Effect of Integrated Nutrient Management Practices on Growth, Yield, Qualityand Economics of Indianmustard (*Brassica juncea* L.)

ABSTRACT

A field experiment was conducted to assess the effect of integrated nutrient management practices on growth, yield and economics of mustard during the *rabi*season of 2022-23 at farmer's field in Kandhamal district of Odisha under Krishi Vigyan Kendra, Kandhamal, OUAT, Bhubaneswar.The experiment was laid out in Randomized Block Design (RBD)consisted of four treatments withseven replications. Thetreatments comprised of T_1: Farmer's practice (FYM @ 0.5 t ha^{-1}, average fertilizer @ 20.5-23-0 kg N-P_2O_5-K_2O ha^{-1}), T_2: STBFR + FYM @ 2 t ha^{-1} + Biofertilizers (*Azotobacter*, *Azospirillum* and *PSB* @ 1:1:1, 4 kg each per ha, T_3: RDF + FYM @ 5 t ha^{-1} + S @ 25 kg ha^{-1} and B @ 1 kg ha^{-1}and T_4: STBFR + FYM @ 2 t ha^{-1} + Soil application of Zn @ 5kg ha^{-1} and B @ 1kg ha^{-1} along with S @ 40 kg ha^{-1}. The significantly higher growth attributes *viz.*, plant height, number of primary and total branches per plant, Yield attributes *viz*., number of siliqua per plant, number of seeds per siliqua, test weight and seed and stover yield as well as quality and economic parameters viz., oil content, oil yield, gross and net return and B:C ratio recorded under STBFR + FYM @ 2 t ha^{-1} + Zn @ 5 kg ha^{-1} + S @ 40 kg ha^{-1} + B @ 1 kg ha^{-1} over rest of the tratment combinations.

Keywords: Growth, yield, qualityeconomics, INM, Indian mustard

INTRODUCTION

After food grains, oilseeds emerge as one of the most crucial agricultural commodities serving as both a nutritional staple and a vital ingredient in various industrial applications for the ever-expanding global population. Mustard is an oilseed crop, which is nutritionally very rich and its oil content varies from 37-49% [Annapoorna, P. and Chandranath, H.T. 2021]. Mustard oil is used as condiment in pickles, flavouring curries and vegetables and in the tanning industry for softening of leather. The mustard cake is used mostly for cattle feed and manure [Vijayeswarudu, C.Y.N.A. and Singh, P. 2021]. India secures the third position in rapeseed and mustard production after Canada and China. Rapeseed mustard ranks second in overall oil production in India after peanuts [Gupta, D., et al. 2024]. Mustard is grown in India in an area of 6.78 million hectares with average production of 9.12 million tonnes at a productivity of 1345 kg ha^{-1} [Singh, L.M., et al. 2023]. In India mustard is predominantly cultivated in the states like Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat. Rajasthan alone contributed 41.44 % to the total area and 45.03 % to the total production of rapeseed mustard of India. In Odisha, the mustard is grown in an area of 106300 ha with a production of 46350 tonnes but the productivity is only 436 kg ha^{-1}[Anonymous, 2019]. This is much lower than the national average productivity. If we visualize the figure of mustard cultivation in Kandhamal district, it is cultivated in an area of 18600 ha with a productivity of 428 kg ha^{-1}. The main reasons for low productivity of mustard in the district are imbalanced fertilizer application, use of sub-optimal dose of organic inputs and deficiencies of secondary and micronutrients in soil. Thus, there is a need for establishment of improved suitable nutrient management practices in order to achieve better crop growth and productivity of mustard in the district.

The macro and micronutrient reserves of soil are depleted due to intensive cropping with high yielding cultivars. As a result, the deficiency of micro-nutrients like zinc and boron, in addition to primary nutrients-nitrogen, phosphorus, potassium and sulphur are becoming more and more common in Indian soils [Singh, T., et al. 2022]. Sulphur is an important element for the production of fatty acids, amino acids and the action of proteolytic enzymes. Sulphur is one of the primary components of three amino acids cysteine, cystine and methionine. Application of sulphur is also important for acerating the efficiency of other plant nutrients [Kumar, S., et al. 2013]. Adequate sulphur application in combination with balanced amounts of other nutrients enhances the yield, yield attributes and oil yield of mustard [Sharma, A.K., et al. 2022 and Verma, H. and Dawson, J. 2019].

Mustard is very responsive to the micronutrient boron, which promotes plant growth and partially compensating for calcium deficiency. It is associated with meristematic activity, auxin, cell wall, and protein and pectin metabolism, maintaining correct water relations within the plant, sugar translocation, fruiting processes etc. [Choudhary, S. and Bhogal, N.S. 2017, Durbak, A.R., et al. 2014, Wasaya, A., et al. 2017]. Among the micronutrients zinc deficiency is notably prevalent in Indian soils. Zinc plays a critical role in increasing the productivity and quality of mustard. Application of zinc sulphate in mustard improves zinc utilization efficiency, correct the zinc deficiencies, improve yield and quality and mitigate stress conditions [Manasa, N., et al. 2024].

Biofertilizers are well-known to play important roles in increasing soil fertility and productivity of different crops. Application of *Phosphate Solubilizing Bacteria (PSB), Azotobacter and Azospirillum* inoculants promote seed germination and initial vigour of plants by producing growth promoting substances. Application of biofertilizers resulted in increasing mineral and water uptake, root development, vegetative growth, water transportation, uptake of nutrients and nitrogen-fixation [Gupta, D., et al. 2024].Organic manures are known to promote the activity of soil microorganisms as well as improve the physicochemical and biological properties of soil.The yield and quality of mustard are largely determined by the combined use of major and micronutrients [Srinivas, M and Mohammad, S. 2002]. In order to enhance the productivity of mustardthe proper nutrient management practices must have to be followed. Mustard requires relatively large amount of nutrients for realization of yield potential but inadequate supply of nutrients often leads to low productivity [Rathore, S.S., et al. 2020]. It is estimated that for production of 1 tonne of mustard seed per hectare, the crop requires 80–120 kilogram of nitrogen, 12.4-42.7 kilogram of phosphorous, 20–40-kilogram of potassium, 2–20 kilogramof sulphur, 100 gram of zinc and 36 gram of boron per hectare [Kumar, A., et al. 2010]. Integrated use of organic and inorganic fertilizers plays a major role in improving the soil health, increasing productivity, yield sustainability andprofit from mustard cultivation.

However, no study has been carried out to evaluate the combined application of macro and micro nutrients on growth, seed yield and economics of mustard in Kandhamal district which comes under North Eastern Ghat Agroclimatic zone of Odisha.

MATERIALS AND METHODS

A field experiment was conducted to assess the effect of integrated nutrient management practices on growth, yield and economics of mustard (*Brassica juncea* L.) grown in North Eastern Ghat Zone of Odisha during the *Rabi* season of 2022-23 at different farmer's field in Kandhamal district of Odisha under Krishi Vigyan Kendra, Kandhamal, Odisha University of Agriculture and Technology, Bhubaneswar.The district lies between $19^{0}34'$ to $20^{0}36'$ N latitude and $83^{0}34'$ to $84^{0}34'$ E longitude. This trial was conducted at different locations of G. Udayagiri and Tikabali blocks of the district.The initial soil samples before conducting the trial were collected and analyzed. The pH was determined by electric pH meter and available nitrogen was determined by alkaline permanganate method as reported by Piper, C.S. [2019] and available phosphorus and potash by Bray's No. 1 method and flame photometer method, respectively. The Electrical Conductivity (EC) was determined by Conductivity Bridge as described by Jackson, M.L.[1967]. The oxidizable soil organic carbon content (g kg^{-1}) was analysed by the method proposed by Walkley, A.J. and Black, C.A.[1934]. The available sulphur (0.15% $CaCl_2$ extractable) was analysed as proposed by Chesnin, L and Yien, C.H.[1951] and the boron content in the soil was determined by spectrophotometer using azomethine-H [John, M.K., et al. 1975]. The soils of the experimental site were acidic in reaction and the pH varied between 5.14 and 5.46, sandy clay loam in texture and the content of available nitrogen, phosphorus, potassium, sulphur, boron and zinc were varied between 238.2 and 268.6 kg ha^{-1}, 11.5 and 15.7 kg ha^{-1}, 197.5 and 296.1 kg ha^{-1}, 6.7 and 9.2 mg kg^{-1}, 0.28 and 0.41 mg kg^{-1}, and 0.42 and 0.53 mg kg^{-1}, respectively. The organic carbon content at initiation of the experiment was in a range of 3.2 to 5.1 g kg^{-1} soil.The experiment was laid out in Randomized Block Design (RBD)consisted of four treatments withseven replications. Thetreatments comprised of T_1: Farmer's practice (FYM @ 0.5 t ha^{-1}, average fertilizer @ 20.5-23-0 kg N-P_2O_5-K_2O ha^{-1}), T_2: STBFR + FYM @ 2 t ha^{-1} + Biofertilizers (*Azotobacter*, *Azospirillum* and *PSB* @ 1:1:1, 4 kg each per ha, T_3: RDF + FYM @ 5 t ha^{-1} + S @ 25 kg ha^{-1} and B @ 1 kg $ha^{-1}$and T_4: STBFR + FYM @ 2 t ha^{-1} + Soil application of Zn @ 5kg ha^{-1} and B @ 1kg ha^{-1} along with S @ 40 kg ha^{-1}.

The mustard variety M-27 was sown @ 5-6 kg seed ha^{-1} during October 2022 with a spacing of 30 cm× 10 cm. The recommended doseof fertilizer (RDF) @50-25-25 Kg N-P_2O_5-K_2O $ha^{-1}$was applied in T_3 treatment, whereas the NPK as per soil test recommendations was applied in T_2 & T_4 treatments. The fertilizer @ 20.5-23-0 Kg N - P_2O_5 - K_2O ha^{-1} and FYM @ 0.5 t ha^{-1} were applied in T_1 treatment (Farmer's practice).In the present investigation, the micronutrient boron wasapplied through basal in the form of borax @ 10 kg ha^{-1} to the treatments T_3 and T_4. Sulphur was applied through basal in the form of bentonite-S, which contained 90% sulphur to the treatments T_3 and T_4. While zinc was applied through basal in the form of zinc sulphate to the treatments T_4 only. For each treatment N was applied in two equal splits first at sowing as basal and rest 50% at 21DAS. The full dose of P & K was applied as basal dose. As per the treatments FYM was applied and mixed in the soil at the time of final land preparation. The entire quantity of S, Zn and B as per treatment were applied at the time of sowing as basal. The biofertilizer was incubated with FYM for seven days and applied at the time of sowing in Treatment T_2. Irrigation and other interculturaloperations were followed as per the recommendedpackage of practices. Ten plants were randomlyselected excluding the boundary area to record observations for various growth and yield contributing charactersofmustard. All the necessary cultural practices were uniformly carried out for successful harvest of the crop. The crop was harvested by cutting the entire plant at ground level. Plant height was measured from base of the plant to tip of the main shoot randomly at 60 and 80 days after sowing (DAS). Number of siliquae was counted from the tagged plants express as number of siliqua plant-1 and total length measured in centimeter. 1000 seeds from bulk seed yield of each treatment were taken for measured test weight. Total weight of clean and dried seeds from each treatment weighted and converted to q ha^{-1}. The stover yield was obtained by deducting the seed yield from the respective biological yield and expressed in q ha-1. Oil content in grains was determined by using Soxhlet extraction procedure AOAC [1995]. The mustard seeds of individual plots were dried at 60°C for 6 hours; grinded in pestle & mortar and 2 g sample was weighed in thimble and placed in Soxhlet extractor. The oil was extracted with petroleum ether (40-60°C) for 6 hours in a distillation flask. After distillation of sample, petroleum ether was evaporated in an oven for one hour at 100-105°C. The sample was cooled and weighed and oil percentage was then calculated as per the given formula:

$$Oil\ content\ in\ seed\ (\%) = {(Weight\ of\ extracted\ oil)}\Big/{(Weight\ of\ sample)} \times 100$$

Oil yield was calculated from oil content of individual sample multiplied by respective seed yield and expressed in kg ha^{-1}.

To determine the most economic treatment, the economics of each treatment were calculated based on the current market price of the produce and inputs used. Benefit cost ratios (B:C) for each treatment were determined after calculating the gross and net return. Gross return (Rs ha^{-1}) was calculated by multiplying total produce (yield) by the relevant market prices at the time.The economic parameters were calculated by using the following formula.

$$\text{Net return (/ha)} = \text{Gross return (/ha)} - \text{Cost of cultivation (/ha)}$$

$$\text{Gross return} \left(\frac{}{ha}\right) = \text{Priceof the produce} \left(\frac{}{q}\right) \times \text{Yield}\left(\frac{q}{ha}\right)$$

$$\text{Bene it cost ratio} = {\text{Gross return (/ha)}}\Big/{\text{Cost of cultivation (/ha)}}$$

The data obtained during the trial wereanalyzed by following the standard statistical procedure given for RBD by Panse, V.G.and Sukhatme, P.V.[1985]. To evaluate whether there was a significant difference between the treatments, the Critical Difference (CD) at the 5% level was utilized.

RESULTS AND DISCUSSION

Effect on growth parameters

Data pertaining to growth parameters plant height and number of branches per plant are presented in Table1.

Table 1. Effect of integrated nutrient management practices on growth parameters of Indian mustard

Treatments	Plant height (cm)		Number of branches $plant^{-1}$
	60DAS	80 DAS	Total branches
T_1- Farmer's practice	68.6	95.4	17.8
T_2- STBFR* + FYM @ 2 t ha^{-1} + Biofertilizer	81.4	102.6	18.3
T_3- RDF** + FYM @ 5 t ha^{-1} + S @ 25 kg ha^{-1} + B @ 1 kg ha^{-1}	97.7	113.8	19.8
T_4- STBFR + FYM @ 2 t ha^{-1} + Zn @ 5 kg ha^{-1} + S @ 40 kg ha^{-1} + B @ 1 kg ha^{-1}	108.5	124.2	21.6
CD $_{(0.05)}$	2.29	3.06	0.78

SEm	0.77	1.03	0.26
** STBFR (Soil test-based fertilizer recommendation), ** RDF (Recommended dose of fertilizer @ 50-25-25 kg N-P_2O_5-K_2O ha^{-1})*			

The results revealed that application ofSTBFR +FYM @ 2 t ha^{-1} +Zn+B+S) recorded the maximum plant height of 108.5 cm and 124.2 cm at 60 and 80 DAS, respectivelyas well as number of primary (3.09) and total (21.6) branches per plant as compared to over rest of treatments. Contrarily, a significant response of adequate available sulphur in soil might be contributed to enhance cell division, elongation, tissue development, multiplication and synthesis of essential amino acidsas a result of higher plant height.Whereas, similar results have been reported by Kumar et al. (2011), Parmar and Parmar (2012) and Bhindaet al. (2023).Zinc play role in carbohydrate metabolism as being a constituent of enzymes involved in photosynthesis and a precursor of IAA biosynthesis in auxin metabolism was responsible for higher number of primary branches per plant (Alloway, 2008). These findings are supported by Kumaret al. (2011), Parmarand Parmar(2012), Singhet al (2017), Bhalavi et al (2023), Bhinda et al. (2023) and Kaur and Verma(2023).

Effect on yield attributing parameters

Data pertaining in Fig 1 (A,B,C, D)clearly revealed thatthe significantly maximum number of siliqua per plant (301.50), siliqua length (5.71 cm), number of seeds per siliqua (10.84) and testweight (3.86 g) were recorded under the treatment T_4 (STBFR +FYM @ 2 t ha^{-1} +Zn+B+S) followed by T_3 (RDF +FYM @ 5 t ha^{-1} + S+B) with the values of 279.10, 5.22 cm, 10.39 and 3.43 g, respectively over rest of the treatments.

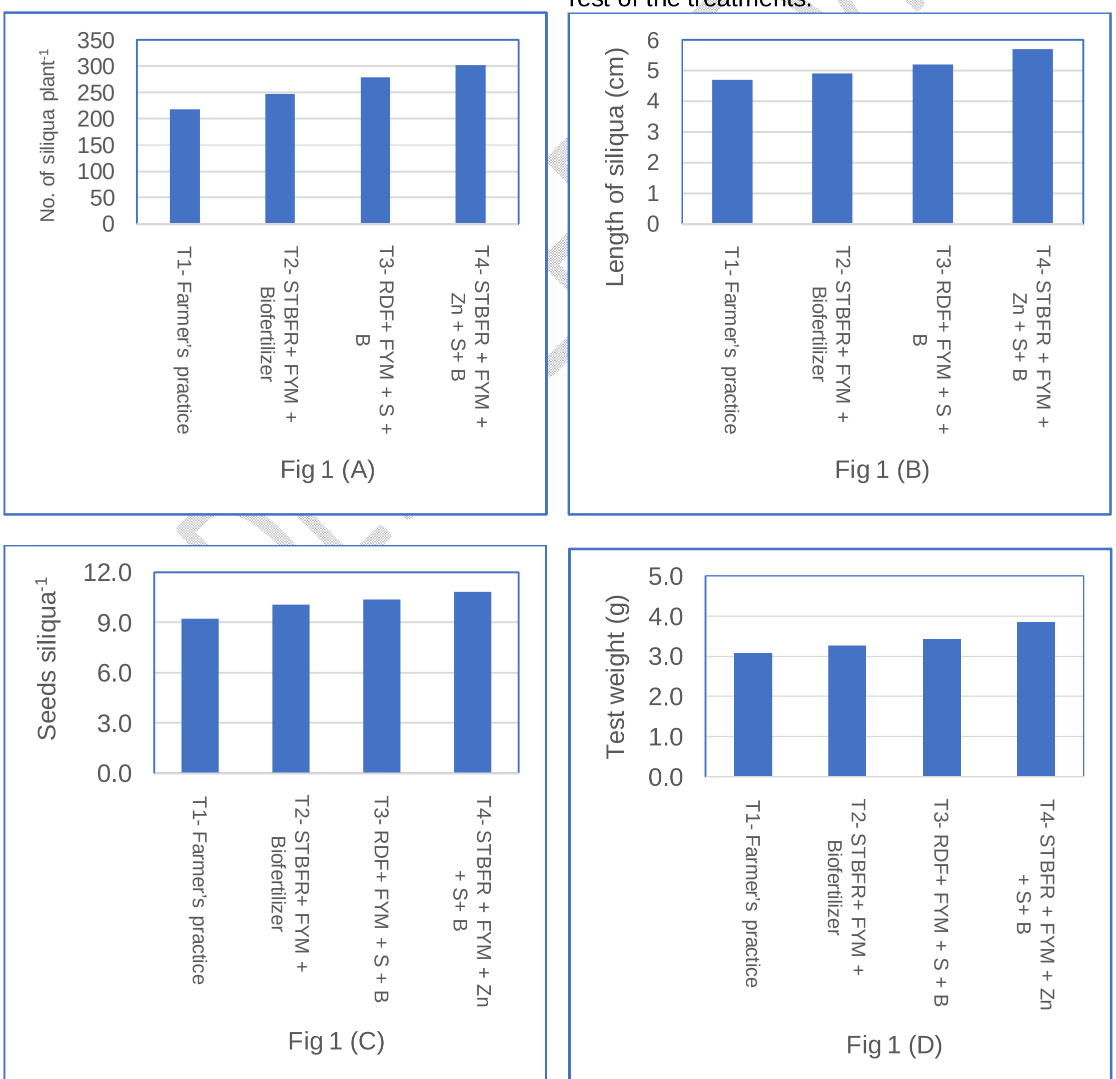

Fig 1 (A,B,C,D): Effect of integrated nutrient management practices on yield attributing

parameters of Indianmustard

The chemical and organic fertilizers along with micronutrient in integrated pattern might have supplied sufficient nutrients throughout the growth period and provide opportunity for seeds to grow their full potential as observed in the study.These findings are supported by Jatand Ahlawat(2006), Kumaret al. (2018) and Ajnarand Namdeo (2021).

Effect on seed yield and oil content

A significant increase in seed yield of mustard was found with addition of Zn, B and S and soil test based NPK over farmers practice (Table 2).

Table 2 Effect of integrated nutrient management practices on seed yield and oil content of Indian mustard

Treatments	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
T_1- Farmer's practice	4.7	15.9	36.1	169.6
T_2- STBFR* + FYM @ 2 t ha^{-1} + Biofertilizer	5.4	18.4	37.4	202.1
T_3- RDF** + FYM @ 5 t ha^{-1} + S @ 25 kg ha^{-1} + B @ 1 kg ha^{-1}	6.1	21.2	38.9	237.3
T_4- STBFR + FYM @ 2 t ha^{-1} + Zn @ 5 kg ha^{-1} + S @ 40 kg ha^{-1} + B @ 1 kg ha^{-1}	6.6	24.8	40.4	266.5
CD $_{(0.05)}$	0.26	1.15	0.91	10.63
SEm	0.08	0.38	0.30	3.57

** STBFR (Soil test-based fertilizer recommendation), ** RDF (Recommended dose of fertilizer @ 50-25-25 kg N-P_2O_5-K_2O ha^{-1})*

The higher seed (6.6 q ha^{-1}) and stover (24.8 q ha^{-1}) yield of was recorded in T_4 (STBFR +FYM @ 2 t ha^{-1} +Zn+B+S) followed by T_3 (RDF + FYM @ 5 t ha^{-1} + S @ 25 kg ha^{-1} + B @ 1 kg ha^{-1}) 6.1 q $ha^{-1}$and T_2 (STBFR+ FYM @ 2 t ha^{-1} + Biofertilizer) 5.4 q ha^{-1} with respective toincrease of 40.4, 29.8 and 14.9 per cent over farmer's practice. The increased in seed yield might be due to balanced nutrition and role of boron in viability, germination and growth of pollen tubes. The combined application of S, Z and B provided balanced and adequate amounts of all the nutrients required by the mustard crop to produce higher seed yield. The results are in close conformity with Kouret al. (2017) and Meenaet al.(2022). Likewise, the stover yield of mustard increased significantly and maximum of 24.8 q ha^{-1} was recorded with addition of soil test based NPK, FYM @ 2 t ha^{-1}, Zn, B and S. It has also been reported that S and B application significantly influenced the dry matter and seed yield of mustard (Jaiswalet al. 2015 and Chakrabortyand Das 2000).

The oil content and oil yield increased significantly by conjoint application of zinc, boron and sulphur along with soil test based NPK and FYM @ 2 t ha-^{1} (Table 2). The highest oil content (40.4 %) and oil yield (266.5 kg ha^{-1}) were recorded in the treatment T_4 (soil test based NPK, FYM @ 2 t ha^{-1}, Zn, B and S) and the lowest oil content (36.1%) and oil yield (169.6 kg ha^{-1}) were also observed in T_1 (Farmer's Practice). Sulphur is a constituent of glucosinolate which plays a vital role in synthesis of mustard oil. The application of sulphur might have favoured the synthesis of CoA and lipoic acid resulting in increased oil content of mustard (Mathewand George 2013). The increment of oil yield was also due to balanced and adequate availability of S, Zn and B nutrients, resulted higher oil content and seed yield.

Effect on economics

It was observed from table 3 that the highest gross return of ₹34,320/- ha^{-1}, net return of ₹17,720/- ha^{-1} and Benefit: Cost ratio (B:C) of 2.1 were recorded in the treatment T_4 (STBFR +FYM @ 2 t ha^{-1} +Zn+B+S) followed by T_3 (RDF + FYM @ 5 t ha^{-1} + S + B) with values of ₹31,720/- ha^{-1}, ₹15,820/- ha^{-1} and 2.0, respectively.

Table 3 Effect of integrated nutrient management practices on economics of Indian mustard

Treatments	Cost of cultivation (₹ ha-1)	Gross return (₹ ha-1)	Net return (₹ ha-1)	B:C ratio
T_1- Farmer's practice	13900	24440	10540	1.8
T_2- STBFR* + FYM @ 2 t ha^{-1} + Biofertilizer	14600	28080	13480	1.9
T_3- RDF** + FYM @ 5 t ha^{-1} + S @ 25 kg ha^{-1} + B @ 1 kg ha^{-1}	15900	31720	15820	2.0
T_4- STBFR + FYM @ 2 t ha^{-1} + Zn @ 5 kg ha^{-1} + S	16600	34320	17720	2.1

@ 40 kg ha^{-1} + B @ 1 kg ha^{-1}				
** STBFR (Soil test-based fertilizer recommendation), ** RDF (Recommended dose of fertilizer @ 50-25-25 kg N-P_2O_5-K_2O ha^{-1})*				

In case of biofertilizer applied treatment (T_2) the gross return of ₹28,080/- ha^{-1}, net return of ₹13,480/- ha^{-1} and Benefit: Cost ratio (B:C) of 1.9 were also recorded. However, the lowest gross return of ₹24,440/- ha^{-1}, net return of ₹10,540/- ha^{-1} and Benefit: Cost ratio (B:C) of 1.8 were calculated in the treatment T_1 (Farmer's Practice). The highest economic parameters were recorded in T_4 and this might be due to application of balanced fertilization including micro and secondary nutrients boosted the seed yield of mustard. Similar results were reported earlier by Ojha et al. (2020), Annapoona and Chandranath (2021) and Verma et al. (2021).

CONCLUSION

It has been identified that the productivity of mustard crop in Kandhamal district is very low due to poor soil fertility status especially secondary and micronutrients. Therefore, there is need to apply nutrients in balanced manner to enhance the mustard productivity in Kandhamal district. It has been concluded from the experiment that the growth, yield and yield attributes, quality as well as economics of Indian mustard can be enhanced by following the integrated nutrient management practices which includes soil test based NPK application + FYM @ 2 t ha^{-1} + Zn @ 5 kg ha^{-1} + B @ 1 kg ha^{-1} +S @ 40 kg ha^{-1}. Thus, balanced application of nutrients is responsible for higher growth parameters, yield attributes, yield and economics of mustard under North Eastern Ghat Zone of Odisha.

Disclaimer (Artificial intelligence)

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

Reference

A.O.A.C. 1995. Association of Official Analytical. In Chemists: Official Methods of Analysis of the AOAC. *16th Edition.* Washington D.C. USA.

Ajnar, P. and Namdeo, S. 2021. Effect of integrated nutrient management on Indian mustard yield attributes and yield. *Journal of Pharmacognosy and Phytochemistry*. 10(2): 545-548.

Alloway, B.J. 2008. Zinc in soils and crop nutrition (2nd Ed), IZA and IFA Publication.

Annapoorna, P. and Chandranath, H.T. 2021. Productivity enhancement of mustard through integrated nutrient management practices. *Journal of Farm Sciences*. 34(3): 255-259.

Anonymous. 2019. Odisha Agriculture Statistics-2018-19, Department of Agriculture and Farmers' Empowerment, Govt. of Odisha. Pp:87

Bhalavi, S., Sirothia, P., Mishra, A., Mishra, U.S., Raghav, R.S., Singh, O.K. and Jendre, A. 2023. Effect of integrated nutrient management on growth parameters, yield attributes and yield of mustard crop in Chitrakoot area.*International Journal of Plant and Soil Science*. 35 (21): 343-348.

Bhinda, N.K., Singh, Y., Dixit, A.K. and Kumar, D. 2023. Effect of sulphur, zinc and boron on growth and yield of irrigated Indian mustard (*Brassica juncea* L) in Bundelkhand region.*Journal of Oilseed Brassica*. 14 (2): 99-104.

Chakraborty, A.K. and Das, D.K. 2000. Interaction between B and S on different quality parameters of rape (*B. compestris*), *Research on Crops*. 1: 326-329.

Cheshin, L. and Yien, C.H. 1951. Turbidimetric determination of available sulphate. *Soil Science Society of America Pro.*15, 149-151.

Choudhary, S. and Bhogal, N. S. 2017. Effect of boron on yield, quality and its uptake in Indian mustard (Brassica Juncea L) genotypes.*Annals of Plant and Soil Research*.19(4): 394-397.

Durbak, A.R., Phillips, K.A., Pike, S., O'Neill,M.A., Mares, J., Gallavotti, A., Malcomber, S.T., Gassmann, W. and McSteen, P. 2014. Transport of boron by the tassel-less1 aquaporin is critical for vegetative and reproductive development in maize. *The Plant Cell*. 26: 2978–2995.

Gupta, D., Kalhapure, A. Sah, D., Kumar, A., Singh, N., Chaubey, A.K., Maurya, S.K., Verma, R. and Panwar, S. 2024. Effect of biofertilizers and nutrients on mustard (Brassica juncea): A review. *International Journal of Plant and Soil Science*. 36(3): 291-297.

Gupta, D., Kalhapure, A., Sah, D., Kumar, A., Singh, N., Chaubey, A.K., Maurya, S. K., Verma, R. and Panwar, G.S. 2024. Effect of Biofertilizers and Nutrients on Mustard (Brassica juncea): A Review.*International Journal of Plant & Soil Science*. 36 (3): 291-297, ~~ISSN: 2320-7035~~.

Jackson, M.L. 1967. Prentice Hall of India. Pvt Ltd., New Delhi, 498.

Jaiswal, A.D., Singh, S.K., Singh, Y.K., Singh, S. and Yadav, S.N. 2015. Effect of sulphur and boron on yield and quality of mustard (*Brassica juncea* L) grown in Vindhyan Red soil.*Journal of Indian Society of Soil Science*, 63(3): 362-364.

Jat, R.S. and Ahlawat, I.P.S. 2006. Direct and residual effect of vermicompost, biofertilizers and phosphorous on soil nutrient dynamics and productivity of Chickpea-fodder maize sequence.*Journal of Sustainable Agriculture*. 28 (1): 41-54.

John, M.K., Chuah, H.H. and Neufied, J.H. 1975. Application of improved azomethine-H method to the to the determination of boron in soils and plants. *Analytical Letters*. 8: 559-568.

Kaur, G. and Verma, K. 2023. Effect of integrated nutrient management on mustard crop (*Brassica juncea* L).*Plant Archives*. 23(1): 234-238.

Kour, S., Gupta, M., Kachroo, D. and Bharat, R. 2017. Direct and residual effect of zinc and boron on productivity, nutrient uptake and quality of mustard (*B. juncea*) and succeeding maize (*Z. mays*) in subtropical *Inceptisols* of Jammu.*Journal of Indian Society of Soil Science.* 65: 334-340.

Kumar, A., Premi, O. P. and Tomas, L. 2010. Rapeseed-Mustard cultivation in India-An overview. National Research Centre on Rapeseed-Mustard, Bharatpur.

Kumar, D., Singh, R.P., Awasthi, U.D., Uttam, S.K., Kumar, R. and Kumar, M. 2018. Effect of biofertilizer and moisture conservation practices on growth and yield behaviour of mustard under rainfed condition. *Journal of Pharmacognosy and Phytochemistry*. 7(1): 2038-2041.

Kumar, S., Patel, S.K. and Ghosh, G. 2013. Response of Different Boron and Sulphur Levels on Chickpea Based Mustard Intercropping System.*Trends in Biosciences.*6 (3): 256-258.

Kumar, S., Verma, S.K., Singh, T.K. and Singh, S. 2011. Effect of nitrogen and sulphur on growth, yield and nutrient uptake by Indian mustard (*B. juncea*) under rainfed condition.*Indian Journal of Agricultural Sciences*. 81: 145-149.

Manasa, N., Krishna, K.V., Nayak, B.B. and Kumar, C.H.S.2024. Impact of biofertilizers and zinc foliar spray on mustard growth, chlorophyll content and yield. *African Journal of Biological Sciences*. 6(13): 6622-6636, doi: 10.48047/AFJBS.6.13.2024.6622-6636.

Mathew, J. and George, S. 2013. Synergistic influence of sulphur and boron in enhancing the productivity Sesame (*Sesamum indicum*) grown in an *Entisol* of Kerala. *Journal of the Indian Society of Soil Science*. 61: 122-127.

Meena, V.S., Meena, M.K., Dotaniya, M.L., Meena, M.D., Choudhary, R.L., Singh, N., Meena, V.D. and Rai, P.K. 2022. Profitability and productivity of Indian mustard affected by micro and secondary nutrient application in calcareous soil. *Journal of Oilseed Brassica*, 13: 53-58.

Ojha, I., Borah, D., Rabha, H. and Deka, P. 2020. Performance of toria using INM under late sown rainfed condition in rice fallow of Udalguri district of Assam, India. *International Journal of Current Microbiology and applied Science*. 9(7): 2799-2805.

Panse, V.G., Sukhatme, P.V.1985. Statistical methods for Agricultural Workers. ICAR Publications. New Delhi.

Parmar, J.K. and Parmar, R.M. 2012. Effect of nitrogen and sulphur on quality characteristics and accumulation of fatty acids in mustard seeds grown under loamy and soil of North Gujarat.*Asian Journal of Soil Science*. 7: 167-171.

Piper, C.S. 2019. Soil and plant analysis. Scientific Publishers.

Rathore, S. S., Kapila, S. and Rajanna, G. A. 2020. Land configurations in surface drip irrigation for enhancing productivity, profitability and water-use efficiency of Indianmustard (*Brassica juncea*) under semi-arid conditions. *Indian Journal of Agricultural Sciences*. 90 (8): 1538-1543.

Sharma, A.K., Samuchia, D., Sharma, P. K., Mandeewal, R. L., Nitharwal, P. K. and Meena, M. 2022. Effect of Nitrogen and Sulphur in the Production of the Mustard Crop [*Brassica juncea* (L.)]. *Int. J. Clim. Chang*. 12: 132-137.

Singh, L. M., Singh, A. K.,Singh, T. B., Gulleibi, N. C., Singh, T. D., Dkhar, K. and Gadi, G. 2023. Nutrient management of rapeseed for its improved growth, yield and quality in an acid *Inceptisol*.*Journal of Crop and Weed*. 19(2): 120-125.

Singh, S.P., Singh, R.A., Yadav, V.R., Chaudhary, S. and Kumar, A. 2017. Effect of different nutrient combinations on yield and quality of mustard varieties (*Brassica juncea* L).*International Journal of Current Microbiology and Applied Science*. 6(2): 1343-1347.

Singh, T., Bohra, J. S., Singh, R. K., Singh, D. N. and Singh, P. 2022. Effect of sulphur and boron levels, and integrated nutrient management on growth and yield of Indian mustard [(*Brassica juncea*L.) Czernj. and Cosson*]. Ann. Agric. Res*. New Series. 43 (3): 311-316.

Srinivas, M. and Mohammad, S. 2002. Performanceof green gram and response functions asinfluenced by different levels of N and P. *Crop Research*. 24: 458-462.

Verma, G.R., Satish, P., Hussain, S.A. and Sharma, S.H.K. 2021. Effect of integrated nutrient management on productivity and economics of Indian mustard (*Brassica juncea* L.), *International Journal of Environment and Climate Change*. 11(6): 169-176.

Verma, H., and Dawson, J. 2019. Response of sowing methods and different levels of sulphur and boron on growth and yield of yellow sarson (*Brassica campestris* L.). *International Journal of Current Microbiology and Applied Sciences*. 7(3): 1558-1564.

Vijayeswarudu, C.Y.N.A and Singh, R. 2021. Effect of Biofertilizers and Sulphur Levels on Growth and Yield of Yellow Mustard (*Sinapis alba*), *Biological Forum – An International Journal*. 13(3a): 140-143.

Walkley, A.J. and Black, C.A.1934. Estimation of soil organic carbon by the chronic acid titration method. *Soil Science* 37,29–38.

Wasaya, A., Shabir, M.S., Hussain, M., Ansar, M., Aziz, A., Hassan, W. and Ahmad, I. 2017. Foliar application of zinc and boron improved the productivity and net returns of maize grown under rainfed conditions of Pothwar plateau. *Journal Soil Science Plant Nutrition*. 17:33–45.