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To study the effect of biofertilizers, phosphorus and sulphur on yield, yield attributes and economics of Indian mustard (*Brassica juncea* L.)

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Abstract
A field experiment was carried out at Agronomy Instructional Farm, School of Agricultural Sciences, Career Point University, Kota, Rajasthan during Rabi season of 2019-20 and 2020-21 to Studies on the Effect of Phosphorus, Sulphur and PSB on Mustard [*Brassica juncea* (L.)] growth, Yield and Quality. The experiment was laid out in Split plot design with sixteen treatments each replicate thrice whereas four levels of phosphorus (RDF-N constant, 20 kg, 40 kg, 60 kg) and two levels of sulphur (40 kg, 60 kg) and phosphate solubilizing bacteria (control and inoculation). The experiment results revealed that the growth parameters such as yield attributes *viz*., During 2019-20, maximum number of siliquae per plant in mustard (323.64), seeds per siliquae (15.83), length of siliquae (8.23 cm), test weight of mustard crop (5.06 g) was recorded, During the next year of study 2020-21, similar trend was observed and maximum number of siliquae per plant (367.30), seeds per siliquae (16.95), siliquae length (9.05 cm), test weight of mustard crop (5.06 g) significantly recorded in the treatment T_{16}. However, during the first year 2019-20, maximum biological yield (74.23 q/ha), seed yield (21.63 q/ha), stover yield of 52.63 q/ha, harvest index of 28.24 per cent, During the year 2020-21, Maximum biological yield (81.47 q/ha), seed yield (21.63 q/ha), stover yield (60.16 q/ha), harvest index (31.21 per cent) was recorded under the treatment T_{16}. During the year 2019-20, maximum gross income was obtained under the treatment T_{16} (Rs. 129491/ha), net returns of Rs. 98031/ha, B: C ratio (3.1: 1) was achieved with treatment T_{16} followed by treatments T_{14}. During the year 2020-21, maximum gross income was obtained under the treatment T16 (Rs. 143207/ha), net returns of Rs. 111747/ha, B: C ratio (3.6: 1) was achieved with treatment T16 (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) among all treatments.

Keywords: Mustard, biofertilizers, sulphur, siliquae, seed yield and economics

Introduction
Despite having the world's largest area of grown oilseeds, India imports enormous quantities of edible oils, hence rapeseed-mustard crops are essential to the Indian economy. Oil seeds are extremely significant in Indian agriculture and industry. Oils and fats are utilized in cosmetics, soaps, lubricants, paints and varnishes, and have medical and therapeutic value, in addition to their tremendous significance in our food. Given the ever-increasing population, the need for vegetable oils and fats will skyrocket in the next years. (Kumar *et al*., 2016) [3].
It is primarily grown in sub-tropical climates in India, but recent statistics show that it also thrives in dry and cool climates. It requires a temperature range of 10º to 25º Celsius. The crop is particularly susceptible to frost and requires 625-1000 mm of yearly rainfall for good growth. Because of its deep root structure, it may be grown in light to heavy loamy soils with a pH of 6-7.5. It is commonly mixed planted with gram, wheat, and lentils in the tropics, especially during the rabi seasons. (Chauhan *et al*., 2020) [10].
Phosphate fertilizers being a source of major nutrients are of paramount importance in increasing crop yields. The most of researches have observed favorable response to applied phosphorus by mustard (Jaggi and Sharma, 1997) [3].
Sulphur is the key component of balanced nutrient application for higher yields and superior quality produce of mustard. Sulphur plays a vital role in the synthesis of amino acids (Rathore *et al.*, 2015) [4].
Bio-fertilizers are known to play several important roles in soil fertility, productivity and crop yields in agriculture, as they are environmentally friendly, but cannot replace chemical fertilizers. capital needed to obtain maximum crop yields. They add chemical fertilizers to meet the general nutritional needs of plants, they also promote seed germination and early plant vigor by producing growth promoters. (Yadav *et al*., 2010) [5].

Use of biofertilizer can have a greater impact in increasing fertilizers use efficiency. Phosphate solubilizing bacteria-PSB (microorganisms) is distributed well in several ecosystems. Bacteria (*Bacillus, Pseudomonas, Micrococcus, Flavobacterium* etc.) have been isolated, which have consistent capacity to solubilize insoluble phosphorus such as a rock phosphate, tricalcium phosphate, iron phosphate, aluminum phosphate etc. Phosphate solubilizing bacteria (PSB) are solubilizing the unavailable phosphates in the soil through excretion of organic acids such as butyric, tartaric, aspartic, glutamic, lactic, citric, fumaric, oxalic, glucolic, malic, fumaric and a-ketobutyric acids (Bardiya and Gaur, 1972; Gaur and Pareek, 1974) [6, 7] which lower down the soil pH and liberate bound phosphate. Besides, some of the hydroxy acids may chelate calcium and iron resulting in effective solubilization and thereby higher utilization of soil phosphates by plants. They also produce an enzyme phosphatase, which enhance the process of solubilization of insoluble phosphate (Gangwal *et al*., 2011) [8]. These aspects of mustard cultivation have received very little attention particularly on sandy loam soil of sub humid Aravali plains and southern hills of Rajasthan.

Materials and Methods

The experiment was supervised for two consecutive years during *rabi* 2019-20 and 2020-21 at agriculture research farm of Career Point University, Kota, Rajasthan. The experimental site was located at 25.0112°N, 75.9139°E at an altitude of 271 meters. on msl. The site has been leveled with good irrigation facilities. Pusa Jai Kisan (Bio 902) variety used for sowing Indian mustard. The experiment laid out in split plot design which consisting of 16 treatments with **T1**: RDF (N2 constant) + 40 Kg Sulphur ha-1 + No Inoculation, **T2**: RDF (N2 constant) + 60 kg Sulphur ha-1 + No Inoculation, **T3**: RDF (N2 constant) + 40 Kg Sulphur/ha-1 + PSB Inoculation, T4: RDF(N2 constant) + 60 Kg Sulphur ha-1 + PSB Inoculation, T5: 20 kg P ha-1 + 40 Sulphur ha-1 + No Inoculation, T6: 20 kg P ha-1 + 60 Sulphur ha-1 + No Inoculation, T7: 20 kg P ha-1 + 40 kg Sulphur ha-1 + Inoculation with PSB, T8: 20 kg P ha-1 + 60 kg Sulphur ha-1 + Inoculation with PSB, T9: 40 kg P ha-1 + 40 kg Sulphur ha-1 + No Inoculation, T10: 40 kg P ha-1 + 40 kg Sulphur ha-1 + No Inoculation, T11: 40 kg P ha-1 + 40 kg Sulphur ha-1 + Inoculation with PSB, T12: 40 kg P ha-1 + 60 kg Sulphur ha-1 + Inoculation with PSB, T13: 60 kg P ha-1 + 40 kg Sulphur ha-1 + No Inoculation, T14: 60 kg P ha-1 + 60 kg Sulphur ha-1 + No Inoculation, T15: 60 kg P ha-1 + 40 kg Sulphur ha-1 + Inoculation with PSB, T16: 60 kg P ha-1 + 60 kg Sulphur ha-1 + Inoculation with PSB were replicate thrice.

The experimental site was uniform in topography and sandy loam in texture, nearly saline in soil reaction (PH 8.10), low in Organic carbon (0.41%), medium available N (165.70 kg ha-1), medium available P (13.70 kg ha-1) and medium available K (245.50 kg ha-1). Nutrient sources were Urea, DAP, MOP to fulfill the necessity of Nitrogen, phosphorous and potassium. Gypsum used to fulfill the requirement of sulphur. The application of fertilizers was applied as basal at the time of sowing. Nitrogen applied as split dose half as basal dose remaining as top dressing. In the period from germination to harvest several plant growth parameters were recorded at frequent intervals along with it after harvest several yield parameters were recorded those parameters are growth parameters, plant height, fresh shoot's weight, dry shoot's weight, number of green leaves^{-1}, branches per plant, days taken to flowering at 50 percent, and days to maturity are recorded. The yield parameters like siliquae per plant, seeds per siliquae, length of siliqua, grain yield, test weight (1000 seeds), biological yield, stover yield and harvest index were recorded. The economic parameters Gross return, Net return, B:C ratio were estimated and statistically analyzed using analysis of variance (ANOVA) suggested for "Split Plot Design" to examine the significance of overall differences across treatments using the 'F' test.

Results

1. Yield attributes

Data pertaining to yield attributes of mustard crop during 2019-20 and 2020-21 is presented in Table 1. During 2019-20, maximum number of siliquae per plant in mustard (323.64), seeds per siliquae (15.83), length of siliquae (8.23 cm), test weight of mustard crop (5.06 g) was recorded under the treatment T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB). During the next year of study (2020-21), similar trend was observed and maximum number of siliquae per plant (367.30), seeds per siliquae (16.95), siliquae length (9.05 cm), test weight of mustard crop (5.06 g) was recorded under the treatment T_{16}. However, T14 and T15 which were statistically at par with PSB + Sulphur at 60 kg/ha + Phosphorus at 60 kg/ha.

2. Yield and Yield attributes

Data pertaining to yield and attributes of mustard crop during 2019-20 and 2020-21 is presented in Table 2. As far as the data collected during the first year (2019-20), maximum biological yield (74.23 q/ha), seed yield (21.63 q/ha), stover yield of 52.63 q/ha, harvest index of 28.24 per cent was recorded under the treatment T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB).

During the year 2020-21, again similar trend was observed for biological yield among different treatments as observed during the first year of study. Maximum biological yield (81.47 q/ha), seed yield (21.63 q/ha), stover yield (60.16 q/ha), harvest index (31.21 per cent) was recorded under the treatment T_{16} (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB). However, T14 and T15 which were statistically at par with PSB + Sulphur at 60 kg/ha + Phosphorus at 60 kg/ha.

3. Economics

Data in table 3 tabulated Experimental results revealed that During the year 2019-20, maximum gross income was obtained under the treatment T_{16} (Rs. 129491/ha), net returns of Rs. 98031/ha, B: C ratio was achieved with treatment T_{16} (3.1: 1) followed by treatments T14.

During the year 2020-21, maximum gross income was obtained under the treatment T16 (Rs. 143207/ha), net returns of Rs. 111747/ha, B: C ratio was achieved with treatment T16 (3.6: 1) followed by treatments T14.

Discussion

It was observed that application of phosphorus up to 60 kg P2O5 ha-1 gave significant increase in yield attributes of mustard *viz*., siliquae plant-1, seed siliqua-1 (Table 1) and test-weight (g) (Table 1) increased significantly up to 60 kg P2O5 ha-1. This could be attributed to overall improvement in crop growth and yield attributes. The favorable effect of phosphorus fertilization on yield components might be probably due to the fact that phosphorus is well known for its role as 'Energy Currency' and plays a key role of energy transformation in various metabolic processes. Tisdale *et al.* (1984) [9]. The significant increase in test-weight due to phosphorus application might be on account of better uptake and translocation of nutrients specially phosphorus resulting into bold seed formation by increasing the size and weight of grains. Tisdale *et al.*, (1984) [9]. Similar results were also observed by Khatkar *et al.* (2009) [10], Lone N.A *et al*. (2010) [11], Yadav *et al.* (2014) [12], Sirothia, P *et al*. (2016) [13].

Results presented in preceding chapter showed that application of phosphorus @ 60 kg P_2O_5 ha^{-1} significantly increased the seed, straw and biological yields over control and 40 kg P_2O_5 ha^{-1} (Table 2). Net returns were higher by 46.74 percent over control during on pooled data basis (Table 1) and application of 60 kg P_2O_5 ha^{-1}significante gave maximum B:C 3.6 (Table 3). Many workers have also reported improvement in yield of mustard with the increasing levels of phosphorus (Singh & Thenua *et al.* 2016, Solanki. R.L *el al*. 2018, Potdar Ds. *Et al*. 2019) [14, 15].

Application of sulphur up to 60 kg S ha^{-1} significantly increased the seed, straw and biological yield and harvest index of mustard (Table 2). Seed yield of mustard is chiefly a product of yield attributing characters *viz,* siliquae plant^{-1}, seed siliqua^{-1} and test- weight (g) increased significantly up to 60 kg S ha^{-1} (Table 1). Such a positive effect of sulphur application observed, might be due to sulphur nutrition which enhances cell multiplication, elongation, expansion and imparts a deep green colour to leaves due to better chlorophyll synthesis, which in turn increases the effective area for photosynthesis, resulting in relatively greater amount of photosynthates accumulation in plant and their translocation, which reflect in terms of increased yield attributes of crop and finally. Sulphur application may also help in thickening of xylem and collenchyma fibers. The application of 60 kg S ha^{-1} net returns was higher by 45.46 percent over control during on pooled data basis (Table 1) and application of 60 kg S ha^{-1}significante gave maximum B:C 3.1 (Table 3). These findings are in accordance with those reported by Pratap *et al.*, (2016) [17], Singh *et al*. (2018) [18].

Results of several multilocation trials showed that inoculation with PSB increased the yield of rice, wheat, Bengal gram, potato and soybean (Gaur, 1985 and Dubey, 1996). On the basis of pooled analysis, results indicated that seed inoculation with PSB (phosphorus solubilizing bacteria) significantly increased the growth and yield attributes i.e. plant height plant^{-1}, number of branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliqua^{-1} and test weight which ultimately resulted significantly higher seed and straw yield of mustard over uninoculated control (Table 1, Table 2). Thus, the results obtained in the investigation are in line with the findings of Kumar *et al.* (2018), Vipin Kumar and Sandeep Singh (2019) [20].

Table 1: Effect of Phosphorus, sulphur and PSB on yield attributes in mustard

Treatments	No. of siliquae per plant		No. of seed per siliqua		Length of Siliqua (cm)		Test weight (g/1000 seeds)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T_1	272.53	306.19	11.24	12.36	5.43	6.25	4.23	4.39
T_2	276.48	310.14	12.74	13.86	6.14	6.96	4.38	4.54
T_3	274.61	308.27	12.56	13.68	5.86	6.68	4.36	4.52
T_4	278.71	312.37	12.92	14.04	6.22	7.04	4.49	4.65
T_5	281.46	315.12	13.11	14.23	6.39	7.21	4.54	4.70
T_6	283.17	316.83	13.42	14.54	6.56	7.38	4.59	4.75
T_7	284.89	318.55	13.65	14.77	6.74	7.56	4.63	4.79
T_8	286.63	320.29	13.88	15	6.98	7.8	4.64	4.80
T_9	288.41	322.07	14.09	15.21	7.21	8.03	4.72	4.88
T_{10}	289.73	323.39	14.24	15.36	7.45	8.27	4.79	4.95
T_{11}	295.48	329.14	14.51	15.63	7.74	8.56	4.83	4.99
T_{12}	298.27	341.93	14.86	15.98	7.89	8.71	4.90	5.06
T_{13}	303.64	347.30	15.22	16.34	8.02	8.84	4.94	5.10
T_{14}	308.49	352.15	15.64	16.76	8.17	8.99	5.01	5.17
T_{15}	313.29	356.95	15.31	16.43	8.13	8.95	5.03	5.19
T_{16}	323.64	367.30	15.83	16.95	8.23	9.05	5.06	5.22
S.Em (±)	3.56	3.68	0.58	0.63	0.21	0.24	0.14	0.19
C.D. (@5%)	8.38	8.42	1.47	1.86	0.65	0.73	0.48	0.54

Table 2: Effect of Phosphorus, sulphur and PSB on yield in mustard

Treatments	Biological yield (q ha^{-1})		Seed yield (q ha^{-1})		Stover yield (q ha^{-1})		Harvest index (%)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
T_1	50.46	57.70	12.43	14.05	39.28	44.81	23.57	26.54
T_2	57.46	64.70	13.39	15.01	41.86	47.39	24.09	27.06
T_3	55.28	62.52	13.12	14.74	43.29	48.82	23.89	26.86
T_4	59.49	66.73	13.87	15.49	44.32	49.85	24.21	27.18
T_5	60.82	68.06	14.68	16.3	45.16	50.69	24.53	27.5
T_6	61.47	68.71	14.82	16.44	45.68	51.21	24.88	27.85
T_7	63.43	70.67	15.35	16.97	46.53	52.06	25.04	28.01
T_8	65.83	73.07	16.21	17.83	47.14	52.67	25.19	28.16
T_9	66.51	73.75	16.87	18.49	47.26	52.79	25.24	28.21
T_{10}	68.26	75.50	17.51	19.13	48.34	55.87	25.65	28.62
T_{11}	69.54	76.78	17.86	20.48	49.27	56.83	26.02	28.99
T_{12}	71.31	78.55	18.34	20.96	50.18	57.71	26.41	29.38
T_{13}	72.19	79.43	18.89	21.51	50.79	57.32	26.83	29.8

T_{14}	73.47	80.71	20.49	23.11	51.86	59.39	27.89	30.86
T_{15}	72.68	79.92	19.82	22.44	51.41	58.94	27.21	30.18
T_{16}	74.23	81.47	21.63	23.85	52.63	60.16	28.24	31.21
S.Em (±)	2.92	3.17	0.79	0.86	2.07	2.29	-	-
C.D. (@5%)	8.21	8.94	2.18	2.74	5.83	6.32	NS	NS

Table 3: Economics of cultivation of mustard using different sulphur, phosphorus and PSB combinations

Treatments	**Total cost (Rs ha^{-1})**		**Gross Return (Rs ha^{-1})**		**Net Returns (Rs ha^{-1})**		**B: C ratio**	
	2019-20	**2020-21**	**2019-20**	**2020-21**	**2019-20**	**2020-21**	**2019-20**	**2020-21**
T_1= RDF (N constant) + 40 Kg Sulphur ha^{-1} + No Inoculation	24220	24220	76221	86237	52001	62017	2.1	2.6
T_2= RDF (N constant) + 60 kg Sulphur ha^{-1} + No Inoculation	24560	24560	82017	92033	57457	67473	2.3	2.7
T_3= RDF (N constant) + 40 Kg Sulphur/ha^{-1} + PSB Inoculation	25690	25690	80818	90834	55128	65144	2.1	2.5
T_4= RDF(N constant) + 60 Kg Sulphur ha^{-1} + PSB Inoculation	26560	26560	85149	95165	58589	68605	2.2	2.6
T_5= 20 kg P_2O_5 ha^{-1} + 40 Sulphur ha^{-1} + No Inoculation	25460	25460	89772	99788	64312	74328	2.5	2.9
T_6= 20 kg P_2O_5 ha^{-1} + 60 Sulphur ha^{-1} + No Inoculation	26000	26000	90646	100662	64646	74662	2.5	2.9
T_7= 20 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB	26560	26560	93731	103747	67171	77187	2.5	2.9
T_8= 20 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB	27450	27450	98583	108599	71133	81149	2.6	3.0
T_9= 40 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + No Inoculation	28390	28390	102237	112253	73847	83863	2.6	3.0
T_{10}= 40 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + No Inoculation	29550	29550	105973	116389	76423	86839	2.6	2.9
T_{11}= 40 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB	29850	29850	108084	124006	78234	94156	2.6	3.2
T_{12}= 40 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB	30220	30220	110906	126822	80686	96602	2.7	3.2
T_{13}= 60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + No Inoculation	29900	29900	114053	129769	84153	99869	2.8	3.3
T_{14}= 60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + No Inoculation	31220	31220	123067	138983	91847	107763	2.9	3.5
T_{15}= 60 kg P_2O_5 ha^{-1} + 40 kg Sulphur ha^{-1} + Inoculation with PSB	31100	31100	119292	135208	88192	104108	2.8	3.3
T_{16}= 60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB	31460	31460	129491	143207	98031	111747	3.1	3.6

Conclusion

On the basis of the experimental findings, it may be concluded that application of recommended doses of fertilizers with optimum doses of phosphorus and Sulphur inoculation with PSB increase the growth and yield of mustard. Phosphorus and Sulphur are important elements in sustaining yield attributes and yield of mustard. This is reflected in terms of significant increase in yield attributing characters, maximum number of siliquae per plant in mustard, seeds per siliquae, length of siliquae, test weight and Maximum biological yield, seed yield, stover yield, harvest index. Maximum growth of yield attributes, yield and maximum gross income, net returns, B: C ratio of mustard was recorded in T16 (60 kg P_2O_5 ha^{-1} + 60 kg Sulphur ha^{-1} + Inoculation with PSB) application, thus the application of these elements in deficient areas is recommended to increase the yield and productivity of mustard in the region.

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