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Effect of sulphur and phosphorus on growth and yield of Indian mustard (*Brassica juncea* L.)

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Abstract
A field experiment was conducted at Research Farm of Vivekananda Global University, Jaipur (Rajasthan) during *Rabi*, 2023-24 on loamy sand soil, which consisted 10 treatments with different combination of sulphur and phosphorus. For experimentation, mustard variety Bio-902 was used.
The results of one year study clearly showed that combination of phosphorus and sulphur application brought an additive effect in increasing growth and yield parameters of mustard as compared to control. Maximum plant height, dry matter accumulation, number of silique plant^{-1}, number of seeds silique^{-1}, seed yield, stover yield and biological yield of mustard was significantly obtained with 45 kg phosphorus ha^{-1} + 40 kg sulphur ha^{-1} (T_9) over rest of the treatments. The plant population, number of branches plant^{-1}, test weight and harvest index of mustard was remained unchanged under phosphorus and sulphur applications. Therefore, application of 45 kg phosphorus ha^{-1} + 40 kg sulphur ha^{-1} (T_9) were found most profitable as it gave highest seed yield.

Keywords: Indian mustard, sulphur, zinc, sarson, treatment

Introduction
Rapeseed and mustard belong to family *Cruciferae*, which is grown in India comprising indigenous species namely Indian mustard (*Brassica juncea*), brown sarson (*Brassica compestris* var. brown Sarson), Yellow sarson (*Brassica compestris* var. yellow Sarson), Toria (*Brassica compestris* var. toria) and Taramira (*Eruca sativa*) along with nontraditional species like Gobhi sarson (*Brassica napus*), White mustard (*Brassica alba*) and Ethiopian mustard (*Brassica carinata*). It is the most important group of Rabi oilseed crop and contribute a major share to the vegetable fat economy of the country.
The oil content in mustard seeds varies from 37-49 percent (Bhowmik *et al*., 2014) [1], the seeds are highly nutritive containing 38-57 % eruric acid, and 27% oleic acid. The oil cake left after extraction is utilized as cattle feed and manure containing 5.1 % N, 1.8% P_2O_5 and 1.1 % K_2O. The seed is used as a condiment in the preparation of pickles and for flavouring curries and vegetables. The oil is utilized for human consumption throughout the northern India for cocking purpose. This is a potential crop in winter (*Rabi*) season due to its wider adaptability and suitability to exploit residual moisture (Mukherjee, 2010) [7]. Oil and fats comprise a vital component of human diet as these are good source of energy and act as carriers of fat soluble vitamins. Oil cake or meal has high nutritional values in animal diet. Seed sowing to its high content of good quality protein. In general 55g edible oil per day per head is essential for human diet.
Amongst the required essential nutrients, phosphorus (P) and sulphur (S), being crucial element for optimum growth and yield of all crops (Ryan *et al*., 2001) [11] throughout the world. Phosphorus availability in optimum quantities is needed for early growth stages, development of the reproductive parts, root growth, reduced disease incidence and early maturity. Compared to vegetative growth, P availability in considerable quantities is critically needed for seed formation (Gidago *et al*., 2012) [3]. Sulphur are most vital nutrients for growth and development oil seeds. Sulphur is considered to be the fourth important essential nutrient after nitrogen, phosphorus and potassium for the plant growth. Sulphur performs many physiological functions like synthesis of cysteine, methionine, chlorophyll and oil content of oil seed crops.

It is also responsible for synthesis of certain vitamins (B, Biotin and Thiamine), metabolism of carbohydrates, proteins and oil formation of flavor compounds in crucifers. In recent years, sulphur deficiency has been aggravated in the soil due to continuous removal by crops and use of high analysis sulphur devoid coupled with intensive cropping with high yielding varieties and reduction in use of organic manure and sulphur containing fungicides and insecticides resulted in sulphur deficiency in soils.

Materials and Methods

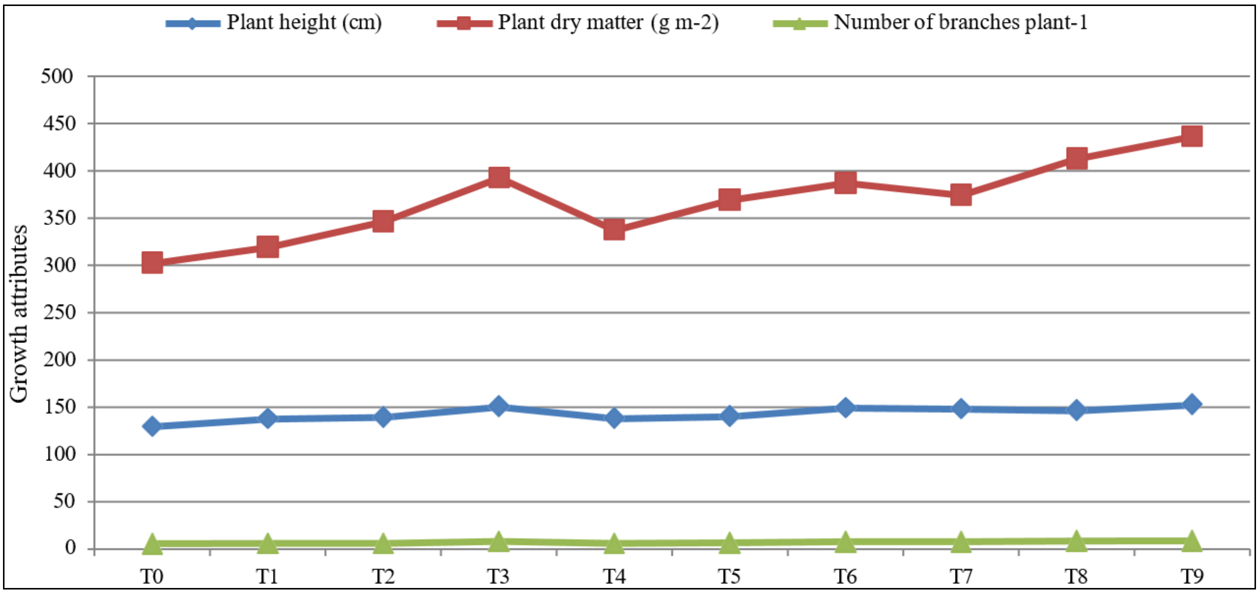
The field experiments were carried out during *Rabi* season (2023-24) to study the "Effect of Sulphur and Phosphorus Fertilizer on Growth, Yield and Quality of Mustard (*Brassica juncea* L.) in Limited Irrigation Condition of Rajasthan" in randomized block design (RBD) with consisted ten treatments of sulphur and phosphorus combinations *viz.* control (T_0), 15 kg phosphorus ha^{-1} (T_1), 15 kg phosphorus ha^{-1} + 20 kg sulphur ha^{-1} (T_2), 15 kg phosphorus ha^{-1} + 40 kg sulphur ha^{-1} (T_3), 30 kg phosphorus ha^{-1} (T_4), 30 kg phosphorus ha^{-1} + 20 kg sulphur ha^{-1} (T_5), 30 kg phosphorus ha^{-1} + 40 kg sulphur ha^{-1} (T_6), 45 kg phosphorus ha^{-1} (T_7), 45 kg phosphorus ha^{-1} + 20 kg sulphur ha^{-1} (T_8) and 45 kg phosphorus ha^{-1} + 40 kg sulphur ha^{-1} (T_9) at Research Farm, Vivekanada Global University- Jaipur, Rajasthan. The experimental farm is geographically located at 75° 51'44" E longitude, 26°48'35'' N latitude and an altitude of 432 m above mean sea level (AMSL). The experimental fields were clay loam and the soil fertility status contained available nitrogen (137.8 kg ha^{-1}), available phosphorus (16.3 kg ha^{-1}) by Olsen *et al*. 1954 and available potassium (250.12 kg ha^{-1}) by Jackson, 1973. The organic carbon content was from 0.34-0.38 per cent. The weekly mean maximum and minimum temperatures were of temperature during both summers (40.6° C) and winters (2.7° C). The mean relative humidity fluctuated from 63.50 to 91 per cent during the crop season. The average rainfall is 557 mm per annum, which is mostly received during july to september. The sporadic showers during winters are also common, which are probably observed during this period. The experiments were laid out in randomized block design (RBD) with three replications and 10 treatments. The observation were recorded at harvest was analysed by statistical methods (Fisher, R.A. 1950) [2].

Results and Discussion

It is clear from the result of present study that, sulphur and phosphorus applications had significantly affected the growth and yield parameters of Indian mustard at harvest. 45 kg phosphorus ha^{-1} + 40 kg sulphur ha^{-1} (T_9) recorded the highest growth attributes *viz*. plant height (152.91 cm), dry matter accumulation (436.47 g m^{-2}), number of branches plant^{-1} (8.72) at harvest, however; treatments *i.e.* T_6, T_3 and T_4, T_2 statistically remained at par with each other (Table-1). The increase in plant height due to adequate availability of phosphorus and sulphur attributed to better nutritional environment for plant growth at active vegetative stages as result of enhancement in root growth, energy providing, multiplication, cell elongation and cell expansion in the plant body which ultimately increased the height of plant. The results of present investigation are in agreement with the finding of Khanpara *et al.* (2020) [5] and Kumar and Kumar (2021) [6]. Dry matter production successively increased till maturity due to favorable effect of phosphorus and sulphur on the growth and development of plants. Increase in number of primary and secondary branches plant^{-1}, plant height and number of leaves plant^{-1} is directly responsible for increasing the dry matter accumulation in plants at higher levels of sulphur. Singh and Dhiman (2005) [14], Potdar *et al.* 2019 [10] and Sahoo *et al*. 2021 [12] also reported the similar results. Further yield attributes and yields like number of silique plant^{-1} (340.58), number of seeds silique^{-1} (13.45), seed yield (1897.98 kg ha^{-1}), stover yield (4723.33 ha^{-1} kg ha^{-1}) and biological yield (6621.22 kg ha^{-1}) presented in table 2, which significantly higher recorded with the application of 45 kg phosphorus ha^{-1} + 40 kg sulphur ha^{-1} (T_9), further, treatments *i.e.* T_6, T_3 and T_4, T_2 statistically remained at par with each other's. However, test weight and harvest index (Singh and Stoskopt, 1971) [13] was found non-significant by sulphur and phosphorus application in Indian mustard. Yield components by enhancing cell division, cell elongation process and photosynthetic activity leading to production and accumulation of more carbohydrates and auxins which favours retention of more flowers ultimately leading to more number of reproductive parts plant^{-1}.

Table 1: Effect of sulphur and phosphorus fertilizers on growth attributes of Indian mustard

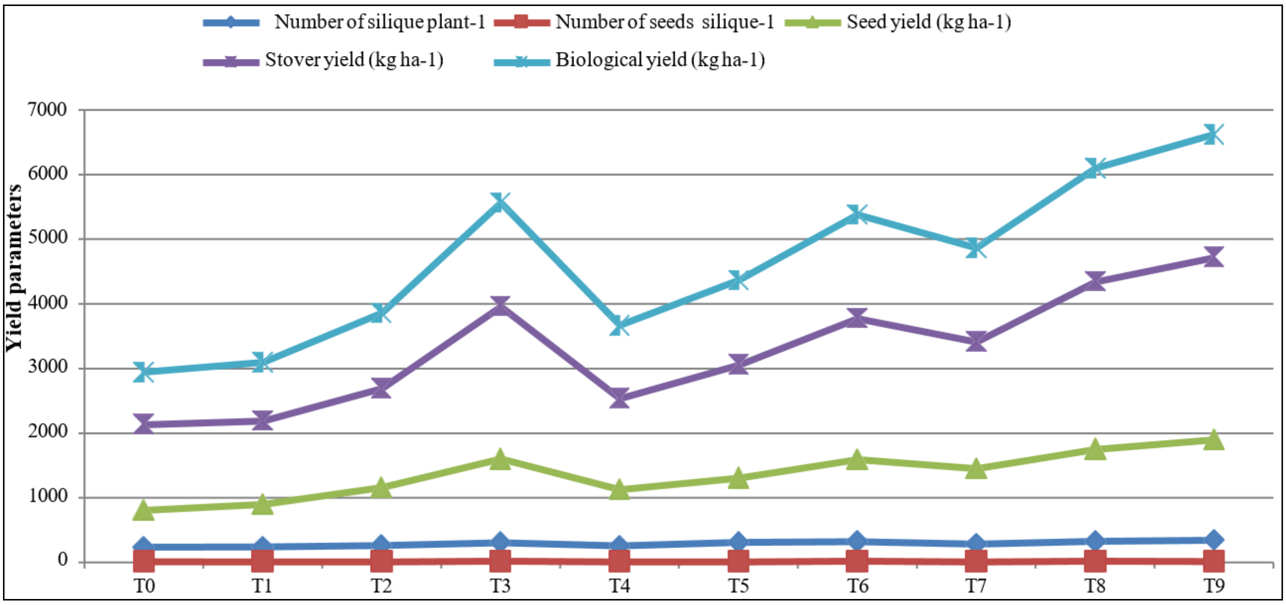
Treatments	Plant height (cm)	Plant dry matter (g m^{-2})	Number of branches plant^{-1}
T0: Control	129.91	303.0	5.63
T_1: 15 kg ha^{-1} Phosphorus	138.18	319.84	5.79
T_2: 15 kg ha^{-1} Phosphorus + 20 kg ha^{-1} Sulphur	139.89	346.96	6.03
T_3: 15 kg ha^{-1} Phosphorus + 40 kg ha^{-1} Sulphur	150.95	393.22	7.95
T_4: 30 kg ha^{-1} Phosphorus	138.21	337.78	5.89
T_5: 30 kg ha^{-1} Phosphorus + 20 kg ha^{-1} Sulphur	140.50	369.68	6.57
T_6: 30 kg ha^{-1} Phosphorus + 40 kg ha^{-1} Sulphur	149.80	387.67	7.91
T_7: 45 kg ha^{-1} Phosphorus	148.65	374.74	7.84
T_8: 45 kg ha^{-1} Phosphorus + 20 kg ha^{-1} Sulphur	146.85	413.32	8.31
T_9: 45 kg ha^{-1} Phosphorus + 40 kg ha^{-1} Sulphur	152.91	436.47	8.72
SEm+	2.89	6.94	0.14
CD at (p= 0.05)	4.75	11.05	0.38
CV (%)	6.90	7.12	6.12



Graph 1: Effect of sulphur and phosphorus fertilizers on growth attributes of Indian mustard

Table 2: Effect of sulphur and phosphorus fertilizers on yield attributes and yields of Indian mustard

Treatments	Number of silique plant^{-1}	Number of seeds silique^{-1}	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})
T_0: Control	233.65	11.73	805.20	2134.67	2939.87
T_1: 15 kg ha^{-1} Phosphorus	237.29	11.82	896.16	2193.33	3089.49
T_2: 15 kg ha^{-1} Phosphorus + 20 kg ha^{-1} Sulphur	259.40	12.15	1160.72	2693.33	3854.05
T_3: 15 kg ha^{-1} Phosphorus + 40 kg ha^{-1} Sulphur	304.91	12.94	1599.46	3963.33	5562.79
T_4: 30 kg ha^{-1} Phosphorus	252.92	12.07	1126.35	2540.07	3666.42
T_5: 30 kg ha^{-1} Phosphorus + 20 kg ha^{-1} Sulphur	308.19	12.36	1305.56	3060.00	4365.56
T_6: 30 kg ha^{-1} Phosphorus + 40 kg ha^{-1} Sulphur	320.59	12.83	1593.67	3780.00	5373.67
T_7: 45 kg ha^{-1} Phosphorus	280.54	12.59	1449.35	3413.33	4862.68
T_8: 45 kg ha^{-1} Phosphorus + 20 kg ha^{-1} Sulphur	323.42	13.14	1750.46	4346.67	6097.13
T_9: 45 kg ha^{-1} Phosphorus + 40 kg ha^{-1} Sulphur	340.58	13.45	1897.89	4723.33	6621.22
SEm$\pm$	7.23	0.20	54.36	191.08	245.44
CD at (p= 0.05)	13.26	0.17	142.98	340.30	483.28
CV (%)	7.41	7.04	7.02	7.50	8.20



Graph 2: Effect of sulphur and phosphorus fertilizers on yield attributes and yields of India mustard

Conclusion

Based on one-year experimentation it may be concluded that phosphorus and sulphur combination brought an additive effect in increasing growth and yields of Indian mustard. Significantly higher seed yield, stover yield and biological yield of mustard was obtained with 45 kg phosphorus ha^{-1} + 40 kg sulphur ha^{-1} (T_9) as compared to control and over rest of the treatments. These results are only indicative and require further experimentation for some more years to derive credible conclusion.

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