DIFFERENTIAL PHOSPHORUS REQUIREMENT AND UTILIZATION EFFICIENCY OF BRASSICA GENOTYPES

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Brassica is an important oil seed crop of Pakistan, which commonly suffers from P deficiency. A solution culture experiment was conducted to evaluate the differential growth response and P utilization efficiency of ten Brassica genotypes supplied with deficient (20 µM) and adequate (200 ~IM) P, in Johnsons' modified solution. The genotypes differed significantly ($p < 0.01$) in their shoot growth, root development and root: shoot ratio at both P levels. Phosphorus concentration and uptake in shoot and P utilization efficiency was also significantly different among various Brassica genotypes. Shoot and root dry matter yield as well as total biornass production correlated significantly ($p < 0.01$) with their shoot P uptake and P utilization efficiency. Genotypes, which were efficient in P utilization, were efficient accumulators ofbiomass under adequate as well as deficient level of P supply.

INTRODUCTION

Brassica is an important oil seed crop, which has low per acre yield in Pakistan compared to several other countries. Soils of Pakistan are alkaline calcareous in nature and have low P availability. A major portion (88-99%) of total P in these soils ex itx as Ca-phosphates of varying solubilities (Rahrnatullah et al., 1994). Furthermore, plant utilization of applied fertilizer P on these soils is seriously low (Zia et al., 1991). So there is a need to adopt approaches that can sustain crop yields on these P-deficient soils.

Genetic variability and plant ability to absorb, translocate, assimilate and use of mineral element are important in adapting plants to a mineral stress environment (Vase, 1984). Inter and intra specific diversity for uptake, translocation. distribution and use of nutrients especially P has been recognized for many years (Vose. 1984: Clark and Duncan, 1991: Gill et al., 1994). So identification of nutrient efficient genotypes may play a significant role in sustaining crop yields in resource poor environment.

Categorization of the existing Brassica genotypes for P-use efficiency may help not only in sustaining production in the country but also for providing database to the breeders for their future ventures.

Keeping in view we evaluated 10 commonly grown Brassica genotypes for their efficiency to utilize P and their relative tolerance to P-delicicncy stress in the growth medium.

MATERIALS AND METHODS

Different genotypes of brassica tested were: B. S. A., Brown Raya, Con-I. Dunkled, Peela Raya, Rainbow, Gold Rush, Toria, Toria Selection and Sultan Raya, Seeds were germinated in polyethylene lined iron trays containing pre-washed riverbed sand and irrigated with distilled water for seed germination and seedling establishment. Ten days old uniform sized seedlings were transplanted in foam plugged holes (one plant per hole) in thermopal sheets floating on continuously aerated half strength modified Johnson's solution (Johnson *et al.*, 1957) in two polyethylene lined iron tubs. The solutions were modified to maintain deficient (20 pM P) and adequate (200 ~IM P) P levels. The pH of the solution was daily monitored and maintained at 5.5 ± 0.5 using HCI or NaOH. Completely randomized factorial design was followed with six repeats of each cultivar. Plants harvested 30 days after transplanting were washed with distilled water, blotted dry with tissue paper and separated into shoots and roots. The samples were dried at 70°(' for 48 hours in forced air driven oven to a constant weight and dry weights were recorded. The shoot samples were ground to 40-mesh. The samples (0.5 g each) were digested in a mixture of nitric acid and perchloric acid (3: I). Phosphorus concentration in shoot was estimated by vanadate-molybdate yellow color method (Chapman and Pratt, 19(1) using spectrophotometer.

Phosphorus stress factor (PSF) for shoot dry matter was calculated by the formula given below:

$$PSF = \frac{SDM_{(adequate\ 1')} - SDM_{(deficient\ 1')}}{SDM_{(adequate\ 1'1)}} \times 100$$

Where, SDM is shoot dry matter (g plant') in the respective treatment.

Phosphorus Utilization Efficiency (PUE) was calculated according to Siddique and Glass (1983).

$$PUE\ (g^2\ SDM\ mg^{-1}\ P) = \frac{1}{P\ concentration\ (mg\ g^{-1})} \times SDM\ (g\ plant^{-1})$$

The data was statistically analyzed according to standard procedures (Steel and Torrie, 1980) using computer software MSTAT-C (Russel and Eisensrnith, 1983).

RESULTS AND DISCUSSION

Phosphorus deficiency in the growth medium caused sharp decrease in most of the parameters studied except root shoot ratio, P utilization efficiency and Ca concentra!ion in shoot.

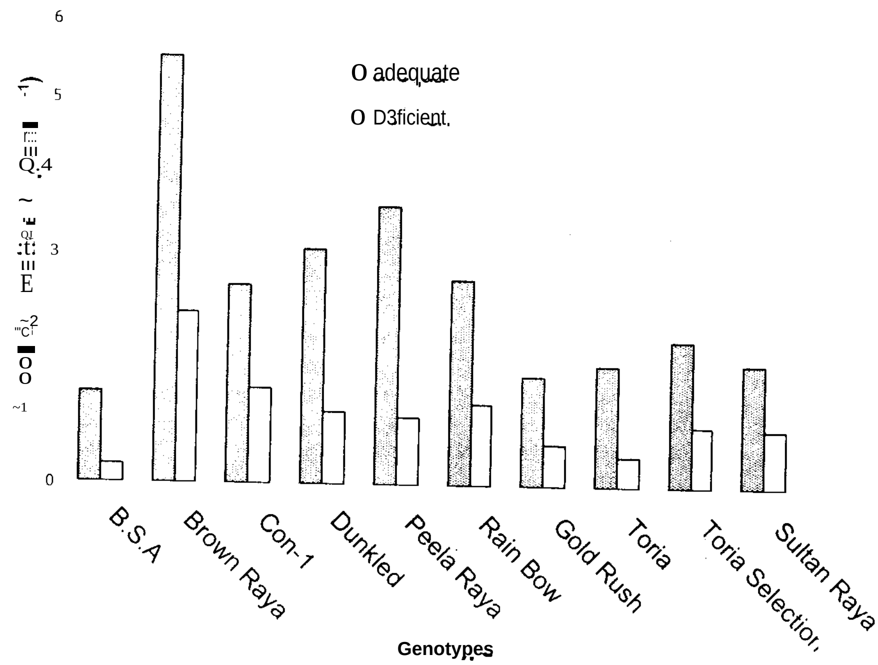

Fig. 1. Shoot dry matter of Brassica genotypes grown with deficient and adequate levels of P.

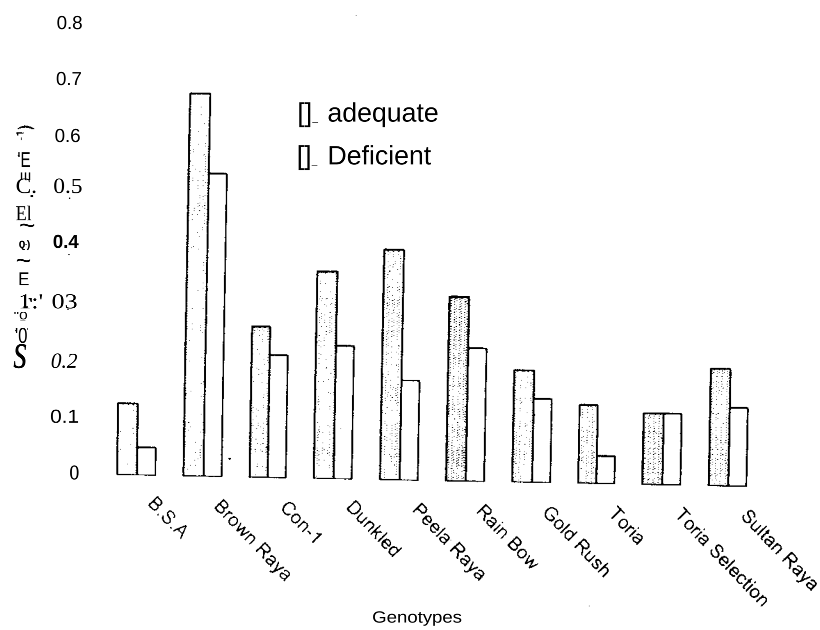

Fig. 2. Root dry matter of Brassica genotypes grown with deficient and adequate levels of P.

Biomass production

Brassica genotypes and rate of P supply had a significant ($p < 0.01$) main and interactive effect on shoot growth, root development and total biomass production (Fig. 1 & 2). Highly significant differences in SDM production due to P level X genotype interaction is a clear indication of the existence of useful genetic differences for responsiveness to P application. Such genotype-by-environment interactions are important in crop cultivar development (Kang, 1998). Averaged over all genotypes SDM production decreased about 2.8-fold in deficient P level. Jain et al. (1996) and *Jaggi* et al. (1997) also observed a

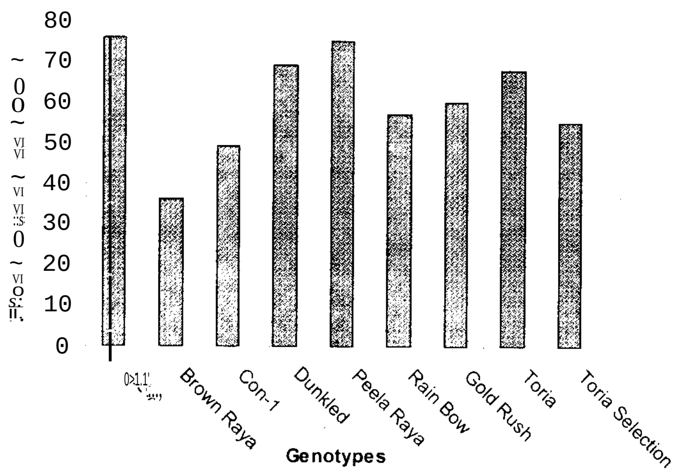

Fig. 3. Relative reduction in SDM of Brassica genotypes due to P deficiency

Table I. Shoot P and Ca concentration, P uptake and PUE of Brassica genotypes grown at deficient and adequate P level

Genotypes	Shoot P conc. (mg g.l)		Shoot P uptake (mg plant")		PUE (g2 SDM mg·1p)		Shoot Ca conc. (mg g.l)	
	Deficient	Adequate	Deficient	Adequate	Deficient	Adequate	Deficient	Adequate
B.S.A	0.85 NS	5.22 a	0.21 NS	5.94 d	0.30 e	0.23 c	10.56 e	5.38 de
Brown Raya	0.88	4.70 be	1.95	25.75 a	2.51 a	1.18 a	19.10 a	6.28 c-e
Con-I	0.89	5.04 a	1.08	12.90 b	1.37b	0.51 be	16.85 be	8.56 ab
Dunkled	0.88	3.63 f	0.80	I 1.04 be	1.04 be	0.84 ab	17.14 b	7.24 be
Peela Raya	0.79	4.06 e	0.70	14.52 b	1.08 be	0.89 ab	17,39 b	5.13 de
Rain Bow	0.86	4.17 e	0.89	11,18 be	1.23 be	0.63 be	18.04ab	7.26 be
Gold Rush	0.88	4.96 ab	0,48	6.91 cd	0.61 de	0.28 c	15.60 cd	9.29 a
Toria	0.97	4.57 cd	0.38	7.09 cd	0,41 e	0.34 c	I 1,80 e	4.94 e
Toria Selection	0.70	4.29 de	0.54	7.96 cd	1,10 be	0,44 c	14.26 d	6.07 c-e
Sultan Raya	0.78	4.16 e	0.58	6,48d	0.94 cd	0.39 c	11,71 e	6.97 cd

Means followed by the same letters are not statistically significant at P<O.OI

Table 2: Correlation Matrix of different parameters of Brassica genotypes studied at deficient P level.

	SDM	RDM	TDM	P Cone.	PUE	P Uptake	RSR
SDM							
ROM	0.757**						
TOM	0.991 **	0.837**					
P-Conc.	0.055 NS	0.034 NS	0.053 NS				
PUE	0.982**	0.748**	0.974**	-0.105"s			
P uptake	0.985**	0.739**	0.975**	0.1991\S	0.935**		
RSR	-0.0 Ii's	0,467**	0.0051\S	-0.061 NS	_0.112 NS	_0.103I\S	
Ca	0.544**	0.689**	0.525**	0.052 NS	0.529**	0.538**	0.375*

ROM: Root dry matter
TOM: Total dry matter
PUE: Phosphorus utilization efficiency
RSR: Root:. Shoot ratio

decrease in SDM of Brassica with a decrease in P supply. Brown Raya yielded maximum SDM at both the P levels and proved to be highly efficient and responsive (Fig. I).

Relative reduction in SDM due to P-deficiency was significantly (p<O.O 1) different among genotypes (PSF) indicating their relative tolerance to low P conditions (FigA). The genotypes showing relatively lower PSF values such as Brown Raya, Con-l and Sultan Raya may be considered suitable for growing under P limiting conditions. Relative reduction in SDM of the genotypes ranged between 36% (Brown Raya) and 76% (B.S.A).

Root dry matter of Brassica genotypes was decreased 1.5-fold due to P deficiency (Fig.2). Ahmad et al. (2001) reported similar reduction in root dry matter of other crops due to P-deficiency. Shoot P uptake and P utilization efficiency had significant (p < 0.0 I) and positive correlation with total dry matter production in Brassica genotypes (Table 2).

Phosphorus concentration and content in shoot

Various Brassica genotypes and rate of P supply had a significant (p < 001) main and interactive effecton shoot P concentration or Brassica genotypes. Shoot P concentration was significantly lower (5-fold) in P-stressed genotypes compared to those grown with adequate P (Table 1).

A decrease in P supply (20 fold) in the root medium decreased about IS-fold P content in shoot of Brassica genotypes. Brown Raya exhibited maximum shoot P content while minimum was observed in B.S.A and Gold Rush averaged over both P levels. Phosphorus uptake in shoot had a highly significant (p < 0.0 I) positive correlation with RDM and SDM (Table 2), suggesting that the genotypes with higher RDM accumulated higher amount of P in their shoot. Fawole et al. (1982) also reported a positive correlation between SDM, RDM and P uptake.

Phosphorus Utilization Efficiency (PUE)

Genotypes and level of P had a significant (p < 0.0 I) effect on PU E of Brassica genotypes (Table I). About 2-fold decrease in PU E was observed with increasing P from 20 to 200 pM in the growth medium, implying that less dry mater was produced for each additional unit of P absorbed. The hiuhest and lowest PUE was observed in Brown Raya and B.S.A averaged over both treatments, respectively. Eliot and Lauchli (1985), Fageria et al. (1988) and Gill et al. (2002) also reported significant differences in PUE of various crops. P utilization efficiency exhibited a significant (p < 0.0 I) and positive relationsh ip with shoot P uptake, SDM and RDM at both P levels (Table 2).

Calcium concentration in shoot

Various Brassica genotypes and rate of P supply had a significant (p < 0.0 I) main and interactive effect on Ca concentration in Brassica shoot. Calcium concentration in shoot of Brassica genotypes decreased 2.25 times with increasinz P from 20 to 200 pM in the growth medium. This rnav be attributed to growth dilution effect, which is clear frOl~ the difference in SDM production (Table I) at both P levels.

CONCLUSIONS

Considerable genetic variability was observed in SDM, RDM, shoot P contents and PUE of the brassica genotypes at both P levels in nutrient solution. Genotypes, which were efficient in P utilization such as Brown Raya, were also efficient accumulator of biomass at both P levels. Brown Raya was the efficient genotype in terms of SDM production at stress P level while B.S.A. and Toria were inefficient in terms of SDM production. Shoot dry matter and RDM of all Brassica genotypes correlated significantly with their shoot P content, P utilization efficiency and calcium concentration in shoot. However, validation of these results need further field experimentation.

REFERENCES

Ahmad, Z., M. A. Gill, R. H. Qureshi, H. Rehman and T. Mahmood. 2001. Phosphorus nutrition of cotton cultivars under deficient and adequate levels in solution culture. Commun. Soil Sci. Plant Anal. 32(1&2): 171-187.

Chapmann, H. D. and P. F. Pratt. 1961. Phosphorus. p. 160-170. In: "Methods of Analysis for Soils, Plants and Waters". Div. of Agric. Sci., Univ. California, Berkeley, USA.

Clark, R. B. and R. R. Duncan. 1991. Improvement of plant mineral nutrition through breeding. Field Crop Res. 27: 219-246.

Elliot, G.e. and A. Lauchli. 1985. Phosphorus efficiency and phosphate ion interaction in maize. Agron. J. 77: 399-403.

Fageria, N. K., R. 1. Wright and V. e. Baligar. 1988. Rice cultivar evaluation for P use efficiency. Plant Soi I 3: 105-108.

Fawole, I., W.H. Gableman and G.e. Gerloff. 1982. Genetic control of root development in beans grown under P stress. J. Am. Soc. Hort. Sci. 107: 98-100.

Gill, M. A., Rahmatullah and M. Salim. 1994. Growth responses of twelve wheat cultivars and their phosphorus utilization. 1. Agron. Crop Sci. 173: 204-209

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.

Jaggi, R.e. and D.K. Sharma. 1997. Effect of sulphur and phosphorus on yield and their uptake by Indian mustard *(Brassicajuncea)*. Ind. J. Agron. 42 (2): 352-356.

Jain, N.K., A.K. Vyas and A.K. Singh. 1996. Yield and quality of Indian mustard *(Brassica juncea)* as influenced by phosphorus and sulfur fertilization. Indian 1. Agri. Sci. 69(9): 539-40.

Johnson, e.M., R.R. Strut, T.e. Brayer and A.B. Carlton. 1957. Comparative chlorine requirements of different species. Plant Soil 8: 327-353.

Kang, M.S. 1998. Using genotype-by-environment interaction for crop cultivar development. . Adv. Agron. 62: 199-251..

Miller, R.O. 1998. Nitric-Perchloric Wet Acid Digestion in an open vessel. . pp. 57-62. In: Kalra, Y.P. (Ed.) Hand book of Reference Methods for Plant Analysis, CRC Press, Washington, DC..

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

Russel, D.F. and S.P. Eisensmith. 1983. MSTAT-C. . Crop and Soil Science Department, Michigan State University, East Lansing, Ml..

Siddique, M.Y. and A.D.M. Glass. 1983. Utilization index: A modified approach to the estimation and comparison of nutrient utilization efficiency in plant . J. Plant Nutr.. 4: 289-302.

Steel, R.G.D. and 1.H. Torrie. 1980. Principles and Procedures of Statistics. Me Graw Hill Book Co. Inc.. New York, U.S.A.

Vase, P. B. 1984. Effect of genetic factors on nutritional requirement of plant. . p. 67-114. In: P. B. Vase and S. G. Blixit (Eds.) Crop breeding: A contemporary basis. Perm an Press, Oxford, UK.

Zia, M. S., M. A. Gill, M. Aslam and M. F. Hussain. 1991. Fertilizer use efficiency in Pakistan. Progressive Farming 11: 35-38.