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SOLUBLIZATION OF TRI-CALCIUM PHOSPHATE BY DIFFERENT WHEAT GENOTYPES

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Major proportion of total Phosphorus in Pakistani soils resides in compounds of calcium with varying solubilities. We investigated the differential growth response and P solubilization efficiency of seven wheat genotypes supplied with tri-calciurn phosphate (TCP) and ammonium di-hydrogen phosphate as different P sources, in Johnson's modified solution. The genotypes differed significantly ($p < 0.001$) in biomass accumulation. Phosphorus concentration and uptake in shoot and P utilization efficiency was also significantly differ for various wheat genotypes. Shoot and root dry matter yield as well as total biomass production correlated significantly ($p < 0.01$) with their shoot P uptake and P utilization when grown with TCP indicating that genotypes efficient in P solubilization accumulated more biomass.

INTRODUCTION

Wheat is one of the most common cereals produced throughout the world. Phosphorus deficiency is common in agricultural crops produced on alkaline calcareous soils of Pakistan. Much of total P present in the soil is not available to plants either because of its fixation by calcium carbonate or formation of sparingly soluble compounds with Ca in soil (Zia et al., 1991; Rahmatullah et al., 1993). Nonetheless, P deficiencies in these soils can be corrected by adding phosphatic fertilizer. But country's production of phosphatic fertilizer is very low and to meet the needs of farmers a huge quantity of phosphatic fertilizer is to be imported every year by spending county's scarce foreign exchange earnings.

Low utilization efficiency of applied P (Ahmad et al., 1990; Zia et al., 1992), coupled with low levels of its application and substantial hike in prices of phosphatic fertilizer over the years, impel to devise alternate strategies aiming at increasing P utilization efficiency in agriculture. The possibility of exploitation of genetic differences in absorption and utilization of nutrients to improve fertilizer use efficiency (Gill et al., 2002) is such an approach currently emphasized for Low Input Sustainable Agriculture, especially in developing countries like Pakistan.

Plants can solublize P from sparingly soluble P compounds through root acidification (Nye and Kirk, 1987; Gill *et al* 1994). It has been reported that rape seed roots are able to mobilize rock phosphate due to exudation of organic acids with in the rhizosphere (Hoffland *et al.,* 1989). It is also well recognized that the genotypes within species widely differ in their ability to absorb and use mineral elements (Ponnamperuma, 1982; Clark and Duncan, 1991). The differential responses and growth of genotypes in a 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 distribution in plant shoots, nutrient utilization in metabolism and growth processes (Gerloff and Gabelman, 1983).

Taking advantages of these differences, selection of plant genotypes which can grow efficiently by utilizing native soil P compounds of low solubility, may be an important future strategy to reduce dependence on synthetic P fertilizers.

The experiment was conducted to evaluate the P solublizing potential of seven commonly growing wheat genotypes grown with soluble and sparingly soluble P sources; ammonium phosphate and tri-calcium phosphate, in solution culture.

MATERIALS AND METHODS

Seeds of seven wheat genotypes were collected from Nuclear Institute for Agriculture and Biology, Faisalabad. The different genotypes were a) Blue Silver, b) Aquab 2000, c) M. Pak 65, d) Inqlab 91, e) Rohtas 90, f) Pak 81 and Khyber 87. The seeds were germinated in plastic trays containing riverbed sand and irrigated with canal water. Twenty days old seedlings were transplanted in foam plugged holes of thermopal sheets floating on modified Johnson's nutrient solution (Johnson et al., 1976), in two polythene lined iron tubs (200-L capacity) containing 250-J..lM P as ammonium phosphate ($NH_4H_2PO_4$) and tri-calcium phosphate (TCP) (@ 0.2g L^{-1}), respectively. The pH of the solution was maintained at 5.5 ± 0.5 with HCI or NaOH. The experiment was laid out according to completely randomized factorial design (Steel and Torrie, 1980) with seven repeats of each genotype. The plants were harvested after 28 days of transplanting and thoroughly washed with distilled water and separated into root and shoot.. Dry matter yield was recorded after drying these samples at 70°C in a forced air driven oven to a constant weight.. 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 on a spectrophotometer (Chapman and Pratt, 1961).

Phosphorus utilization index (PUI) of various rice genotypes was calculated according to Siddiqi and Glass (1981).

$$PUI = \frac{1}{\text{P Conc. (mg g-1)}} \times \text{Shoot dry matter (g plant}^{-1}\text{)}$$

The data was analyzed statistically using software MSTAT-C (Russel and Eisensmith, 1983).

RESULTS

Biomass Production

Different P sources and wheat genotypes had a significant (P< 0.01) main and interactive effect on shoot growth, root development and total biomass production (Table 1). Shoot dry matter was 3 fold lower in plants grown with TCP compared to control (ammonium phosphate). Genotypes differed significantly for SDM in both treatments. Blue Silver, Khyber 87 and Aquab 2000 were the most efficient in SDM production when grown with TCP as well as in control except Khyber 87, which was inefficient in control. Rohtas and Inqlab 91 were lowest in SDM production when grown with TCP. All the genotypes showed differential growth response to P sources in both the treatments.

Averaged overall genotypes RDM was lower but statistically similar in both treatments. Blue Silver, Khyber 87 and Pak 81 responded quite differently compared to all other genotypes i.e. their RDM was higher in TCP treatments compared to control. The RDM of the wheat genotypes ranged between 0.21-0.34 and 0.22-0.50 g plant in TCP and control treatment respectively. Genotypes differed significantly for root shoot ratio (Fig. 2). Root shoot ratio was significantly («0.01) higher (1.5 fold) in plants grown at TCP compared to control. The maximum RSR was exhibited by Blue Silver at TCP treatment.

Genotypes differed significantly for relative reduction in biomass accumulation when grown with TCP (Fig. 1). The maximum reduction in biomass accumulation was observed in Inqlab 91 and Aquab 2000 while Khyber 87 and Pak 81 showed less reduction in biomass accumulation and hence can be grown with sparingly soluble P compounds.

Phosphorus Concentration and Utilization Efficiency

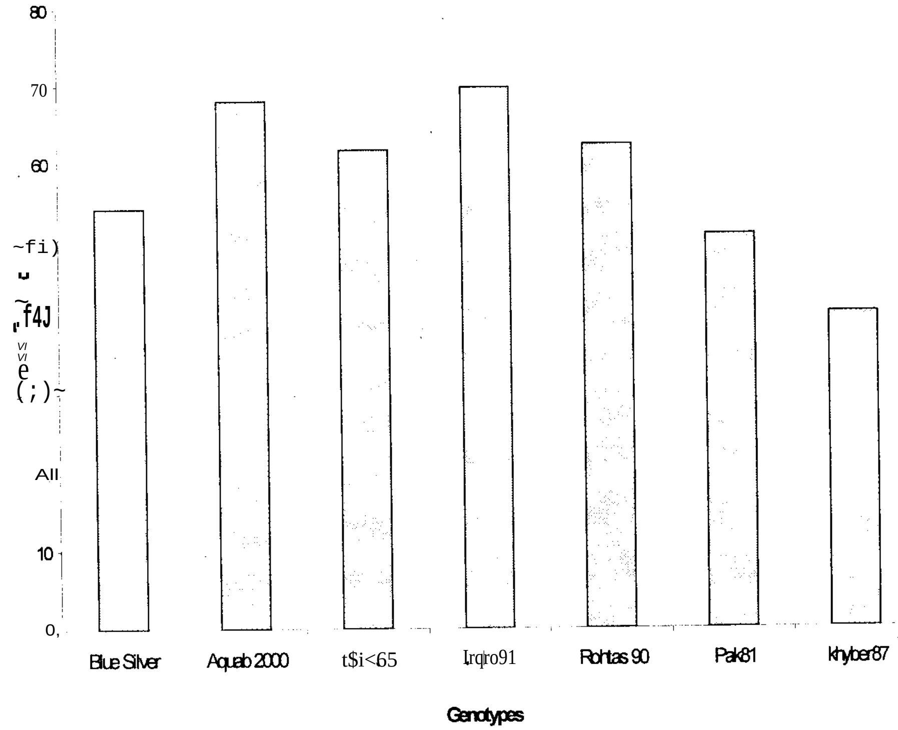
Genotypes and P sources had significant main and interactive effect on P concentration in shoot of wheat genotypes (Table 1). Genotypes differed greatly for P concentration at both the treatments. The P concentration was about 2 fold lower in shoots of plants grown at TCP compared to control. Phosphorus concentration was ranged between 2044 and 2.98 $mg g^{-1}$. Inqlab 91 and Rohtas 90 had maximum P concentration. Genotypes differed for P uptake and utilization efficiency at both P sources (Table 1; Fig. 3). Phosphorus uptake and utilization efficiency was lower in wheat plants grown in TCP compared to control. Blue Silver and Khyber 87 exhibited maximum P uptake while Inqlab 91 and Rohtas 90 exhibited lower uptake when grown with TCP. Maximum P utilization efficiency (PUE) was exhibited by Blue Silver and Aquab 2000 at both P levels.

DISCUSSION

Selection of genotypes efficient in solublizing Ca-phosphate compounds may cope the problem of low solubility and unavailability of applied P fertilizer (Zia et al., 1990) as the major portion of total P in Pakistani soils exists as Ca-phosphates of varying solubilities (Rahmatullah et al., 1994). Genotypes differed in SDM, RDM, TDM, RSR at both P sources which agrees with the earlier repots (Gill, et al., 2002; Akhtar et al., 2002; Gill, et al., 1994).

Table 1. Shoot dry matter, root dry matter, P concentration and P uptake of wheat genotypes grown with ammonium phosphate (AP) and tri-calcium phosphate (TCP)

S.No.	Genotypes	Shoot Dry Matter (g plant")		Root Dry Matter (g plant")		P Concentration (mg g-1 SDM)		P. Uptake (mg 2plant-1)	
		AP	res	Adequate	res	Adequate	res	Adequate	res
1	Blue Silver	2.77 ab	1.08 a	0.32 be	0.34 a	4.5 cd	2.74 b	12.45 be	3.00 a
2	Aquab 2000	3.27 a	0.9 ab	0.5 a	0.31 ab	4.87 e	2.62 e	15.80 a	2.36 b
3	Mpak 65	2.23 ba	0.75 be	0.32 be	0.23 e	5.92 ab	2.66 e	13.01 b	2.00 e
4	Inqlab 91	2.55 b	0.67 e	0.35 be	0.21 cd	6.14 a	2.59 cd	15.06 a	1.73 d
5	Rohtas 90	2.1 e	0.65 e	0.24 e	0.23 c	6.18 a	2.72 b	12.83 be	1.77 d
6	Pak81	1.82 cd	0.73 be	0.24 c	0.29 b	5.93 ab	2,44 e	10.76 c	1.82 cd
7	khyber87	1.84 cd	0.91 ab	0.22 c	0.32 a	5.64 b	2.98 a	9.78 d	2.80 ab
	Mean	2.37 A	0.81 B	0.31 A	0.28 B	5.60A	2.68 B	12.81 A	2.21 B



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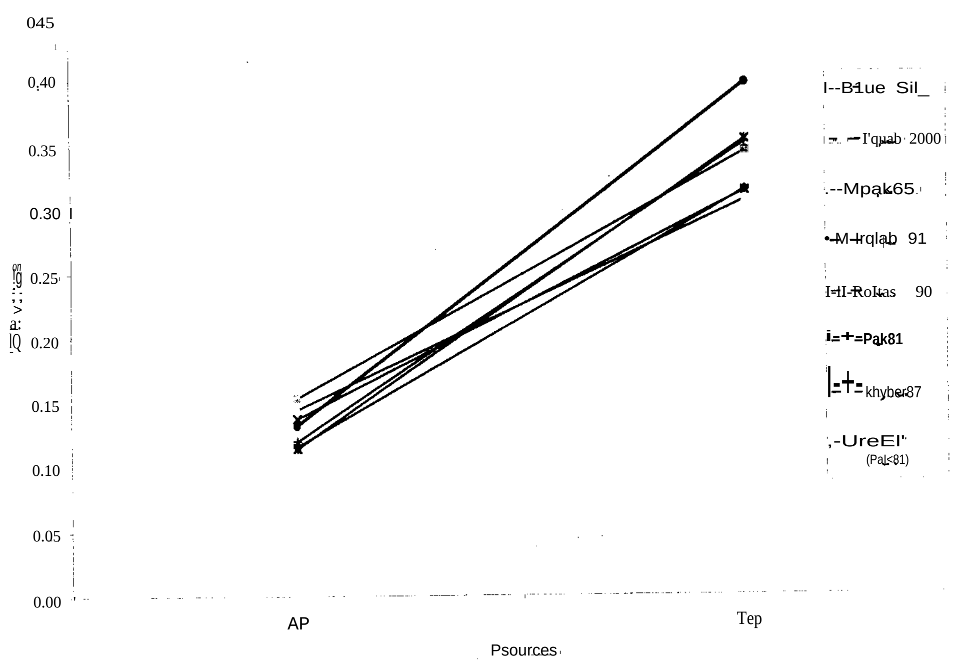

Fig. 2. Root Shoot Ratio of wheat genotypes affected by different P sources

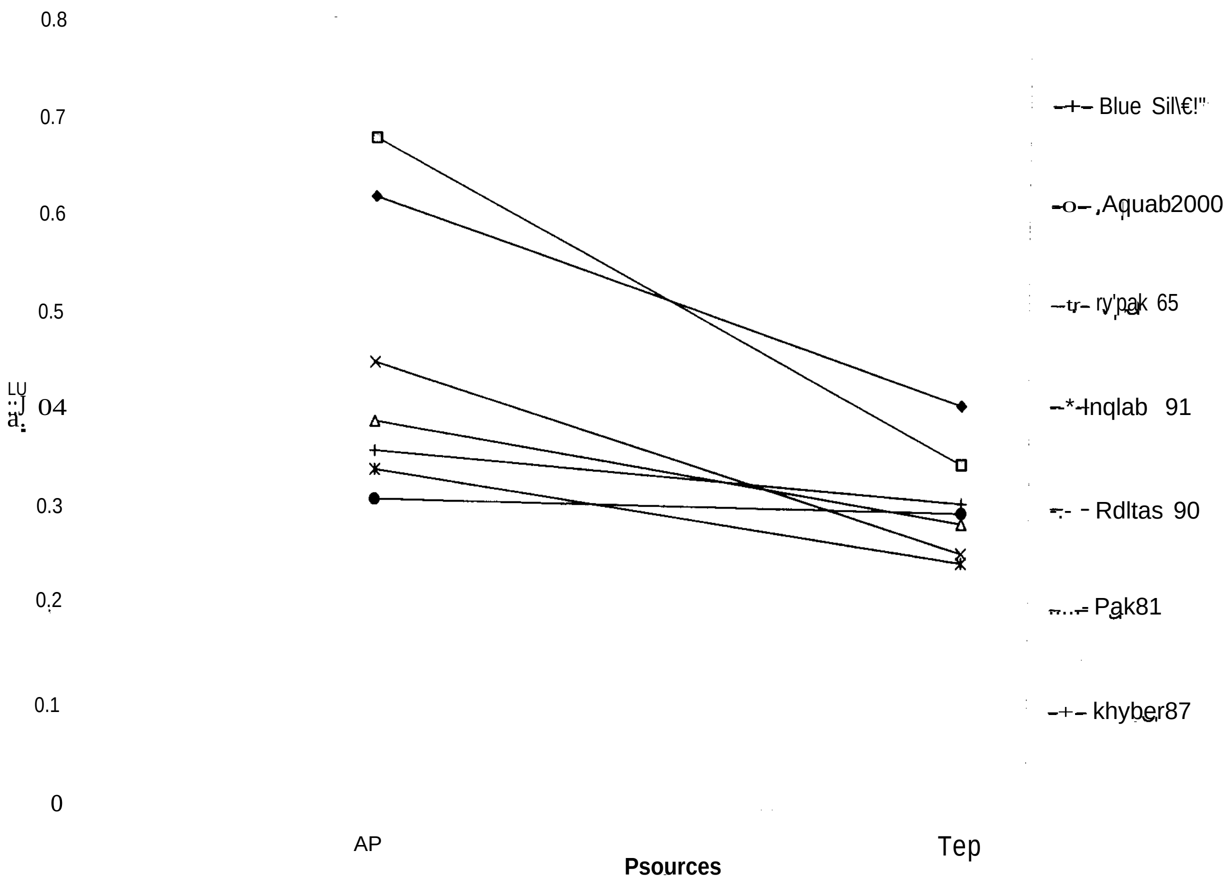

Fig. 3. Phosphorus Utilization Efficiency of wheat grown at diffrent P sources (ammonium phosphate and tri-calcium phosphate)

Phosphorus availability also tended to influence the partitioning between shoot and root (Gill et al., 2002). Root dry matter was reduced in plants grown with TCP treatment but the reduction was much lower compared to SOM, which is clear from RSR. In nutrient stress environment, root had to perform more than shoot so translocation of photosynthates from shoot to root influence the RSR (Gaume et al., 2001; Fageria et al., 1989). Rootshoot ratio of genotypes grown in TCP was much higher compared to control. Highly significant differences in biomass production due to P sources X genotypes interaction is a clear indication of the existence of useful genetic differences for the P solubilization. Such genotype-by-environment interactions are important in cultivator development (Kang, 1998). Genotypes differed for reduction in biomass due to lower availability of P in TCP which agrees with the earlier reports (Ahmad et al., 2001; Yaseen et al., 1998; Akhtar et al., 2002; Gill et al., 2002; Fageria et al., 1989). The maximum increase in PUE was observed in Aquab 2000 and minimum was exhibited by Pak 81 as former produced maximum SOM per unit P uptake and later produced the lowest.

Phosphorus concentration and uptake in shoot had a highly significant ($P<0.01$) and positive correlation with ROM suggesting that the genotypes with higher ROM accumulated higher amount of P in their shoot (Fawole et al., 1982). Shoot dry matter was significantly correlated with P content and concentration in shoot grown with TCP indicating that genotypes which accumulated higher P produced higher SOM which may be attributed to higher ROM of these genotypes in this treatment.

CONCLUSION

Genotypes differed in SOM, ROM, RSR, P concentration, P uptake and P utilization efficiency when grown in TCP treatment indicating the existence of useful genetic differences among wheat genotypes for solubilization of P from sparingly soluble P. Shoot dry matter and root dry matter correlated significantly with shoot P content and P utilization efficiency. However, validation of these results needs further field experimentation.

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