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Direct and residual effects of sources and levels of phosphorus and farmyard manure in maize (*Zea mays*)-mustard (*Brassica juncea*) cropping sequence

H.L. MAHALA, M.S. SHAKTAWAT AND R.K. SHIVRAN

Department of Agronomy, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313 001

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ABSTRACT

A field experiment was conducted during rainy *(kharif)* and winter *(rabi)* seasons of 2001-02 and 2002-03 to evaluate the direct and residual effects of sources and levels of phosphorus and farmyard manure (FYM) applied in maize *(Zea mays* L.*)* on the succeeding Indian mustard [*Brassica juncea* (L.) Czernj & Cosson]. Phosphorus application through single superphosphate (SSP) recorded the maximum grain and stover yields of maize and were on a par with that of Udaipur rock phosphate (URP) +SSP (1:1). Application of URP + phosphate-solubilizing bacteria (PSB) recorded the highest available P after maize harvest. Grain and stover yields of maize significantly increased up to 60 kg P_2O_5/ha, whereas the available N and P status of the soil after maize harvest increased up to 80 kg P_2O_5/ha. FYM also significantly improved the grain and stover yields as well as the availability of N and P in the soil after maize harvest. Residual effect of P sources was found equally effective in improving the yield and nutrient uptake of mustard. Residual effect of URP+PSB recorded the highest available P in the soil after mustard harvest. Residual effect of increasing P levels up to 80 kg P_2O_5/ha significantly increased the seed and straw yields, nutrient uptake and the available N and P status of soil after mustard harvest. Residual effect of FYM also had a significant positive impact on these aspects of mustard crop as well as on the available N and P in soil.

Key words : Phosphorus sources and levels, FYM, Direct and residual effects, Maize-mustard sequence

Phosphatic fertilizers and organic manure have a carry-over effect on the succeeding crops. The utilization efficiency of applied phosphatic fertilizers seldom exceeds 15% by the first crop, but a substantial amount of them is left as residue for the next crop (Roy *et al.,* 1978). Out of the total utilizable nutrient content of FYM, only one-third N and two-thirds P are available to the current-season crop, leaving the rest to the succeeding crops (Yawalkar *et al.,* 1992). Maize-mustard is one of the important cropping systems in Udaipur region of Rajasthan, where the poor tribal farming community is not using phosphorus (a major limiting plant nutrient) regularly in the system due to higher cost of the conventional phosphatic fertilizers like SSP and diammonium phosphate (DAP). Hence it became necessary to find out some low-priced indigenous alternatives. There are vast deposits of rock phosphate in the adjoining areas of Udaipur. There are examples of using rock phosphate in non-acid soils with some amendments like SSP and organic manures and the use of phosphate solubilizing microorganisms (Gaur, 1990). Therefore an attempt was made to find out a viable strategy of integrated phosphorus management in maize-mustard cropping system by incorporating the locally available resources.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* and *rabi* 2001-02 and 2002-03 at the research farm of Rajasthan College of Agriculture, Udaipur. The zone has typical subtropical, subhumid climate with mild winter, moderate summer and high relative humidity during July-September. The soil was clay loam, medium in organic carbon (0.67 and 0.70%), available nitrogen (272.8 and 286.0 kg/ha) and phosphorus (18.1 and 17.4 kg/ha) and high in potassium (363.5 and 370.7 (kg/ha) with slightly alkaline soil reaction (pH 7.8 and 7.9) in 2001 and 2002 respectively. The treatments consisted of four sources of phosphorus, *viz.* single superphosphate (SSP), Udaipur rock phosphate (URP), URP+SSP (1:1) and URP + seed inoculation with phosphate-solubilizing bacteria (PSB), three phosphorus levels (40, 60 and 80 kg P_2O_5/ha), 2 FYM levels (0 and 10 tonnes/ha) along with two extra treatments of FYM @ 10 tonnes/ha (alone) and an absolute control. These treatments were evaluated in factorial randomized block design with four replications. As per the treatment, FYM was incorporated 3 weeks before sowing, and phosphate-solubilizing bacteria *(Bacillus megatherium* var. *phosphaticum)* was applied as seed treatment @ 10 g/

kg seed. Finely ground 74-mesh Udaipur rock phosphate (34% P_2O_5) was incorporated with FYM in 1:2 ratio for 3 weeks before the application to increase the availability of phosphorus and was then applied in furrows at the time of sowing as per treatment. URP and SSP were mixed on P basis in 1:1 ratio. Maize composite 'Navjot' was sown at a spacing to 60 cm × 25 cm in the first week of July and harvested in second week of October. After maize harvest, mustard 'Pusa Bold' was raised on the residual fertility at a spacing of 30 cm × 10 cm. Uniform application of nitrogen @ 90 and 60 kg/ha was made in maize and mustard respectively. Available N and P contents in the soil from each plot after maize and mustard harvest were estimated.

RESULTS AND DISCUSSION

Phosphorus sources

Direct effect : Application of P sources significantly influenced the grain and stover yields of maize during both the study years (Table 1). Among P sources, application of SSP and URP+SSP (1:1) recorded significantly higher grain and stover yields over URP+PSB and URP alone application. However, SSP was at par with URP+SSP, and URP+SSP with URP. This might be ascribed to better growth and development of crop under readily available P sources (SSP and URP+SSP) in the early stage of crop growth, resulting in higher productivity of the crop. Our results are in agreement with the findings of Singaram *et al.* (1995). Phosphorus sources had significant effect on the available P status in the soil after maize harvest, but not on the available N status. Among P sources, maximum build-up of available P in the soil was estimated under URP + SSP (1:1) application, which was significantly higher over all other sources during both the years of experimentation (Table 1).

Residual effect : Residual effect of P sources was non-significant in improving the seed and straw yields of mustard. However, the highest seed and straw yields were recorded under residual effect of URP+SSP (1:1), but all the sources were found equally effective in their residual effects (Table 1). It was because the availability of phosphorus from rock phosphate was increased with time and water-soluble SSP did not maintain the same level of available P for a long time. Singaram and Kothandaraman (1992) also reported similar results. The uptake of nutrients showed variable response to the residual effect of P

Table 1. Direct and residual effect of sources and levels of phosphorus and FYM on yields of maize and succeeding mustard as well as soil-fertility status after maize harvest

Treatment	Maize (direct effect) yield				Mustard (residual effect) yield				Available nutrient in soil after maize (kg/ha)			
	Grain (q/ha)		Stover (q/ha)		Seed (q/ha)		Straw (q/ha)		N		P	
	2001	2002	2001	2002	2001-02	2002-03	2001-02	2002-03	2001	2002	2001	2002
Treatment												
Absolute control	29.20	28.76	73.90	67.25	17.24	17.95	50.70	52.05	241	241	18.2	16.7
Rest treatments	39.47	37.70	89.06	82.84	21.80	22.38	58.74	60.02	270	266	30.9	27.7
'F' test	**	**	**	**	**	**	**	**	**	**	**	**
FYM (sole)	34.70	33.40	80.21	74.40	19.96	20.20	55.65	57.05	256	251	24.8	23.0
P treatments	39.67	37.88	89.43	83.20	21.87	22.47	58.86	60.15	270	266	31.1	27.9
'F' test	**	**	*	*	NS	*	NS	NS	**	**	**	**
P sources												
SSP	42.73	40.52	95.59	88.29	22.16	22.72	59.24	60.76	271	269	31.6	28.8
URP	36.77	35.21	83.38	77.92	21.32	21.87	57.62	58.56	269	265	29.1	25.3
URP+SSP (1:1)	41.15	39.38	93.97	86.12	22.52	23.11	60.03	61.36	272	267	33.0	30.1
URP+PSB	38.02	36.40	48.78	80.45	21.50	22.18	58.56	59.90	268	265	30.8	27.6
CD (P=0.05)	1.96	1.84	4.54	3.93	NS	NS	NS	NS	NS	NS	1.0	1.1
P_2O_5 (kg/ha)												
40	35.61	34.03	84.38	77.48	20.67	21.15	56.51	57.76	265	261	26.6	24.9
60	40.97	39.10	90.90	84.93	21.91	22.36	58.74	59.74	271	268	30.9	27.7
80	42.41	40.51	93.01	87.18	23.04	23.90	61.35	62.95	275	270	35.9	31.3
CD (P=0.05)	1.70	1.60	3.93	3.40	0.97	0.94	2.71	2.58	5	6	1.0	0.9
FYM (t/ha)												
0	37.83	35.76	85.25	79.57	21.10	21.51	56.74	57.97	262	256	29.4	26.2
10	41.50	40.00	93.62	86.82	22.65	23.43	60.99	62.32	278	277	32.9	29.7
CD (P=0.05)	1.39	1.30	3.21	2.78	0.79	0.77	2.21	2.11	4	5	0.8	0.8

URP, Udaipur rock phosphate; PSB, phosphate-solubilizing bacteria
*P=0.05, **P=0.01

sources during both the years of study. The N uptake was significantly influenced during 2001-02 and P uptake during 2002-03. Maximum uptake of N and P was recorded under the residual effect of URP+SSP (1:1) during both the years (Table 2). The residual effect of P sources applied to maize crop had non-significant effect on the available N of the soil after mustard harvest, whereas available P was significantly influenced during 2002-03. Maximum available P in the soil after mustard harvest was recorded in the URP+PSB-treated plots and the lowest was recorded in the SSP-treated plots (Table 2). This may be attributed to the solubilization of rock phosphate by phosphate solubilizing bacteria slowly and gradually but the water-soluble SSP failed to maintain the same level of P for a long period.

Phosphorus level

Direct effect : Grain and stover yields of maize increased significantly up to 60 kg P_2O_5/ha. Further increase in P from 60 to 80 kg P_2O_5/ha, though increased the grain and stover yields, failed to record statistical significance. Application of 60 kg P_2O_5/ha increased the grain yield by 15.05 and 14.90% and stover yield by 7.73 and 9.62% over that of 40 kg P_2O_5/ha during 2001 and 2002 respectively (Table 1). These results are in close conformity with the findings of Kumpawat and Rathore (1995). The available P in the soil after maize harvest increased significantly on increase in P level from 60 to 80 kg/ha, but the available N increased significantly only up to 60 kg P_2O_5/ha. The increase in P level from 40 to 60 and 60 to 80 kg P_2O_5/ha increased the available P in the soil by 16.2 % during 2001-02 and 11.2 and 13.0 % during 2002-03 respectively (Table 1). These results are in close conformity with the findings of Singaram and Kothandaraman (1992).

Residual effect : The seed and straw yields of mustard were significantly increased under the residual effect of increasing P level up to 80 kg P_2O_5/ha. The residual effect of 80 kg P_2O_5/ha increased the seed yield of mustard by 5.16 and 6.89 % over 60 kg P_2O_5/ha and 11.47 and 13.00% over 40 kg P_2O_5/ha during 2001-02 and 2002-03 respectively (Table 1). Surendra and Sharanappa (2000) also reported significant response of mustard crop to residual phosphorus. The residual effect of increase in P level from 40 to 80 kg P_2O_5/ha significantly increased the accumulation of N and P by mustard. This might be as-

Table 2. Residual effect of sources and levels of phosphorus and FYM on nutrient uptake by mustard and available nutrient status in soil after mustard harvest

Treatments	Nutrient uptake (kg/ha)				Available nutrient status in soil after mustard (kg/ha)			
	N		P		N		P	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
Treatment								
Absolute control	93.4	96.1	19.5	19.9	226	228	13.1	12.6
Rest treatments	119.8	122.5	26.1	26.7	256	254	20.4	19.1
'F' test	**	**	**	**	**	**	**	**
FYM (sole)	108.3	110.9	22.9	23.3	253	249	15.8	15.2
P treatments	120.3	123.0	26.3	26.9	256	254	20.6	19.3
'F' test	**	*	**	**	NS	NS	**	**
P sources								
SSP	121.7	124.5	26.6	27.2	257	253	20.1	18.3
URP	117.2	119.3	25.6	26.0	253	254	20.6	19.7
URP+SSP (1:1)	123.8	126.5	26.9	27.7	257	254	20.5	18.9
URP+PSB	118.6	121.7	26.0	26.6	256	254	21.0	20.4
CD (P=0.05)	4.4	NS	NS	1.1	NS	NS	NS	0.9
P_2O_5 (kg/ha)								
40	113.3	115.3	24.4	24.9	250	248	17.6	16.5
60	120.3	122.4	26.2	26.6	256	254	20.6	19.0
80	127.3	131.3	28.2	29.1	261	259	23.5	22.4
CD (P=0.05)	3.8	4.7	0.9	1.0	5	5	0.7	0.8
FYM (t/ha)								
0	113.7	115.5	24.9	25.3	246	243	19.4	18.4
10	127.0	130.6	27.7	28.4	265	265	21.7	20.2
CD (P=0.05)	3.1	3.8	0.7	0.8	4	4	0.6	0.7

URP, Udaipur rock phosphate; PSB, phosphate-solubilizing bacteria
*P=0.05, **P=0.01

cribed to higher availability of phosphorus in the soil, resulting in marked increase in the concentration of P and its uptake by the crop. Further, P had a synergistic effect on the uptake of other nutrients. The available N and P in the soil after mustard harvest increased significantly under the residual effect of increasing P levels up to 80 kg P_2O_5/ha (Table 2).

Farmyard manure

Direct effect : FYM @ 10 tonnes/ha had a significant positive effect on the grain and stover yields of maize, increasing the grain yield by 9.70 and 11.86 % and stover yield by 9.82 and 9.11 % over the control during 2001 and 2002 respectively. FYM had a favourable effect on the chemical, physical and biological properties of soil, resulting in better growth conditions for the crop, leading to higher grain and stover yields. The available N and P status of the soil was also significantly improved under FYM application. FYM 10 tonnes/ha improved the available N by 6.2 and 7.9 % and available P by 11.9 and 13.4 % compared with its non-application during 2001-02 and 2002-03 respectively (Table 1).

Residual effect : The residual effect of FYM 10 tonnes/ha significantly improved the seed and straw yields of mustard over no FYM application during both the years. The results indicating a profound influence of residual effect of FYM on mustard productivity are in close conformity with the findings of Sahoo and Panda (1999). The uptake of N and P by mustard was also significantly improved by the residual effect of FYM applied to the preceding crop. Further, the residual effect of FYM had significant positive effect also on the available N and P status of the soil after mustard harvest (Table 2). This might be due to the fact that it modified the soil environment besides improving the physical properties of the soil, and also the slow microbial decomposition of humus gradualy increased the nutrients during the succeeding crop, which was manifested in higher nutrient uptake by the mustard crop.

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