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Nutrient Management Through Inorganic Fertilizers and Bio-stimulants in Mustard (*Brassica juncea* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The field experiment was conducted to find out the effect of fertilizer levels and bio-stimulants on growth, yield and economics of mustard (*Brassica juncea* L.).
Study Design: This experiment was laid out in strip plot design comprising three fertilizer levels in horizontal strips and five bio-stimulants in vertical strips replicated thrice.

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Place and Duration of Study: The field trial was carried out at the Instructional Farm, Department of Agronomy, College of Agriculture, Dr. B.S.K.K.V., Dapoli, Ratnagiri, Maharashtra, India during *Rabi* 2023-24.
Methodology: The treatments consist of three horizontal strips of fertilizer levels *viz*., 80% RDF (F_1), 100% RDF (F_2), 120% RDF (F_3) and five vertical strips of bio-stimulants *viz*., 0.5% humic acid (B_1), 0.5% chitosan (B_2), 3% vermiwash (B_3), 1% Konkan kalp (B_4), 0.1% triacontanol (B_5). The seeds of mustard var. Varuna were sown at the spacing of 30 cm × 10 cm. The recommended dose of fertilizer (RDF) used for the crop was 90:45:00 NPK kg ha^{-1}. Foliar application of bio-stimulants were carried out at 20, 40 and 60 days after sowing (DAS).
Results: Among the fertilizer levels, application of 120% RDF (F_3) recorded significantly higher growth, yield attributes and yield of mustard as well as it shows higher net returns (Rs. 25739 ha^{-1}) and benefit: cost ratio (1.41). The seed and stover yield of mustard was increased by 12.95% and 8.30% respectively, with the application of 120% RDF as compared to the application of 80% RDF (F_1) which recorded significantly minimum seed and stover yield in mustard. The growth parameters, yield attributes and yield of mustard were found significantly higher with the foliar application of 0.5% humic acid (B_1) and it remained at par with the treatment foliar sprays 0.5% chitosan (B_2). The net returns (Rs. 26760 ha^{-1}) and benefit: cost ratio (1.43) was also found higher with the treatment of 0.5% humic acid (B_1). With respect to bio-stimulants, foliar sprays of 0.5% humic acid (B_1) showed 17.38% and 13.90% increase in seed and stover yield, respectively over foliar application of 0.1% triacontanol (B_5) which recorded lowest yield in mustard. Combined application of 120% RDF and foliar sprays of 0.5% humic acid (F_3B_1) recorded significantly higher seed and stover yield of mustard and it remained at par with the treatment combination of 120% RDF and foliar sprays of 0.5% chitosan (F_3B_2).
Conclusion: Application of 120% RDF along with foliar application 0.5% humic acid or 0.5% chitosan might improve the yield and economic returns in mustard.

Keywords: Fertilizer levels; bio-stimulants; mustard; growth; yield; quality.

1. INTRODUCTION

Indian mustard (*Brassica juncea* L.) is one of the major oilseed crop in India and has been cultivated since ancient times. India is the third largest Rapeseed-Mustard producer in the world. It is second most important edible oilseeds after groundnut which sharing 27.8% in oilseed economy of India. Mustard is cool season crop and follows C_3 pathway, grow well under low temperature and average temperature of 25°C is required at the time of sowing for optimum germination. Oil content in mustard varies from 37-49%, carbohydrate 14-15%, protein 25-30%, fibre 10-12%, minerals and vitamins 1-1.5%, glucosinolate 2-3%. Mustard oil contains about 40-60% of erucic acid, linolenic acid 4.5 to 13% and oleic acid 25-30% (Biswas et al*.,* 2024). Monounsaturated and polyunsaturated fatty acids, such as omega-3 and omega-6 fatty acids, which are good for the heart, are abundant in mustard oil. Phytochemicals found in mustard seeds have anti-inflammatory and antioxidant activity, which adds to their health advantages (Sachan et al., 2024). In Maharashtra, 0.13 lakh hectare area is under cultivation of mustard with 0.05 lakh tonnes of production and 340 kg ha^{-1} of productivity (Anonymous, 2024).

Nutrient management in mustard is key factor for maximizing yields and thereby high returns. The rescheduling of recommended dose of fertilizers is an effective nutrient management technique for increasing the productivity and nutrient use efficiency of mustard. It is not only for obtaining higher yield but also a cost-effective nutrient management technique for farmers of the Konkan region. The existing fertilizer recommendations are proving to be sub-optimal for attaining higher productivity levels and need a fresh look to revise them to optimum and more balanced levels considering yield, soil health and economics by using bio-stimulants. Nutrients also have important role in plant metabolism, growth and developmental processes and helps in increasing the biomass production and yield. Nutrient management should be aimed at achieving maximum production and economic returns.

Bio-stimulants are the substances or microorganisms or a combination of both whose function is to stimulate physiological processes in plants and to improve growth, yield, nutrition

efficiency and crop quality when applied to plants. Humic substances are formed by decomposition of plant, animal into organic matter and it influence on physiological condition of the plant which helps to avoid abiotic stress in plants. Chitosan obtained from deacetylation of chitin is one of the natural non-toxic bio-stimulants found in insect wings, filamentous fungi, sea creatures like crabs, shrimps, etc. (Hongal et al*.,* 2023). The bio-stimulants have great potential, its application and accrual assessment etc., have to be judiciously planned in terms of optimal concentration, stage of application and season. The liquid bio-stimulants may offer a powerful and ecofriendly approach of nutrients management along with inorganic fertilizers. In this context, a field experiment was conducted to study the effect of fertilizer levels and foliar application of bio-stimulants on growth, yield and economics of mustard under lateritic soils of Konkan region.

2. MATERIALS AND METHODS

2.1 Experimental Site

The field experiment was carried out at the Instructional Farm, Department of Agronomy, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra, India during *Rabi* 2023-24. Geographically, the site of experiment is situated at 17.10° North latitude and 73.10° East longitude having elevation of 250 m above the mean sea level. The topography of the experimental plot was uniform and suitable for cultivation of mustard. The experimental plot was sandy clay loam in texture, low in available nitrogen (218.35 kg ha^{-1}) and phosphorus (9.40 kg ha^{-1}), medium in available potassium (275.35 kg ha^{-1}), very high in organic carbon (11.18 g kg^{-1}) and acidic in reaction (pH 5.74).

2.2 Treatment Details

The experiment was laid out in strip plot design allocating fertilizer levels in horizontal strips *viz*., 80% RDF (F_1), 100% RDF (F_2), 120% RDF (F_3) and bio-stimulants in vertical strips *viz*., 0.5% humic acid (B_1), 0.5% chitosan (B_2), 3% vermiwash (B_3), 1% Konkan kalp (B_4), 0.1% triacontanol (B_5). The mustard variety Varuna (T-59) was used for the experimentation. Seed rate adopted was 4 kg ha^{-1}. The seeds are sown at a spacing of 30 cm × 10 cm. Thinning operation was carried out at 12 days after sowing. The recommended dose of fertilizer (RDF) for mustard is 90 kg N and 45 kg P_2O_5 ha^{-1}. The half the dose of nitrogen was applied as basal dose in the form of urea (46% N) and full dose of P_2O_5 was applied through single super phosphate (16% P_2O_5) as per the treatments. Remaining half dose of N was applied 30 days after sowing according to treatments. The required amount of inorganic fertilizers per hectare at different stages as per the fertilizer level treatments are given in Table 1.

The different bio-stimulants used in the experiment were applied at 20, 40 and 60 days after sowing (DAS) in mustard. The spraying was done using knapsack sprayer of 15 liter capacity and water used for spraying was clean and salt free. The foliar application of bio-stimulants was carried out with their respective concentration as mentioned in the treatments. The periodical observations on growth were recorded at 30, 60 DAS and at harvest. The observations on yield attributes were recorded at the time of harvest. The grain and straw yield were recorded from the net plot and converted into the hectare basis.

2.3 Statistical Analysis

Experimental data were analyzed statistically by applying techniques of analysis of variance as applicable in strip plot design. The significance of the treatment difference was tested by table value of F at 0.05 level of probability and critical difference was calculated where ever the effects were significant for comparison and statistical interpretation of significance between treatments mean (Panse and Sukhatme, 1967).

Table 1. Requirement of inorganic fertilizers as per the treatments for mustard (ha^{-1})

Fertilizer levels	Urea (kg ha^{-1})			SSP (kg ha^{-1})
	50% (Basal)	50% (30 DAS)	Total	
F_1: (80% RDF)	78	78	156	225
F_2: (100% RDF)	98	98	196	281
F_3: (120% RDF)	117	117	234	338

3. RESULTS AND DISCUSSION

3.1 Effect of Fertilizer Levels

Data presented in Table 2 clearly indicated that the growth parameters of mustard was noticeably influenced due to the application of different levels of fertilizers. The growth parameters of mustard *viz*., plant height, number of branches plant^{-1} and dry matter plant^{-1} were found significantly higher with the higher level of fertilizer (F_3) which was found significantly superior over rest of the treatments throughout the growing period. Greater plant height and number of branches plant^{-1} may be due to receiving balanced fertilization which led to better metabolic activities carried out by mustard at optimum fertilizer level (Basumotary et al*.,* 2020). The increase in plant height and number of branches plant^{-1} might be the reason for increased dry matter production in mustard. Similar results were reported by Gupta et al. (2019) and Kumar et al*.* (2022).

Similarly, application of 120% RDF through inorganic fertilizer recorded significantly higher values of yield attributes *viz*., number of siliquae plant^{-1}, weight of siliquae plant^{-1}, length of siliqua, number of seeds siliqua^{-1} as well as seed (1483.94 kg ha^{-1}) and stover yield (3333.45 kg ha^{-1}) of mustard (Table 3) and it was found significantly superior over rest of the fertilizer levels. This might be due to the fact that higher doses of fertilizers might have improved leaf area and have enhanced the production of photosynthates and their translocation to sink which resulted into the better yield attributes led to increase the yield of mustard (Kumar et al*.,* 2022). The results are in accordance with the findings of Chauhan et al*.* (2020) and Sharma et al*.* (2020).

Data from Table 3 indicated that the application of 120% RDF (F_3) fetched higher net returns (Rs. 25739 ha^{-1}) and benefit: cost ratio (1.41). This might be due to the increased productivity resulted in increased net returns. Similar results were obtained by Dhruw et al*.* (2018).

3.2 Effect of Bio-Stimulants

Foliar application of various bio-stimulant significantly influenced different growth attributes during the growing of mustard (Table 2). Foliar application of 0.5% humic acid produced taller plants, increased number of branches plant^{-1} and dry matter production plant^{-1} which was found statistically identical with the treatment of 0.5% chitosan at all stages of growth in mustard. It is known that the bio-stimulants are the sources of micro and macronutrients. These nutrients are quickly absorbed by plants when applied to foliage as a foliar spray. Macronutrients like N, P and K are associated with different plant processes *viz*., cell enlargement, translocation of solutes, formation of carbohydrates, etc. It is associated with the increase in plant height and number of branches which led to increased dry matter production in mustard. These finding were found consistent with those of Barekati et al*.* (2019) and Guddhe et al*.* (2019).

According to data presented in Table 3, the foliar sprays of various bio-stimulants significantly improved the yield attributes and yield of mustard. The yield attributes *viz*., number of siliquae plant^{-1}, weight of siliquae plant^{-1}, length of siliqua, number of seeds siliqua^{-1} as well as seed (1473.36 kg ha^{-1}) and stover yield (3357.17 kg ha^{-1}) of mustard was found significantly higher with the foliar application of 0.5% humic acid (B_1) and it was found at par with the treatment 0.5% chitosan (B_2) as compared to rest of the treatments. This might be due to the fact that bio-stimulants causes increase in photosynthesis activity therefore, more flowers will be formed in mustard plant which is effective on formation of fertile siliquae and seed production. The results are in close conformity with those of Amiri et al*.* (2019) and Barekati et al*.* (2019).

With respect to economic returns (Table 3), foliar application of 0.5% humic acid incurred higher net returns (Rs. 26759 ha^{-1}**)** and benefit: cost ratio (1.43) followed by foliar sprays of 0.5% chitosan. This might be due to the higher yield of mustard thus, produced maximum economics. Similar result was reported by Guddhe et al*.* (2019).

3.3 Interaction Effect

The dry matter plant^{-1}, seed and stover yield of mustard was significantly influenced due to combined application of fertilizers along with foliar sprays of bio-stimulants (Table 4). The application of 120% RDF + foliar sprays of 0.5% humic acid (F_3B_1) recorded significantly higher dry matter plant^{-1}, seed and stover yield of mustard which remained at par with the treatment combination of 120% RDF + foliar sprays of 0.5% chitosan (F_3B_2) with respect to dry matter plant^{-1} and seed yield of mustard. The results are in concordance with the findings reported by Szczepanek et al*.* (2017) and Harshitha et al*.* (2021).

Table 2. Growth parameters of mustard as influenced periodically due to different treatments

Treatments	Plat height (cm)			Number of branches plant^{-1}			Dry matter plant^{-1} (g)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Horizontal strips: Fertilizer levels (F)									
F_1: 80% RDF	10.87	151.51	153.35	2.20	4.73	5.06	2.95	16.00	34.78
F_2: 100% RDF	11.33	157.06	158.43	2.85	5.09	5.31	3.19	19.67	36.63
F_3: 120% RDF	12.45	165.37	168.20	3.92	6.38	6.78	3.94	24.53	38.98
S. Em. ±	0.20	1.96	2.29	0.17	0.13	0.08	0.18	1.24	0.53
C.D. at 5%	0.80	7.68	9.00	0.66	0.51	0.33	0.69	4.85	2.07
Vertical strips: Bio-stimulants (B)									
B_1: Humic Acid 0.5%	12.56	164.97	168.71	3.38	5.85	6.58	4.02	22.31	42.47
B_2: Chitosan 0.5%	11.93	161.61	164.20	3.25	5.69	6.01	3.59	21.16	40.04
B_3: Vermiwash 3%	11.67	158.66	160.16	3.03	5.34	5.89	3.38	19.83	37.31
B_4: Konkan kalp 1%	10.87	156.03	156.76	2.74	5.23	5.38	3.10	19.19	35.42
B_5: Triacontanol 0.1%	10.72	148.63	150.13	2.54	4.90	4.73	2.71	17.84	28.74
S. Em. ±	0.21	1.70	1.61	0.15	0.13	0.18	0.14	0.39	0.96
C.D. at 5%	0.69	5.55	5.26	0.48	0.42	0.60	0.46	1.27	3.13
Interaction (F×B)									
S. Em. ±	0.47	2.89	3.23	0.37	0.33	0.29	0.30	1.16	1.28
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	3.83

Table 3. Yield attributes, yield and economics of mustard as influenced periodically due to different treatments

Treatments	Number of siliquae plant^{-1}	Weight of siliquae plant^{-1} (g)	Length of siliqua (cm)	Number of seeds siliqua^{-1}	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Net return (Rs. ha^{-1})	B: C ratio
Horizontal strips: Fertilizer levels (F)								
F_1: 80% RDF	169.31	15.53	4.22	12.11	1313.77	3077.97	19296	1.32
F_2: 100% RDF	186.45	16.05	4.44	12.27	1357.72	3110.50	20433	1.33
F_3: 120% RDF	221.89	17.46	4.89	13.60	1483.94	3333.45	25739	1.41
S. Em. ±	5.40	0.13	0.06	0.30	12.00	18.19	-	-
C.D. at 5%	21.22	0.53	0.25	1.19	47.10	71.41	-	-
Vertical strips: Bio-stimulants (B)								
B_1: Humic Acid 0.5%	227.92	17.28	4.97	13.47	1473.36	3357.17	26760	1.43
B_2: Chitosan 0.5%	212.09	17.06	4.77	13.33	1443.75	3292.96	24717	1.40
B_3: Vermiwash 3%	188.91	16.54	4.50	12.73	1399.67	3187.72	22666	1.37
B_4: Konkan kalp 1%	172.42	16.00	4.36	12.33	1353.70	3084.44	18786	1.30
B_5: Triacontanol 0.1%	161.42	14.83	3.99	11.44	1255.26	2947.58	16183	1.27
S. Em. ±	6.23	0.13	0.10	0.20	10.21	29.93	-	-
C.D. at 5%	20.31	0.43	0.34	0.66	33.31	97.60	-	-
Interaction (F×B)								
S. Em. ±	13.72	0.21	0.19	0.48	14.60	35.33	-	-
C.D. at 5%	NS	NS	NS	NS	43.78	105.93	-	-

Table 4. Interaction effect between fertilizer levels and bio-stimulants on dry matter plant^{-1} at harvest, seed and stover yield of mustard

Vertical strips- Bio-stimulants (B)	Horizontal strips: Fertilizer levels (F)								
	Dry matter plant^{-1} at harvest			Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
B1	40.58	41.15	45.69	1388.65	1448.86	1582.56	3264.66	3332.87	3473.99
B2	37.65	37.41	45.05	1362.45	1429.83	1538.96	3249.13	3273.85	3355.90
B3	33.86	37.26	40.81	1359.02	1363.71	1476.28	3099.10	3119.85	3344.21
B4	32.27	34.22	39.77	1287.85	1345.93	1427.31	2985.57	3012.01	3255.73
B5	29.53	33.13	23.56	1170.88	1200.28	1394.61	2791.40	2813.91	3237.42
S. Em. ±	1.28			14.60			35.33		
C.D. at 5%	3.83			43.78			105.93		

4. CONCLUSION

The bio-stimulants have great potential, its application and accrual assessment etc., have to be judiciously planned in terms of optimal concentration, stage of application and season. It can be concluded that the application of 120% RDF along with foliar sprays of 0.5% humic acid and/or 0.5% chitosan at 20, 40 and 60 DAS might increase the yield and economic returns in mustard.

DISCLAIMER (ARTIFICIAL INTELIGENCE)

Author(s) have declared that NO generative AI technologies, such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing and editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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