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Effect of phosphate solubilizing bacteria and different phosphatic fertilizers on nutrient content of rice

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Abstract: A pot culture experiment was conducted in the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh with acidic soil of the Madhupur upzilla under Tangail district to evaluate the effect of three phosphate solubilizing bacteria (PSB) with addition of three different phosphatic fertilizers (triple superphosphate, single superphosphate and Moroccan rock phosphate) at recommended dose on nutrients content of transplant aus rice (*Oryza sativa* L.) cv. BR26. PSB significantly increased the N, P, K, Ca, Mg, Fe and Mn content in rice grains and while in straw the content of N, P, K, Ca, Mg, Fe, Zn, Mn and Cu increased. Application of different P fertilizer significantly increased all the nutrients content except Fe in grains and K, Fe, & Zn in straw studied. P fertilizers accentuated the performance of PSB in increasing the nutrient content of rice.

Key words: PSB, TSP, SSP, rock phosphate, nutrient content of rice

Introduction

Phosphorus (P) deficiency is an important factor limiting crop production in tropical and sub tropical soils. Phosphatic fertilizers are applied to soil to minimize this situation. But a large portion of these fertilizers can not be utilized. Inorganic P is rapidly immobilized. It forms insoluble compounds with Al^{3+} and Fe^{3+} in acidic soils and Ca^{2+} in neutral to alkaline soils. Globally crop yield up to 30-40% of arable land is limited by P availability (vonUexkull and Mutert, 1995). Availability of P is low at both low and high pH values under upland conditions and high under wetland rice culture. P availability of Bangladesh soils is low in *rabi* season due to low temperature and it increases in *kharif* season with the rise of temperature (Saleque *et al.*, 1996). The recovery of fertilizer P by rice is usually 8-20% and a considerable residue remains in soil.

It is recognized that rhizosphere inhabiting bacteria of several taxonomic classes are capable of increasing availability of P to plants either by mineralization of organic phosphate or by solubilization of inorganic phosphate producing organic acids (Islam *et al*., 2007). A significant reduction in the use of P fertilizer could be achieved if solubization of soil-insoluble P is made available to crop plants (Thakuria *et al*., 2004). Plant root-associated phosphate solubilizing bacteria (PSB) could be possible alternatives for inorganic P fertilizers for promoting plant growth and yield (Vikram *et al.*, 2007). Alternatively seed or soil inoculation with PSB improved solubilization of fixed soil P and applied phosphates resulting in higher crop yields (Yadav and Dadarwal, 1997). Considering the role of PSB in P solubilization in acid soils, the present piece of research work was undertaken to study the effect of phosphate solubilizing bacteria in presence of different P fertilizers on nutrient content in rice.

Materials and Methods

The study was conducted at the net house and the laboratory of the Department of Agricultural Chemistry, BAU, Mymensingh during the period from April, 2007 to August, 2007. Roots of rice seedlings cv. BR 26 were inoculated with PSB strains B1, B2 and B3 before transplanting in pots (30cmx30cm) containing acidic red soil of Madhupur (Clayey loam textured having pH 4.89) in Aus season. The experiment was laid out in Completely Randomized Design (CRD) with two factors viz. PSB inoculants {i.e. Inoculation without PSB strain (B_0), with PSB strain B1, B2 and B3} and different P fertilizer {without P fertilizer (P_0), TSP (P_1), SSP (P_2) and Rock phosphate at the recommended dose of P i.e.$P_{1,}$ P_2 and P_3} with 3 replications in the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh. N, P, K, S, and Zn were applied at per recommended dose (95 kg N, 12 kg P, 45 kg K, 8 kg S and 1 kg Zn ha^{-1}) as urea, MOP, gypsum and zinc sulphate ($ZnSO_4$), respectively. All nutrients, except N, were applied as broadcast and incorporated with soils prior to transplanting. N was applied in three splits. The first one-third was applied at final pot preparation and the second third one at rapid tillering stage (30 DAT) and before panicle initiation stage (60 DAT), respectively. Both of these installments were broadcast and incorporated with soil followed by weeding. Intercultural operations were done in the pot for ensuring and maintaining proper growth and development of the crop. After harvesting, the grain and straw samples of rice plant were oven dried were analyzed for total N, P, K, Ca, Mg, S, Fe, Zn, Mn and Cu contents following standard methods (Jackson, 1973). Correlation- regression studies were also done to find out the statistical relationship between P content and N, K, Ca, Mg, S, Fe, Zn, Mn and Cu contents in grains and straw of rice cv. BR26.

Results and Discussion

Effect on nutrients content of rice grain

The content of nutrients such as N, P, K, Ca, Mg, S, Fe, Zn, Mn and Cu in rice grain and straw as influenced by inoculation of rice seedlings with three selected PSB strains alone and along with fixed dose of three different sources of P fertilizers has been studied (Table 1-3) . All the three PSB strains accelerated the content of all the nutrient elements studied except Mn. B_2 alone exalted best performance in augmenting N, P, K, Ca, Mg, S and Fe while the content of Mn in B_0 (58.93 µg g^{-1}). The content of N, P, Ca, Mg, Fe and Cu was lowest (0.923, 0.167, 0.047, 0.097% and 39.38 and 5.24 µg g^{-1}, respectively) in B_0 while content of K was lowest in B_3 (0.313%). The content of Zn and Cu did not vary significantly due to PSB inoculation.

The content of all the elements studied was significantly increased by the application of different sources of P fertilizers. The highest content of P (0.198%), K (0.340%), Ca (0.056%), Mg (0.106%) and S (0.158%) was obtained with P_1, N (1.061%) and Cu (5.28 µg g^{-1}) in P_2, Fe (58.26 µg g^{-1}) in P_0, Zn (43.65 µg g^{-1}) in P_3 (Table 2).

Table 1: Effect of PSB on the content of different nutrient elements in grains of T. *aus* rice cv. BR26

PSB Isolates	Nutrients content in rice grains									
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (µg g^{-1})	Zn (µg g^{-1})	Mn (µg g^{-1})	Cu (µg g^{-1})
B_0	0.923	0.167	0.315	0.047	0.097	0.140	39.38	42.46	58.93	5.24
B_1	1.013	0.191	0.317	0.051	0.099	0.139	43.43	42.33	55.31	5.25
B_2	1.030	0.192	0.320	0.054	0.101	0.142	47.47	42.60	56.95	5.25
B_3	0.949	0.171	0.313	0.051	0.099	0.139	42.08	42.72	57.43	5.24
LSD at 5% level	0.026	0.008	0.008	0.0026	0.0026	-	4.34	-	0.88	-
CV (%)	3.56	4.41	1.46	6.01	3.20	2.09	12.12	0.84	1.86	1.59

Table 2: Effect of different phosphatic fertilizers on the content of different nutrient elements in grains of T. *aus* rice cv. BR26

Phosphatic Fertilizers	Nutrients content in rice grains									
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (µg g^{-1})	Zn (µg g^{-1})	Mn (µg g^{-1})	Cu (µg g^{-1})
P_0	0.839	0.155	0.295	0.047	0.096	0.124	58.26	42.06	59.80	5.18
P_1	1.031	0.198	0.340	0.056	0.106	0.158	35.34	42.09	54.96	5.27
P_2	1.061	0.195	0.331	0.053	0.099	0.149	35.34	42.30	55.81	5.28
P_3	0.983	0.174	0.299	0.048	0.096	0.128	43.43	43.65	58.05	5.25
LSD at 5% level	0.026	0.008	0.008	0.003	0.003	0.008	4.343	0.294	0.882	0.070
CV (%)	3.56	4.41	1.46	6.01	3.20	2.09	12.12	0.84	1.86	1.59

Table 3: Interaction effect of PSB and different phosphatic fertilizers on the content of different nutrient elements in grains of T. *aus* rice cv. BR26

PSB × P fertilizers	Nutrients content in rice grains									
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (µg g^{-1})	Zn (µg g^{-1})	Mn (µg g^{-1})	Cu (µg g^{-1})
B_0P_0	0.709	0.131	0.293	0.043	0.092	0.125	47.47	41.99	60.87	5.133
B_0P_1	0.985	0.190	0.340	0.052	0.103	0.159	31.29	41.94	58.98	5.290
B_0P_2	1.073	0.195	0.330	0.051	0.096	0.148	31.29	42.38	56.53	5.327
B_0P_3	0.924	0.153	0.297	0.044	0.096	0.128	47.47	43.53	59.33	5.210
B_1P_0	0.931	0.174	0.296	0.048	0.098	0.123	63.65	41.44	59.58	5.190
B_1P_1	1.069	0.205	0.343	0.057	0.105	0.158	31.29	41.99	50.54	5.233
B_1P_2	1.064	0.199	0.327	0.055	0.099	0.151	36.68	42.17	53.71	5.230
B_1P_3	0.989	0.188	0.304	0.045	0.096	0.125	42.08	43.71	57.40	5.333
B_2P_0	0.947	0.181	0.293	0.048	0.098	0.125	63.65	42.35	58.28	5.270
B_2P_1	1.050	0.201	0.343	0.060	0.110	0.161	47.47	42.04	53.61	5.227
B_2P_2	1.092	0.197	0.341	0.056	0.103	0.151	31.29	42.27	57.83	5.307
B_2P_3	1.029	0.190	0.303	0.052	0.095	0.132	47.47	43.73	58.10	5.200
B_3P_0	0.770	0.136	0.298	0.048	0.095	0.124	58.26	42.45	60.47	5.130
B_3P_1	1.023	0.195	0.335	0.053	0.104	0.156	31.29	42.41	56.72	5.337
B_3P_2	1.015	0.189	0.326	0.052	0.099	0.148	42.08	42.39	55.83	5.260
B_3P_3	0.989	0.166	0.294	0.049	0.097	0.129	36.68	43.64	57.37	5.237
LSD at 5% level	0.053	0.017	0.017	-	-	-	8.685	-	1.764	-

CV (%)	3.56	4.41	1.46	6.01	3.20	2.09	12.12	0.84	1.86	1.59

The interaction effect of PSB strains and P fertilizers shows that the accumulation of Ca, Mg and S was highest in rice grains (0.060, 0.110 and 0.161%, respectively) due to B_2P_1 treatment and N content was highest in B_2P_2 (1.092%) and P content was highest in B_1P_1 (0.205%). The K content was highest and same in B_1P_1 and B_2P_1 (0.343%). The content of all these elements were lowest at B_0P_0 (0.709% N, 0.131% P, 0.293% K, 0.043% Ca, 0.092% Mg and 0.125% S). Both highest and lowest content of Fe, Zn, Mn and Cu in rice grain was different in different treatments. The content of Fe in rice grains was same and highest in B_1P_0 and B_2P_0 (63.65 µg g^{-1}) and it was lowest in B_0P_1 and B_0P_2 (31.29 µg g^{-1}), Zn content was highest in B_2P_3 (43.73 µg g^{-1}) and lowest in B_1P_0 (41.44 µg g^{-1}), Mn content was highest (60.87 µg g^{-1}) in B_0P_0 and lowest in B_1P_1 (50.54 µg g^{-1}) and Cu content was highest in B_3P_1 (5.337 µg g^{-1}) and lowest in B_0P_0 (5.133 µg g^{-1}). The over all interaction effect of PSB and different P fertilizers indicate that all the three PSB strains when used without any P fertilizers the accumulation of all the nutrient elements except Zn was remarkably increased.

Effect on nutrients content of rice straw

The content of different nutrients such as N, P, K, Ca, Mg, S, Fe, Zn, Mn and Cu in rice straw as influenced by the effect of inoculation of rice seedlings with three selected PSB strains individually and in association with three different sources of P fertilizers have been studied (Table 4, 5 & 6). The content of all the nutrient elements varied significantly due to the different PSB strains except that of S. The highest amount of N (0.454%), P (0.074%) and Mn (587.67 µg g^{-1}) was obtained by treatment B_1; Ca (0.393%), Mg (0.284%), S (0.075%), Fe (211.96 µg g^{-1}) and Cu (11.59 µg g^{-1}) by B_2 but the content of K (1.294%) and Zn (67.24 µg g^{-1}) was highest in B_0. On the contrary, the accumulation of all the nutrients except K and Zn was lowest in B_0. This indicate the PSB strains favoured accumulation of nutrient elements in rice straw and was in the order of $B_1 > B_2 > B_3$ (Table 4).

Table 4: Effect of PSB on the content of different nutrient elements in straw of T. *aus* rice cv. BR26

PSB Isolates	Nutrients content in rice straw									
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (µg g^{-1})	Zn (µg g^{-1})	Mn (µg g^{-1})	Cu (µg g^{-1})
B_0	0.412	0.058	1.294	0.319	0.267	0.072	203.87	67.24	584.26	11.41
B_1	0.454	0.074	1.275	0.363	0.284	0.073	209.94	66.57	587.67	11.57
B_2	0.450	0.070	1.279	0.393	0.284	0.075	211.96	66.87	587.21	11.59
B_3	0.428	0.071	1.283	0.324	0.269	0.073	207.92	66.89	587.51	11.47
LSD at 5% level	0.026	0.008	0.008	0.026	0.008	-	5.743	0.4141	2.673	0.1116
CV (%)	7.32	6.56	1.24	9.67	6.10	4.33	3.31	0.74	0.55	1.16

Table 5: Effect of different phosphatic fertilizers on the content of different nutrient elements in straw of T. *aus* rice cv. BR26

Phosphatic Fertilizers	Nutrients content in rice straw									
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (µg g^{-1})	Zn (µg g^{-1})	Mn (µg g^{-1})	Cu (µg g^{-1})
P_0	0.383	0.057	1.307	0.303	0.243	0.057	238.25	66.92	575.73	11.22
P_1	0.503	0.079	1.250	0.391	0.316	0.092	193.09	66.08	597.45	11.73
P_2	0.452	0.076	1.268	0.374	0.290	0.083	195.79	66.26	592.08	11.80
P_3	0.408	0.061	1.307	0.331	0.255	0.061	206.57	68.32	581.41	11.27
LSD at 5% level	0.026	0.008	0.008	0.026	0.008	0.008	5.743	0.414	2.673	0.112
CV (%)	7.32	6.56	1.24	9.67	6.10	4.33	3.31	0.74	0.55	1.16

The content of different nutrient elements in rice straw varied significantly dew to the single effect of three different sources of P fertilizers (Table 5) and the treatment P_1 was found to induce highest accumulation of N (0.503%), P (0.079%), Ca (0.391%), Mg (0.316%), S (0.092%) and Mn (597.45 µg g^{-1}) while the highest amount of K (1.307%), Fe (238.25 µg g^{-1}) and Zn (66.92 µg g^{-1}) and lowest amount of all other nutrient elements in rice straw were in P_0 (without P fertilizers).

The content of N, P, Fe and K only in rice straw varied significantly, while the content of Ca, Mg, S, Zn, Mn and Cu was not significantly influenced by the interaction effect of PSB inoculants and P fertilizers. The content of all nutrients except K, Fe, Zn and Cu was lowest in B_0P_0. The lowest amount of K (1.231%) was found in B_1P_1, Fe (193.09 µg g^{-1}) in B_0P_1 and B_0P_2, Zn (65.55 µg g^{-1}) in B_1P_1 and Cu (11.19 µg g^{-1}) in B_1P_0. The highest content of N (0.565%), Ca (0.454%), Mg (0.332%) and S (0.094%) was found in B_2P_1; P (0.088%), Mn (599.33 µg g^{-1}) and Cu (11.90 µg g^{-1}) in B_1P_1 and the highest content of K (1.318%) in B_0P_0 and B_0P_3, Fe (249.71 µg g^{-1}) in B_0P_1 and Zn (68.60 µg g^{-1}) in B_0P_3. The performance of B_1 and B_2 strains with or without P_1 i.e. TSP seems favoured the accumulation of different nutrient elements in rice straw under study.

Table 6: Interaction effect Interaction effect of PSB and different phosphatic fertilizers on the content of different nutrient elements in straw of T. *aus* rice cv. BR26

PSB × P fertilizers	Nutrients content in rice straw									
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe ($\mu g\ g^{-1}$)	Zn ($\mu g\ g^{-1}$)	Mn ($\mu g\ g^{-1}$)	Cu ($\mu g\ g^{-1}$)
B_0P_0	0.331	0.042	1.318	0.281	0.235	0.057	220.05	67.34	573.26	11.22
B_0P_1	0.448	0.069	1.260	0.348	0.308	0.092	193.09	66.49	597.30	11.58
B_0P_2	0.471	0.071	1.281	0.348	0.284	0.081	193.09	66.54	589.12	11.61
B_0P_3	0.399	0.050	1.318	0.301	0.243	0.058	209.26	68.60	577.37	11.21
B_1P_0	0.413	0.065	1.296	0.301	0.243	0.057	249.71	66.22	576.33	11.19
B_1P_1	0.551	0.088	1.231	0.428	0.324	0.091	187.70	65.55	599.33	11.90
B_1P_2	0.453	0.079	1.263	0.401	0.308	0.084	193.09	65.91	592.64	11.85
B_1P_3	0.401	0.066	1.312	0.321	0.259	0.058	209.26	68.59	582.39	11.31
B_2P_0	0.401	0.061	1.299	0.321	0.243	0.058	247.01	67.08	577.75	11.24
B_2P_1	0.565	0.084	1.235	0.454	0.332	0.094	193.09	66.03	596.68	11.86
B_2P_2	0.429	0.072	1.281	0.414	0.292	0.084	198.48	66.24	592.72	11.92
B_2P_3	0.406	0.065	1.300	0.381	0.268	0.065	209.26	68.14	581.69	11.32
B_3P_0	0.387	0.058	1.315	0.308	0.251	0.057	236.23	67.05	575.57	11.24
B_3P_1	0.448	0.075	1.273	0.334	0.300	0.090	198.48	66.25	596.46	11.58
B_3P_2	0.453	0.085	1.246	0.334	0.275	0.082	198.48	66.32	593.83	11.79
B_3P_3	0.425	0.065	1.298	0.321	0.251	0.062	198.48	67.95	584.18	11.25
LSD at 5% level	0.053	0.017	0.017	-	-	-	11.49	-	-	-
CV (%)	7.32	6.56	1.24	9.67	6.10	4.33	3.31	0.74	0.55	1.16

Sarkar (2007) reported that the inoculation of seedlings with PSB strains significantly increased the content of N, P, K, Ca, Fe, Mn and Zn in rice at tillering stage. Alam (2007) reported that inoculation of seedlings with some novel strains of PSB significant increased the content of P in both straw and grain of rice cv. BRRI dhan39. Kar *et al*. (2005) reported that nutrient contents and their uptake by plants improved under *Azospirillum*-inoculated plants. Sharma (2003) showed that inoculation of *Pseudomonas striata* with RP increased the N uptake (by 18-38 kg ha^{-1}), P uptake (by 2.7-6.6 kg ha^{-1}), and K uptake (by 16-41 kg ha^{-1}) of the rice-wheat system. Kundu and Gaur (1983) showed that PSB: *Azotobacter chroococcum, Pseudomonas striata* and *Aspergillus awamorii* appreciably increased uptake of nutrients with or without chemical fertilizers. Sattar and Habibullah (1987) reported that P solubilizers, *Aspergillus awamori Aspergillus niger, Pseudomonas striata, Bacillus megaterium and Bacillus polymyxa* significantly increase P uptake by rice over control at all the levels of TSP (at 0, 60 and 90 kg P_2O_5 ha^{-1}) but it was identical when mixed culture was incorporated with the rice seedling root before transplanting. The efficiency of TSP was also increased when applied with phosphate dissolving cultures. They also reported that the bacterium in combination with RP produced the desired effect more prominently than when bacterium applied in combination with SSP. Tamgale *et al*. (2006) reported the highest uptake and availability of P when Messoorie RP was used with organics and PSB. Chinnusamy *et al* (2006) reported that the inclusion of PSB significantly improve the Zn nutrition of the paddy and the P utilization of the applied RP. Yasmin *et al.* (2004) demonstrated that inoculation of *Bacillus* sp. Z3-4 and *Azospirillum* sp. Z3-1 isolates resulted in higher total N and P contents on Tanzanian rice variety. Mathews *et al.* (2006) showed inoculation *Azospirillum* and phosphobacterin with 150% RDF (RDF; 75, 75 and 90 kg N, P and K ha^{-1}, respectively) and $ZnSO_4$ at 25 kg ha^{-1} resulted in the highest total uptake of N, P, K and Zn at all the stages of growth of rice.

The study ventilated that PSB isolated from rice rhizosphere could be used for sustainable P nutrition in rice crop production system in Bangladesh. The study also revealed that application of Phosphatic fertilizer especially SSP and TSP could be applied particularly in acidic soil along with PSB inoculation.

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