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Effect of phosphorus and biofertilizers with and without FYM on mustard and soil fertility

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Abstract
A field experiment was conducted at Rajasthan College of Agriculture, Udaipur to study the effect of integrated phosphorus management on yield and quality of mustard and soil fertility. The experiment was laid out in split plot design with four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}), two levels of FYM (0 and 5 t ha^{-1}) and four levels of microbial inoculum (no inoculum, PSB, VAM and PSB + VAM). The maximum seed and straw yield of mustard was significantly enhanced with 60 kg P_2O_5 ha^{-1}, 5 t FYM ha^{-1} and PSB + VAM inoculation. Significantly higher available N, P, K and S content in soil after harvest of mustard was reported with 60 kg P_2O_5 ha^{-1}, 5 t FYM ha^{-1} and PSB + VAM inoculation. Integrated application of 60 kg P_2O_5 ha^{-1} + 5 t FYM ha^{-1} reported significantly higher seed yield, straw yield, oil yield and available P and S after harvest of mustard. Application of 5 t FYM ha^{-1} along with PSB + VAM inoculation reported significantly higher available P.

Keywords: Mustard, phosphorus, FYM, PSB, VAM and biofertilizers

Introduction
Mustard, an important oil seed crop of India, is mainly cultivated in the states of Rajasthan, Uttar Pradesh, Hariyana, Madhya Pradesh and Gujarat. Mustard oil is an important component of the diet of northern and eastern parts of India. The mustard cake is used mostly for cattle feed and manure. Green stem and leaves are a good source of fodder for cattle.

Although it is major oil seed crop but its productivity is quite low due to imbalanced and inadequate supply of nutrients and poor fertility status of soils. The soils of this region are deficient not only in nitrogen but phosphorus and sulphur also. About 98 percent of the cultivated soils of India need phosphorus fertilization for good yield (Luthura *et al*. 1983) [9].

Phosphorus is necessary for Maintaince and transmission of energy, transfer of genetic characteristics and beneficial for root development, vigorous growth, better yield and quality and nodule formation in legume crops. Phosphorus fixation is the major problems in productivity of crops concerning not only its actual deficiency in soil but also its availability to crop plants. Approximately 15-20 per cent of applied fertilizer phosphorus is utilized by the crops and rest of the gets fixed in the soil (Toro, 2007) [15]. For enhancing availability and reducing the fixation of phosphorus, integrated phosphorus management (IPM) is the only viable strategy. In order to bring the soil well supplied with all essential plant nutrients and also to maintain good soil health it is necessary to use organic source like FYM, biofertilizers as PSB and VAM along with inorganic fertilizers. It not only enhances the phosphorus availability to crop plants, but reduce fixation, release the fixed form of phosphorus and improves the soil fertility (Arbad and Ismail, 2011) [1]. The experiment was, therefore conducted to study the effect of integrated phosphorus management on productivity of mustard, quality, nutrient uptake and fertility status.

Materials and Methods
The experiment was conducted during *rabi* 2016-17 and 2017-18 at Rajasthan College of Agriculture, (MPUAT) Udaipur. The soil of the experimental plot was clay loam in texture and alkaline in reaction having pH (7.98 and 8.05), organic carbon (0.67 and 0.71%), and the available N (261.6 and 270.1 kg ha^{-1}), P (21.06 and 19.48 kg ha^{-1}) and K (287.1 and 308.4 kg ha^{-1}), respectively in the year 2016-17 and 2017-18. The treatments consisted of four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}), two levels of FYM (0 and 5 t FYM ha^{-1}) as main

plot treatments and four levels of microbial inoculum (no inoculum, PSB, VAM and PSB + VAM) as sub plot treatments.

Required quantity of FYM was incorporated as per the treatment. Full dose of P and half dose of nitrogen fertilizers were drilled just before the sowing in the form of urea and DAP and remaining half dose of nitrogen was applied 30 days after sowing. Inoculum of VAM, *Glomus fasciculatum* was drilled below seed in soil and the seeds were inoculated with *Bacillus megatherium* var. phosphaticum for PSB as per treatment. The observation of growth parameters and yield attributes and yields were recorded at the time of harvest. At harvest of crops, soil samples were analyzed for available N, P, K and S as per standard laboratory method.

Result and Discussion

Yield and quality

Application of phosphorus @ 60 kg P_2O_5 ha^{-1} resulted in the significantly higher seed yield, straw yield and oil content (18.70 q ha^{-1}, 48.31 q ha^{-1} and 38.05 per cent, respectively) over control and it was at par with 40 kg P_2O_5 ha^{-1} in pooled analysis (Table 1). The mustard seed oil yield was significantly improved with application of 60 kg P_2O_5 ha^{-1} over rest of the phosphorus levels (Table 1). The increased supply of phosphorus might have helped in early root initiation and establishment of the crop (Gangwal *et al.*, 2011) [4]. Application of phosphorus favorably influenced the photosynthesis, biosynthesis of proteins and phospholipids and other metabolic processes of the plant. These results are in conformity with Chouksey *et al*. (2017) [3].

Significantly the highest seed and straw yield was reported by application of FYM @ 5 t ha^{-1} (18.65 q ha^{-1} and 48.97 q ha^{-1}, respectively) which was enhanced by 28.89 and 30.59 per cent, respectively over no FYM. The increase in yield might be due to higher availability of nutrients under FYM application. The oil content and oil yield of mustard was enhanced by 1.23 and 30.37 per cent with FYM @ 5 t ha^{-1} over control (Table 1). The gradual release and steady supply of plant nutrients from FYM throughout the growth and development of plants maintained the photosynthetic efficiency and production of metabolites at higher level. These conclusions are in consonance with Pathak and Pal (2016) [10].

The seed and straw yield of mustard was significantly higher with PSB + VAM inoculation and it was enhanced by 11.22 and 13.93 per cent, respectively over no inoculation. The oil content in seed was not influenced significantly with inoculation treatments. Oil yield was significantly enhanced with PSB+VAM inoculation no inoculation and found at par with PSB inoculation (Table 1). This might be attributed due to the solublization of native as well as applied phosphorus and enhanced P uptake by phosphate solubilizing microorganisms and VAM (Somani, 2004) [13]. These findings of present investigations are supported by Lingaraju, 2016) [8] who observed increase in seed and stover yield of mustard due PSB and VAM inoculation.

Integrated application of 60 kg P_2O_5 ha^{-1} along with 5 t FYM ha^{-1} recorded significantly higher seed yield (20.37 q ha^{-1}), straw yield (53.33 q ha^{-1}) and oil yield (780.75 kg ha^{-1}) of mustard, however they were at par with 40 kg P_2O_5 ha^{-1} along with 5 t FYM ha^{-1} (Table 2). These results are in accordance with Kumar *et al.* (2017) [7] who observed combined application of phosphorus and FYM had synergistic effect in increasing seed and straw yield of mustard.

Table 1: Effect of phosphorus, FYM and microbial inoculum on seed yield, Straw yield, oil content and oil yield of mustard (Mean of 2 years)

Treatments	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
Phosphorus levels (P_2O_5 kg ha^{-1})				
0	13.75	35.75	37.41	515.25
20	16.06	42.01	37.73	606.42
40	17.74	46.86	37.98	674.08
60	18.70	48.31	38.15	713.60
S.Em+	0.43	0.69	0.20	11.72
CD at 5%	1.23	2.00	0.56	33.77
FYM levels (t ha^{-1})				
0	14.47	37.50	37.58	544.63
5	18.65	48.97	38.05	710.04
S.Em+	0.30	0.49	0.15	8.29
CD at 5%	0.87	1.41	0.42	23.88
Microbial inoculum				
No inoculation	15.60	39.98	37.75	589.89
PSB	16.77	44.03	37.83	635.71
VAM	16.53	43.32	37.82	626.07
PSB + VAM	17.35	45.55	37.86	657.67
S.Em+	0.19	0.53	0.11	10.76
CD at 5%	0.53	1.49	NS	30.33

Table 2: Interaction effect of phosphorus and FYM on seed yield, straw yield and oil yield of mustard (Mean of 2 years)

Phosphorus levels (P_2O_5 kg ha^{-1})	Seed yield (q ha^{-1})		Straw yield (q ha^{-1})		Oil yield (kg ha^{-1})	
	FYM levels (t ha^{-1})		FYM levels (t ha^{-1})		FYM levels (t ha^{-1})	
	0	5	0	5	0	5
0	10.63	16.87	28.44	43.06	395.18	635.32
20	14.29	17.83	36.62	47.41	535.87	676.97
40	15.93	19.54	41.64	52.08	601.04	747.13
60	17.03	20.37	43.28	53.33	646.46	780.75
S.Em+	0.60		0.98		16.58	
CD at 5%	1.74		2.83		47.75	

Soil fertility

The post harvest available N, P, K and S content of soil was significantly higher with application of 60 kg P_2O_5 ha^{-1} over control and at par with 40 kg P_2O_5 ha^{-1} (Table 3). The highest available N, P, K and S (267.43, 21.1, 309.35 and 9.94 kg ha^{-1}, respectively) in soil was recorded with 60 kg P_2O_5 ha^{-1}. The increased soil nutrient status might be due to enhanced enzymatic activities in soil and soil microbial activity as a result of phosphorus application. The similar results were observed by Solanki *et al.* (2015) [12].

Incorporation of 5 t FYM ha^{-1} significantly improved the available N, P, K and S content of soil after harvest of mustard over no FYM (Table 4). The available N, P, K and S content of soil after harvest of mustard was enhanced by 8.86, 10.94, 744 and 19.35 per cent respectively over no FYM. The increase in available nutrients in soil after harvest of crop might be due to direct addition and slow release of nutrients from FYM added to soil, reduction in nutrient fixation in soil and release of fixed nutrients by the organic acids produced during decomposition of FYM (Tandon, 1987) [14]. These results are in conformity with the earlier findings of Singh *et al*. (2015) [11].

Duel inoculation of PSB+VAM reported significantly higher available N, P, K and S over no inoculation, however available N and S was at par with PSB inoculation (Table 3). Enhanced available nutrient status of soil with PSB+VAM inoculation might be due to release of organic acids and enzymes and remobilization of fixed nutrients by PSB and VAM in soil and resulted in suitable conditions in rhizosphere. The findings are in close agreement with those obtained by Khandelwal *et al*. (2012) [6].

Integrated application of 60 kg P_2O_5 ha^{-1} + 5t FYM ha^{-1} reported significantly higher available phosphorus (21.70 kg ha^{-1}) after harvest of mustard and it was at par with 40 kg P_2O_5 ha^{-1} + 5 t FYM ha^{-1} (21.50 kg ha^{-1}) in pooled analysis (Table 4). Release of nutrients with decomposition of FYM and solubilization of unavailable nutrients due to organic acids might have helped in increasing the nutrient status of soil. The favorable effect of FYM in conjunction with chemical fertilizers in enhancing the availability of P in soil was also reported by Chesti *et al.* (2013) [2].

The available phosphorus content in soil after harvest of mustard was significantly influenced for FYM and microbial inoculum interaction (Table 5). Application of 5 t FYM ha^{-1} alongwith duel inoculation of PSB+VAM reported significantly higher available phosphorus (21.70 kg ha^{-1}) which was at par with 5 t FYM ha^{-1} + PSB inoculation. The organic manure FYM is known to be a very good source of available nutrients which released during mineralization. The P solubilizers on the other hand transforms fixed and insoluble forms of P into soluble forms and increase the availability of phosphorus. Similar results were also obtained by Khanday and Ali (2012) [5].

On the basis of results, it was concluded that the application of 60 and 40 kg P_2O_5 ha^{-1} along with 5 t FYM ha^{-1} found equally beneficial for yield and quality of mustard in Rajasthan and maintaining the fertility of soil.

Table 3: Effect of phosphorus, FYM and microbial inoculum on available nitrogen, phosphorus, potassium and sulphur in soil after harvest of mustard (Mean of 2 years)

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available S (kg ha^{-1})
Phosphorus levels (P_2O_5 kg ha^{-1})				
0	255.17	19.07	289.46	8.87
20	259.32	20.02	299.20	9.42
40	263.81	20.73	305.66	9.76
60	267.43	21.13	309.35	9.94
S.Em+	1.48	0.18	2.40	0.11
CD at 5%	4.27	0.51	6.92	0.32
FYM levels (t ha^{-1})				
0	250.31	19.19	290.12	8.66
5	272.49	21.29	311.71	10.34
S.Em+	1.05	0.13	1.70	0.08
CD at 5%	3.03	0.36	4.90	0.22
Microbial inoculum				
No inoculation	258.20	19.34	294.97	9.28
PSB	263.16	20.52	302.75	9.57
VAM	259.41	20.16	298.91	9.52
PSB + VAM	264.83	20.89	307.06	9.63
S.Em+	1.33	0.13	1.54	0.06
CD at 5%	3.73	0.35	4.33	0.18

Table 4: Effect of phosphorus and FYM interaction on available phosphorus and available sulphur of mustard (Mean of 2 years)

Phosphorus levels (P_2O_5 kg ha^{-1})	Available phosphorus (kg ha^{-1})		Available sulphur (kg ha^{-1})	
	FYM levels (t ha^{-1})		FYM levels (t ha^{-1})	
	0	5	0	5
0	17.45	20.65	8.30	10.27
20	18.79	21.21	8.78	10.36
40	19.90	21.50	8.72	10.31
60	20.50	21.70	8.84	10.41
S.Em+	0.25		0.09	
CD at 5%	0.72		0.25	

Table 5: Effect of FYM and microbial inoculum interaction on available phosphorus in soil after harvest of mustard (Mean of 2 years)

Phosphorus levels (P_2O_5 kg ha^{-1})	Available phosphorus (kg ha^{-1})	
	FYM levels (t ha^{-1})	
	0	5
No inoculation	18.01	20.67
PSB	19.41	21.50
VAM	19.13	21.19
PSB + VAM	20.09	21.70
S.Em+	0.18	
CD at 5%	0.50	

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