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Effect of integrated phosphorus management on growth, yield and quality of mustard (*Brassica juncea* L.)

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Abstract
A field experiment was conducted at Rajasthan College of Agriculture, Udaipur to study the effect of fertilizer P, FYM and microbial inoculum alone and in combinations on growth, yield, quality and nutrient uptake by mustard. Thirty two treatment combinations consisting of four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) and two levels of FYM (0 and 5 t ha^{-1}) and four levels of microbial inoculum (no inoculum, PSB, VAM and PSB + VAM). Application of 60 kg P_2O_5 ha^{-1}, FYM @ 5 t ha^{-1} and PSB + VAM inoculation significantly enhanced the plant height, number of branches $plant^{-1}$, dry matter accumulation, number of siliquae $plant^{-1}$, seeds $siliqua^{-1}$, test weight, seed yield, straw yield and oil yield of mustard over respective control. Integrated application of 60 kg P_2O_5 ha^{-1} + FYM @ 5 t ha^{-1} reported significantly higher dry matter accumulation $plant^{-1}$, number of siliquae $plant^{-1}$, seed yield, straw yield and oil yield. Application of FYM @ 5 t ha^{-1} along with PSB + VAM inoculation reported significantly higher number of siliquae $plant^{-1}$.

Keywords: Mustard, phosphorus, FYM, PSB, VAM, yield and oil content

Introduction
Mustard is one of the important edible oil seed crop of India next to groundnut and soybean. In India mustard is predominantly cultivated in the states of Rajasthan, Uttar Pradesh, Hariyana, Madhya Pradesh and Gujarat. Rajasthan ranks first in area and production of rapeseed and mustard with 2.50 million ha area and 3.71 million tonnes production (Anonymous, 2017) [2]. Mustard oil is used as condiment in pickles, flavouring curries and vegetables, preparation of hair oils, medicines, soap making and in the tanning industry for softening of leather. The mustard cake is used mostly for cattle feed and manure.

Phosphorus is a component of key molecules such as nucleic acids, phospholipids and ATP. It 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. Approximately 15-20 per cent of applied fertilizer phosphorus is utilized by the crops and rest of the gets fixed in the soil and becoming unavailable to crop plants (Toro, 2007) [19]. Thus, availability of phosphorus is the major problems in productivity of crops concerning not only its actual deficiency in soil but also its availability to crop plants. For increasing phosphorus availability, integrated phosphorus management (IPM) is the only viable strategy. The IPM helps to restore and sustain soil fertility, crop productivity and is economic also. In view of this, the present investigation was undertaken to find out the response of mustard to different levels of phosphorus, FYM and microbial inoculation of PSB and VAM.

Materials and Methods
The experiment was conducted for two consecutive years during *rabi* 2016-17 and 2017-18 at Instructional Farm, Rajasthan College of Agriculture, (MPUAT) Udaipur with mustard as test crop. 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}) and four levels of microbial inoculum (no inoculum, PSB, VAM and PSB + VAM) in split plot design with three replications.

Required quantity of FYM was incorporated as per the treatment. Full dose of P, S and half dose of nitrogen fertilizers were drilled just before the sowing in the form of urea, DAP and

gypsum and remaining half dose of nitrogen was applied after first irrigation in earmarked plots. 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.

Result and Discussion

The findings obtained from the present research as well as supportive relevant discussion have been summarized under following heads.

Effect on growth and yield attributes

Effect of phosphorus

The growth and yield attributes of mustard were significantly affected by different levels of phosphorus. Application of phosphorus @ 60 kg P_2O_5 ha^{-1} resulted in the significantly higher plant height, number of branches $plant^{-1}$, dry matter accumulation $plant^{-1}$, number of siliqua $plant^{-1}$, number of seed $siliquae^{-1}$ and test weight of mustard over control and at par with 40 kg P_2O_5 ha^{-1} (Table 1). Significantly higher seed and straw yield of mustard was reported by 60 kg P_2O_5 ha^{-1} over control and it was at par with 40 kg P_2O_5 ha^{-1}. The seed and straw yield was enhanced by 36.00 and 35.13 per cent, respectively with use of 60 kg P_2O_5 ha^{-1} over control in pooled mean (Table 4). This might be due to the fact that the increased supply of phosphorus might have help in early root initiation and establishment of the crop thereby leading to increase growth parameters (Gangwal *et al.*, 2011) [5]. Application of phosphorus favorably influenced the photosynthesis, biosynthesis of proteins and phospholipids and other metabolic processes of the plant. Comparable results were also noted by Singh and Thenua (2016) [14] and Kumar *et al.* (2017b) [8].

Table 1: Effect of phosphorus, FYM and microbial inoculum on plant height (cm). number of branches $plant^{-1}$, dry matter accumulation (g.) $plant^{-1}$, siliquae $plant^{-1}$, seeds $siliqua^{-}$, test weight (g) of mustard

Treatments	Plant height (cm)	Number of branches $plant^{-1}$	Dry matter accumulation (g $plant^{-1}$)	Number of siliquae $plant^{-1}$	Number of seeds $siliqua^{-1}$	Test weight (g)
P. Phosphorus levels (P_2O_5 kg ha^{-1})						
0	173.13	19.88	59.39	334.80	14.07	5.16
20	182.98	22.01	65.70	374.21	15.25	5.38
40	190.91	23.72	70.39	414.55	16.25	5.55
60	194.36	25.11	74.03	423.22	16.83	5.67
SE ±	4.47	0.94	2.65	7.20	0.47	0.13
CD at 5 %	12.87	2.71	7.63	20.75	1.36	0.38
M. FYM levels (t ha^{-1})						
0	176.60	21.50	60.09	358.24	14.55	5.27
5	194.09	23.86	74.66	415.14	16.65	5.60
SE ±	3.16	0.67	1.87	5.09	0.33	0.10
CD at 5 %	9.10	1.92	5.40	14.67	0.96	0.29
I. Microbial inoculum						
No inoculation	179.02	21.51	64.36	357.88	15.03	5.26
PSB	187.40	23.15	68.63	394.65	15.83	5.49
VAM	184.81	22.31	67.19	381.94	15.48	5.41
PSB + VAM	190.16	23.75	69.33	412.31	16.07	5.58
SE ±	3.47	0.50	1.47	6.10	0.25	0.07
CD at 5 %	9.79	1.42	4.14	17.20	0.70	0.21

Effect of FYM

Incorporation of FYM @ 5 t ha^{-1} had significant influence on plant height, dry number of branches $plant^{-1}$, matter accumulation $plant^{-1}$, number of siliqua $plant^{-1}$, number of seed $siliquae^{-1}$ and test weight over control in pooled mean (Table 1). The results further indicated that there was significant increase in seed and straw yield (18.65 and 48.97 kg ha^{-1}, respectively) with application of FYM (Table 4). 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 Kumawat *et al*. (2014) [10] and Pathak and Pal (2016) [12].

Effect of microbial inoculum

The significant increase in number of branches $plant^{-1}$, dry matter accumulation $plant^{-1}$, number of siliqua $plant^{-1}$, seeds $siliqua^{-1}$, test weight (Table 1) as well as seed and straw yield (Table 4) over no inoculation due to duel inoculation of PSB and VAM in pooled analysis. The maximum seed and straw yield was recorded with the dual inoculation of PSB + VAM and it was 11.22 and 13.93 per cent higher over no inoculation, respectively. This might be attributed due to the solublization of native as well as applied phosphorus by phosphate solubilizing microorganisms through production of organic acids. VAM enhances the nutrients uptake through a reduction of the distance that nutrients must diffuse to plant roots by extending hyphae and transporting nutrients to plant roots (Somani, 2004) [17]. These findings of present investigations are supported by Singh *et al*. (1993) [15] who observed increase in seed and stover yield of mustard due PSB and VAM inoculation.

Interaction effect

Integrated application of 60 kg P_2O_5 ha^{-1} along with FYM @ 5 t ha^{-1} significantly enhanced dry matter accumulation $plant^{-1}$, number of siliqua $plant^{-1}$ and seed and straw yield of mustard, however number of siliqua $plant^{-1}$, seed yield and straw yield were at par with 40 kg P_2O_5 ha^{-1} along with FYM @ 5 t ha^{-1} (Table 2 and 5). The highest seed and straw yield of 20.37 and 53.33 q ha^{-1} was recorded with 60 kg P_2O_5 ha^{-1} in

combination with FYM @ 5 t ha^{-1}. These results are in accordance with Alam *et al.* (2010) and Kumar *et al.*(2017a) [1, 9] who observed combined application of phosphorus and FYM had synergistic effect in increasing seed and straw yield of mustard.

Integrated application of 60 kg P_2O_5 ha^{-1} alongwith duel inoculation of PSB+VAM recorded significantly higher number of siliquae $plant^{-1}$ (440.07) which was at par with 40 kg P_2O_5 ha^{-1} alongwith PSB + VAM inoculation (434.38) (Table 3). Yaragoppa *et al.* (2003) and Suri and Choudhary (2013) [20, 18] reported positive interactive effect of phosphorus and phosphatic biofertilizers on growth of mustard.

Table 2: Effect of phosphorus and FYM interaction on dry matter accumulation (g $plant^{-1}$) and number of siliquae $plant^{-1}$ of mustard

Phosphorus levels (P_2O_5 kg ha^{-1})	Dry matter accumulation (g $plant^{-1}$)		Number of siliquae $plant^{-1}$	
	FYM levels (t ha^{-1})		FYM levels (t ha^{-1})	
	0	5	0	5
0	54.53	64.25	308.42	361.18
20	60.56	70.84	335.55	412.87
40	65.30	75.48	388.08	441.01
60	59.99	88.07	400.93	445.51
S.Em±	3.75		10.19	
CD at 5 %	10.80		29.34	

Table 3: Effect of phosphorus and microbial inoculum interaction on number of siliquae $plant^{-1}$ of mustard

Phosphorus levels (P_2O_5 kg ha^{-1})	Number of siliquae $plant^{-1}$			
	Microbial inoculum			
	No inoculation	PSB	VAM	PSB+VAM
	Pooled			
0	281.00	348.07	334.77	375.37
20	348.45	380.30	368.67	399.42
40	394.05	422.17	407.58	434.38
60	408.00	428.05	416.75	440.07
S.Em±	11.20			
CD at 5 %	31.81			

Effect on quality

Effect of phosphorus

The oil content in mustard seed was significantly improved with application of 60 kg P_2O_5 ha^{-1} over control and it was at par with 40 kg P_2O_5 ha^{-1} (Table 4). Oil yield of mustard was enhanced significantly up to 60 kg P_2O_5 ha^{-1} over rest of the phosphorous levels. An increase in the oil content in mustard seed might be because of synthesis of fatty acids in plants in presence of ATP and phosphate. These fatty acids play an important role in increasing the oil content of seed. The results are in obedience given by Bharose *et al*. (2011) and Chouksey *et al*. (2017) [3, 4].

Table 4: Effect of phosphorus, FYM and microbial inoculum on number of seed yield (q ha^{-1}), straw yield (q ha^{-1}), oil content (%) and oil yield (kg ha^{-1}) of mustard.

Treatments	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
P. 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
SE ±	0.43	0.69	0.20	11.72
CD at 5 %	1.23	2.00	0.56	33.77
M. FYM levels (t ha^{-1})				
0	14.47	37.50	37.58	544.63
5	18.65	48.97	38.05	710.04
SE ±	0.30	0.49	0.15	8.29
CD at 5 %	0.87	1.41	0.42	23.88
I. 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
SE ±	0.19	0.53	0.11	10.76
CD at 5 %	0.53	1.49	NS	30.33

Effect of FYM

The oil content and oil yield was significantly influenced with the application of FYM. Significantly higher oil content (38.05 %) in seed was observed with the application of FYM @ 5 t ha^{-1} (Table 4) over no FYM (37.58 %). The oil yield was enhanced by 30.37 per cent with application of FYM @ 5 t ha^{-1} over control (Table 4). The deciding factor for increase in oil yield is the significant increase in the seed yield due to FYM addition. These findings are in conformity with the results of Sipai *et al*. (2015) and Pathak and Pal (2016) [16, 12].

Effect of microbial inoculum

The oil content in seed was not significantly influenced, but oil yield (Table 1) were increased significantly due to inoculation treatments. (Table 4). Numerically higher oil content was found with PSB+VAM inoculation in pooled analysis. Significantly increased seed yield and non-significant improvement in oil content due to PSB + VAM inoculation resulted in significantly higher oil yield over control and VAM inoculation. The PSB + VAM duel inoculation ultimately helped in increasing oil yield was due to beneficial effect of PSB + VAM on seed yield. The findings are in consonance with earlier researchers Imade *et al*. (2010) and Khan *et al.* (2015) [6, 7].

Interaction effect

The treatment combination of 60 kg P_2O_5 ha^{-1} + 5 t FYM ha^{-1} reported significantly higher oil yield (780.75 kg ha^{-1}) over rest of the combinations of phosphorus and FYM except 40 kg P_2O_5 ha^{-1} + 5 t FYM ha^{-1} (747.13 kg ha^{-1}) which was at par to each other in pooled data (Table 5). Improvement in soil physical and biological condition, increased availability native and applied nutrients and better proliferation of roots might have helped for better uptake of all nutrients with integrated use of organic and inorganic fertilizers. Increase in oil yield with integrated use of organic and inorganic fertilizers also reported by Singh and Rai (2004) [13] and Nagdive *et al*. (2007) [11].

Table 5: Effect of phosphorus and FYM interaction on seed yield (q ha^{-1}), straw yield (q ha^{-1}) and oil yield (kg ha^{-1}) of mustard

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})					
	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	

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