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SHORT COMMUNICATION

PHOSPHORUS USE EFFICIENCY OF WHEAT, RYE AND TRITICALE UNDER DEFICIENT AND SUFFICIENT LEVELS OF PHOSPHORUS

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Low phosphorus (P) availability in soils and diminishing P reserves emphasize the need to create plants that are more efficient P users. A pot experiment was conducted to examine differences in P uptake and utilization efficiency of three cereals, *viz.* Triticale (*Triticale octoploide* cv DT-46) and its parents wheat (*Triticum aestivum* L. cv PBW-34) and rye (*Secale cereale* L. cv. R-308), under two levels of P fertilization, i.e. 0 (P_0) and 60 (P_{60}) kg P_2O_5 ha^{-1}. The number of tillers per plant was lesser at P_0 compared to P_{60} in all the three species. The reductions were 13%, 37% and 50% for rye, wheat and triticale, respectively. The reduction in shoot and root dry matter was in order of 40 and 36% at P_0 compared to P_{60} irrespective of the species. Root-to-shoot ratio at P_0 was higher for wheat and rye than triticale. Root, shoot and total plant P uptake under P_0 were 2.5, 1.5 and 1.6 fold lower, respectively compared to P_{60}. The amount of dry matter produced per unit P uptake was higher in rye, though the P levels had no significant effect. Thus, it was observed that wheat was responsive to P application but rye was more efficient in utilization of P.

Key words: **Dry matter, phosphorus utilization efficiency, rye, triticale, wheat.**

Phosphorus (P) is one of the major limiting nutrients, next to nitrogen, in crop production. Phosphorus deficiency is a common phenomenon that seriously limits crop production all over the world. In India, about 49 million hectare of land is acidic in nature suffering from acute P deficiency. Data available on P status of Indian soils indicates that 49.3% of soils fall under low P category, 48.8% in medium and only 1.9% have high P status (Hasan 1994). Large applications of P fertilizers are the traditional ways to increase crop production in low P soils (Gahoonia *et al.* 1999). A major portion of P fertilizers is applied to cereals all over the world (Clark 1990). However, utilization efficiency of P fertilizers is often very low, ranging from 10-30% in the year applied (Bolland and Gilkes 1998), resulting in continuous accumulation of P in the soil. Also, concerns are being expressed that due to the limited P resources, P fertilizers may become a serious problem in the future. Selection and breeding of cereal species with high P efficiency is, therefore, an alternative approach (Lynch 1998). There are reports of genotypic differences in P uptake and utilization (Clark 1990, Gahoonia *et al.* 1999, Zhu *et al.* 2001). However, limited information is available under Indian conditions. Therefore, in the present study, an attempt has been made to examine the differences in three cereal species in terms of phosphorus use efficiency (PUE) under deficient and applied levels of phosphatic fertilizer.

Seeds of triticale (*Triticale octoploide*, cv. DT-46), and its parents wheat (*Triticum aestivum* L., cv. PBW-34) and rye (*Secale cereale* L., cv. R-308), were obtained from the Division of Genetics, Indian Agricultural Research Institute, New Delhi and raised under natural conditions in circular earthen pots (20 cm diameter) containing about 7 kg of field soil. The available P content of the soil was lowered by growing soybean and maize crops in the preceding years and was 7.8 mg P kg^{-1} soil

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as determined by the method described by Olsen *et al.* (1954). The pH of soil was 8.2. There were two levels of P application, ie. 0 (P_0) and 60 (P_{60}) kg P_2O_5 ha^{-1}; the latter is the recommended dose of P for cereal cultivation in northern plains. Basal dose of P was applied as single super phosphate (SSP) along with recommended dose of nitrogen (120 kg N ha^{-1}) and potash (40 kg K_2O ha^{-1}). The soil was mixed thoroughly with the fertilizers before filling the pots. The mean day/night temperature during the growth period was 28/12°C. The moisture content of the soil was maintained around field capacity (17%) during the course of the experiment. Three plants were maintained in each pot. Each treatment was replicated four times. The experiment was terminated 60 days after sowing. Observations were recorded on number of tillers, dry weight of shoot and root. Tissue P concentration of shoot and root were estimated colorimetricaly (AOAC 1998) following tri-acid digestion. Total P accumulation per plant and P utilization efficiency (PUE) were calculated. The PUE was expressed as the amount of biomass produced per unit of P uptake (mg dry matter/mg P absorbed). The experiment was laid out in completely randomized design (CRD). The statistical significance of difference between means was assessed by two-way ANOVA using MSTATC (V 1.41). The means were compared by calculating the least-squares difference (LSD) at *P*=0.05.

Number of tillers per plant was significantly different among species as well as for applied P (Table 1). Under P_0, triticale produced lowest number of tillers while rye produced maximum tillers per plant. Similar trend was observed for tiller production among the species under P_{60}. The reduction in tiller number at P_0 over P_{60} was only 13% in rye while in wheat and triticale it was 37 and 50%, respectively. Shoot, root and total plant dry weight differed significantly between the two P fertilization treatments as well as interaction between P and genotype. The reduction in shoot, root and total plant dry matter was found to be 66, 56 and 62% respectively, at P_0 over P_{60}. Wheat showed maximum shoot, root and total plant dry weight under both P levels followed by rye and triticale. The root-to-shoot ratio was higher under P_0 compard to P_{60} (Fig. 1) in wheat and rye.

The P concentration in shoot and root tissue were significantly different among the cereal species (Fig. 2). However, the interaction effect for shoot P concentration was non-significant at 5% probability level. At P_0, the shoot P concentration were higher compared to P_{60}, while reverse was true for root P concentration. The maximum root tissue P concentration was recorded in wheat followed by rye and triticale at P_{60} whereas at P_0, rye possessed lowest P concentration. In terms of shoot tissue P concentration, wheat did not respond significantly to P fertilizer application, while rye and triticale recorded higher P concentration in shoot at P_0.

The three cereal species differed significantly in terms of shoot, root and total plant P uptake under P

Table 1. Number of tillers, shoot, root and total plant dry matter production in wheat, rye and triticale under sufficient and deficient levels of P (0 and 60 kg ha^{-1} applied P) 60 days after sowing

Cereal species	Tillers (number/plant)		Shoot dry weight (g/plant)		Root dry weight (g/plant)		Total plant dry weight (g/plant)	
	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0
Wheat	4.38	2.75	1.38	0.74	0.80	0.48	2.18	1.22
Rye	5.63	4.88	1.20	0.69	0.63	0.42	1.84	1.14
Triticale	2.25	1.13	0.89	0.68	0.57	0.39	1.46	1.06
Mean	4.08	2.92	1.16	0.71	0.67	0.43	1.83	1.14
LSD at 5%	C=0.252, P=0.205		C=0.083, P=0.067		C=0.038, P=0.031		C=0.104, P=0.085	
	CxP=0.356		CxP=0.117		CxP=0.054		CxP=0.147	

C=cereal species, P=phosphorus levels, CxP=interaction

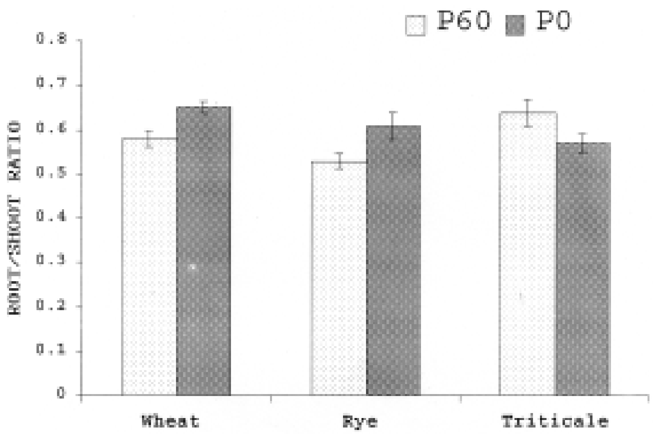

Fig. 1. Variability in root-to-shoot ratio in wheat, rye and triticale under sufficient and deficient levels of P (0 and 60 kg ha^{-1} applied P) 60 days after sowing.

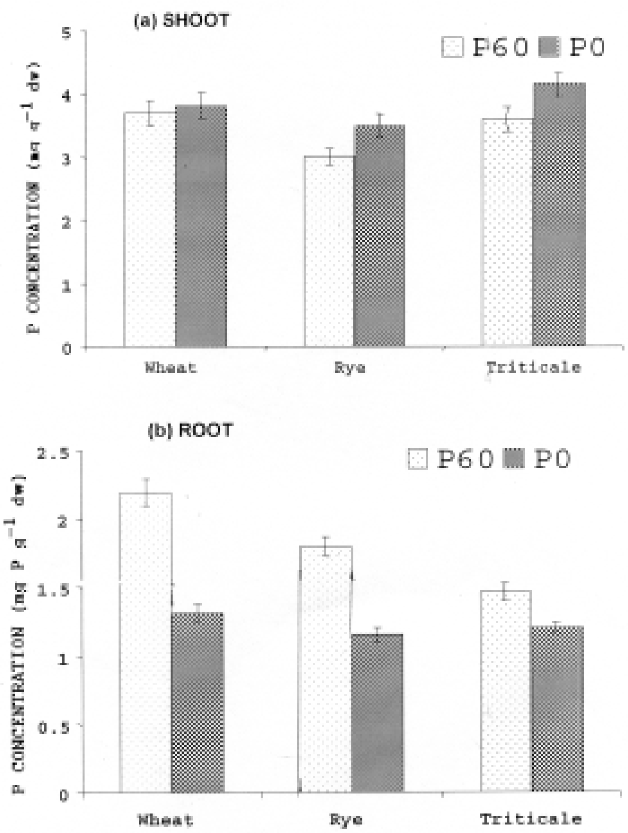

Fig. 2. Variability in phosphorus concentration in (a) shoot and (b) root tissue of wheat, rye and triticale under sufficient and deficient levels of P (0 and 60 kg ha^{-1} applied P) 60 days after sowing.

deficient and sufficient levels (Table 2). The mean values for P uptake averaged over three species showed 1.5, 2.5 and 1.6-fold increase in shoot, root and total plant P uptake respectively, at P_{60} compared to P_0. Among the cereals, wheat recorded significanty higher P uptake in shoot, root and total plant at both the levels of P. The production of dry matter per unit of P uptake, i.e. P utilization efficiency (PUE), was significantly different among the species whereas the response to P application was non-significant. Maximum PUE was observed in rye followed by triticale. Wheat had the lowest PUE out of three species examined.

The results revealed differences in shoot, root and total plant dry matter production for these species under P_0 and P_{60}. Bollons and Barraclough (1997) found a 3-fold difference in whole shoot dry weight of wheat plants when grown under P deficient condition. The differences in whole shoot weight were largely due to difference in the number and weight of tillers. A negative correlation between tiller numbers and shoot dry weight was observed in wheat under P deficiency (Pandey 2001). The primary effect of P on shoot growth was observed in terms of an increase in the tiller numbers. Tiller production under P stress is considered a qualitative trait for selection of species under P stress environments. The adverse effect of P deficiency on shoot yield could be attributed to a delay in leaf emergence on the main culm, which subsequently delayed the emergence and normal development of tillers and reduced the weight of an individual plant part (Elliot *et al.* 1997).

In the present study, P concentration in shoot and root tissues and PUE were significantly different among the cereal species. The high PUE may be related to a better use of stored Pi (Hart and Colville 1988) or its translocation between shoot organs (Youngdahl 1990). Clark (1983) observed that P-efficient genotypes have a greater ability to remobilize P from inactive to active tissues, thus, utilizing P more efficiently. Rye was found more efficient in P utilization, i.e. it produced more dry matter per unit of P uptake, compared to wheat and triticale. Furthermore, it was observed that under P deficient condition, triticale showed much more similarity with wheat in terms of tiller production, tissue P concentration, P uptake and PUE. This suggests that triticale might have inherited the P efficiency traits from

Table 2. Phosphorus uptake and utilization efficiency (PUE) in wheat, rye and triticale under sufficient and deficient levels of P (0 and 60 kg ha^{-1} applied P) 60 days after sowing.

Cereal species	Root P uptake (mg P/plant)		Shoot P uptake (mg P/plant)		Total plant P uptake (mg P/plant)		PUE (mg dry matter/mg P uptake)	
	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0	P_{60}	P_0
Wheat	1.76	0.63	5.12	2.83	6.88	3.46	316.9	352.6
Rye	1.13	0.46	3.61	2.45	4.74	2.91	388.2	391.8
Triticale	0.83	0.40	3.20	2.83	4.03	3.23	362.3	328.2
Mean	1.24	0.49	3.98	2.70	5.22	3.20	355.8	357.5
LSD at 5%	C=0.084, P=0.069		C=0.255, P=0.209		C=0.325, P=0.265		C=23.36, P=N.S.	
	CxP=0.119		CxP=0.361		CxP=0.459		CxP=33.04	

C=cereal species, P=phosphorus levels, CxP=interaction.

wheat and not rye. Singh and Singh (2001) also observed that for most of the photosynthetic parameters triticale showed similarity with wheat rather than rye. On the other hand, Graham (1988) reported that triticale inherits nutrient efficiency from rye parentage. Since, P efficiency is a heritable trait (Graham 1988), an effort can be made to transfer P utilization efficiency from rye to wheat either through conventional or molecular breeding in order to combine these traits into a single gtenotype of commercial importance.

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