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Effect of Applied Phosphorus, Sulphur and Bio-fertilizers on Growth and Yield of Indian Mustard (*Brassica juncea* L.) in Agri-horti System

Kumar A.[1*], Singh J.K.[2], Choudhary S.K.[3] and Anand S.[4]
[1]M.Sc. Scholar, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (Uttar Pradesh), India.
[2]Professor, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (Uttar Pradesh), India.
[3]Ph.D. Scholar, Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (Uttar Pradesh), India.
[4]Ph.D. Scholar, Department of Mycology and Plant Pathology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (Uttar Pradesh), India.

(Corresponding author: Kumar A.)*
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ABSTRACT: The rising population increases demand for vegetable oil day by day especially in developing countries like India. But the cultivable lands are decreasing gradually, which needs a modified farming system to fulfil the daily requirement of the people. To overcoming this situation the agroforestry seems to be a good alternative. Therefore, present investigation entitled "Effect of applied phosphorus, sulphur and bio-fertilizers on growth and yield of Indian mustard (*Brassica juncea* L.) in agri-horti system" was studied during *Rabi* season, 2021-22 at Agricultural Research Farm, R.G.S.C. (BHU), Barakachha, Mirzapur (U.P.). The field experiment was laid out in Factorial Randomized Block Design with six treatments in Indian mustard variety 'JD-6' (Pusa Mahak) under 13 years old stone apple based agri-horti system with three replication. The results exhibited that the combined application of 50, 25 kg PS ha^{-1}, significantly increased yield and yield attributing characters *viz*., plant height, number of primary branches per plant and length of siliquae. It also significantly improved the oil content and oil yield. Moreover, the use of PSB and SDB improved all yield contributing characters, such as number of siliquae per plant, number of seed per siliquae and the seed weight, as compared to control. However, seed inoculation with SDB was achieved the maximum yield (772 kg ha^{-1}) as compared with PSB and control. The maximum oil contain and oil yield of Indian mustard were recorded for the application of seed inoculation with SDB under stone apple based agri-horti system.

Keywords: Agri-horti system, Bio-fertilizer, Indian mustard, Phosphorus, Sulphur.

INTRODUCTION

Agro-forestry is the practice of merging agriculture, forestry, and livestock management into an integrated land management system. It is a technology with four primary features: competitiveness, complexity, productivity, and long-term viability. It also improves the Indian economy in both tangible and intangible ways. It has contributed to soil conservation and restoration and also increased farm productivity. In addition to fulfilling household's subsistence needs such as food, fuel, fibre and medicine. Agroforestry support nearly half of the demand for fuel wood, two-thirds of the demand for small timber, 70-80 percent of wood for plywood, 60 percent of raw material for paper pulp, and 9-11 percent of the green fodder requirement of livestock (Khalid *et al*., 2005). The agri-horti system, which is one of the most important components of agroforestry, is being used to incorporate fruit trees into agriculture. Fruit crops such as aonla, ber, guava, custard apple, citrus, wood apple and other promising fruits are appropriate for agri horticultural systems. Due to their short fruiting season, consistent income, insurance coverage and aesthetic qualities, fruit crops are farmer's primary choice in an agroforestry system. The agri-horti system was set up in India to extend the growing season and boost production per unit area per unit time. Aside from the benefits listed above, fruit trees provide useful by-products such as fodder and fuel wood as a result of their annual maintenance and fruits, which are supposed to boost and sustain human health (Singh *et al.*, 2016).

Indian mustard *[Brassica juncea* (L.) *Czern & Cosson*] is the most important *Rabi* season oilseed crop. It is simple and inexpensive to cultivate, can tolerate intense heat, and can survive in a wide range of soil types and agroforestry systems. Mustard oil provides for one-third of India's total edible oil output. Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, and Gujarat are the states in which it is mainly grown. Mustard is the major source of income in rainfed areas, especially for marginal and small farmers, because it can survive in low-resource environments Negi *et al.* (2017). Phosphorus (P) is a crucial component in the production of *Brassica* species. Plants with short roots acquire stunted growth due to a lack of the phosphorus. In Indian mustard, sulphur (S) is required for the formation of proteins, enzymes, vitamins, and chlorophyll. Sulphur is a component of various amino acids and vitamins found in plant and also essential for protein synthesis, particularly in the formation of oils within the seed. As a result, sulphur is a main determinant of food nutritional quality. Keeping these facts into consideration the present investigation entitled "Effect of applied phosphorus, sulphur and bio-fertilizers on growth and yield of Indian mustard (*Brassica juncea* L.) in agri-horti system".

MATERIALS AND METHODS

The field experiment was conducted during the *Rabi* season of 2021-22 on the mustard crop grown in an alley of a 13-year-old wood apple tree which was planted at a spacing of 7m × 7 m. The experimental trial was laid out in Factorial Randomized Block Design with three replications and six treatments in Indian mustard variety 'JD-6' (Pusa Mahak) at Agricultural Research Farm, Rajiv Gandhi South Campus, BHU, Barakachha, Mirzapur, Uttar Pradesh (Table 1). The soil of the experimental field was sandy loam in texture with low available nitrogen (180.33 N kg/ha), medium in available phosphorus (13.24 kg P_2O_5/ha) and potassium (227.46 K_2O kg/ha) having acidic in nature (pH 5.9). The recommended doses of nitrogen and potassium were applied at the rate of 80 kg ha^{-1} and 40 kg ha^{-1} through urea and muriate of potash (MOP). Entire quantity of phosphorus and sulphur as per treatment in the form of single super phosphate (16% P_2O_5) were applied in furrow at the time of sowing. Seeds were treated with PSB and SDB cultures according to treatment and then sown after drying in the shade for 3 - 5 hours. The selected cultivar "JD-6" were sown manually (2-3cm) deep and 30 cm apart rows. A seed rate of 5 kg ha^{-1} was used for optimal plant population management. Plant spacing of 10 cm within row was maintained by thinning 15 days after sowing. The crop was harvested at fully ripened stage.

Table 1: Combinations of treatments

Sr. No.	Treatment	Symbol	Treatment details
1.	T_1	P_1S_1	20kg P_2O_5+ 15kg S
2.	T_2	P_2S_2	35kg P_2O_5+ 20kg S
3.	T_3	P_3S_3	50kg P_2O_5+ 25kg S
4.	T_4	B_1	PSB
5.	T_5	B_2	SDB
6.	T_6	Control	—

Note: -P= Phosphorus, S = Sulphur and Bio-fertilizers [Phosphorus solubilizing bacteria (B1) and Sulphur Dissolving Bacteria (B2)]

Biometric observation: Observations were 20 and 60 DAS, as well as at harvesting for the traits Plant height (cm), leaf area index (cm^2), number of primary branches per plant, number of siliquae per plant, length of siliquae (cm), Number of seeds per siliquae, seed weight (g), seed yield (kg ha^{-1}), biological yield (kg ha^{-1}), harvest index (%), oil content (%) and oil yield (kg ha^{-1}). In each plot area, five plants were randomly tagged and data were recorded.

Statistical analysis: The Microsoft excel was used as a statistical software package for analyzing the data for the analysis of variance and other statistical parameter (McCullough and Wilson 2005). Critical difference values at $p = 0.05$ were used to determine the significance of differences between mean values of treatments (Draper and Smith 1998).

RESULTS AND DISCUSSION

A. Effect of applied phosphorus and sulphur on growth parameters

Results from the experiment showed that the phosphorus and sulphur levels had significant impact on growth parameters such as plant height, number of primary branches per plant and length of siliquae (cm) (Table 2). The plant height (168 cm), number of primary branches (7.01) and length of siliquae (4.8 cm) at harvest were maximum in case of 50,25 kg PS ha^{-1}. Furthermore, it was noted that the results at 35,20 kg PS ha^{-1}were comparable to those at 50,25 kg PS ha^{-1}. However, a substantial difference was detected between (50,25) and (20,15) kg PS ha^{-1}. The application of fertilizer would have helped to increase the crop's availability of phosphorus and sulphur because the soil was deficient in these nutrients (Vijayeswarudu and Singh 2021). A similar finding was reported by Birle *et al.* (2011), who investigated the effects of phosphorus and zinc on the yield of mustard and found a significant increase in plant height, siliquae per plant, seeds per siliquae and test weight of seed at the application of 50 kg P_2O_5 ha^{-1} over control. It enhances the production of flowers, encourages crop uniformity and increases disease resistance, all of which would have increased the crop's overall quality (Yadav *et al.*, 2014). Moreover, Katiyar *et al.* (2006); Singh *et al*. (2016) also reported a significant increases in plant height of Indian mustard with the application of 25 kg S ha^{-1}.

B. Effect of applied phosphorus and sulphur on yield attributes

The yield attributes of Indian mustard show the impact of varied levels of phosphorus and sulphur (Table 2). The results showed the significant effect on seed and biological yield at the application of various level of phosphorus and sulphur. The seed and biological yield has dramatically risen as phosphorus and sulphur levels have increased (20,15; 35,20; 50,25) kg PS ha^{-1}. The higher seed yield (795 kg ha^{-1}) was obtained by the application of 50, 25 kg PS ha^{-1} over the control (548 kg ha^{-1}). Similarly, the maximum biological yield (2811 kg ha^{-1}) was also obtained at 50, 25 kg PS ha^{-1} over the control (2433 kg ha^{-1}). Similar findings were reported by Mani *et al.* (2006); Nath *et al*. (2018), who observed expanding seed size on application of increasing quantities of phosphorus. The contribution of phosphorus in bold seed production by expanding the size of the seed may account for the increase in seed weight by the application of increase in number of seeds per siliquae, number of siliquae per plant, seed weight, length of siliquae and other growth characteristics are possible causes of the increase in yield. The major improvement in the crop's growth and yield characteristics would be the cause of the increased economic yields. However, "sulphur" was available in sufficient quantities during the entire cropping period for improved vegetative growth and development of mustard plants, rising sulphur levels would have an impact on growth (Rana *et al.*, 2020). The greater availability of sulphur and their translocation, which are reflected in the crop's increased yield attributes.

C. Effect of applied phosphorus and sulphur on oil content and oil yield

The oil content and oil yield also varied with different levels of phosphorus and sulphur. Although higher oil yield (297 kg ha^{-1}) and oil content (37.27 per cent) were obtained at 50, 25 kg PS ha^{-1}. It was statistically equivalent to 35, 20 kg PS ha^{-1}. Lanjewar and Selukar (2005) also reported similar outcomes. It might be because of a greater supply of fertilizer containing phosphorus and sulphur, which increases the oil content in Indian mustard. Enhanced phosphate and sulphur fertilizer caused more branch development, more siliquae to form, longer siliquae to form and more seeds per siliquae to form, all of which would have increased the oil yield (Singh *et al*., 2015).

D. Effect of bio-fertilizers on yield attributes and yield

The results exhibited that the applied PSB and SDB improved yield contributing characteristics, such as number of siliquae per plant, number of seed per siliquae and the seed weight, as compared to the control (Table 2). However, Seed inoculation with SDB was achieved the maximum yield (772 kg ha^{-1}) as compared to PSB and control. These results are in similarity with Singh *et al*. (2015); Negi *et al*. (2017); Nandan and Bhatnagar (2022). This might be due to sulphur oxidizing bacteria promotes high germination rate, enhance root development, plant growth and improves the uptake of sulphur and makes it readily available to the plant, ultimately improve plant yield attributes (Khalid *et al*, 2005).

E. Effect of applied bio-fertilizers on oil content and oil yield

The maximum oil contain and oil yield of Indian mustard were recorded by the application of seed inoculation with SDB as compared to PSB and control. Mani *et al*. (2006) also showed an improvement in the oil formation in mustard on inoculation with SDB. Since, sulphur is the primary nutrient for the synthesis of seed oil as its role in the formation of oil composites and sulphur oxidising bacteria made more available sulphur for plant use.

Table 2: Effect of phosphorus, sulphur levels and bio-fertilizer inoculation on growth parameters and yield attributes in Indian mustard under agri-horti system.

Treatment	Plant height (cm)		Leaf area index		Number of primary branches		Number of siliquae $plant^{-1}$	Length of siliquae (cm)	Number of Seeds per siliquae	Seed weight (g)	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Oil content (%)	Oil yield (kg ha^{-1})
Levels of P & S (kg ha^{-1})	At harvest	60 DAS	60 DAS	20 DAS	At harvest	60 DAS	At harvest	At harvest	At harvest	At harvest	At harvest	At harvest	At harvest	At harvest	At harvest
20,15	156	118	5.8	0.9	6.14	4.81	165	4.1	11	3.64	682	2414	28.28	35.1	241.81
35, 20	163	121	6.2	1.02	6.7	5.01	180	4.4	12.24	3.95	693	2477	27.96	36.38	252.63
50, 25	168	127	6.18	1.28	7.01	5.23	194	4.8	13.15	4.24	795	2811	28.26	37.39	297.4
SEm±	2.6	2.32	0.19	0.04	0.15	0.11	3.42	0.13	0.3	0.11	21.81	66.24	0.38	1.64	11.06
CD (P=0.05)	5.5	4.9	0.4	0.08	0.31	0.24	7.18	0.28	0.62	0.24	45.81	139.16	NS	3.45	23.23
Bio-fertilizer															
Control	118	154	5.72	1.08	6.12	4.81	166	4.1	10.9	3.47	687	2433	28.24	35.67	245
PSB	122	163	6.19	1.04	6.81	4.95	177	4.3	12.4	3.87	711	2511	28.31	36.57	260.2
SDB	126	170	6.26	1.09	6.86	5.29	195	4.9	13.2	4.49	772	2759	27.95	36.73	283.5
SEm±	2.32	2.63	0.19	0.04	0.15	0.11	3.42	0.13	0.3	0.11	21.81	66.24	0.38	1.64	11.06
CD (P=0.05)	4.87	5.52	0.4	0.08	0.31	0.24	7.18	0.28	0.62	0.24	45.81	139.16	NS	NS	23.23

DAS- Days after sowing; P- Phosphorus; S- Sulphur; PSB- Phosphorus solubilizing bacteria; SDB- Sulphur dissolving bacteria

CONCLUSION AND FUTURE SCOPE

The present investigation suggest that the application of phosphorus, sulphur and bio-fertilizers (PSB and SDB) significantly increases the yield and yield attributing traits in Indian mustard variety 'JD 6' grown under the wood apple based agri-horti system of Vindhyan region of Mirzapur. It also significantly improve the oil content and oil yield. Since this issue only contains the results of a one-year experiment, it is advised that the experiment be repeated for another two or three years in order to arrive at a reliable conclusion.

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Conflict of Interest. None.

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