Effect of Inorganic Phosphorus Fertilizer and Inoculants on Yield and Phosphorus Use Efficiency of Wheat

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Abstract: To investigate the response of mineral phosphatic fertilizer and inoculum alone or integrated use of these sources on the growth, yield, nutrient uptake and phosphorus use efficiency of wheat. Treatment combinations were: T_0=Control, T_1= *Pseudomonas* sp, T_2= *Klebsiella* sp, T_3= *Pseudomonas* sp + 15 kg P ha^{-1}, T_4= *Klebsiella* sp + 15 kg P ha^{-1} and T_5= 30 kg P ha^{-1}. Trials were laid out in a randomized block design with four replications having unit plot size of 5 m × 3 m and wheat was the test crop. Maximum grain and straw yield (2.13 and 2.84 t ha^{-1}) were recorded in T_3 (PSB 7 + 15 kg P ha^{-1}) and T_4 (PSB 19 + 15 kg P ha^{-1}) treatments at Pabna and Rajshahi, respectively. *Pseudomonas sp* for Pabna and *Klebsiella sp* for Rajshahi along with triple super phosphate showed better performance than other treatments in respect of wheat yield, nutrient uptake and quality of soil. Phosphate solubilizing bacteria alone also increased phosphorus use efficiency during crop production. A positive significant correlation was observed between yield contributing characters and grain yield of wheat. Based on these reults it may be concluded that, phosphate solubilizing bacteria contributed from unavailable to available form of soil phosphorus and stimulated the available form of applied phosphatic fertilizer as a result increased nutrient uptake and yield of wheat.

Key Words: Wheat, Phosphate solubilizing bacteria, Phosphorus use efficiency, Yield

Introduction

Wheat is the second most important cereal crop next to rice on the basis of cultivated area and production in Bangladesh (BBS, 2008). The farmers of Bangladesh usually do not follow improved management packages during crop production especially in problem soils. Poor socio-economic condition of the farmers and suitable technology are the main barrier behind it. Phosphorus is a non-renewable source and a major plant nutrient for higher crop yield. It limits the crop production because only about 20% of applied phosphorus is utilized by crop and remaining part is converted into insoluble forms in acid and alkaline soils (Rodriguez and Fraga, 1990). In Bangladesh, most of the soils are acidic or alkaline nature (FRG, 2012) as a result, the availability of phosphorus for the nutrition of crops is very low due to its fixation excessive mineral phosphatic fertilizer creates eutrophication. Adequate supply of cost effective and environmental friendly phosphatic biofertilizer could play a vital role in improving the wheat yield as well as increases phosphorus use efficiency. In this context, P-solubilization ability of micro-organisms is considered to be one of the most important traits associated with plant P nutrition (Chen et al., 2006, Adesemoye and Kloepper, 2009). Several bacterial species are referred to as phosphate solubilizing bacteria (PSB) that have been considered as biofertilizer for improving the plant growth and yield of crops due to increase the availability of applied and

soil phosphorus (Vessey, 2003). The beneficial effects of phosphate solubilizing bacteria on crop productivity have been widely described but the use of PSB as biofertilizer is scarcely documented in wheat. Be keeping in mind, the present investigations were planned to evaluate the performance of phosphate solubilizing bacteria either alone or in combination with triple super phosphate on wheat.

Materials and Methods

Field experiments were carried out at two locations of Bangladesh is situated between latitudes 20~34' and 26~38' north and latitudes 88~01' and 92~41' east. Two locations were Gangetic river flood plain at Pabna and Barind tract of Rajshahi in Bangladesh. Soil samples were randomly collected at 0 – 15 cm depth during the time of land preparation from several spots of the experimental land and composited it. The soils were sandy loam and clayey in texture having pH 7.5 and 4.8 with 1.0 and 1.8 per cent organic matter, 0.11 and 0.13 per cent total nitrogen, 14.00 and 30.63 ppm P in Pabna and Rajshahi, respectively. The treatment combinations were : T_0=Control, T_1= *Pseudomonas* sp, T_2= *Klebsiella* sp, T_3= *Pseudomonas* sp + 15 kg P ha^{-1}, T_4= *Klebsiella* sp + 15 kg P ha^{-1} and T_5= 30 kg P ha^{-1}. The trials were laid out in randomized block design using four replications having unit plot size of 5 m × 3 m and wheat was the test crop. One third of 90 kg N ha^{-1} as urea, 42 kg K_2O ha^{-1} as muriate of potash, 10 kg S ha^{-1} as gypsum and phosphorus as triple super phosphate as per treatment were applied at the time of final land

preparation then mixed well with soil by spading. PSB application with seed coating at 7.5 kg ha^{-1} of peat based carrier having a bacterial load of 10^8 cells per gram. The rest 60 kg N as urea was applied in two splits at maximum vegetative phage and panicle initiation stage. Cultural practice was done whenever necessary. At harvesting stage, 10 plants were randomly selected and harvested from each unit plot to record yield contributing characters, grain and straw yield, nitrogen and phosphorus uptake in grain and straw. Dried seed and straw samples were digested in di-acid mixture of HNO_3 : $HClO_4$ (9 : 4) and phosphorus was determined by ascorbic acid reductant method (Watanabe and Olsen, 1965). Soil samples were analyzed to determine the content of phosphorus both at initial and after harvest of wheat. Recovery efficiency (RE) is uptake of phosphorus (kg) by a wheat crop from 1 kg of applied phosphorus to the field. Recovery efficiency can be calculated by dividing agronomic use efficiency with physiological use efficiency.

$$RE = \frac{(U - U_0)}{P}$$

where U and U_0 is P uptake in fertilized and unfertilized plot, respectively. P is triple super phosphate was applied in different treatments except control. Available phosphorus in post harvest soil was calculated using this formula

Available P = Amount of initial phosphorus in soil - Amount of P in post harvest soil in different treatments

where amount of available phosphorus was expressed in kg ha^{-1}. Data were statistically analyzed and Duncan's Multiple Range was applied to examine significant differences between the treatment means (Steel and Torrie, 1980).

Results

Pabna

The combined application of mineral phosphatic fertilizer and inoculum contributed to increase yield of wheat over control. Grain yield ranged from 1.53 to 2.13 t ha^{-1}. The yield increase (%) was varied with different treatments. Maximum yield (39%) was achieved in T_3 (*Pseudomonas* sp + 15 kg P ha^{-1}) followed by T_4 (38%) and T_5 (31%) treatments. The minimum increase in grain yield (1.53 t ha^{-1}) was obtained from control plots. Higher grain yield in T_3 treatment might have resulted from the favorable effect of the number of effective tiller hill^{-1}, filled grain per panicle^{-1} and 1000 seed weight. Straw yield also showed a significant variation for different treatments. Among the treatments, T_5 (30 kg P ha^{-1})

produced the highest straw yield (6.09 t ha^{-1}) and the lowest straw yield (3.59 t ha^{-1}) was obtained from the control. Nitrogen uptake both in grain and straw was significantly influenced by different treatments. Maximum nitrogen uptake in grain (36.72 kg ha^{-1}) and straw (18.23 kg ha^{-1}) was found in T_3 treatment and the minimum nitrogen uptake in grain (26.94 kg ha^{-1}) and straw (11.23 kg ha^{-1}) was obtained from T_0 treatment. Combined application of mineral phosphatic fertilizer and inoculum (T_3) also increased the nitrogen uptake in grain of wheat which was identical to T_4, T_1, T_5 and T_2 treatments. Performance of *Pseudomonas* sp was better than that of *Klebsiella* sp in respect of nitrogen uptake in grain and straw of wheat. On the other hand, integrated application of mineral phosphatic fertilizer with inoculants significantly influenced the phosphorus uptake in grain and straw of wheat. Maximum phosphorus uptake in grain (7.25 kg ha^{-1}) and straw (1.34 kg ha^{-1}) was found in T_3 treatment and the minimum phosphorus uptake in grain (3.94 kg ha^{-1}) and straw (0.47 kg ha^{-1}) was obtained from T_0 treatment. *Pseudomonas* sp in combination with 15 kg p ha^{-1} performed better results than that of 30 kg P ha^{-1} in respect of phosphorus uptake in grain and straw of wheat. From these results, it may be concluded that inoculum had good capacity to 50 per cent mineral phosphorus in wheat production. Grain yield was significantly correlated with yield contributing characters (plant height, spike length, tiller number, filled grain, unfilled grain and 1000 seed weight) of wheat (Table 2). Recovery efficiency of phosphorus ranged from 0.09 to 1.16 per cent. Maximum phosphorus use was observed in T_1 treatment and the minimum phosphorus use efficiency was found in 30 kg P ha^{-1} treatment. Available phosphorus in post harvest soil varied from -0.22 to 15.8 kg P ha^{-1} with lowest (negative trend) in control and the highest in *Pseudomonas* sp in combination with 15 kg P ha^{-1}.

Rajshahi

Results on the effect of mineral phosphatic fertilizer and inoculum are presented (Table 1). Grain yield ranged from 1.81 to 2.84 t ha^{-1}. The yield increase (%) was varied with different treatments. Maximum yield (57%) was achieved in T_4 (*Klebsiella* sp + 15 kg P ha^{-1}) followed T_3 (54%) and T_5 (34%) treatments. The minimum grain yield (1.81 t ha^{-1}) was obtained from control plots. Straw yield was showed a significant variation for different treatments. Among the treatments, T_4 (*Klebsiella* sp + 15 kg P ha^{-1}) produced the highest straw yield (6.69 t ha^{-1}) and the lowest straw yield (4.14 t ha^{-1}) was found in control. Nitrogen uptake both grain and straw was significantly influenced by different treatments. Maximum nitrogen uptake in grain (42.74 kg ha^{-1})

and straw (22.05 kg ha^{-1}) was found in T_4 and the minimum nitrogen uptake in grain (28.53 kg ha^{-1}) and straw (13.34 kg ha^{-1}) was obtained from T_0 treatment. Combined application of mineral phosphatic fertilizer and inoculum (T_4) increased the nitrogen uptake in wheat grain markedly which was identical in T_3, T_5, T_2 and T_1 treatments. Performance of *Klebsiella* sp was better than that of *Pseudomonas* sp in respect of nitrogen uptake in grain and straw of wheat. Similar trend was found in phosphorus uptake in grain and straw of wheat. Performance of *Klebsiella* sp in combination with 15 kg p ha^{-1} was better than that of 30 kg P ha^{-1} in respect of phosphorus uptake in wheat

grain. The results in table 2 revealed that grain yield was significantly correlated with yield contributing characters (plant height, spike length, tiller number, filled grain, unfilled grain and 1000 seed weight) of wheat. Recovery efficiency of phosphorus ranged from 0.15 to 2.52 per cent. The maximum phosphorus use efficiency was observed in T_2 treatment and the minimum phosphorus use efficiency was found in 30 kg P ha^{-1} treatment. Available phosphorus in post harvest soil varied from -6.3 to 0.8 kg P ha^{-1} with lowest (negative trend) in control and highest in the *Klebsiella* sp in combination with 15 kg P ha^{-1}.
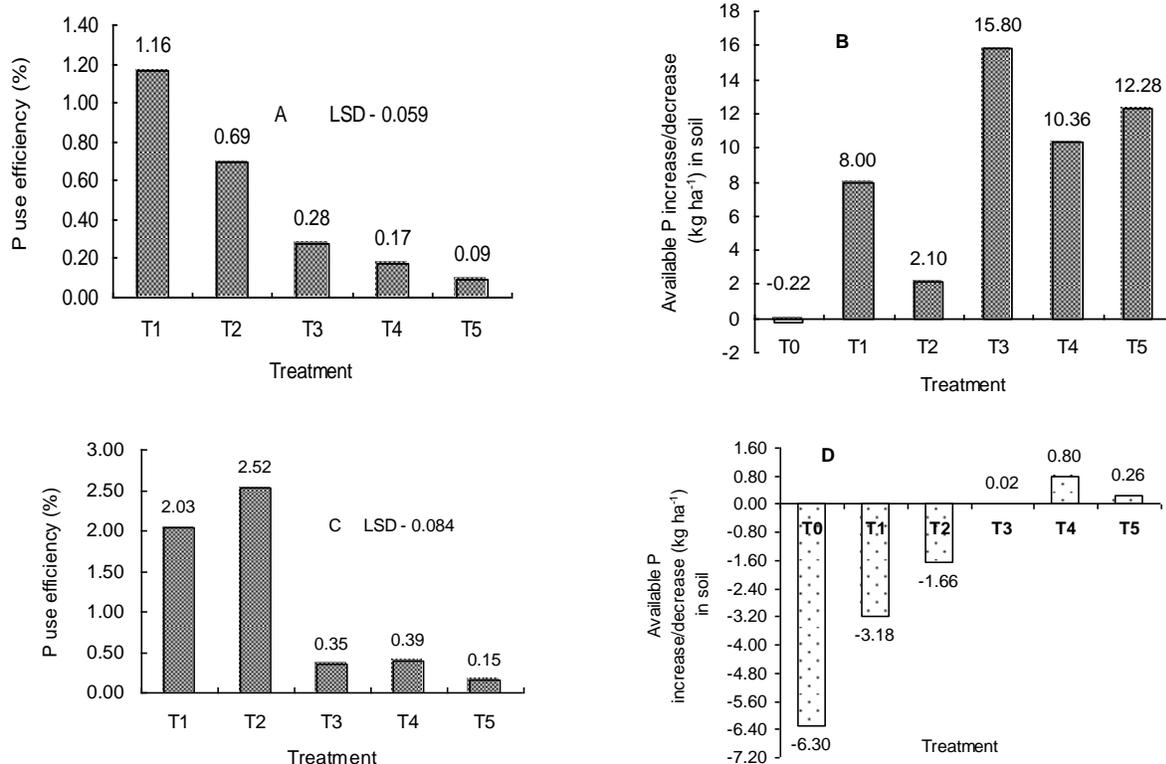

Fig. 1. Effect of chemical phosphorus fertilizer and inoculants on phosphorus use efficiency of wheat (A & B- Phosphorus use efficiency and available phosphorus in soil at Pabna, C & D- Phosphorus use efficiency and available phosphorus in soil at Rajshahi

Discussion

Triple super phosphate (TSP) in combination with phosphate solubilizing bacteria had a significant effect on yield of wheat. Soil microorganisms are enormous potential in providing soil phosphates for plant growth. Phosphatic biofertilizer in the form of microorganisms can help in increasing the availability of fixed phosphates for plant growth by solubilization (Ekin, 2010, Shah *et al.*, 2001 and Richardson, 2001). *Pseudomonas* sp had a stimulatory effect on wheat, maize and cotton growth, yield, N, P uptake and soil

P content (Egamberdiyeva *et al.*, 2004). From this studied observations *Pseudomonas* sp and *Klebsiella* sp alone or in combination with triple super phosphate showed different yield performance of wheat at different locations because microrganisms behaved differently at different environmental conditions due to their adaptation capacity into the soil after inoculation. The correlation coefficients of all the above mentioned parameters (Table 2) helped to improve yield of wheat. Because yield of wheat increased with the increase of spike length, tiller per

hill, filled grain per plant and decreasing unfilled grain per plant. Positive influence of treatments on available phosphorus content in soil was markedly changed in these results. Phosphate solubilizing bacteria contributed from unavailable to available form of soil phosphorus and stimulated the available form of applied phosphatic fertilizer as a result increased the phosphorus content in postharvest soil (Kumar and Narula, 2001). Soil phosphate is rendered available either by plant roots or by soil microorganisms through secretion of organic acids (formic, acetic, propionic, lactic glycolic, fumaric and succinic acids). These organic acids play in correcting phosphorus deficiency for crop plants (Cakmakci *et al.*, 2006). Last of all, our results showed that the possibility of partial substitution of phosphorus using phosphate solubilizing bacteria, without any reduction of yield in wheat. *Pseudomonas* sp and *Klebsiella* sp in combination with 15 kg P ha^{-1} was enough to ensure the standard level of yield. Therefore, these results indicated that the best management of phosphatic fertilizer with phosphate solubilizing bacteria ensured good yield as well as to enrich phosphorus in soil.

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Table 1. Effect of chemical phosphorus alone or incombination with phosphate solubilizing bacteria on yield and nutrient uptale of wheat

Treatments	Pabna						Rajshahi					
	Yield (t ha^{-1})		Nutrient uptake (kg ha^{-1})				Yield (t ha^{-1})		Nutrient uptake (kg ha^{-1})			
			Nitrogen		Phosphorus				Nitrogen		Phosphorus	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_0	1.53c	3.59c	26.94b	11.23b	3.94c	0.47d	1.81d	4.14d	28.53b	13.34b	8.88b	0.55c
T_1	1.90abc	4.59bc	34.85a	17.13a	4.79c	0.78bc	2.15c	5.98c	32.81ab	19.26a	10.45ab	1.01b
T_2	1.63bc	4.48bc	29.35ab	17.06a	4.48c	0.62cd	2.24c	6.03bc	34.46ab	19.95a	10.93ab	1.02b
T_3	2.13a	5.41ab	36.72a	18.23a	7.25a	1.34a	2.79ab	6.14b	42.65a	20.17a	13.40a	1.27ab
T_4	2.11a	4.91ab	36.02a	17.83a	6.06b	0.91b	2.84a	6.69a	42.74a	22.05a	13.86a	1.44a
T_5	2.00ab	6.09a	34.65a	18.16a	5.95b	1.20a	2.43abc	6.09bc	41.01a	21.38a	12.67a	1.32a
CV (%)	14.06	18.79	14.00	13.37	11.81	20.13	15.72	13.76	17.73	10.68	18.34	15.13

Figures in a column having common letters do not differ significantly at 5 per cent level of significance, CV(%)- co-efficient of variation

Table 2. Correlation coefficient among grain yield and yield contributing parameters of wheat at Pabna and Rajshahi

Parameters	Grain yield	Plant height	Spike length	No. of tiller	Filled grain	Unfilled grain	1000 seed weight
			Pabna				
Grain yield	-	0.849**	0.867**	0.929**	0.935**	-0.919**	0.729**
Plant height		-	0.688**	0.774**	0.943**	-0.933**	0.976**
Spike length			-	0.988**	0.826**	-0.703**	0.583**
No. of tiller				-	0.895**	-0.789**	0.666**
Filled grain					-	-0.936**	0.885**
Unfilled grain						-	-0.883**
1000 seed weight							-
			Rajshahi				
Grain yield	-	0.964**	0.806**	0.901**	0.923**	-0.208^{NS}	0.853**
Plant height		-	0.927**	0.923**	0.954**	-0.360*	0.888**
Spike length			-	0.833**	0.828**	-0.522**	0.816**
No. of tiller				-	0.925**	-0.542**	0.952**
Filled grain					-	-0.350*	0.901**
Unfilled grain						-	-0.398*
1000 seed weight							-

n=24 : *, ** indicate significant at 5% and 1% level of probability, respectively