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Growth parameters, nutrient uptake and soil fertility under wheat (*Triticum aestivum*) as influenced by levels of phosphorus and phosphate-solubilizing micro-organisms

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ABSTRACT

A field experiment was conducted during the winter season of 1998–99 and 1999–2000, to study the effect of phosphorus levels and phosphate-solubilizing micro-organisms on growth parameters, nutrient uptake and soil fertility under wheat (*Triticum aestivum* L. emend. Fiori & Paol.) crop. The treatments consisted of 4 levels of phosphorus (0, 30, 60 and 90 kg P_2O_5/ha) and of phosphate-solubilizing micro-organisms (no inoculation, *Pseudomonas striata, Aspergillus awamori* and *Pseudomonas striata* + *Aspergillus awamori*). The growth parameters like dry-matter production, root dry weight yield and nitrogen and phosphorus uptake were significantly improved with application of 60 kg P_2O_5/ha. Similarly, all these parameters were significantly increased owing to combined inoculation with *Pseudomonas striata* + *Aspergillus awamori* over individual and no inoculation. Nitrogen and phosphorus uptake of wheat crop increased significantly only up to 60 kg P_2O_5/ha. Though increasing levels of phosphorus (up to 90 kg/ha) left the soil rich significantly in respect of post-harvest status of phosphorus. However, successive higher levels of phosphorus declined the available soil nitrogen status, though significant depletion was observed only up to 60 kg P_2O_5/ha. Inoculation with phosphate-solubilizing micro-organisms also reduced the post-harvest status of available soil nitrogen and phosphorus pool. Highest deciine was observed due to combined inoculation with *Pseudomonas striata* + *Aspergillus* awamori.

Key words : Wheat, Nitrogen, Phosphorus, Growth parameters

Phosphorus is an important plant nutrient, next only to nitrogen and classed along with nitrogen and potassium as a major plant nutrient. It is involved in a wide range of plant process from cell division to the development of good root system and to ensure timely and uniform ripening of the crop. Indian soils are generally very poor in available phosphorus. The soil micro-organisms which are associated with plant roots and its immediate environment play a key role in the uptake of phosphorus by the plant. The rhizosphere micro-flora can therefore be manipulated to allow crops to grow with lesser fertilizer without impairing soil fertility.

MATERIALS AND METHODS

The field experiment was conducted during the winter season of 1998–99 and 1999–2000 at Agronomy Research Farm, Indian Agricultural Research Institute, New Delhi. The soil was sandy clay loam, low in organic carbon and available nitrogen. The status of the available phosphorus was low to medium with high exchangeable potassium. The experimental treatments consisting of 4 levels of phosphorus (0, 30, 60 and 90 kg P_2O_5/ha) and 4 phosphate-solubilizing micro-organisms (no inoculation, *Pseudomonas striata, Aspergillus awamori* and *Pseudomonas striata* + *Aspergillus awamori*) were replicated 3 times in factorial randomized block design. The bread wheat variety 'HD 2329' was raised by following all other recommended cultural practices. The mean maximum and minimum temperatures recorded during the crop season were 43.26°C and 5.57°C in 1998–99 and 38.40°C and 5.49°C in 1999–2000, respectively. Plant samples were taken from sampling row at 40 and 80 days after sowing (DAS) and at harvest to work out the growth parameters. Nutrient uptake was calculated from plant samples taken at harvest. Soil samples were collected before sowing and after harvest of crop for assessing the influence on nitrogen and phosphorus status of soil. The initial status of available soil nitrogen was 165.94 kg/ha and 161.26 kg/ha (A.O.A.C., 1960) during 1998–99 and 1999–2000 respectively. While the respective figures for initial status of available soil phosphorus were 12.96 kg/ha and 12.42 kg/ha (Olsen *et al.*, 1954).

RESULTS AND DISCUSSION

Growth parameters

The growth of wheat in terms of dry-matter accumulation, root dry weight and finally yield improved with phosphorus fertilization. Successive increase in phosphorus levels from 0 to 60 kg P_2O_5/ha significantly increased dry-matter production, and root dry weight at all the stages of crop growth (Table 1).

The possible reason for increase in dry-matter production could be correlated with the increased number of tillers. The increased trend of tillers production ultimately enhanced the dry-matter production. Such increase in tiller production could be the effect of increased root biomass through cell division and multiplication which was influenced by the added as well as native soil phosphorus. The increased root biomass improved the nutrient-uptake pattern by exploiting greater volume of soil which resulted in better physiological activity inside the plant system. Besides, phosphorus being the component of ATP–the energy currency in the metabolic activities might have directly contributed to a larger photosynthetic and luxuriant vegetative growth. These observation confirmed the findings of Lu and Barber (1995), Israel (1991) and Sharma and Parmar (1998).

The vegetative growth parameters also showed increasing trend with the inoculation of phosphorus-solubilizing micro-organisms. The significantly higher values were observed with combined application of *Pseudomonas striata* and *Aspergillus awamori* compared to their individual application. However, the application of *Pseudononas striata* and *Aspergillus awamori* individually also proved beneficial in comparison to uninoculated plots (Table 1).

The inoculation with phosphate-solubilizing micro-organisms possibly invoked favourable change in growth attributes because of improved phosphorus uptake which could be due to better distribution of the absorbing network, greater surface and the mineralization of organic phosphorus. Phosphate-solubilizing micro-organisms solubilize soil phosphorus through production of organic acids chelaing acids phosphatase with net result of an enhanced availability of the element to the plant, which increased the root biomass and then number of tillers. Increased number of tillers per unit contributed towards higher values of growth attributes. Increased availability of phosphorus is also known to influence favourably the ratio of photosynthesis, since it is directly involved in energy transfer reactions. The low phosphate-solubilizing micro-organisms in association improved phosphorus uptake more efficiently than their application in isolation. This is because of the fact that range of organic acid and plant growth-promoting substance increased substantially. These different types of acid and growth-promoting substances secreted by these 2 micro-organisms are additive in action and synergistic in effect as it was observed in present investigation. The results confirm the findings of Gaur and Gaind (1999) and Whitelaw (2000).

Nutrient uptake

Application of phosphorus significantly increased the uptake of nitrogen. It was owing to possible positive interaction of nitrogen and applied phosphorus. As phosphorus fertilization augmented the higher productivity, it resulted in higher nitrogen accumulation.

Table 1. Effect of treatments on growth parameters of wheat

Treatment	Dry-matter production (q/ha)						Root dry weight (g/plant)	
	1998–99			1999–2000				
	Grain yield	Straw yield	Biological	Grain yield	Straw yield	Biological yield	1998–99	1999–2000
Phosphorus (kg P_2O_5/ha)								
0	40.75	62.44	103.19	37.54	61.17	98.71	0.567	0.547
30	47.34	68.34	115.68	45.06	64.64	109.70	0.637	0.618
60	51.19	72.17	123.36	48.48	68.25	116.73	0.684	0.656
90	52.55	73.29	125.84	49.41	70.01	119.42	0.596	0.673
CD (P=0.05)	1.572	2.436		1.467	2.347		0.0210	0.0217
Phosphate-solubilizing microorganism								
No inoculation	44.56	65.39	109.95	42.07	62.35	104.42	0.598	0.590
Pseudomonas striata	48.39	69.62	118.01	45.32	66.39	111.71	0.659	0.632
Aspergillus awamori	47.13	68.08	115.21	44.37	65.48	109.85	0.639	0.613
Pseudomonas striata + Aspergillus awamori	51.75	73.13	124.88	48.72	69.84	119.56	0.686	0.659
CD (P=0.05)	1.572	2.436		1.467	2.347		0.0210	0.0217

The phosphorus fertilization increased substantially the total phosphorus uptake by wheat crop. Phosphorus 60 kg P_2O_5/ha resulted in significantly higher P uptake by wheat plants compared to rest of the treatments (Table 2). This high phosphorus uptake could be attributed to increased dry-matter production and partly due to increase in its concentration. The improvement in phosphorus uptake in different plant parts ultimately resulted in higher uptake at harvest stage.

Inoculation with phosphate-solubilizing micro-organisms also significantly increased the content and uptake of nitrogen which may be due to enhanced availability and uptake of phosphorus, which is known to be positively related with nitrogen uptake. Higher biomass production due to phosphate-solubilizing micro-organisms also contributed towards higher uptake of nitrogen.

The inoculation with phosphate-solubilizing micro-organisms also enhanced the phosphorus uptake to a level of significance compared to uninoculated plot. Higher phosphorus uptake could be possible due to higher biomass production as well as due to more plant-accessible phosphate made available by solubilization of native and applied phosphorus.

Soil fertility

Both phosphorus levels as well as phosphate-solubilizing micro-organisms significantly reduced the soil nitrogen status. It is attributed to the positive interaction be-

Table 2. Effect of phosphorus treatments on nitrogen and phosphorus (kg/ha) uptake by wheat

Treatment	N uptake (kg/ha)		P uptake (kg/ha)	
	1998–99	1999–2000	1998–99	1999–2000
Phosphorus (kg P_2O_5/ha)				
0	88.16	83.09	13.47	12.72
30	100.24	93.68	15.77	14.87
60	108.35	101.05	17.48	16.31
90	111.27	104.37	18.17	16.97
CD (P=0.05)	4.344	3.397	0.694	0.737
Phosphate-solubilizing micro-organism				
No inoculation	94.42	88.48	14.59	13.78
Pseudomonas striata	102.94	96.04	16.47	15.29
Aspergillus awamori	100.34	94.28	15.84	14.98
Pseudomonas striata+Aspergillus awamori	110.33	103.33	18.10	16.82
CD (P=0.05)	4.344	3.397	0.694	0.737

Table 3. Effect of phosphorus tretments on soil fertility

Treatment	Post-harvest status				Net change (net gain/loss)			
	Available soil N (kg/ha)		Available soil P (kg/ha)		Available soil N (kg/ha)		Available soil P (kg/ha)	
	1998–99	1999–2000	1998–99	1999–2000	1998–99	1999–2000	1998–99	1999–2000
Phosphorus (kg P_2O_5/ha)								
0	173.84	169.60	9.79	9.35	+7.90	+8.38	–3.17	–3.07
30	166.42	161.85	13.52	13.07	+0.48	+0.59	+0.56	+0.65
60	159.48	155.19	15.36	14.80	–6.46	–6.07	+2.40	+2.38
90	156.71	151.84	17.56	16.88	–9.23	–9.42	+4.60	+4.46
CD(P=0.05)	4.463	4.426	0.616	0.646				
Phosphate-solubilizing micro-organism								
No inoculation	172.14	165.53	16.51	16.10	+6.20	+4.27	+3.55	+3.68
Pseudomonas striata	162.59	158.57	13.73	13.28	–3.35	–2.69	+0.77	+0.86
Aspergillus awamori	164.59	160.51	14.14	13.61	–1.35	–0.75	+1.18	+1.19
Pseudomonas striata+ Aspergillus awamori	157.14	153.88	11.85	11.12	–8.80	–7.38	–1.11	–1.30
CD(P=0.05)	4.463	4.426	0.616	0.646				

Initial status of available soil nitrogen (kg/ha); 165.94 and 161.26 in 1998–99 and 1999–2000; initial status of available soil phosphorus (kg/ha) 12.96 and 12.42 in 1998–99 and 1999–2000 tween nitrogen and phosphorus use. The increased availability of phosphorus resulted in increased uptake of nitrogen and consequent negative soil nitrogen balance. Further, there is a net gain in soil N at control mainly due to poor removal of soil nitrogen by wheat crop, which left the soil rich in respect of soil nitrogen (Table 3).

With regard to phosphorus balance in the soil, it is evident from data that increase in phosphorus levels has resulted in substantial increase in soil phosphorus status. This could be explained in terms of poor phosphorus utilization. Moreover since the excessive dose of fertilizer P does not result into luxury consumption, naturally the unutilized portion goes into soil system and becomes unavailable fraction of soil phosphorus mainly because of its inherent chemical nature of fast fixation in the soil system.

Though the inoculation with *Pseudomonas striata* and *Aspergillus awamori* registered net positive balance over initial status but it was lower than no inoculation (Table 3). This higher balance in no inoculation plots is attributed to lesser solubilization and utilization by crop. Combined application of *Pseudomonas striata* and *Aspergillus awamori* depleted more native as well as added phosphorus and hence registered net negative balance. This could be explained in terms of better utilization by the crop which could be due to the effective solubilization of native as well as added phosphorus.

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