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Differential Growth Behaviour of Selected Wheat Genotypes for Phosphorus Deficiency Stress Tolerance I: Growth Characteristics

Yaseen M. and T. Hussain
Department of Soil Science, University of Agriculture, Faisalabad, Pakistan

Abstract: Response of genotypes was measured in terms of shoot (SDM) and root (RDM) dry matter weights, root-shoot ratio and relative SDM, P concentration. Relative reduction in SDM ranged from none to 54 percent. Genotypes with none or little influence of P deficiency stress on SDM were Kohinoor-83, Pb.85, Parvaz-94 and 4770. Highly P responsive genotypes includes Faisalabad-83, Chakwal-86, Pasban-90, 4072, 4943, 5039, 6529-11 and 6544-6. Differences in SDM exhibited the presence of genetic variation among wheat genotypes under P-deficient conditions. There was 29 percent increase in SDM with increase in P supply. Phosphorus supply levels significantly affect the root dry matter. High RDM at rock-P level indicated adoptation to the P stress. This was also clear from high root-shoot ratio at this P level. Genotypes with high root-shoot ratio showed better adoptation to low P conditions. Except Pak.81 and Parvaz-94 all the other wheat genotypes had greater ratio at rock-P than at adequate P level.

Key words: Wheat, genotype, phosphorus, deficiency, tolerance, hyroponics

Introduction

Crop varieties differ in acidifying their rhizosphere (Flach *et al*., 1987) and in their ability to take up and utilize mineral elements (Clark and Duncan, 1991). Total root length and root extension rate are of great importance in phosphorus uptake (Fohse *et al*., 1991). Gahoonia and Nielsen (1996) reported genetic variability in wheat and barley for several root characters. Cultivars adapted to low P conditions have a good capacity to extract P from insoluble sources (Gunawardena *et al*., 1992). This depends upon the size and distribution of root (Vase, 1990; Fohse *et al*., 1991), root hairs (Fohse *et al*., 1991), root induced pH change (Gahoonia *et al*., 1992) and root exudation (Marschner, 1995). Variability within the plant for nutrient acquisition and use reflects differences in root morphology and differences in mechanisms that either aid or prevent ion movement into the root.
Genotypes producing high harvestable product per unit of P absorbed are called phosphorus efficient (Clark, 1990; El-Bassam, 1989). Therefore, genotypes having greater ability to produce higher biomass under phosphate rock treatment, would be able to extract phosphorus efficiently from low P soils.

Materials and Methods

Healthy seeds of each genotype were sown in washed gravel contained in iron trays in green house. Distilled water was used to keep the seeds moist. 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*., 1957), contained in 200 L capacity polyethylene lined tubs. Two seedlings of each genotype per hole were repeated four times. Two phosphorus treatments were established by adding 100 gram powdered phosphate rock material (stress P level) and 250 µMP (adequate P level). Plants of all genotypes were grown for four weeks. At harvesting, plants were carefully uprooted, thoroughly washed with distilled water, dried with tissue paper and separated into roots and shoots. Dried weights of root and shoot were recorded. Growth parameters i.e. root, shoot, and total plant dry weights, root-shoot ratio and phosphorus stress factors were calculated.

Results and Discussion

Results on evidence of substantial differences among wheat genotypes for their ability to produce plant dry matter (shoot, root or total plant dry matter) at adequate (250 µMP) and stress (rock-P) P levels are given in Table 1 and 2. Genetic differences for shoot dry matter production under differential substrate phosphorus levels have also been reported by Jones *et al*. (1989; 1992), Farooq (1994), Liu *et al*. (1997) and El-Bassam (1989) in wheat. It is obvious from data (Table 1) that increasing P supply increased the shoot dry matter weight (SDM). Wheat genotypes differed significantly in dry matter production. Genotypes Kohinoor-83, Pb.85, Parvaz-94 and 4770, however, exhibited very little influence of increasing P supply in the growth medium as there were negligible change in their shoot dry matter weights. Genotypes with least or non-significant differences in shoot dry matter weights at both P levels illustrated the potential of these genotypes either efficient in extracting P from phosphate rock or had better internal P use ability in rock-P treatment. Genotypes having minimum relative reduction in shoot dry matter due to P stress or having phosphorus stress factor (PSF) close to unity, had such abilities. Relative reduction in shoot dry matter ranged from none to 54 percent (Table 1). Inqlab-91, Kohinoor-83, Pb.85, Parvaz-94 and 4770 showed none or least reduction in their shoot dry matter. This might be due to better P acquisition, uptake and utilization abilities of these genotypes. Growth is the end effect of many integrated processes such as acquisition, uptake, translocation and accumulation of nutrients (Clark, 1990; Vase, 1990; El-Bassam, 1989). Highly positive and significant correlation between root dry matter (RDM) and SDM ($r = 0.664^{**}$, $p<0.01$) explained that about 44 percent variability was attributed to SDM by root under P stress. Highly significant and substantial differences in PSF values of wheat genotypes were useful for the selection of P-efficient genotypes. Partitioning of plant biomass between shoot and root also revealed that relatively more plant biomass was converted into shoot than root. A highly positive correlation of SDM with total plant dry matter ($r = 0.990^{**}$ and 0.996^{**}) at both P levels, respectively indicated that more than 90 percent plant biomass was comprised of shoot material.

Table 1: Shoot and root dry matter weights (g 2 plant^{-1}) and phosphorus stress factor (%) of 15 wheat genotypes at rock P and adequate levels of phosphorus

Genotypes	Shoot dry matter			Root dry matter			Phosphorus stress factor
	Rock-P	250 µMP	Mean	Rock-P	250 µMP	Mean	
Inqlab-91	1.91^{NS}	2.32^{NS}	2.12 B-F	0.26^{NS}	0.20^{NS}	0.23 D-F	17.67 EF
Pak.81	2.06	2.61	2.34 A-D	0.34	0.41	0.38 AB	21.07 E
Kohinoor-83	1.78	1.85	1.82 C-F	0.46	0.30	0.38 AB	3.78 GH
Faisalabad-83	0.96	2.07	1.52 EF	0.14	0.23	0.19 F	53.62 A
Punjab-85	1.69	1.83	1.76 C-F	0.23	0.19	0.21 EF	7.65 FG
Chakwal-86	1.24	1.95	1.60 D-F	0.29	0.23	0.26 C-F	36.41 CD
Pasban-90	1.03	1.75	1.39 F	0.21	0.22	0.21 EF	41.14 BC
LU-26S	1.79	2.51	2.15 A-E	0.36	0.29	0.32 A-D	28.69DE
Parvaz-94	2.18	2.04	2.11 B-F	0.33	0.28	0.31 A-E	- 6.86 H
4072	1.79	2.94	2.37 A-C	0.44	0.36	0.40 A	39.12 B-D
4770	2.10	2.23	2.17 A-E	0.35	0.33	0.34 A-C	5.83 G
4943	2.30	3.42	2.86 A	0.41	0.32	0.36 AB	32.75 CD
5039	1.82	3.59	2.71 AB	0.35	0.41	0.38 AB	49.30 AB
6529-11	1.36	2.22	1.79 C-F	0.22	0.20	0.21 EF	38.74 B-D
6544-6	2.13	3.37	2.75 AB	0.30	0.28	0.29 B-E	36.80 CD
Mean	1.74 B	2.45 A		0.31	0.28		27.04

Means with different letter (s) differ significantly at p = 0.05

Table 2: Total dry matter weight (g 2 $plant^{-1}$) and root:shoot ratio of 15 wheat genotypes at rock-P and adequate levels of phosphorus

	Total dry matter			Root:Shoot ratio		
Genotypes	Rock-P	250 µMP	Mean	Rock-P	250 µMP	Mean
Inqlab-91	2.17^{NS}	2.52^{NS}	2.34 B-F	0.17 c	0.11 ab	0.14 BC
Pak.81	2.40	3.02	2.71 A-D	0.17 c	0.17 a	0.17 A-C
Kohinoor-83	2.24	2.15	2.19 C-G	0.28 a	0.16 ab	0.22 A
Faisalabad-83	1.10	2.30	1.70 FG	0.14 c	0.12 ab	0.13 C
Punjab-85	1.92	2.02	1.97 D-G	0.16 c	0.11 ab	0.13 BC
Chakwal-86	1.53	2.18	1.86 E-G	0.26 ab	0.13 ab	0.20 A-C
Pasban-90	1.24	1.97	1.61 G	0.28 a	0.14 ab	0.21 AB
LU-26S	2.15	2.80	2.47 B-E	0.20 bc	0.13 ab	0.16 A-C
Parvaz-94	2.51	2.32	2.42 B-F	0.16 c	0.16 ab	0.16 A-C
4072	2.23	3.30	2.76 A-C	0.25 ab	0.13 ab	0.19 A-C
4770	2.45	2.56	2.51 A-E	0.17 c	0.16 ab	0.16 A-C
4943	2.70	3.74	3.22 A	0.21 bc	0.10 ab	0.15 A-C
5039	2.17	4.00	3.09 AB	0.20 bc	0.12 ab	0.16 A-C
6529-11	1.58	2.42	2.00 D-G	0.17 c	0.11 ab	0.14 BC
6544-6	2.43	3.65	3.04 AB	0.15 c	0.08 c	0.12 C
Mean	2.05 B	2.73 A		0.20 A	0.13 B	

Means with different letter (s) differ significantly at p = 0.05

This means that root favoured the shoot growth at both P levels. However, P stress favoured more root growth because shoot has marked influence on nutrient uptake by roots under P stress conditions. Moreover, smaller shoot size than root has been used as a measure to study plant's ability to acquire nutrients when nutrients are limited (Clark, 1990; Fohse *et al.*, 1991). Wheat genotypes also differed for root dry matter with P levels in growth medium (Table 1). Differences in root dry matter in response to low P were reported by Jones *et al*. (1989) and Gahoonia *et al*. (1992). Root plays an important role in tolerance of low P (Gahoonia and Nielsen, 1996). A greater heritability among wheat genotypes for root dry matter weight (RDM) was observed at P stress level (Rock-P). Most of the genotypes attained higher RDM at this level. A high root:shoot ratio was also evident of higher RDM and it decreased with the increase in P supply (Table 2). Larger root develops in response of diversion of photosynthate towards root due to the stimulation effect of phosphorus stress (Burauel *et al.*, 1990). Increasing P supply, therefore, decreased the root dry weight. Results are in agreement with the findings of Vase (1990), Fohse *et al*. (1991) and Farooq (1994). Highly positive correlation between SDM and RDM (r = 0.664** and 0.633**) at rock-P and adequate P, respectively, suggested that shoot growth was highly dependent on root growth. Increased root growth under P stress condition is an inheritable character. Plants with greater root weight and more intense physiological activity absorb more P (Fohse *et al.*, 1991). The traits of these root characteristics are quantitatively inheritable (Schettini *et al.*, 1987). These traits can be used to improve P efficiency of a genotype through back cross breeding programme (Gerath, 1993).

Increased root growth under P stress conditions causes enhanced P acquisition (Vase, 1990; Fohse *et al.*, 1991). Differences in ability to absorb P among genotypes could be explained partly through variations in root morphology (Fohse *et al.*, 1991; Gahoonia *et al.*, 1992). Root morphology is related to root weight, root:shoot weight ratio and root hair density. High root growth, therefore, resulted in greater P uptake per unit of root weight. Plants adapted to low p conditions can absorb P at higher rates per unit weight of root than unadapted plants (Chapin and Bieleski, 1982).

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