Pak. J. Agri. Sci., Vol. 40(1-2), 2003

RELATIVE PHOSPHORUS UTILIZATION EFFICIENCY OF WHEAT GENOTYPES IN HYDROPONICS

H. Salma Kosar, Maqsood A. Gill, Tariq Aziz*, Rahmatullah and Mukkram A. Tahir
Department of Soil Science, University of Agriculture, Faisalabad-38040

Different crop species and varieties differ genetically in responding to root medium P. We evaluated seven commonly grown wheat genotypes for their response to P deficiency stress in hydroponics. Wheat genotypes differed significantly ($p<0.001$) in their biomass accumulation, root: shoot ratio, P concentration, total P uptake in shoot and P utilization efficiency. Total P uptake and P utilization efficiency correlated significantly ($p<0.001$) with their shoot dry matter yield, root dry matter yield and total biomass production. Chenab 2000 and Dirk proved to be efficient and responsive genotypes to P application.

Key words: wheat, genotypic variability, phosphorus utilization

Corresponding author's E-mail: tasuaf@hotmail.com

INTRODUCTION

Phosphorus availability is limited on most of alkaline calcareous soils and imparts a declining effect on crop productivity on these soils (Ahmad et. al., 1992). Although plentiful in the earth crust soil phosphorus often exits in insoluble mineral forms that render it unavailable to plants (Raghothama, 1999; Plaxton and Carswell, 1999). The plant use efficiency of both applied and native soil P is quite low, as a large proportion of applied P becomes immobile due to high P fixation by calcium carbonate (Rahmatullah et. al., 1993).

Fear of depletion of world's reserves of rock P (Plaxton and Carswell, 1999) coupled with substantial hike in price of synthetic phosphatic fertilizers, impel to devise strategies aiming at increasing P utilization efficiency in agriculture. A number of strategies have been proposed for more efficient utilization of root medium P by plants (Gill et. al., 2002; Gill and Ahmad, 2003). It includes exploitation of genetic differences among plants in absorption, translocation, assimilation and utilization of nutrients in a resource poor environment (Gill et al., 2002). Differential response of genotypes in nutrient stress environment may be related to morphological root features, efficiency of ion uptake mechanism, nutrient movement across roots and delivery to the xylem nutrient utilization in metabolism and growth processes (Gerloff and Gableman, 1983; Gill et al., 2002; Gill and Ahmad, 2003). Therefore selection of plant genotypes efficient in biomass accumulation under P stress (deficiency) is an important strategy for areas of low fertilizer inputs, especially in developing countries like Pakistan. The present experiment was conducted to evaluate wheat genotypes for P use efficiency in solution culture.

MATERIALS AND METHODS

The experiment was conducted in a rain protected wire house. Seven wheat genotypes studied in this experiment were (a) Dirk, (b) Chenab 2000, (c) Pothohar 93, (d) Pirsabak 91, (e) Pavon, (f) Kaghan 93 and (g) Sutleg 86. Seeds were germinated in sand taken in plastic trays, irrigated with distilled water. Two week old seedlings were transplanted in foam plugged holes of thermopal sheets floating on half strength modified Johnson's nutrient solution (Johnson et al., 1976), in two polythene lined iron tubs (200-L capacity) containing 200-μM P and 20-μM P as ammonium phosphate ($NH_4 H_2PO_4$), respectively. The pH of the solution was monitored and maintained daily at 5.5 ± 0.5 with HCl or NaOH as required. Completely randomized factorial design was employed in the experiment (Steel and Torrie, 1980) with seven repeats of each genotype. The plants were harvested after four weeks of transplanting and thoroughly washed with distilled water and separated into root and shoot. Dry matter yield was recorded after drying these samples to constant weight at 70°C in a forced air driven oven. Dried plant samples were fine ground to 40-mesh sieve before digesting their 0.5-g portion with 10 ml of di-acid mixture of Nitric acid (HNO_3) and Perchloric acid ($HClO_4$) (3:1). Phosphorus concentration in plant digest was estimated by vanadomolybdate yellow color method using a spectrophotometer (Chapman, 1961). The data were analyzed statistically using software MSTAT-C (Russel and Eisensmith, 1983).

RESULTS AND DISCUSSION

Biomass accumulation

Growth behavior of the seven wheat genotypes was remarkably different at the deficient and adequate levels of P supply in the root medium. It was revealed by significant interactive effect ($P<0.01$) of P rates and genotypes on shoot dry matter (SDM), root dry matter (RDM) and root: shoot ratio (RSR) (Table 1). Such interactions are important for crop cultivar development (Kang, 1998). Shoot dry matter of wheat genotypes decreased two fold when P supply was reduced from

Table 1. Growth performance of the seven wheat genotypes grown at adequate and deficient levels of P supply.

Genotypes	Shoot Dry Matter (g plant^{-1})		Root Dry Matter (g plant^{-1})		Root: Shoot Ratio		Percent Reduction in SDM
	Adequate P supply	Deficient P supply	Adequate P supply	Deficient P supply	Adequate P supply	Deficient P supply	
Dirk	2.94 a	1.28 b	0.35 ^{NS}	0.43 bc	0.12 d	0.34 e	56 bc
Chenab 2000	2.5 b	1.48 a	0.39	0.58 a	0.16 b	0.39 d	41 d
Pothohar 93	2.82 a	1.12 bc	0.42	0.44 bc	0.15 bc	0.39 d	60 b
Pirsabak91	2.11 c	0.99 c	0.29	0.47 b	0.14c	0.47 b	53 c
Pavon	2.15 c	0.64 d	0.33	0.26 e	0.15 bc	0.41 c	70 a
Kaghan 93	2.09 c	0.92 c	0.39	0.36 d	0.19 a	0.39 d	56 bc
Sutlej 86	1.89 d	0.8 cd	0.32	0.4 c	0.17 ab	0.5 a	58 b
Mean	2.36 A	1.03 B	0.36 A	0.42 B	0.15 B	0.41 A	56

Similar letters in the columns are statistically similar at probability >0.01
Adequate P supply: 200 mM P
Deficient P supply: 20 mM P

200 mM to 20 mM, in the growth medium. In deficient P supply, Chenab 2000 and Dirk produced higher SDM while minimum production was observed in Pavon followed by Sutleg 86. Genotypes differed significantly (P<0.01) in terms of relative reduction in SDM due to P deficiency stress (Table 1). At deficient P supply, reduced SDM is attributed to enhanced ability of plants to invest in root biomass which jeopardizes yield potential of above ground portions (Gill et al., 2002). The maximum reduction in SDM production due to P deficiency was observed in Pavon while minimum reduction was observed by Chenab 2000. Root growth had a non-significant effect on P uptake by plants at adequate level of P supply in the root medium. (Romer et. al., 1989). At deficient level of P supply root growth is of greater significance regarding P uptake by plants (Caradus, 1995). All genotypes differed significantly (P<0.01) for their RDM at low P supply (Table 1). Chenab 2000 had a maximum RDM at deficient P supply which was minimum in Pavon. Phosphorus supply, in the root medium, significantly modified RSR in all the wheat genotypes. It increased significantly (P<0.01) with decreasing P supply in the root medium, which can be attributed to translocation of photosynthates from shoot to root (Johansen et. al., 1994; Gaume et al., 2001; Gill et. al., 2002). Sutleg 86 and Pirsabak 91 had maximum RSR at deficient P supply while Dirk had minimum at both P levels.

Phosphorus Contents

There were significant (P<0.01) main and interactive effects of P levels and genotypes on P content in plants (Table 2). Phosphorus concentration in shoot of wheat genotypes grown at deficient level of P supply ranged between 1.06 and 1.73 mgg^{-1}, which is below the critical level for P sufficiency. It ranged between 5.1 and 7.14 mg g^{-1} at adequate P supply. At both P levels the maximum P concentration in shoot was observed in Chenab 2000. Pirsabak and Kagan 93 showed minimum P concentration at adequate P supply while Pothohar 93 and Kagan 93 were at lowest in P concentration at deficient P supply (Table 2).

Genotypes differed significantly at both P levels for P uptake (Table 2). Phosphorus uptake ranged between 11.78 and 17.64 mg plant^{-1} and 0.99 and 2.44 mg plnat^{-1} at adequate and deficient levels of P supply, respectively. Phosphorus utilization efficiency differed significantly among wheat genotypes. On the basis of phosphorus utilization efficiency, various genotypes were grouped into four categories viz: efficient and responsive (ER), non-efficient and responsive (NER), efficient and non-responsive (ENR), and non-efficient and non-responsive (NENR) (Fageria and Baligar, 1993). Genotypes grouped ER (Chenab 2000, Dirk, Pothohar 93 and Pirsabak), are the most desirable as per their performance at both levels of P supply in the root medium (Fig.1). The most undesirable genotypes are the NENR type (Pavon and Sutleg 83) as per their poor performance even at adequate P supply. Phosphorus uptake and RDM of NENR genotypes were inferior to ER genotypes while concentration was almost similar or higher in NENR genotypes than ER genotypes except in Chenab 2000. This means the greater P efficiency was due to P-use efficiency rather than to differences in P concentration. Gardiner and Christensen (1990) and Fageria and Baligar (1999) also reported similar results for wheat cultivars in relation to P-use efficiency.

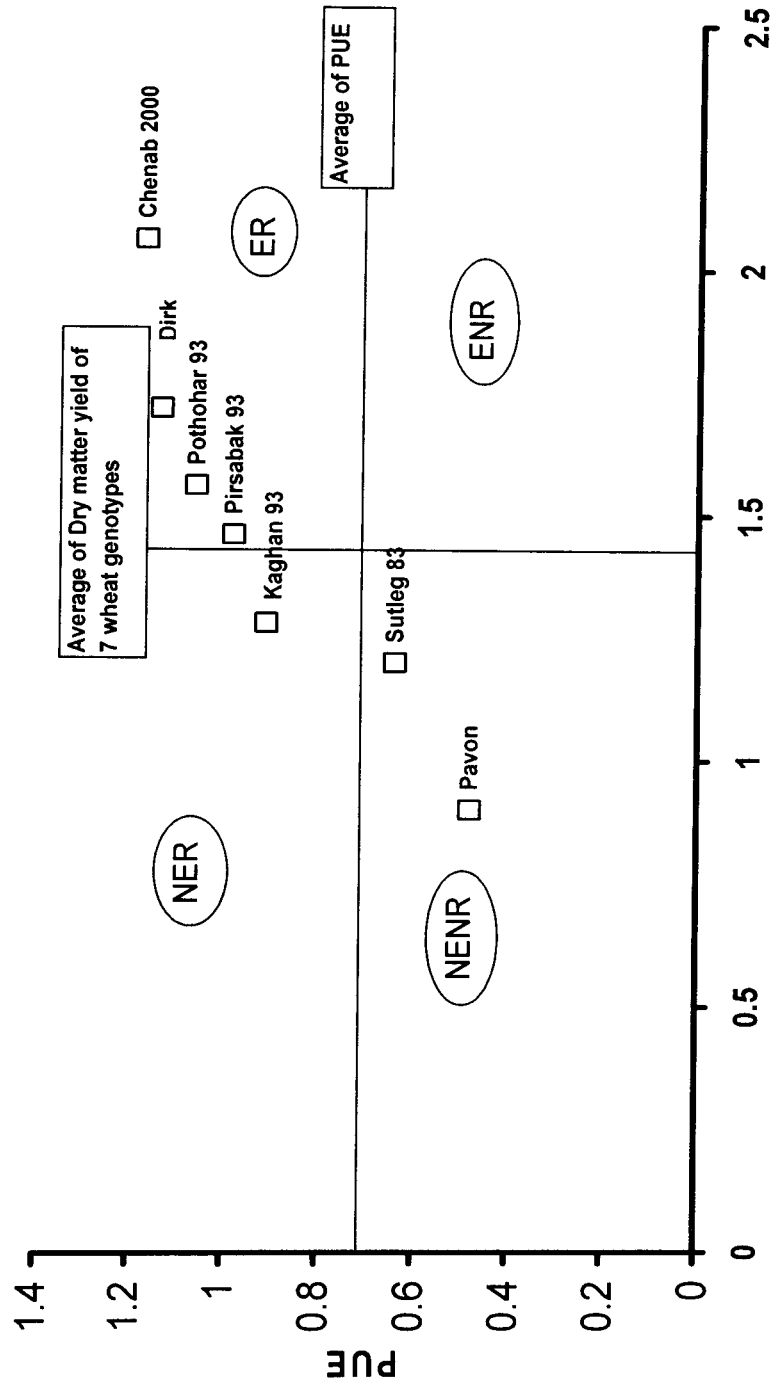

Fig. 4. Classification of wheat genotypes for P-use efficiency

ER: Efficient and responsive
ENR: Efficient but non responsive
NER: Non efficient but responsive
NENR: Non efficient and non responsive

Table 2. Phosphorus concentration, uptake and Utilization efficiency of wheat genotypes grown at adequate and deficient P levels.

Genotypes	P. Concentration (mg g^{-1})		P uptake (mg SDM^{-1})		P utilization Efficiency (mg SDM g^{-1}P)	
	Adequate P supply	Deficient P supply	Adequate P supply	Deficient P supply	Adequate P supply	Deficient P supply
Dirk	5.1 d	1.2 cd	14.76 b	1.55 bc	0.6 a	1.14 a
Chenab 2000	7.14 a	1.73 a	17.64 a	2.44 a	0.36 cd	1.17 a
Pothohar 93	5.11 d	1.06 d	14.02 b	1.19 cd	0.58 b	1.06 ab
Pirsabak91	5.8 c	1.26 cd	12.09 c	1.31 c	0.37 cd	0.98 b
Pavon	5.62 cd	1.61 b	11.96 cd	1.02 cd	0.39 cd	0.48 d
Kaghan 93	5.8 c	1.08 d	11.78 cd	0.99 d	0.38 cd	0.91 bc
Sutlej 86	6.74 b	1.39 c	12.83 c	1.08 cd	0.32 d	0.64 cd
Mean	5.90 A	1.33 B	13.58 A	1.37 B	0.43 B	0.90 A

Means with similar letters are statistically not different at probability P<0.01
Adequate P supply: 200 mM
Deficient P supply: 20 mM

CONCLUSION

Genotypes differed significantly for biomass accumulation and P relations at both P levels. Chenab 2000 and Dirk can be grouped into efficient and responsive as they produced maximum biomass and P utilization efficiency. However, the results warrant their verification under field situation.

LITERATURE CITED:

Ahmad, N., M. T. Saleem and I. T. Twyford. 1992. Phosphorus research in Pakistan. A Review. pp. 59-92. In: Symposium on the role of phosphorus in crop production. National Fertilizer Development Centre, Islamabad.

Caradus, J. R. 1995. Genetic control of phosphorus uptake and phosphorus status in plants. pp. 55-75.In: Johansen, C., K. K. Lee, K. K. Sharma, G. V. Subbarao and E. A. Kueneman (Eds.) Genetic Manipulation of Crop Plants to Enhance Integrated Nutrient Management in Cropping Systems 1. Phosphorus. Proceeding of an FAO-ICRISAT expert consultancy workshop 15-18 March, ICRISAT Asia Centre, Patancheru, India.

Chapman, H. D and P. F. Pratt. 1961. Phosphorus. p. 160-170. In: Methods of Analysis for Soils, Plants and Waters. Div. of Agri. Sci., Uni. California, USA.

Fageria N. K. and V.C. Baligar. 1993. Screening crop genotypes for mineral stresses. pp. 142-159. In: Proceedings of the workshop on adaptation of plants to soil stresses. INTSORMII. Publication No. 94-2. University of Nebraska, Lincola, NE.

Fageria, N. K. and V. C. Baligar. 1999. Phosphorus use efficiency in wheat genotypes. J. Plant Nutr. 22(2): 331-340.

Gardiner, D. T. and N. W. Christensen. 1990. Characterization of phosphorus efficiencies of two winter wheat cultivars. Soil Sci. Soc. Am. J. 54: 1337-11340.

Gaume, A., F. Machler, C. D. Leon, L. Narro and E. Frossard. 2001. Low-P tolerance by maize (Zea mays L.) genotypes: Significance of root growth, and organic acids and acid phosphatase root exudation. Plant and Soil 228:253-264.

Gerloff, C.G. and W.H. Gabelman 1983. Genetic basis of inorganic plant nutrition. pp. 453-480. In: . Lauchli, A. and R.L. Beileski (eds.) Encyclopedia of Plant Physiology. New Series Vol. 15 B. Inorganic plant nutrition. Berlin, Germany: Springer-verlag.

Gill, M. A. and Z. Ahmad. 2003. Inter-varietal Differences of absorbed-phosphorus utilization in cotton exposed to P-free nutrition: Part II. P-absorption and remobilization in plant. Pak. J. Sci. Res. 55(1-2): 10-14.

Gill, M. A., S. Mansoor, T. Aziz, Rahmatullah and M. S. Akhtar. 2002. Differential growth response and phosphorus utilization efficiency of rice genotypes. Pak. J. Agric. Sci. 39(2): 83-87.

Johansen, C., G. V. Subbarao, K. K. Lee and K. K. Sharma. 1995. Genetic manipulation of crop plants to enhance integrated nutrient management in cropping systems-The case of phosphorus. pp. 9-

30. In: Proceeding of a FAO-ICRISAT expert consultancy workshop 15-18 March, ICRISAT Asia Centre, Patancheru, India.

Johnson, C. M., T. Stout, C. Broyer and A. B. Carlton. 1957. Comparative chlorine requirements of different plant species. Plant Soil 8: 237-353.

Kang, Y. S. 1985. The influence of silicon on growth of rice plants. Res. Rep. Rural Dev. Admin., Plant Environment Mycol., Farm product utilization, Korean Republic 27 (1): 57-72.

Plaxton, W. C., M. C. Carswell. 1999. Metabolic aspects of the phosphate starvation response in plants. pp. 349-372. In:Lerner, H. R., Eds. Plant Responses To Environmental Stresses: From Phytoharmones to Genome Reorganization. Marcel Dekker Inc., New York, NY.

Raghothama, K. G. 1999. Phosphate acquisition: Annu. Rev. Plant Physiol. Plant Mol. Biol. 50:665-693.

Rahmatullah, M. A. Gill, B. Z. Sheikh and M. Saleem. 1994. Bio-availability and distribution of P among inorganic fractions in calcareous soils. Arid Soil Res. Rehab. 8: 227-234.

Romer, W., J. Augustin and G. Schilling. 1999. The relationship between phosphate absorption and root length in nine wheat cultivars. pp. 123-125. In: Loughnan et. al., (eds.) Structural and Functional Aspects of Transport in Root: Proceedings of Roots, 3-7 August 1987, Nitra, Czechoslovakia, Dordracht, The Netherland: Kluwer Academics.

Russel, D. F. and S. P. Eisensmith. 1983. MSTAT-C. Crop Soil Sci. Dept. Michigan State Univ., USA.

Steel, R. G. D. and J. H. Torrie. 1980. Principles and Procedures of Statistics. 3rd Ed. McGraw Hill Book Inc., New York, USA.