GROWTH AND PHOSPHORUS UPTAKE BY BRASSICA CULTIVARS GROWN WITH ADEQUATE AND DEFICIENT PHOSPHORUS LEVELS

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Brassica is an oil seed crop of Pakistan which mostly suffers from low Phosphorus (P) availability in calcareous soils. A sand culture experiment was conducted to study growth response and phosphorus utilization efficiency of ten Brassica cultivars in a green house. Plants were grown for 30 days using half strength modified Johnsons nutrient solution containing two levels of P (20 μM P and 200 μM P). The biomass production of all cultivar varied significantly ($p<0.05$) both at adequate and stress P levels. The dry matter yield correlated significantly ($p<0.05$) with the P uptake ($r=0.91$) and P utilization efficiency ($r=0.80$). The Brassica cultivar B.S.A. proved to be the most efficient P user and therefore seems to have the highest potential for growth on soils with poor P availability.
Keywords: Brassica, phosphorus, uptake, utilization, cultivars.

INTRODUCTION

In Pakistan, Brassica is the second most important source of edible oil after cotton and contributes about 28% to country's edible oil requirements (GOP, 2004) but it has low per acre yield due to many factors including low soil P availability. Phosphorus is an important nutrient having a prominent effect on oil contents and seed yield of oil seed crops (Jain et al., 1996).

About 70 % of Pakistani soils are alkaline and calcareous in nature (Memon et al., 1992) and major portion of total P in these soils is sparingly available to plants as it exists as Ca-Phosphates of varying solubilities (Rahmatullah, et al., 1994). Hence the application of phosphatic fertilizer at larger rate becomes essential for crop production (Memon, 1996) which increases the cost of production tremendously.

Due to reduced P inputs, low soil P availability, rising fertilizer prices, it is necessary to produce more with less P in soils and impels to devise strategies aiming at to increase P utilization efficiency in agriculture. Selection and breeding of P efficient cultivars is promising tool to reduce costs of P fertilization and enhance plant productivity with more P efficient cultivars.

Plants have adopted different mechanisms to cope P deficiency in soil including increased P acquisition and internal use efficiency; and these mechanisms vary within and between species (Clark and Duncan 1991; Gill *et al.*, 2002; Akhtar et al., 2002; Kosar *et al.*, 2003 and Vance et al., 2003).

Keeping this in view, a sand culture experiment was conducted to evaluate genetic potential of 10 Brassica cultivars for their P utilization efficiency and their relative tolerance against P deficiency.

MATERIALS AND METHODS

Brassica cultivars were grown in riverbed sand for this experiment. Seeds of 10 commonly grown Brassica cultivars viz: RL-18, D.G.L, Rainbow, Raya Anmol, Toria, Peela Raya, Dunkled, Khanpur, Shirallee and B.S.A. were collected from the Oil Seed Research Institute, AARI, Faisalabad. Twenty seeds of each cultivar were sown in each pot and thinned to 3 plants pot^{-1} after 4 days of seedling emergence. Plants were nourished with half strength modified Johnson's solution (Johnson et al., 1957) with two P levels including deficient level (20 μM P) and adequate level (200 μM P). The plants were harvested after 30 days of germination. After harvesting, plants were washed thoroughly and blotted dry with tissue papers. Roots were taken out from sand by gentle washing with distilled water. Plant samples were oven dried at 70 ^{0}C to a constant weight in a forced air driven oven and their shoot and root dry weights were recorded using top loaded balance. Dried plant samples were ground to 40 mesh using mechanical grinding mill. Ground plant samples (0.5 g) were digested with 10 mL of di-acid mixture containing nitric acid (HNO_3) and perchloric acid ($HClO_4$) (3: 1) (Miller, 1998). Phosphorus concentration in the plant digest was estimated by vanadomolybdate yellow color method (Chapman and Pratt, 1961) on a UV-Visible spectrophotometer.

Phosphorus utilization efficiency (PUE) was calculated after Siddique and Glass (1983) by the following formula:

$$PUE = \frac{1}{P\ conc.} \times SDM$$

Where PUE is g^2 SDM mg^{-1} P, P concentration is mg g^{-1} and SDM is shoot dry matter in g pot^{-1}.

Analysis of variance (Steel et al., 1996) was used to analyze data statistically using MSTAT-C (Russel and Eisensmith, 1983).

RESULTS AND DISCUSION

Biomass Accumulation

Substantial genetic differences were recorded in Brassica cultivars in their shoot dry matter (SDM) and root dry matter (RDM) production both at adequate and stress P levels (Figs. 1 & 2). Rates of P application and adequate P level. Relative reduction in SDM or P stress factor (PSF) is a good parameter in screening experiments at seedling stage as it reflects the relative tolerance of cultivars to nutrient deficiencies (Gill et al., 2002). In this study, cultivars differed significantly in terms of relative reduction in SDM (Fig. 3) due to P deficiency stress as reported by many of earlier

Figure 1. Shoot dry matter (g pot^{-1}) of Brassica cultivar grown with deficient and adequate P levels.

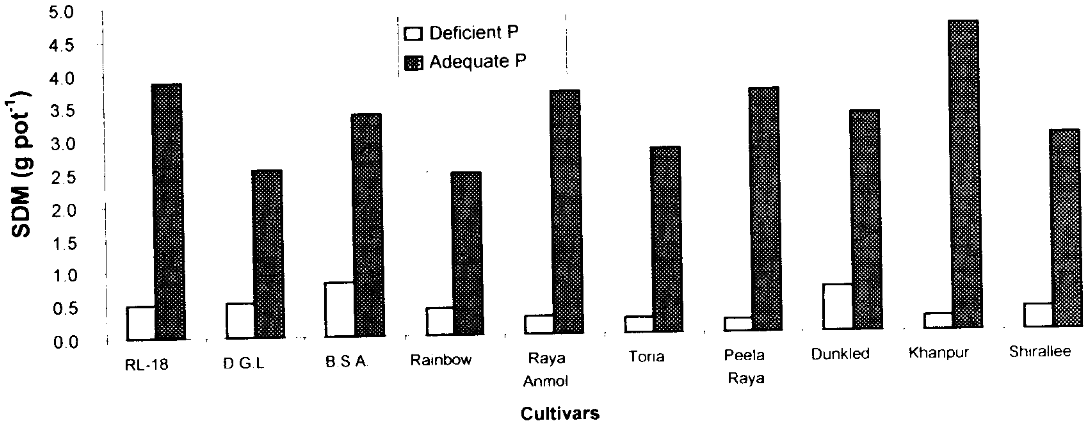
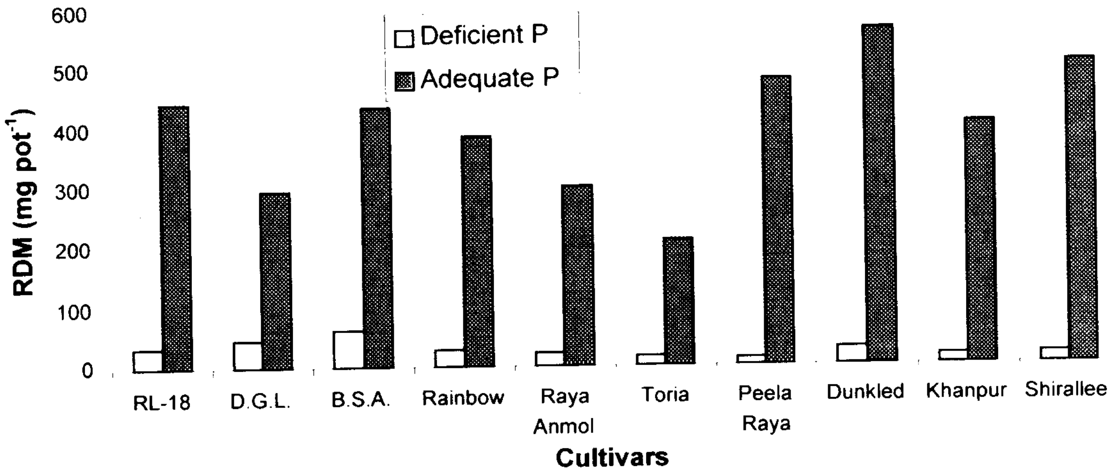


Figure 2. Root dry matter (mg pot^{-1}) of Brassica cultivar grown with deficient and adequate P levels.



Brassica cultivars had their significant main and interactive effect on shoot dry matter yield. Shoot dry matter accumulation was 8-fold higher in plants supplied with adequate P, than those plants grown with deficient P supply. Maximum SDM was produced by B.S.A. at deficient level of P supply and proved to be highly responsive while Khanpur was ranked efficient cultivar as it produced maximum SDM at researchers working with several species (Gill et al., 2002; Akhtar et al., 2002; Kosar et al., 2003). Cultivars with a high value of PSF (Khanpur) are not considered suitable for growing in soils low in P, however these cultivars may be selected for high input agricultural systems because of their higher yield potentials. Cultivars with a lower value of PSF (B.S.A.) are considered suitable for growing in areas of low soil P

Figure 3. Phosphorus Stress factor (%) of Brassica cultivar grown with deficient and adequate P levels.

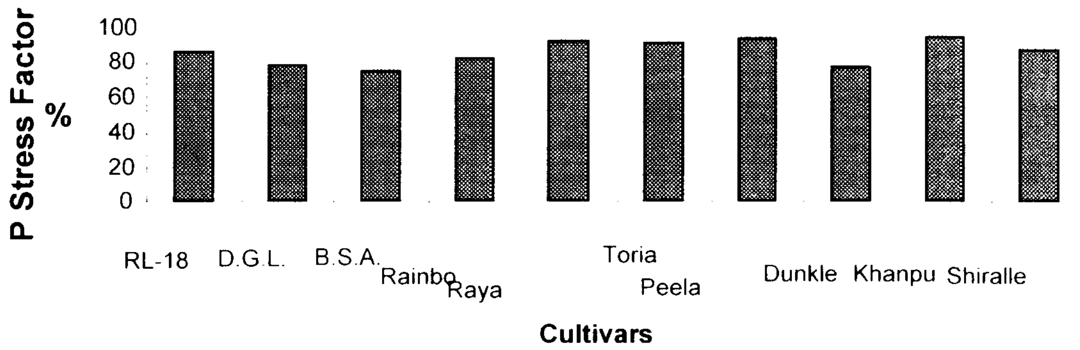


Table 1. Shoot P concentration, P uptake and P utilization efficiency of Brassica cultivars grown at adequate and deficient P level.

Cultivars	Shoot P Conc. (mg g^{-1})		Shoot P Uptake (mg pot^{-1})		PUE (g^2 SDM mg^{-1} P)	
	Deficient P	Adequate P	Deficient P	Adequate P	Deficient P	Adequate P
RL-18	1.34 ab	2.62 b-d	0.69^{NS}	10.19 a-d	0.42 ab	1.49 b
D.G.L.	1.87 a	3.15 b	1.05	07.81 b-d	0.31ab	0.84 d
B.S.A.	1.49 ab	1.86 d	1.20	06.23 d	0.58 a	1.84 b
Rainbow	1.40 ab	2.83 bc	0.57	07.48 cd	0.29 ab	0.97 cd
Raya Anmol	0.46 c	3.26 b	0.12	12.69 a-c	0.54 a	1.13 c
Toria	0.70 bc	2.12 cd	0.16	05.76 d	0.33 ab	1.47 b
Peela Raya	1.29 ab	4.21 a	0.26	15.28 ab	0.15 b	0.89 cd
Dunkled	1.62 a	4.36 a	1.10	15.34 a	0.42 ab	0.75 d
Khanpur	0.74 bc	2.28 cd	0.14	11.04 a-d	0.37 ab	2.03 a
Shirallee	1.17 a-c	2.68 bc	0.44	07.94 cd	0.32 ab	1.12 c

Table 2. Root P concentration, P uptake and P utilization efficiency of Brassica cultivars grown at adequate and deficient P level.

Cultivars	Root P Conc. (mg g^{-1})		Root P Uptake (mg pot^{-1})		PUE (g^2 RDM mg^{-1} P)	
	Deficient P	Adequate P	Deficient P	Adequate P	Deficient P	Adequate P
RL-18	1.20 bc	1.08 d-f	0.63^{NS}	4.05 cd	0.43^{NS}	4.69 b
D.G.L.	1.16 bc	2.94 a	0.62	7.22 b	0.45	1.40 d
B.S.A.	0.94 c	1.28 c-e	0.76	4.24 cd	0.87	3.29 c
Rainbow	1.50 bc	1.92 bc	0.61	4.87 c	0.27	1.30 d
Raya Anmol	1.06 c	0.62 ef	0.29	2.35 de	0.26	5.83 b
Toria	1.87 b	0.50 f	0.45	1.39 e	0.12	5.81 b
Peela Raya	2.57 a	1.67 b-d	0.43	5.89 bc	0.09	2.37 cd
Dunkled	1.56 bc	2.81 a	1.03	9.36 a	0.46	1.17 d
Khanpur	1.41 bc	0.51 f	0.29	2.37 de	0.16	9.16 a
Shirallee	1.29 bc	2.34 ab	0.43	6.93 b	0.32	1.29 d

Means followed by the same letters in each column are statistically similar at 5 % probability.

availability under low input sustainable agriculture systems. However, care must be taken while selecting cultivars on base of PSF that these cultivars must be efficient in biomass production also at deficient P supply.

Roots have to perform more under nutrient deficiency and modification in root system (root biomass, architecture) is well reported under P deficiency in soil (Vance et al., 2003). Plants with larger root systems can perform better by exploring more soil for P hence root dry matter is considered an important parameter in selecting crops for P efficiency. Root dry matter varied significantly between cultivars at both levels of P supply. Significant positive correlation (r = 0.67) was observed between RDM and SDM at 20 μM level of P supply (Table 3) which indicated more SDM production with increased root growth. Genetic differences in RDM production due to P levels among the genotypes of different crops were also reported by Gill et al. (2002); Akhtar et al. (2002) and Kosar et al. (2003).

Phosphorus Utilization Efficiency (PUE)

Brassica cultivars showed substantial differences in terms of P utilization efficiency (PUE) at deficient P level both in root and shoot (Tables 1 & 2). Cultivar B.S.A. showed the maximum utilization efficiency at deficient P level in both root and shoot and was viewed as the best cultivar regarding this parameter, while Khanpur had significantly highest PUE in both shoot and root at adequate P supply regarding it as more responsive but in-efficient cultivar. There was significant positive correlation (r = 0.87) between PUE and SDM at deficient level of P supply (Table 3). This implies that cultivars with higher shoot PUE also produced higher shoot biomass.

Table 3. Correlation matrix at deficient P supply

	SDM	RDM	TDM	Shoot P conc.	PUE (shoot)	PUE (root)	Shoot P uptake
RDM	0.67**						
TDM	0.90**	0.71**					
Shoot P conc.	0.58*	0.33*	0.57*				
Root P conc.	-0.43 NS	-0.53 NS	-0.45 NS	-0.07 NS			
PUE (shoot)	0.87*	0.36*	0.48*	-0.37 NS			
PUE (root)	0.90**	0.80**	0.92**	0.46*	0.49*		
Shoot P uptake	0.91**	0.56**	0.91**	0.83**	0.14*	0.79**	
Root P uptake	0.84**	0.33*	0.82**	0.58*	0.29*	0.54*	0.82**

* = Significant ** = Highly significant NS = Non-significant

Phosphorus Contents

Shoot P concentration can be used to quantify the plant efficiency when grown under P stress conditions (Fhose et al., 1991) and lower shoot P concentration has been attributed to more efficient utilization of P in metabolism (Gerloff, 1987 and Glass, 1989). Shoot P concentration increased in Brassica cultivars with an increase in P supply in the culture medium. Shoot P concentration was negatively correlated (r = -0.37) with shoot P utilization efficiency, reflecting that cultivars with high shoot P concentration were inefficient in P utilization (Table 3). Differences in P concentration in root of Brassica cultivars (Table 2) were not statistically significant at P levels. However, these differences were substantial at adequate P level. Phosphorus uptake in shoot and root increased about 17-fold and 6-fold respectively, with increase in P concentration. Phosphorus uptake in shoot was positively correlated (r = 0.56) with RDM at deficient P level, implying that P uptake by plant is partly dependent on root system. Phosphorus uptake of root was also positively correlated (r = 0.84) with SDM at both P levels.

CONCLUSION

Cultivars differed significantly for their growth and phosphorus utilization efficiencies at deficient as well as adequate P levels. Phosphorus uptake and utilization efficiency was well correlated with biomass production. Cultivars having high P uptake and P use efficiencies, but low in P concentration, accumulated maximum biomass such as B.S.A. and can be categorized as P efficient genotype. These results warrant confirmation under field situation.

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