*	66.7	= 3	*a*	65.7	= 3	*a*	80.8	= 1	*a*	75.0	= 3	*a*
Control (-P soil)	35.2	= 29	*c*	35.3	= 20	*c*	49.3	= 4	*b*	50.0	= 3	*b*	62.5	= 5	*b*	61.0	= 2	*ab*
1% KH_2PO_4	37.0	= 25	*bc*	43.0	= 12	*abc*	46.7	= 1	*b*	52.0	= 1	*ab*	63.5	= 6	*b*	66.7	= 3	*ab*
5% KH_2PO_4	45.7	= 23	*abc*	48.5	= 19	*abc*	52.3	= 1	*ab*	54.0	= 2	*ab*	69.3	= 4	*ab*	66.7	= 2	*ab*
1% NPK	33.2	= 34	*c*	36.3	= 33	*bc*	44.0	= 6	*b*	45.3	= 2	*b*	57.8	= 6	*b*	56.7	= 5	*b*
5% NPK	34.2	= 17	*c*	-	=		43.0	= 2	*b*	-	=		61.7	= 4	*b*		=	

Different letters in the same column showed significant differences at 0.05% levels by the Tukey-Kramer (*n* =3)

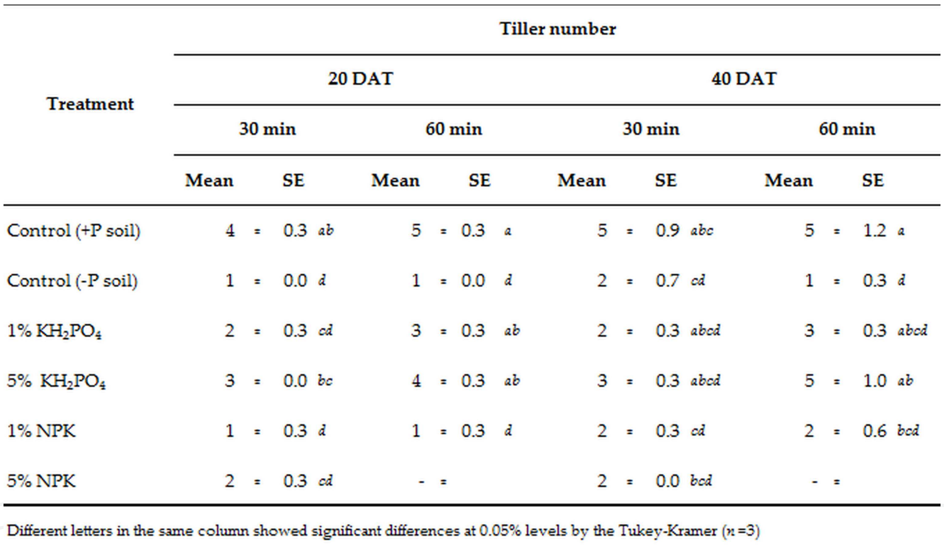
Table 10. Height of rice plant at 20, 40, and 75 days after transplanting as affected by various fertilizers and timing of seedling soaking



Treatment	Leaf age							
	20 DAT				40 DAT			
	30 min		60 min		30 min		60 min	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Control (+P soil)	11.1	± 0.4 *abcd*	11.6	± 0.2 *abc*	13.4	± 0.3 *ab*	13	± 0.3 *ab*
Control (-P soil)	10.1	± 0.2 *cd*	10.3	± 0.4 *bcd*	12.7	± 0.2 *ab*	12	± 0.4 *b*
1% KH_2PO_4	10.2	± 0.1 *cd*	10.6	± 0.3 *bcd*	12.4	± 0.3 *b*	12	± 0.3 *b*
5% KH_2PO_4	11.8	± 0.3 *ab*	12.3	± 0.2 *a*	14.0	± 0.4 *a*	14	± 0.2 *a*
1% NPK	10.7	± 0.3 *abcd*	10.0	± 0.1 *d*	12.7	± 0.1 *ab*	12	± 0.2 *b*
5% NPK	10.4	± 0.6 *bcd*	-	±	12.5	± 0.3 *b*	-	±

Different letters in the same column showed significant differences at 0.05% levels by the Tukey-Kramer (*n* =3)

Table 11. Leaf age of rice plant at 20 and 40 days after transplanting as affected by various fertilizers and timing of seedling soaking



Treatment	Tiller number							
	20 DAT				40 DAT			
	30 min		60 min		30 min		60 min	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Control (+P soil)	4	± 0.3 *ab*	5	± 0.3 *a*	5	± 0.9 *abc*	5	± 1.2 *a*
Control (-P soil)	1	± 0.0 *d*	1	± 0.0 *d*	2	± 0.7 *cd*	1	± 0.3 *d*
1% KH_2PO_4	2	± 0.3 *cd*	3	± 0.3 *ab*	2	± 0.3 *abcd*	3	± 0.3 *abcd*
5% KH_2PO_4	3	± 0.0 *bc*	4	± 0.3 *ab*	3	± 0.3 *abcd*	5	± 1.0 *ab*
1% NPK	1	± 0.3 *d*	1	± 0.3 *d*	2	± 0.3 *cd*	2	± 0.6 *bcd*
5% NPK	2	± 0.3 *cd*	-	±	2	± 0.0 *bcd*	-	±

Different letters in the same column showed significant differences at 0.05% levels by the Tukey-Kramer (*n* =3)

Table 12. Tiller number of rice plant at 20 and 40 days after transplanting as affected by various fertilizers and timing of seedling soaking

3.4. Conclusion

Alternative fertilizer utilizing methods have been developed for small subsistence farmers aiming to reduce quantity of fertilizer used to maintain desired level of crop production and replenish soil fertility. Although, farmers were aware of soil fertilization but they were not able to access to those fertilizers because of shortage of financial resource. Therefore, alternative methods such as 1) fertilizer microdosing, 2) seed coating, and 3) seedling dipping or soaking have been introduced and the potential of the methods also was provided in this chapter.

Effectiveness of fertilizer microdosing method has been proved on sorghum, millet, and pearl millet production grown on low P fertility, in various soils of severe dry semi-arid and Sahel regions of several countries in Africa. Delayed timing of microdosing still increased crop production and income of small farmers. While, fertilizer seed coating method have been developed to overcome the problem relating to loss of fertilizer during planting after mixing fertilizer with dry crop seed. Fertilizer coating rice seed with use of some adhesive materials resulted to more firm attachment of seed and fertilizer. Early growth and root development of plant was well observed over 40 days after sowing. However, more suitable and affordable adhesive materials and handling procedure should be further invertigated. Dipping or soaking seedling of rice in fertilizer slurry has been traditionally practiced in China. Fertilizers were simply mixed with soil and water to make a paste or slurry and rice seedlings were dipped to this slurry before transplanting. This method reduced fertilizer requirement more than 50%. Moreover, soaking rice seedling by chemical fertilizer such as 5% KH_2PO_4 for 30 min before transplanting could extend the growth of shoot and root up to 75 days on P deficit soils. Alternative fertilizer utilizing methods described above showed relatively high potential for improving the growth of rice seedling, and in turn possibly increased crop productivity in low input agriculture in different soils and climates. These methods were considered as affordable technologies for local subsistence farmer who are not able to access sufficient quantity of fertilizer during cropping season.

Acknowledgement

The authors are grateful to the Ministry of Agriculture, Forestry, and Fisheries (MAFF), Japan for a grant on the Project of 'Improvement of Soil Fertility with Use of Indigenous Resources in Rice Systems of Sub-Sahara Africa' through Japan International Research Center for Agricultural Sciences (JIRCAS).

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