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Effect of phosphorus levels on phosphorus, potassium, calcium and magnesium content and seed yield of safflower genotypes

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Abstract : A field experiment was conducted in *rabi* 2003 at ICRISAT experimental farm (Vertisol), Patancheru to study the response of safflower genotypes to phosphorus. At flowering, graded P levels significantly influenced the dry-matter yield of safflower genotypes. Phosphorus uptake by shoot varied from 0.041 to 0.084 g plant^{-1} in different genotypes. The mean uptake ratio of nutrients (P: K: Ca: Mg) was 1.0:11.7:3.9:2.5. The seed yield and susceptibility of genotypes to P stress followed the order Bhima > A-1 > NARI-NH-1. Critical limits of anion-cation ratio for A-1, Bhima and NARI-NH-1 were 0.055, 0.048 and 0.032, respectively.

Additional key words : *Safflower, macro and secondary nutrients, seed yield, anion-cation ratio*

Introduction

Safflower (*Carthamus tinctorius)* is an important oilseed crop of the semi-arid tropics (SAT). Most of the SAT soils are low in nutrient status, but except for irrigated areas, fertilizer use in rainfed areas across the SAT is low (Burford *et al.* 1989). Nitrogen and phosphorus deficiencies in Vertisols in which safflower grows are common (Purvimath *et al.* 1993; Hegde 2003). In safflower, there is a differential genotypic response to P deficiency (Ekshinge *et al.* 1995). Magnesium plays an important role in P transport, especially in legumes and oilseed crops, leading to high content of oil in the seeds (Russell 1973). Therefore, present investigation was undertaken to study the effect of P levels on dry matter production, nutrient content, uptake and their ratios (at flowering stage), seed yield, oil content and test weight of safflower genotypes and to establishment of critical P, K, Ca and Mg uptake ratio to screen P-efficient genotypes.

Materials and Methods

A field experiment was conducted in Vertisol during *Rabi* 2003 at ICRISAT experimental farm, Patancheru with three safflower genotypes. The experimental soil (0-20 cm) had pH 8.1; E.C. 0.2 dS m^{-1}; organic carbon: 6.2 g kg^{-1}, $CaCO_3$ 35 g kg^{-1}, exchangeable Ca + Mg 48.4 cmol (p^+) kg^{-1} and CEC 57.6 cmol(p^+) kg^{-1}. Available nitrogen, phosphorus and potassium were 248.0, 8.0 and 650.0 kg ha^{-1} respectively. The P levels were 0, 20, 40, 60, 80, 100 and 120 kg P_2O_5 ha^{-1} (applied through DAP) and three safflower genotypes (var. A-1, Bhima and hybrid NARI-NH-1). The experiment was laid in two factorial randomised block design with three replications. Nitrogen (40 kg ha^{-1}) was applied as basal dose to all the plots. The shoot samples (above ground parts) of flowering stage was analysed for P by vanadomolybdic acid method, K by flame photometry, Ca and Mg by atomic absorption spectrophotometry using standard procedures (Page *et al.* 1982; Jackson 1973). The yield of dry matter at flowering stage and seed yield, oil content and test weight (100 seed weight) at harvesting stage were recorded.

Results and Discussion

Flowering stage

Dry matter and nutrient concentration

The effect of P levels on dry matter yield and P, K, Ca and Mg concentration in safflower genotypes are shown in Table 1. Application of 40 kg P_2O_5 ha^{-1} significantly influenced the dry matter yield of different genotypes over control. Patel *et al.* (1995) and Bhilegaonkar *et al.* (1995) also reported an increase in dry matter yield due to P application.

The shoot P concentration varied from 0.18 to 0.28 per cent in different genotypes but it was statistically not significant. Potassium concentration in genotypes varied from 1.91 to 6.37 per cent and mean K in A-1 and Bhima varieties were statistically at par but hybrid NARI-NH-1 had significantly higher K. Similarly, Ca concentration in genotypes ranged from 1.02 to 2.13 per cent and it was statistically at par in A-1 and Bhima but it varied significantly in NARI-NH-1. Magnesium concentration varied from 0.27 to 0.64 per cent in different genotypes. The mean concentrations of nutrients in the dry matter of genotypes followed the order : K > Ca > Mg > P (Table 1).

Nutrient uptake

Phosphorus uptake by shoot varied from 0.041 to 0.084 g plant^{-1} and was significant in different genotypes (Table 2). Genotypes mean P uptake was higher at 40 kg P_2O_5 ha^{-1} over control. Ekshinge *et al.* (1995) reported an increase in P uptake by safflower genotypes due to P application upto 30 kg ha^{-1}. Significantly higher P uptake noticed at higher P levels *i.e.* 80 to 120 kg P_2O_5 ha^{-1} which, may not be economical owing to the possibility of high P fixation in black clayey soils. Phosphate use efficiency was higher in Bhima variety upto 40 kg P_2O_5 ha^{-1}, A-1 upto 20 kg P_2O_5 ha^{-1} but in hybrid NARI-NH-1, a general increasing trend was observed due to graded P levels. Ekshinge *et al.* (1995) observed the highest fertilizer use efficiency in safflower genotype Bhima, when fertilizer applied 10 days before sowing and it decreased with increase in N and P fertilizer levels.

Shoot K uptake varied significantly because of P levels and followed the order NARI-NH-1 > Bhima > A-1 (Table 2). The exchangeable K of soil was high probably higher levels of P vis-à-vis luxury consumption of K might have led to higher K uptake in A-1 and Bhima. NARI-NH-1 had a higher K uptake at 40 kg P_2O_5 ha^{-1} dose showing that varieties probably need higher rates of P whereas for hybrid even a lower P rate was enough for higher K uptake.

Phosphorus levels significantly influenced the Ca uptake by crop and it was higher at 80 kg P_2O_5 ha^{-1} in A-1 and Bhima varieties but in NARI-NH-1 at 60 kg P_2O_5 ha^{-1}. Mandal *et al.* (2002) observed a great scope in increasing oilseed production by exploiting the positive interactions among nutrients. Phosphorus levels influenced the Mg uptake and it differed significantly over control in A-1 at 20 kg P_2O_5ha^{-1} and in Bhima and NARI-NH-1 at 40 kg P_2O_5 ha^{-1}.Thus, in Vertisols having low available P; its application induced differential removal of K, Ca and Mg by safflower genotypes. Shoot dry matter yield and phosphorus (r = 0.910**), potassium (r = 0.586**), calcium (r = 0.778**) and magnesium (r = 0.809**) uptake were positively and significantly correlated.

Harvesting stage

Seed yield

Seed yield of Bhima and A-1 were significantly higher at 20 kg P_2O_5 ha^{-1}. For NARI-NH-1 it was at 40 kg P_2O_5 ha^{-1} but was statistically at par with 20 kg P_2O_5 ha^{-1} (Table 3). An increase in safflower seed yield due to P levels (25 to 40 kg P_2O_5/ ha) in black clayey soils was also reported (Patel *et al.* 1995; Bhilegaonkar *et al.* 1995; Ekshinge *et al.* 1995). Genotype variation was significant and followed the order Bhima > A-1 > NARI-NH-1. Ekshinge *et al.* (1995) also recorded a higher seed yield with Bhima among the safflower genotypes (N-62-8, Tara and Bhima). Interaction effect of genotypes and P levels on the seed yield was significant (Table 3). Genotypic variations to P response assigned to the efficiency of genotypes to absorb and use the applied nutrient. The genotype showing highest percentage response was classified as the most susceptible to P stress and *vice versa.* Based on percentage response in seed yield (figures shown in parenthesis), the genotypes order was Bhima (39.3) > A-1 (38.5) > NARI-NH-1 (31.6).

Seed yield correlated significantly and negatively with P (r = 0.468*) and K (r = 0.481*) concentration while significant positive correlations with Mg/Ca (r = 0.522) and Mg/K (r = 0.505*) cation uptake ratios observed

Oil content and test weight (100 seed weight) varied significantly in different genotypes and followed the order NARI-NH-1 > Bhima > A-1 and *vice versa* respectively (Table 3).

Table 1. Drymatter, phosphorus, potassium, calcium and magnesium concentration in safflower genotypes at flowering stage

Genotypes	P levels (kg P_2O_5 / ha)							
	0	20	40	60	80	100	120	Mean
			Dry matter (g/plant)					
A-1	15.60	20.90	26.60	23.17	32.13	24.83	28.87	24.59
Bhima	19.80	24.17	27.03	28.23	30.33	32.23	34.53	28.04
NARI-NH-1	15.43	18.63	21.10	23.43	25.90	30.73	37.00	24.60
Mean	16.94	21.23	24.91	24.94	29.46	29.27	33.47	
				S.Em±	C.D (p=0.05)			
			Genotype	1.44	NS			
			P levels	2.19	6.27			
		Genotype X P levels		3.80	NS			
			Shoot P (%)					
A-1	0.27	0.26	0.26	0.23	0.22	0.23	0.18	0.23
Bhima	0.22	0.19	0.25	0.22	0.25	0.23	0.23	0.23
NARI-NH-1	0.27	0.23	0.23	0.22	0.28	0.23	0.23	0.24
Mean	0.25	0.23	0.25	0.22	0.25	0.23	0.22	
				S.Em±	C.D (p=0.05)			
			Genotype	0.008	NS			
			P levels	0.13	NS			
		Genotype X P levels		0.022	NS			
			Shoot K (%)					
A-1	2.31	3.11	2.06	1.91	2.72	2.79	2.62	2.50
Bhima	3.52	2.88	3.27	2.99	2.65	3.27	3.18	3.11
NARI-NH-1	4.22	4.80	5.18	4.89	5.96	4.22	6.38	5.10
Mean	3.35	3.60	3.50	3.26	3.78	3.43	4.06	
				S.Em±	C.D (p=0.05)			
			Genotype	0.251	0.72			
			P levels	0.384	NS			
		Genotype X P levels		0.664	NS			
			Shoot Ca (%)					
A-1	1.02	1.13	1.15	1.21	1.33	1.34	1.60	1.25
Bhima	1.14	1.28	1.29	1.34	1.46	1.46	1.54	1.36
NARI-NH-1	1.73	1.76	1.82	1.96	1.98	1.99	2.13	1.91
Mean	1.30	1.39	1.42	1.50	1.59	1.60	1.76	
				S.Em±	C.D (p=0.05)			
			Genotype	0.106	0.30			
			P levels	0.162	NS			
		Genotype X P levels		0.250	NS			
			Shoot Mg (%)					
A-1	0.27	0.64	0.52	0.42	0.42	0.46	0.35	0.44
Bhima	0.37	0.40	0.49	0.55	0.58	0.46	0.47	0.47
NARI-NH-1	0.52	0.62	0.64	0.56	0.56	0.53	0.55	0.57
Mean	0.37	0.55	0.55	0.51	0.52	0.48	0.46	
				S.Em±	C.D (p=0.05)			
			Genotype	0.031	0.09			
			P levels	0.048	NS			
		Genotype X P levels		0.083	NS			

Table 2. Phosphorus, potassium, calcium and magnesium uptake by safflower genotypes at flowering stage

Genotypes	P levels (kg P_2O_5 / ha)							
	0	20	40	60	80	100	120	Mean
			Shoot P uptake (g / plant)					
A-1	0.041	0.049	0.069	0.053	0.071	0.056	0.052	0.056
Bhima	0.043	0.045	0.066	0.061	0.073	0.074	0.077	0.063
NARI-NH-1	0.042	0.045	0.050	0.052	0.071	0.070	0.084	0.059
Mean	0.042	0.046	0.062	0.055	0.072	0.067	0.071	
				S.Em±	C.D (p=0.05)			
			Genotype	0.004	NS			
			P levels	0.006	0.018			
		Genotype X P levels		0.011	NS			
			Shoot K uptake (g / plant)					
A-1	0.36	0.57	0.55	0.47	0.90	0.69	0.75	0.61
Bhima	0.70	0.70	0.89	0.86	0.80	1.04	1.08	0.87
NARI-NH-1	0.67	0.91	1.08	1.07	1.58	1.19	2.38	1.27
Mean	0.58	0.73	0.84	0.80	1.10	0.97	1.40	
				S.Em±	C.D (p=0.05)			
			Genotype	0.078	0.22			
			P levels	0.119	0.34			
		Genotype X P levels		0.206	NS			
			Shoot Ca uptake (g / plant)					
A-1	0.15	0.19	0.31	0.27	0.48	0.33	0.41	0.31
Bhima	0.23	0.29	0.31	0.34	0.42	0.43	0.48	0.36
NARI-NH-1	0.27	0.33	0.38	0.47	0.52	0.58	0.80	0.48
Mean	0.22	0.27	0.33	0.36	0.47	0.45	0.57	
				S.Em±	C.D (p=0.05)			
			Genotype	0.036	0.10			
			P levels	0.054	0.16			
		Genotype X P levels		0.094	NS			
			Shoot Mg uptake (g / plant)					
A-1	0.05	0.12	0.14	0.10	0.14	0.12	0.11	0.11
Bhima	0.06	0.09	0.13	0.16	0.18	0.14	0.15	0.13
NARI-NH-1	0.07	0.11	0.14	0.13	0.14	0.15	0.21	0.14
Mean	0.06	0.11	0.14	0.13	0.15	0.14	0.15	
				S.Em±	C.D (p=0.05)			
			Genotype	0.010	NS			
			P levels	0.015	0.04			
		Genotype X P levels		0.026	NS			

Table 3. Seed yield, oil content and test weight of safflower genotypes.

Genotypes	P levels (kg P_2O_5 / ha)							
	0	20	40	60	80	100	120	Mean
			Seed yield (Kg/ha)					
A-1	1403	2281	2032	1913	1876	1951	1847	1900
Bhima	1653	2719	1902	2053	1969	1847	2155	2042
NARI-NH-1	1131	1649	1813	1807	1655	1118	1132	1472
Mean	1396	2216	1916	1924	1833	1638	1711	
				S.Em±	C.D (p=0.05)			
			Genotype	47.5	136			
			P levels	72.6	278			
		Genotype X P levels		125.7	480			
			Oil content (%)					
A-1	26.8	26.6	26.4	26.0	26.4	26.4	26.4	26.4
Bhima	27.9	28.4	28.5	28.6	28.3	28.5	28.1	28.3
NARI-NH-1	30.8	30.5	30.7	30.7	30.4	31.5	29.9	30.6
Mean	28.5	28.5	28.5	28.5	28.4	28.8	28.1	
				S.Em±	C.D (p=0.05)			
			Genotype	0.211	0.6			
			P levels	0.323	NS			
		Genotype X P levels		0.559	NS			
			Test weight (g/100 seed)					
A-1	6.18	5.95	6.26	6.35	6.11	6.50	6.42	6.25
Bhima	5.63	5.72	5.74	5.73	5.53	5.21	5.01	5.51
NARI-NH-1	3.51	3.64	3.72	3.46	3.55	3.72	3.76	3.62
Mean	5.10	5.10	5.24	5.18	5.06	5.14	5.06	
				S.Em±	C.D (p=0.05)			
			Genotype	0.061	0.17			
			P levels	0.093	NS			
		Genotype X P levels		0.161	0.46			

Nutrient ratios

The average nutrient uptake corresponding to the highest seed yield (20 kg P_2O_5 ha^{-1}) was 0.046, 0.726, 0.270 and 0.109 g P, K, Ca and Mg per plant, respectively. At flowering stage, the ratio of the mean uptake of nutrients P: K: Ca: Mg for the optimum safflower seed (20 kg P_2O_5 ha^{-1}) was 1.0:11.7:3.9:2.5. In sorghum, genotypic differences in Mg efficiency had related to the differences in K uptake ratios and there was a tendency for Mg efficient genotypes to have lower K/Mg ratio in the shoots (Keisling *et al.* 1990). Uptake ratios of K/Mg and K/Ca calculated for some oilseed crops varied from 1.88 to 6.30 and from 0.78 to 3.42 (Hegde 2003). In this study, at flowering stage K/Mg and K/Ca uptake ratios in genotypes varied from 9.25 to 5.56 and from 2.65 to 2.00 because of P levels and the order was NARI-NH-1 > Bhima > A-1. While, the anion-cation uptake (P: K+Ca+Mg) ratio followed the order A-1 > Bhima > NARI-NH-1. Critical limits of anion-cation ratio established for A-1, Bhima and NARI-NH-1 were 0.055, 0.048 and 0.032 respectively by quadratic, square root and linear plateau methods. Bhima and NARI-NH-1 has shown lower critical values of 0.041 and 0.020 respectively by linear plateau method.

Genotypic variations of safflower in responding to the graded levels of P and an efficient genotype for P stress condition was identified. Further, P levels have significant influence on seed yield, P, K, Ca and Mg uptake. So, constant monitoring of these nutrients to achieve optimum safflower seed yield is important.

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References

Bhilegaonkar, M.W., Ekshinge, B.S. and Karle, B.G. (1995). Effects of phosphorus, sulphur and boron levels on dry matter and grain yield of safflower. *Journal of Maharashtra Agricultural Universities* **20,** 132.

Burford, J.R., Sahrawat, K.L. and Singh, R.P. (1989). In Management of Vertisols for improved agricultural production, Proc. of an IBSRAM Inaugural Workshop, 18-22 Feb., 1985. (International Crops Research Institute for the Semi Arid Tropics (ICRISAT), Patancheru, India) p. 147.

Ekshinge, B.S., Sondge, V.D. and Arthamwar, D.N. (1995). Studies on uptake of N and P by safflower varieties under advance application of fertilizer levels. *Journal of Maharashtra Agricultural Universities* **20,** 233-236.

Ekshinge, B.S., Sondge, V.D., Shelke, V.B. and Arthamwar, D.N. (1995). Studies on safflower varieties as influenced by different fertilizer levels. *Journal of Maharashtra Agricultural Universities* **20,** 255-258.

Hegde, D.M. (2003). Integrated nutrient management for oilseeds. *In* 'Thematic papers. National seminar on stress management in oilseeds for attaining self reliance in vegetable oils' (Eds. Mangala Rai, Harvir Singh and Hegde, D.M.) pp 221-252. (Indian Society Oil seeds Research : Hyderabad).

Jackson, M.L. (1973). Soil Chemical Analysis, (Prentice Hall of India Pvt. Ltd. : New Delhi).

Keisling, T.C., Hanna, W. and Walker, M.E. (1990). Genetic variation for Mg tissue concentration in pearl millet lines grown under Mg stress conditions. *Journal of Plant Nutrition* **13:**1371-1379.

Mandal, K.G., Ghosh, P.K. Wanjari, R.H., Hati, K.M. Bandyopadhyay, K.K. and Misra, A.K. (2002) Practical implication of nutrient x nutrient interaction to boost oilseeds productivity in India. *Fertiliser News* **47 :** 13-18, and 21-26.

Page, A.L., Miller, R.H. and Keeney, D.R. (1982). In Methods of Soil Analysis, Part 2, Agronomy Monograph No. 9. (Madison, Wisconsin, USA).

Patel, Z.G., Mehta, S.C. and Patel, N.M. (1995). Effect of row spacing, nitrogen and phosphorus on dry matter production, yield and N, P uptake of unirrigated safflower in Vertisol of South Gujarat. *Gujarat Agricultural University Research Journal* **21,**164-167.

Purvimath, S.S., Manure, G.R., Badiger, M.K. and Kavallappa, B.N. (1993). Effect of fertilizer levels of N, P, S and B on the seed and oil yield of safflower on Vertisol. *Journal of the Indian Society of Soil Science* **41**, 780-781

Rssell, E.W. (1973). *Soil Conditions and Plant Growth*, 10th Edition. pp 43 (ELBS.: London)

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