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Effect of Phosphate Solubilizing Microorganisms on Phosphorus Uptake, Yield and Yield Traits of Wheat (*Triticum aestivum* L.) in Rainfed Area

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ABSTRACT

Investigation aimed at evaluating the effects of Phosphate Solubilizing Microorganism inoculants to improve phosphorus uptake and its impact on the yield of wheat was carried out under rainfed conditions. For this purpose, the effect of mixture of *Pseudomonas* and *Bacillus* species on phosphorus uptake, growth and yield of wheat variety 'Rawal - 87' was studied. The treatments resulted in statistically significant increase in seed phosphorus content (%) and tillers per m^2 over control. Grain yield and biological yield were significantly increased by the treatments and maximum yield was recorded when PSM was used with phosphorus alone or along with organic matter. It is concluded that PSM alone or along with other combinations produced profound effect on grain and biological yield, tillers per m^2 and seed phosphorus content. On other parameters its effect was non-significant.

Key Words: Phosphate Solubilizing Microorganisms; Yield; Wheat

INTRODUCTION

In most of the agricultural soils of Pakistan, the supply of phosphorus is low and it is not readily available for plant use. The fixation of added P in calcareous soils is a serious problem (More & Ghonsikar, 1988). On most of the soils the P recovery from an added fertilizer is low, usually 10 to 30% (Gilani *et al*., 1983). It is well known that more than two-third of phosphatic fertilizers are rendered unavailable within a very short period of time after its application due to fixation in soil complex as di-and tri -calcium phosphates (Mandal & Khan, 1972).

Phosphorus solubilizing microorganisms (bacteria and fungi) enable P to become available for plant uptake after solubilization. Several soil bacteria, particularly those belonging to the genera *Pseudomonas* and *Bacillus* and fungi belonging to the genera *Penicillium* and *Aspergillus* possess ability to bring insoluble soil phosphates into soluble forms by secreting acids such as formic, acetic, propionic, lactic, glucolic, fumaric and succinic. These acids lower the pH and bring about the dissolution of bound forms of phosphate. Venkateswarlu *et al*. (1984) have reported that during the solubilization of rock phosphate by fungi, the pH of the culture was lowered from 7 to 3. Since, phosphate solubilizing micro-organisms' (PSM) proportion in natural microbial population is not more than 1%, hence it is a common practice in several Russian States, European and Asian countries to inoculate soil with PSM to increase P concentration in the soil solution (Taha *et al.,* 1969).

Kundu and Gaur (1984) reported that the grain and straw yields of rice increased significantly due to inoculations. They further reported that the phosphate solubilizing microorganisms improved phosphorus uptake over control with and without chemical fertilizers. Tomar *et al*. (1998) applied different combinations of *Azotobacter*, vesicular-arbuscular mycorrhizae (VAM), phosphorus solubilizing bacteria (PSB) and NPK fertilizers in wheat. They reported that yield was 2.63 tones ha^{-1} in control, 3.41 tones ha^{-1} with NPK only and the highest (3.80 tones ha^{-1}) with NPK+VAM+PSB.

There is lack of information on the use of PSM under rainfed conditions for wheat. Therefore a field experiment was conducted to asses the role of microorganisms in phosphorus solubilization and phosphorus uptake by wheat in soils of rainfed area and to determine the effects of 'P' solubilization on yield and yield traits of wheat.

MATERIALS AND METHODS

To determine the effect of phosphorus solubilization on yield and yield traits of wheat a field experiment was conducted at agricultural farm of the University of Arid Agriculture, Rawalpindi. The seedbed was prepared by single ploughing followed by planking. The soil was loamy having pH, 7.4; phosphorus, 0.00047%; potassium, 0.01% and organic matter, 0.56%. The experiment was laid out in randomized complete block design (RCBD) with three replications and a net plot size of 3 x 1.8 m^2. The wheat variety Rawal-87 was sown with a single row hand drill at seed rate of 100 kg ha^{-1} in 30 cm apart rows with a plant to plant distance of 20 cm which was maintained by thinning after germination. A basal dressing of nitrogen @ 120 kg ha^{-1} was applied. PSM were applied manually in the form of slurry after germination. PSM inoculum was obtained from Applied Microbiology Lab. NARC Islamabad. It was a mixture of *Pseudomonas* and *Bacillus* Spp. All agronomic practices were same for all the treatments.

The treatments were (To) control, (T_1) Organic manure, (T_2) P_2O_5, (T_3) PSM, (T_4) Organic Manure + P_2O_5, (T_5) Organic Manure + PSM, (T_6) P_2O_5 + PSM, (T_7) Organic Manure + PSM and P_2O_5 Organic manure was applied in the form of farm yard manure before sowing @ 10 tons per hectare. P_2O_5 was applied before sowing in the form of single super phosphate @ 90 kg P_2O_5 per hectare. Data on following parameters were recorded during the course of study from each plot. Soil phosphorus content (%) (Hussaian & Jabbar, 1985) plant phosphorus content (%), seed phosphorus content (%) (Cottenie, 1980) tillers per m^2, plant height (cm), spike length (cm), spikelets per spike, grains per spike, 1000-grain weight (g) grain yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index.

Statistical analysis. The data collected were analyzed statistically using Fisher's Analysis of Variance Technique and least significant difference test at 5% probability level was used to compare the difference among the treatment means (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

Data (Table I) revealed that phosphorus content of the soil after harvesting were statistically non-significant and all the treatments had less phosphorus than it was before sowing (0.00047%). Plant phosphorus content (%) (Table I) showed a non-significant difference between different treatments. The results are contradictory to the findings of Omar (1998) and Saad *et al.* (1998) who reported that the greatest plant P% was found with co-inoculation of bacteria and mycorrhiza and application of Ca-superphosphate.

Table I. Effect of PSM inoculation on soil, plant, and seed P content (%) of wheat

Treatments	Soil P Content (%)	Plant P Content (%)	Seed P Content (%)
T_0 (Control)	0.00047	0.023	0. 26b
T_1 (O.M)	0.0004	0.020	0.28 b
T_2 (P)	0.00043	0.020	0.27b
T_3 (PSM)	0.00038	0.020	0.27 b
T_4 (P + O.M)	0.00038	0.020	0.27 b
T_5 (O.M + PSM)	0.00040	0.017	0.40 a
T_6 (P + PSM)	0.00038	0.020	0.30b
T_7 (P + O.M + PSM)	0.00047	0.020	0.25 b
Significance level	NS	NS	*
LSD (0.05)	-	-	0.078

All values followed by the same letter within column do not differ significantly (P>0.05); * = Significant (P≤0.05) & NS= Non-significant; O.M= Organic Manure P= Phosphorus (P_2O_5) PSM = Phophate Solubilizing Microorganisms

Data about P-content of seed showed that PSM inoculation significantly increased P-content of wheat seed than control (Table I). The highest P-content (0.4%) was recorded in case of T_5 (OM + PSM) which was significantly higher than all the other treatments. Similar findings about the increase in P-uptake by wheat plant due to PSM inoculation was reported by Mukherjee and Rai (1999). Egamberdeyiva *et al.* (2004) also reported that phosphorus content was significantly increased of cotton plant with *Bacillus meliloti* combined with phosphorus as compared to uninoculated plants growing in the control soil.

Results pertaining to tillers per m^2 (Table II) showed that phosphate-solubilizing microorganisms had a significant effect on number of tillers. The maximum number of tillers per m^2 (215) was recorded in T_5 (O.M+ PSM) followed by T_2 (P) with 163 numbers of tillers. This treatment was found at par with T_3 (PSM), T_4 (Organic manure + P_2O_5), T_6 (P_2O_5+PSM) and T_7 (Organic manure + P_2O_5 +PSM). Treatments T_1 (Organic manure), T_3 (PSM), T_4 (Organic manure+ P_2O_5) and T_6 (P_2O_5+PSM) produced tillers which were statistically similar to To (Control). These results indicated that phosphate-solubilizing microorganisms along with organic matter or with other combinations significantly increased the number of tillers per m^2. These results are in line with the findings of Kumar *et al*. (1999) who reported significant increase in number of plants per meter row length by inoculation of *Azotobacter chroococcum.*

Data (Table II) revealed that none of the treatments had any influence on plant height, spike length, total and fertile spikelets per spike and grains per spike of wheat as compared to control. However Kumar *et al.* (1999) reported a significant increase in sorghum plant height by inoculation of different bacterial strains. Similarly Algawadi (1996) reported an increase in size of ear head and number of spikelets per ear of sorghum by the co-inoculation of *Trichodrma harzianum* and *Pseudomonas striata.*

Data regarding 1000-grain weight presented in Table II showed that the maximum 1000-grain weight (36.38g) was recorded in T_2 (P) which was at par with T_0, T_1, T_4, and T_6 and the minimum 1000-grain weight (34.00 g) was obtained in T_3 (PSM) which was at par with T_0, T_1, T_6, and T_7.

The results indicated that phosphorus and organic matter alone and in combination with each other increased the 1000-grain weight as compared to other treatment means similarly phosphorus in combination with PSM significantly affected the 1000-grain weight. These findings are almost similar to those of Capuno *et al.* (1980) who found that fertilizer increased the 1000-grain weight of sorghum.

Final yield of wheat is a function of integrated effects of its individual yield components. Data regarding grain yield kg ha^{-1} (Table II) showed that PSM inoculation in combination with organic manure and phosphorus fertilizer and a combination of these three significantly increased grain yield over control. The maximum grain yield (2135 kg ha^{-1}) was recorded in treatment T_6 that was significantly higher than all other treatments and control except T_5 and T_7 which were at par with it. The minimum grain yield (1420 kg ha^{-1}) was recorded in T_2, which was at par with T_0, T_1, T_3 and T_4.

Table II. Effect of PSM inoculation on tillers per m^2, plant height (cm) , spike length (cm) Spikelets per Spike, Fertile Spikelets per spike, Grains per Spike, 1000-grain weight (g), grain and biological yield (Kg ha^{-1}) and Harvest Index (%) of wheat

Treatments	Tillers per m^2	Plant height (cm)	Spike length (cm)	Spikelets/ Spike	Fertile Spikelets/ spike	Grains/ Spike	1000 Grain Weight (g)	Grain Yield (Kg ha^{-1})	Biological yield (Kg ha^{-1})	Harvest Index (%)
T_0 (Control)	140 c	91.07	11.63	21	20	61	35.31 ab	1548 b	4833 d	30.90
T_1 (O.M)	138 c	95.07	11.39	21	21	61	36.00 a	1484 bc	4833 d	42.10
T_2 (P)	163 b	93.73	10.96	20	21	62	36.38 a	1420 b	7500 ab	18.93
T_3 (PSM)	152 bc	93.00	10.94	21	20	57	34.00 b	1612 b	6167 bcd	30.37
T_4 (P + O.M)	140 bc	95.67	11.08	20	20	62	36.24 a	1592 b	5000 cd	31.73
T_5 (O.M + PSM)	215 a	92.13	10.88	20	20	58	34.27 b	2045 a	8500 a	30.70
T_6 (P + PSM)	158 bc	94.83	11.02	20	20	62	35.05 ab	2135 a	6500 bc	38.15
T_7 (P + O.M + PSM)	140 b	96.13	10.79	20	20	59	34.40 b	2117 a	6333 bcd	38.03
Significance level	*	NS	NS	NS	Ns	Ns	*	*	*	NS
LSD (0.05)	27.25	-	-	-	-	-	-	1.48	379.98	1623

All values followed by the same letter within column do not differ significantly (P>0.05); * = Significant (P≤0.05) NS= Non significant; O.M= Organic Manure P= Phosphorus (P_2O_5) PSM = Phophate Solubilizing Microorganisms

The results showed that inoculation of PSM with phosphorus or organic matter or both showed positive effect on grain yield of wheat while PSM inoculation or phosphorus application alone did not improve grain yield of wheat over control. These results confirmed with the findings of Dwivedi *et al.* (2004) who reported that pre-sowing inoculation of wheat seeds with PSM led to a yield increase over non-inoculated treatments. Saad and Hammad (1998) also reported that the greatest grain yield of wheat was found with inoculation of bacteria and application of calcium superphosphate.

Data on biological yield given in Table II showed that PSM in combination with organic manure significantly increased biological yield of wheat.

The maximum biological yield (8500 kg ha^{-1}) was reported in case of T_5 (O.M+PSM), which was at par with T_2 (P). The minimum biological yield (4833 kg ha^{-1}) was recorded in control, which was at par with T_1, T_3, T_4 and T_7. The results are well supported by the findings of Omar (1998) who reported that rock-phosphate solubilizing fungi *(Aspergillus niger* and *Pseudomonas titrinum)* along with rock phosphate fertilization significantly increased dry matter yield of wheat plants.

Saad and Hammad (1998) also reported that the highest straw yield was obtained with inoculation of phosphate solubilizing bacteria and application of calcium superphosphate. The results are also in line with Kumar *et al.* (1999), Chabot and Antoun (1996) and Kundu *et al.* (1984) who also reported increase in biological yield of sorghum, maize and rice respectively.

None of the treatments influenced the partitioning of dry matter (Harvest Index) of the wheat as compared with control. On the basis of this study it is concluded that PSM in combination with Phosphorus fertilizer and organic manure significantly improved seed phosphorus content, tillers per m^2, grain and biological yield of wheat.

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