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Use of Industrial Waste and Bye-Products as a P Source for Improving Crop Production II. Effect of Source and Rate of P Application on Growth and P Uptake by Six Crop Species

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Abstract: Pot experiments were conducted to compare DCP, an industrial bye-product, against standard fertilizer SSP for growth and P uptake behaviour and to evaluate the performance of DCP as a P fertilizer source for several crop species. Single superphosphate and DCP were applied @ 0, 22, 44, 88, and 176 mg P kg^{-1} to a loam soil (Lyallpur III series, typic ustocrept). The first crop series grown were wheat, lentil and chickpea while the second series contained sorghum, maize and mungbean and in third series bermuda grass, brassica and berseeem were used. After each crop harvest soil samples were drawn for P analysis and the same P rates from two sources were applied to respective pots. Plants were grown for various time periods before harvesting and P uptake was estimated. Rate of P application increased DMY and P uptake, but the P rate required for maximum DMY varied depending on crop requirements. Brassica, bermuda grass and mungbean were less responsive to applied P while berseem, maize and sorghum responded more to P application. The behaviour of the two sources for DMY and P uptake by the six crop species were mostly alike. However, for crops that responded more to P application, DCP proved similar or sometimes superior to SSP. The amount of residual P after each crop harvest was significantly higher in DCP as compared to SSP applied treatment.

Key words: Crop species, P rate, P response, P source

Introduction

In an effort to use industrial waste and bye-products as nutrient sources for crop production we tried di-calcium phosphate (DCP, containing 42% P_2O_5) and bone meal (containing 20% P_2O_5) as phosphatic source. These materials were compared with mineral fertilizers like SSP, DAP and TSP by growing maize in pot culture. The results were quite encouraging and DCP was found to be a good source of P for maize crop (Latif *et al.*, 1998a). In another pot study, crops like wheat, lentil and chickpea were grown and the behaviour of DCP was compared against the standard fertilizer SSP after applying them at the rate of 0, 22, 44, 88 and 176 $mgPkg^{-1}$ (Latif *et al.*, 1998b). In subsequent studies we grew six more crop species on the same soil on which wheat, lentil and chickpea were grown. These studies were conducted in two crop sequence, the former comprising of sorghum, maize and mungbean while in the later bermuda grass, berseem and brassica were grown. The objectives of these studies were to compare DCP against SSP for growth and P uptake behaviour and evaluate the performance of DCP as a P source for different crop species.

Materials and Methods

2nd crop series: After the harvest of wheat, lentil and chickpea (Latif *et al.*, 1998b), the soil was separately prepared and 0, 22, 44, 88 and 176 $mgPkg^{-1}$ soil from each source (DCP and SSP) were thoroughly mixed and filled back to the same pots. Deionized water was used to maintain the soil near field moisture capacity. Ten seeds of sorghum, maize and mungbean were sown and after germination thinned to 5 plants per pot. Nitrogen was applied @ 75 $mgPkg^{-1}$ as urea solution at thinning and subsequently after first harvest. Two plants per pot were harvested 27 days after sowing while 3 plants per pot were harvested 10 days later. Plant samples were dried in oven to record dry weights.

3rd crop series: After crop harvest the soil was sieved to remove the roots and was replaced to the same pots. DCP and SSP @ 0, 22, 44, 88 and 176 mg P kg^{-1} were again applied to respective pots. Nitrogen @ 75 mg P kg^{-1} as urea was mixed thoroughly with the soil mass before seeding bermuda grass, berseem and brassica. Deionized water was added to maintain water at 100% of field moisture capacity. After germination 5 plants pot^{-1} of each specie were maintained. Two cuttings of bermuda grass at 37 and 74 days after sowing, while six cuttings of berseem at different intervals were obtained (growth period 170 days). In case of brassica, 3 plants pot^{-1} were harvested 37 days after sowing while remaining 2 plants pot^{-1} were harvested after crop maturity (growth period 124 days). Dry matter, straw and grain yields were recorded after drying the samples in forced air oven.

Plant analysis: The plant samples were ground in Wiley mill and one g portions were digested in triacid mixture. The concentration of P in plant samples were determined after developing yellow colour with Bartons' reagent (Jackson, 1962). Total P uptake was calculated by multiplying P concentration with plant yield at respective stage.

Soil analysis: A portion of the soil from each treatment after the final crop harvest was analyzed for available P content. The soil was extracted with $NaHCO_3$ and P was determined by ascorbic acid blue colour method (Watanabe and Olsen, 1965).

Statistical analysis: The data were analyzed statistically employing the two factor factorial in CRD using MSTAT computer program. Duncan's Multiple Range test was used to compare the means.

Results and Discussion

2nd crop series: Application of phosphorus, irrespective of source, increased the dry matter yield (DMY) and P uptake of the three crop species harvested 27 days after sowing (Fig. 1). The differences in DMY obtained due to rates of two P sources were not significant for each crop but P uptake from DCP was significantly higher in mungbean and sorghum. Source x rate interaction for DMY and P uptake was

Table 1: Effect of rate and source of P on dry matter yield and P uptake by thee crop species 37 days after sowing.

Rate mg P kg^{-1}	Dry matter yield, g pot^{-1}			P uptake, μ g pot^{-1}		
	DCP	SSP	Mean	DCP	SSP	Mean
Sorghum						
0	0.46d	0.35d	0.40D	0.33f	0.09f	0.21D
22	11.49c	13.85c	12.67C	20.18e	20.37e	20.28C
44	18.79d	19.29b	19.04B	42.80bc	33.33cd	38.07B
88	20.48b	20.38b	20.43A	50.63b	38.14cd	44.39AB
176	24.06a	20.08b	22.07A	71.70a	29.39de	50.54A
Mean	15.06A	14.79A		37.13A	24.26B	
Maize						
0	3.39ef	1.79f	2.59D	3.15e	1.40e	2.27D
22	11.18d	6.41e	8.80C	24.98bc	10.47d	17.73C
44	13.49cd	12.43cd	12.96B	30.65b	23.03c	26.84B
88	18.59a	16.04abc	17.31A	47.13a	28.75bc	37.94A
176	17.71ab	14.24bcd	15.97AB	41.36a	24.88bc	33.12A
Mean	12.87A	10.18B		29.45A	17.70B	
Mungbean						
0	0.29b	0.37b	0.33B	0.47b	0.47b	0.47B
22	2.65a	2.44a	2.55A	6.34a	5.03a	5.69A
44	2.84a	2.21a	2.52A	6.33a	4.74a	5.53A
88	3.46a	3.22a	3.34A	7.41a	6.55a	6.98A
176	2.46a	2.39a	2.42A	6.39a	4.18a	5.28A
Mean	2.34A	2.12A		5.38A	4.19A	

Table 2: Effect of source and rate of P application on dry matter yield and P uptake by bermuda grass, brassica and berseem

Rate mg P kg^{-1}	Dry matter yield, g pot^{-1}			P uptake, μ g pot^{-1}		
	DCP	SSP	Mean	DCP	SSP	Mean
Bermuda grass						
0	1.26	1.91	1.59C	3.11	4.15	3.63C
22	7.79	7.16	7.48A	33.52	25.08	29.30B
44	6.86	5.99	6.42B	32.16	27.04	30.10B
88	6.20	5.98	6.09B	37.34	28.06	32.70AB
176	6.40	6.14	6.27B	42.75	29.19B	35.97A
Mean	5.70A	5.44A		29.77A	22.90B	
Brassica						
0	3.40	3.79	3.59A	10.43c	9.54c	9.99B
22	5.71	5.22	5.46A	29.92ab	20.38bc	25.15A
44	4.51	5.42	4.96A	26.29ab	24.73ab	25.51A
88	5.67	5.20	5.43A	34.52a	28.78ab	31.65A
176	4.57	6.34	5.45A	29.06ab	29.54ab	29.30A
Mean	4.77A	5.19A		26.04A	22.59A	
Berseem						
0	17.90cd	13.95d	15.92C	39.88d	35.43d	37.65D
22	31.05abc	26.95bc	29.00B	114.09c	94.40c	104.25C
44	34.35ab	30.85abc	32.60AB	139.67bc	121.00c	130.34BC
88	32.90ab	32.06ab	32.48AB	185.62b	142.45bc	164.03B
176	40.70a	37.59ab	39.14A	247.54a	173.88b	210.71A
Mean	31.38A	28.28A		145.36A	113.43B	

significant for sorghum only. Maximum DMY for sorghum was recorded where SSP was applied @ 176 mg P kg^{-1} while maximum P uptake was obtained at 88 mg P kg^{-1} where the source was DCP.

The dry matter accumulation by three crop species at 37 days of growth as influenced by rate of P application is given in Table 1. Application of P improved dry matter yield and plant growth rate in all species calculated from the DMY obtained between first and the second harvest. The mean growth rate of mungbean was slower compared to maize and sorghum. Maximum DMY of sorghum was obtained at the highest P rate of 176 mg P kg^{-1} while for maize and mungbean this rate was 88 mg P kg^{-1}, but for mungbean statistically similar DMY was obtained at 22 mg P kg^{-1} rate of application. The two P sources, DCP and SSP behaved alike for dry matter production of sorghum and mungbean but DCP proved significantly better for the dry matter yield of maize. Latif *et al.* (1998a), however, reported that when the rate of P applied was 50 mg P kg^{-1} the two P sources produced equivalent DMY of maize. These results therefore, indicate that the species very widely in responding the applied phosphorus.

Total P uptake was lowest in mungbean followed by maize and sorghum and may be attributed to their rate of dry matter accumulation. The rate of application increased the P uptake in all species. Maximum P accumulation by sorghum was at 176 mg P kg^{-1} rate which was statistically at par with 88 mg

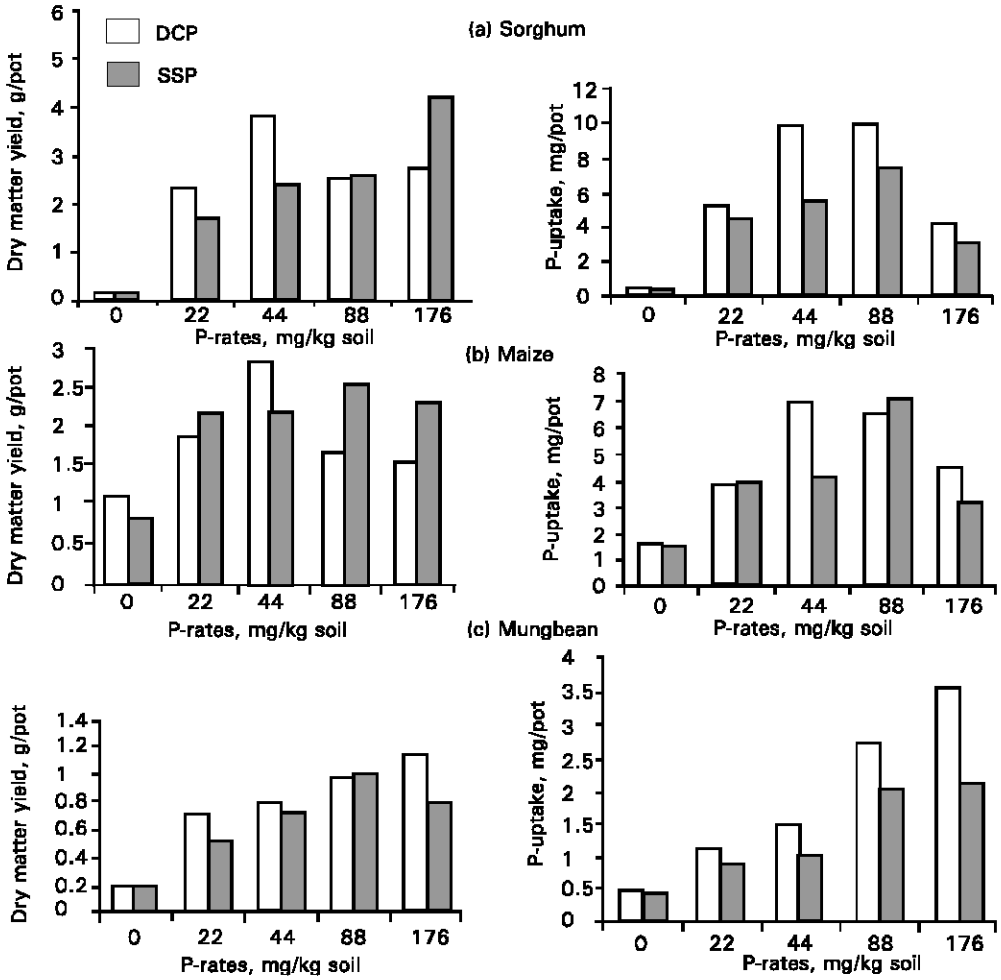

Fig. 1: Effect of P sources and reates on dry matter yield and P uptake by 3 crop species, 27 days after sowing.

P kg^{-1} rate of application while in maize and mungbean maximum P accumulation was noted at 88 mg P kg^{-1}, but in mungbean statistically similar P uptake was obtained at 22 mg P kg^{-1} rate also. Source x rate interaction was not significant for P uptake by mungbean but was significant for sorghum and maize. Phosphorus uptake by sorghum was significantly higher in DCP at each rate of P application. Similar results were reported by Latif *et al.* (1998a). It may be observed that due to applied DCP @ 44 mg P kg^{-1}, the DMY and P uptake by sorghum and maize plants were consistently higher or equivalent to the same or higher rate of applied SSP, indicating higher P absorption from DCP by these crop species.

3rd crop series: The effect of P rate from two sources on dry matter yield and P uptake by bermuda grass is given in Table 2. It may be observed that rate of application had little effect on DMY; the optimum rate observed was 22 mg P kg^{-1} for dry matter production. Total P uptake, however, increased upto the highest rate of application. The two P sources did not differ significantly for DMY of brassica but increased the P uptake, optimum rate being only 22 mg P kg^{-1}. The straw or grain yield at maturity (data not shown) was also not affected due to source or rate of P application, indicating low external P requirement by these crops. Similar results were observed for lentil and chickpea in an earlier study (Latif *et al.*, 1998b). In contrast, the dry matter yield and P uptake by berseem increased significantly due to rate of P application (Table 2). Irrespective of source, optimum rate was 44 mg P kg^{-1} for dry matter production, but plant uptake of P increased linearly upto the highest rate of P application. The two P source differed significantly for P uptake. The P uptakes from DCP were consistently higher at each cutting (Fig. 2). comparatively higher P uptake from DCP compared to SSP, particularly at higher rate of application, may partially be attributed to increased P absorption that might have resulted from higher P availability in soil. The available P status of soil after the harvest of Ist, 2nd and 3rd crop series are given in Table 3. It may be observed that residual available P in soil after each crop harvest depended on the rate of previous applications and generally remained higher due to increased rate of P application.

The residual P in soil from DCP was significantly higher than the residual P from SSP. The significant source x rate interaction also indicate high P availability from DCP as compared to SSP at different rates of application, depending on crop species grown. In general, P applied @ 44 mg P kg^{-1} as DCP or SSP resulted in equivalent residual P after each crop harvest but where P was applied beyond this rate significantly

Table 3: Available P in soil (mg kg^{-1}) after each crop harvest as influenced by source and rate of P application

Rate mg kg^{-1}	Sources								
	DCP	SSP	Mean	DCP	SSP	Mean	DCP	SSP	Mean
	After wheat			After chickpea			After lentil		
0	4.35f	7.55ef	5.95D	7.15e	4.50e	5.82E	4.60f	6.65f	5.62D
22	13.71def	12.05def	12.88C	17.12d	15.65d	16.38D	14.98e	16.38de	15.68C
44	20.11bcd	15.91cde	18.01C	26.37c	19.64cd	23.00C	19.98de	16.51de	18.25C
88	24.71bc	27.04b	25.87B	35.50b	24.84c	30.17B	28.43bc	24.24cd	26.34B
176	73.53a	28.37b	50.95A	75.45a	36.10b	55.77A	80.25a	31.16b	57.21A
Mean	27.28A	18.19A		32.32A	20.14B		29.65A	19.59B	
	After sorghum			After maize			After mungbean		
0	3.50e	5.39e	4.44D	5.65e	7.25e	6.45E	6.35g	5.95g	6.15D
22	5.11e	7.06e	6.08D	6.45e	11.56de	9.01D	10.42fg	13.45fg	11.93D
44	17.89d	16.81d	17.35C	19.90d	20.71d	20.31C	26.23de	21.38ef	23.81C
88	50.17b	33.76c	41.96B	53.20b	31.07c	42.13B	60.82b	34.20cd	47.76B
176	133.82a	48.82b	91.32A	154.40a	47.65b	101.02A	145.07a	41.42c	93.25A
Mean	42.10A	22.37B		47.92A	23.65B		49.78A	23.38B	
	After bermuda grass			After berseem			After brassica		
0	3.15f	1.27f	2.21D	1.53f	2.28f	1.90D	2.53f	2.40f	2.46E
22	10.00f	12.80ef	11.40D	9.10ef	14.20def	11.64C	16.28e	8.80f	12.54D
44	28.48d	24.87de	26.68C	15.40de	16.14de	15.77C	25.68d	18.07e	21.87C
88	71.90b	33.80d	52.85B	38.34b	24.68cd	31.51B	48.16b	25.75d	36.95B
176	136.24a	51.48c	93.86A	124.32a	31.08bc	77.90A	154.88a	33.65c	94.26A
Mean	44.95A	24.84B		37.82A	17.68B		49.51A	17.73B	

Sources x rate interaction was significant at $p<0.01$ as determined by DMR test.

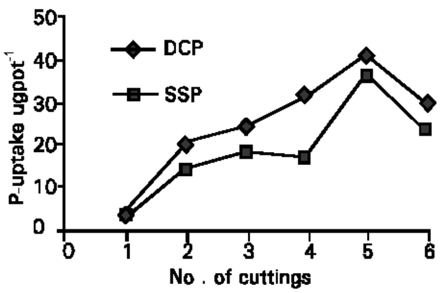

Fig. 2: Effect of P sources on total P uptake by berseem at different cuttings (Means of all rates).

higher ($P<0.05$) residual P were found in DCP as compared to SSP source. Therefore, single heavy P application as DCP may maintain relatively more P available in soil for a longer period of time and have greater residual effect than SSP. From the results, it may be inferred safely that application of P from either source increased the dry matter yield and P uptake by some of the crop species. The rate of P required for maximum DMY and P uptake by crops, however, varied from 22 to 176 mg P kg^{-1}. Brassica, bermuda grass and mungbean were less responsive to applied P while berseem, maize and sorghum responded more to P applications. The behaviour of the two sources for DMY and P uptake by the six crop species tested, was mostly alike. However, for crops that responded more to P application, DCP proved similar or sometimes superior to SSP. After each crop harvest the amount of residual P in soil from DCP was significantly higher than the residual P from SSP particularly at higher rate of application. Thus it may be concluded that DCP competes favourably to SSP as a P fertilizer source.

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