Pak. J. Bot., 40(1): 351-359, 2008.

RESPONSE OF WHEAT GENOTYPES TO DEFICIENT AND ADEQUATE LEVELS OF PHOSPHORUS

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Abstract

Response of wheat genotypes to deficient and adequate levels of phosphorus was studied in solution culture. Substantial differences in growth parameters such as total plant dry matter (TDM), shoot dry matter (SDM), root dry matter (RDM), root: shoot ratio and some phosphorus related parameters were obvious at deficient and adequate P levels. TDM ranged from 0.89 to 1.51 and 1.56 to 2.25 g 2 plants^{-1} at deficient and adequate P levels, respectively. Genotype 91773 produced almost double the SDM of Pasban at deficient P level while 90640 produced the highest RDM at adequate P level. Differences in SDM indicate that more than 50 % of genotypes produced SDM less than the mean average shoot dry matter at both the P levels. Only three genotypes 89626, 90627 and 91773 showed a phosphorus stress factor (PSF) ≤ 30 %. However RDM was higher at deficient P level than that at adequate P level. It is also obvious from high root: shoot ratio of wheat genotype at deficient phosphorus level in the growth medium. Significant differences for P uptake, absorption rate and utilization rates were also in wheat genotypes at deficient and adequate P levels. A significantly positive correlation with root dry matter ($r = 0.698^{**}$, $p < 0.01$) suggested greater P uptake due to greater root biomass at deficient P level. Specific absorption rate also varied significantly among genotypes at adequate level. Specific utilization rate (SUR) was reduced by increasing P supply in the growth medium. Maximum SUR was observed in Inqlab 91 and minimum in Pasban and line 88678. Results showed existence of genetic differences among wheat genotypes with regard to P absorption and utilization. This information may provide useful basis for their selection under field conditions.

Introduction

Variability in P nutrition exists among crop plants and is exhibited in terms of morphological and physiological expressions. Morphological expressions involve the growth and growth contributing parameters such as root (root geometry, root radius and root hairs) shoot growth, number of tillers and root- shoot ratio while physiological expressions are read out by concentrations, absorptions, translocations, accumulation and utilization of specific nutrient element such as phosphorus (Gerloff, 1987; Yaseen *et al*., 1998, 2004).

Phosphorus (P) is the key element in plant growth and its use in the country is erratic. Inadequate and unbalance use of phosphatic fertilizers is considered the most important among several constraints to increase yield per unit area in Pakistan. More than 90 % soils of Pakistan are deficient in required level of phosphorus. Phosphorus is the nutrient that requires large application in the form of chemical fertilizer to maintain high productivity of plants (Ahmad, 1998; Yaseen *et al*., 2004). However, uptake and utilization of applied P by plants is low on alkaline calcareous soils of Pakistan (Zia *et al*., 1991).

The problem of low availability of P can be tackled by exploiting genetic variability existing within crop genotypes for their ability of absorption and utilization of mineral elements from a nutrient stress environment (Clark & Duncan, 1991). Considering differential behavior of varieties of a species in nutrients, particularly P, wheat genotypes were screened at deficient and adequate phosphorus levels for growth and phosphorus utilization.

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Table1. Mean, lowest and highest dry matter yields, phosphorus stress factor, root-shoot ratio, phosphorus uptake, absorption rate and utilization rate of 20 wheat genotypes grown at deficient and adequate phosphorus levels.

Plant part	P levels	
	25 µM Avg. (Range)	250 µM Avg. (Range)
Dry matter (g 2 plant^{-1})		
Total plant (shoot + root)	1.17 (0.89 – 1.51)*	1.84 (1.56 – 2.25)*
Shoot	0.73 (0.52 – 1.04)**	1.60 (1.35 – 2.05)**
Root	0.39 (0.26 – 0.55)*	0.24 (0.18 – 0.32)*
Root-Shoot Ratio	0.55 (0.43 – 0.64)**	0.15 (0.11 - 0.20)**
PSF (%)	51.88 (28.70 – 70.08)**	-
P uptake (g 2 plant^{-1})	3.37 (1.91 – 5.11)**	16.68 (13.11 – 21.53)**
SAR (µmol P g^{-1} RDM day^{-1})	33.92 (18.86 – 51.36)**	250.34 (104.7 – 356.50)**
SUR ((mg SDM mg^{-1} P day^{-1})	31.83 (14.70 – 59.05)**	12.61 (6.60 – 22.83)**

* Values differ significantly at $p<0.05$.
** Values differ significantly at $p<0.01$.
PSF = Phosphorus stress factor
SAR = Specific absorption rate of phosphorus
RDM = Root dry matter
SUR = Specific utilization rate of phosphorus
SDM = Shoot dry matter

Materials and Methods

Seeds of 20 wheat genotypes were sown in plastic trays containing distilled water washed gravels. Distilled water was used for irrigation. Ten days old seedlings were transplanted in foam plugged holes of thermopole sheet floating on a continuously aerated modified Johnson nutrient solution (Johnson *et al*., 1957) contained in two polyethylene lined iron tubs of 200 L capacity. Two phosphorus levels were established by using $NH_4H_2PO_4$ ammonium phosphate salt; adequate (250 µ M) and deficient (25 µ M) P levels. The pH of the solution was maintained at 5.5 ± 0.5 with HCl or NaOH. Two seedlings were transplanted in one hole of a thermopole sheet and each hole was considered as one repeat. Treatments were arranged according to completely randomized factorial design. Each treatment had 7 replications. Two harvests were taken. Three replications were harvested 30 days after transplanting and phosphorus levels were again maintained to original level. While other four repeats were harvested 7 days after first harvest. At each harvest, a plant was rinsed in distilled water, separated into root and shoot and dried with tissue paper. Fresh and dry weight of roots and shoots were recorded. Plant material was dried in an oven at 65 ± 5ºC for 48 hours and ground to 40 meshes with a mechanical grinder.

Shoot and root samples @ 0.25 g each was digested in a mixture of H_2SO_4 and H_2O_2 (Jones, Jr. & Case, 1990) Phosphorus contents in the digested extract was determined on Spectrophotometer by vanadate-molybdate yellow method (Chapman & Pratt, 1961). Phosphorus specific absorption rate (µ mol P g^{-1} RDM day^{-1}) and utilization rate (mg SDM mg^{-1} P day^{-1}) of wheat genotypes were calculated as described by Hunt (1978).

Results and Discussion

Dry matter yields of total plant (TDM), shoot (SDM) and root (RDM) of 20 wheat genotypes differed markedly at deficient and adequate P levels (Table 1). TDM ranged from 0.89 to 1.51 at 25 µM (deficient) while 1.56 to 2.25 g 2plants^{-1} at 250 µM

(adequate) P levels (Table 1, Fig. 1). Therefore, average estimated decrease in TDM was 36 % due to P deficiency. SDM ranged from 1.09 to 0.52 g 2 plants^{-1} and 2.03 to 1.35 g 2 plants^{-1} at deficient and adequate P levels, respectively (Fig. 2). Genotype 91773 at deficient P level while 90640 at adequate produced the highest SDM. Average across all genotypes there was 119 % increase in shoot biomass with increase in P supply from 25 to 250 µM in the growth medium. Genetic differences for SDM under differential P levels were also reported by Gill *et al*., (1994) and Yaseen *et al*., (1998). Genotypes differed significantly for relative reduction in shoot biomass production (PSF) at deficient P level. The maximum reduction in shoot biomass was observed in genotypes 89251, Pasban, Blue silver, 91173, 91169 and FSD-83 while genotypes 89626, 90627 and 91773 showed less reduction in shoot biomass production (Fig. 3) and hence could be grown safely under limited P supply conditions. Variation in TDM and SDM at deficient and adequate P levels were also reported by Gill *et al*., (2002), Kosar *et al*., (2002) and Yaseen *et al*., (2004). Unlike to SDM, there was 50 % reduction in root biomass (RDM) with the increase in P level from 25 to 250 µM in the growth medium (Table 1, Fig. 4). More or less all the wheat genotypes produced higher RDM at deficient P level. This increase in RDM was possibly due to stimulation effect of P deficiency on root growth under P stress conditions. Increase in root biomass production under P was also reported by many workers (Haynes *et al*., 1991; Gill *et al*., 1994; Yaseen *et al*., 1998, 2004). They reported increase in root biomass due to more translocation of photosynthates from shoot to root under P stress which probably can help plant to absorb more P under limited supply in the growth medium. Higher root-shoot ratio at deficient P level was evident at this conclusion. Root-shoot ratio was 2 fold higher in genotypes grown at 25µM (deficient) P compared to that grown at 250 µM (adequate) P level (Table 1, Fig. 5).

Genotypes showed marked differences in P uptake at deficient and adequate levels of P. Uptake of P decreased from 16.68 to 3.37 g 2plants^{-1} when P level in growth medium was lowered 10 fold from 250 µM to 25 µM (Fig. 6). Phosphorus uptake ranged from 1.36 to 4.34 g 2plants^{-1} at deficient P level. Genotypes also differed significantly for specific absorption rate (SAR) and specific utilization rate (SUR) of P at both the P levels. However differences among genotypes for SAR at deficient P level were not prominent although these differences were very wide and 3 fold higher at adequate P level. SUR ranged from 14.70 (Pasban) to 59.05 mg DM mg^{-1} P day^{-1} at deficient P level (Table 1) which decreased with increase of P supply in growth medium from 25 to 250 µM and ranged between 6.60 (genotype 90627) and 22.83 mg DM mg^{-1} P day^{-1} (genotype 91169).

Phosphorus availability and absorption tended to influence P utilization and plant biomass. About 50 % differences in P uptake in shoots of genotypes grown with deficient P supply could be explained due to differences in root dry matter of the genotypes ($r = 0.69$ **, $p<0.01$). This suggested that greater P uptake was associated with genotypes having larger root system. The importance of a larger root system become even greater in soil grown plants, where P supply is diffusion limited (Jungk *et al*., 1990; Gill *et al*., 2002; Kosar *et al*., 2002). It is interesting to note that P uptake in shoots at deficient P level differed significantly. This indicates that wheat genotypes which accumulated more P in their shoots from a deficient growth medium were more tolerant to P deficiency stress. Haynes *et al.,* (1991) also observed similar responses. This differential P uptake had close link with differences in P uptake of roots which were mainly associated with the differences in root P concentration ($r=0.880$ **, $p<0.01$) in the genotypes grown at deficient P level (data is not given) probably because magnitude of differences in P concentration were much wider compared to differences in their root dry matter. Further more shoot P uptake at deficient P level had a significant correlation with SAR. A similar

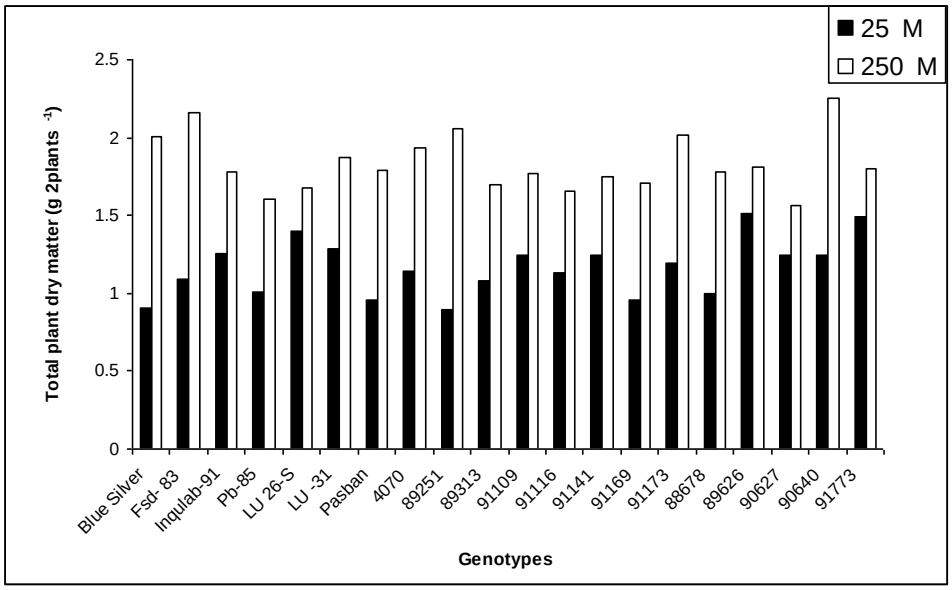

Fig. 1. Differential growth behaviour of 20 wheat genotypes for total plant dry matter production at deficient and adequate phosphorus levels.

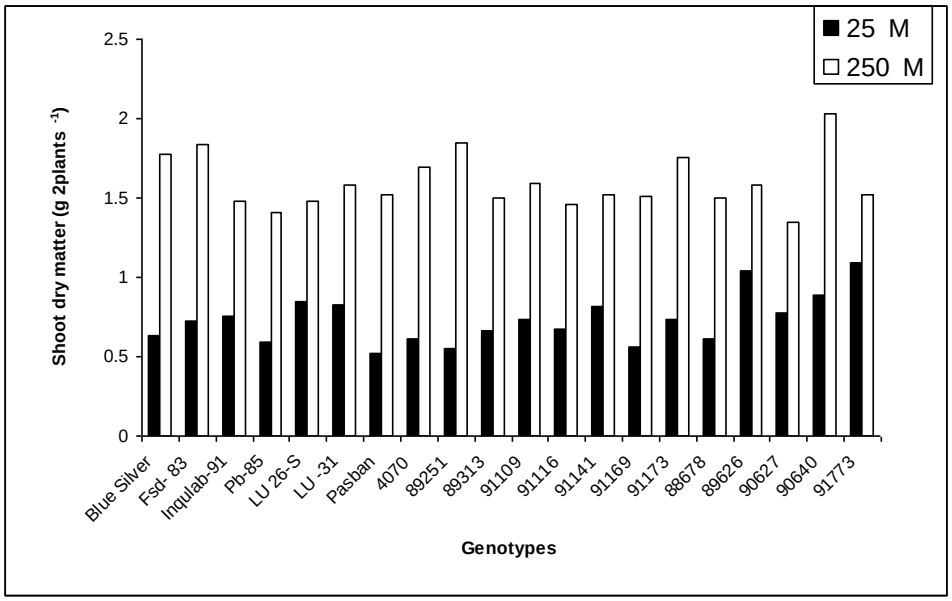

Fig. 2. Differential growth behaviour of 20 wheat genotypes for shoot dry matter production at deficient and adequate phosphorus levels.

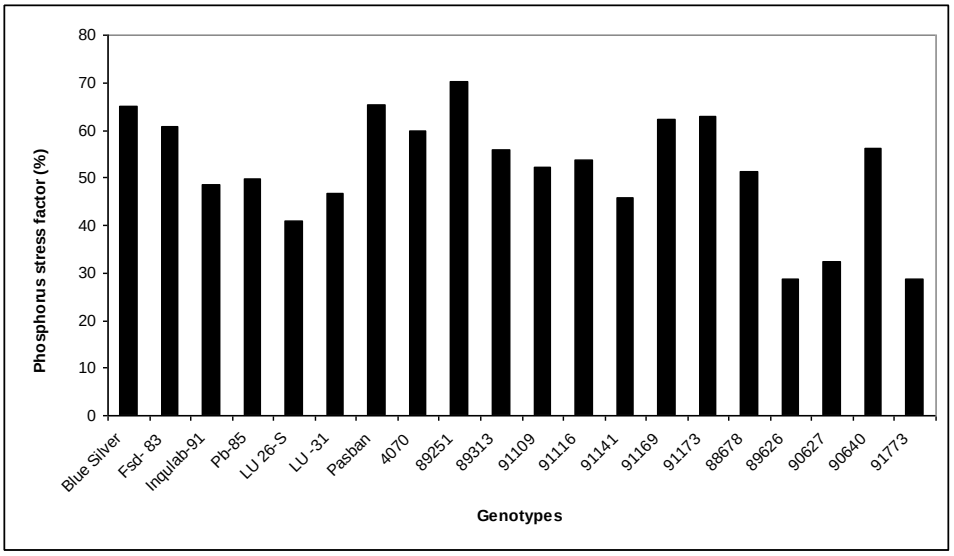

Fig. 3. Relative reduction in shoot growth of 20 wheat genotypes due to phosphorus deficient stress.

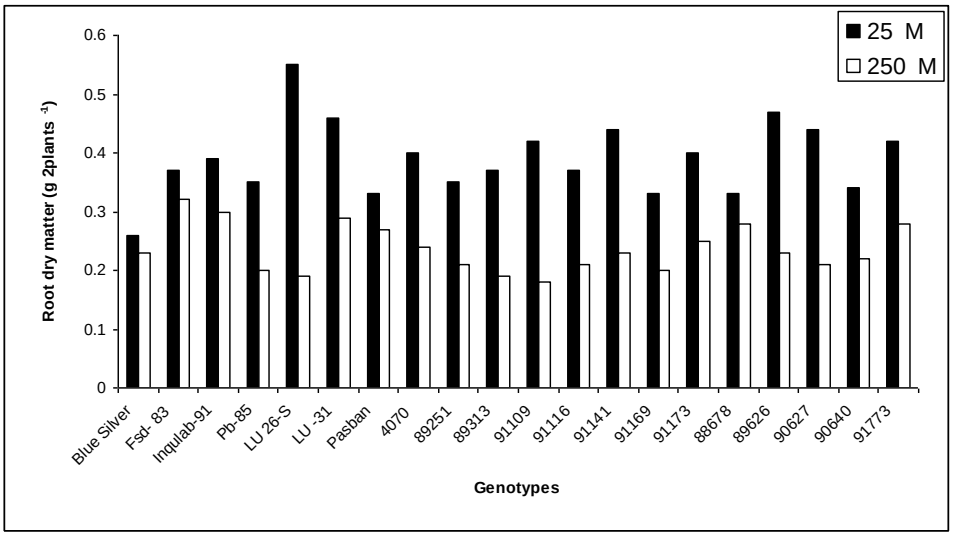

Fig. 4. Differential growth behaviour of 20 wheat genotypes for root dry matter production at deficient and adequate phosphorus levels.

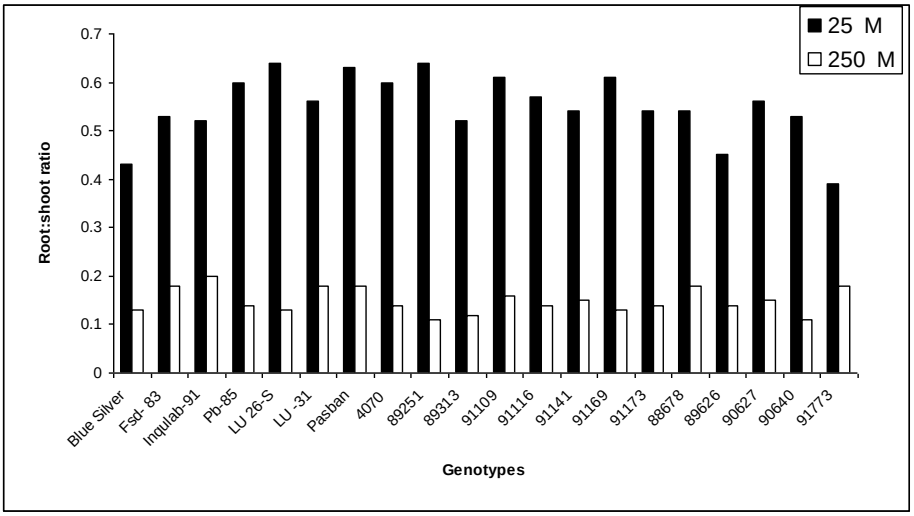

Fig. 5. Differential growth behaviour of 20 wheat genotypes for root-shoot ratio at deficient and adequate phosphorus levels.

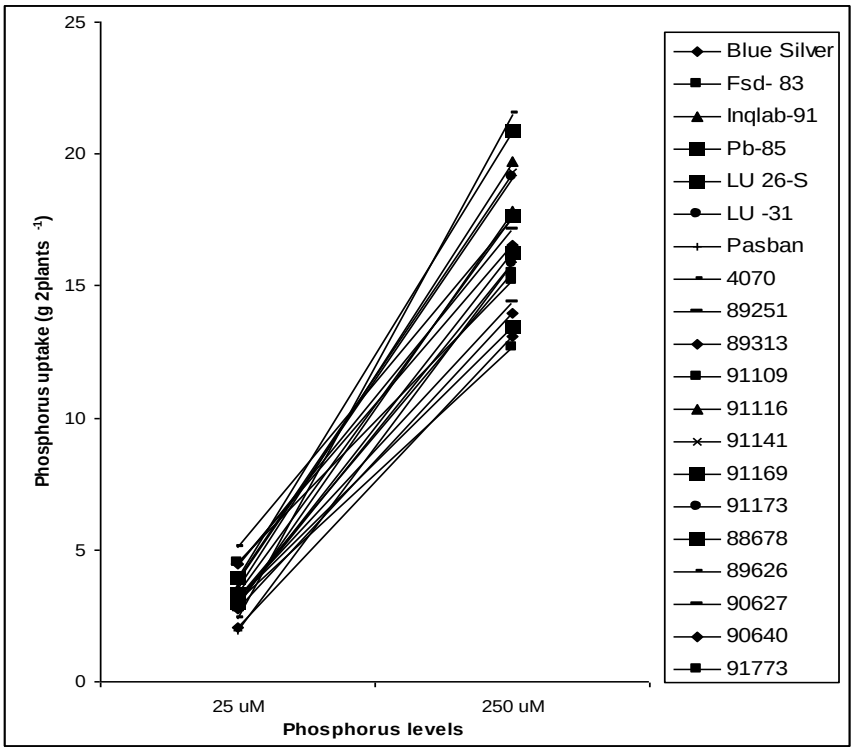

Fig. 6. Differential growth behaviour of 20 wheat genotypes for phosphorus uptake at deficient and adequate phosphorus levels.

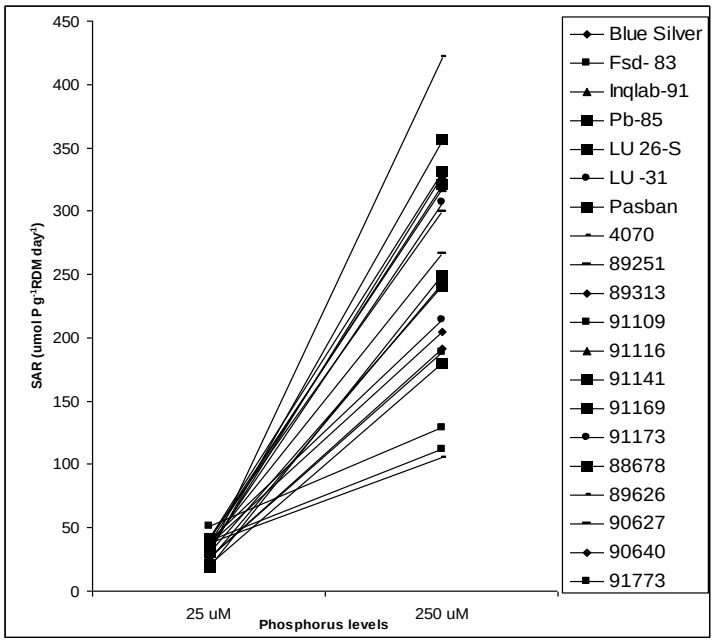

Fig. 7. Differential growth behaviour of 20 wheat genotypes for phosphorus absorption rate at deficient and adequate phosphorus levels.

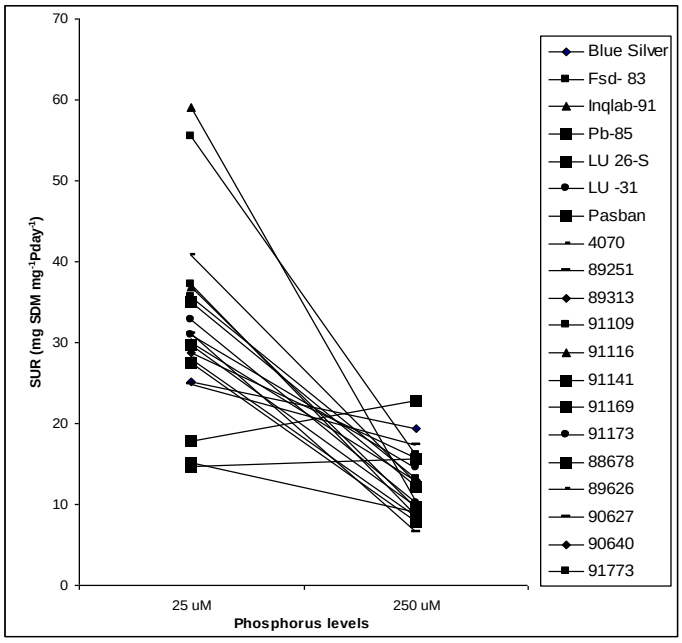

Fig. 8. Differential growth behaviour of 20 wheat genotypes for phosphorus utilization rate at deficient and adequate phosphorus levels.

relationship was found true in genotypes given adequate P supply. This observation pointed out that the genotypes with higher P absorption rate per unit root dry matter were relatively more tolerant to P deficiency stress. SAR ranged from 18.86 to 51.36 and 104.70 to 356.5 μmol P g^{-1} RDM day^{-1} at deficient and adequate P level, respectively (Table 1, Fig. 7). Schenk & Barber (1979) and Coltman *et al*., (1985) reported that differences between genotypes in P absorption were due to morphological and physiological root characteristics. High SUR in deficient P supply (Fig. 8) further conferred the root characteristics and functioning of roots to transport P to shoot under stress conditions. Blume (1988) has already reported similar results.

The results of this study provide useful information about the genetic differences in wheat with regards to P relation. Therefore, involvement of genotypes with better P absorption and utilization mechanism in the breeding programme could be useful to evolve wheat genotypes that can perfoem better on P deficient soils.

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(Received for publication 22 December 2007)