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Quantifying synergistic effects of organic-inorganic nutrient combinations on morpho-physiological traits, productivity and soil fertility restoration in *Brassica juncea*

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Abstract

A field experiment was conducted during the *rabi* season of 2021-22 at the instructional farm of School of agriculture and allied sciences, Dehradun entitled “Quantifying Synergistic Effects of Organic-Inorganic Nutrient Combinations on Morpho-Physiological Traits, Productivity and Soil Fertility Restoration in *Brassica juncea*” to evaluate the best integrated nutrient management treatment to enhance the productivity, quality, soil health and fertility of the Indian mustard. The experimental was laid out in a randomized block design (RBD) with twelve treatments that replicated twelve treatments viz; Control (No fertilizers) (T₁), RDF: 80:40:40 (N:P:K) (T₂), RDF: + Azotobacter (T₃), FYM @ 4 t/ha (T₄), Vermicompost @ 2 t/ha (T₅), FYM @ 4 t/ha + Azotobacter (T₆), Vermicompost @ 2 t/ha + Azotobacter (T₇), 50% RDF + FYM @ 4 t/ha (T₈), 50% RDF + Vermicompost @ 2 t/ha (T₉), 50% RDF + FYM @ 2 t/ha + Azotobacter (T₁₀), 50% RDF + Vermicompost @ 1 t/ha + Azotobacter (T₁₁), 50% RDF + Azotobacter (T₁₂). The mustard variety used in the study was Java Super 30. The results of the study revealed that the significantly higher plant height (147.6 cm) at harvest, dry matter accumulation (58.1 g), root length (26.4 cm), root dry weight (13 g), test weight (4.06 g), seed yield (2872.2) and biological yield (8958.1) was found with the treatment where, 50% RDF + Vermicompost @ 1 t/ha + Azotobacter (T₁₁) was applied and this treatment also improved the soil nutrient status and soil health. This integrated approach demonstrates a viable low cost, sustainable strategy for improved Indian mustard productivity.

Keywords: *Brassica juncea* L., treatments, biofertilizer, vermicompost, plant growth and yield, soil nutrients

Introduction

Indian mustard (*Brassica juncea* L. Czern & Coss.) is a major *rabi* oilseed crop and a cornerstone of India's edible oil economy, contributing nearly one-third of domestic vegetable oil production and ranking among the leading rapeseed-mustard producers globally. Botanically Indian mustard belongs to the family Cruciferae with a chromosome number of 36 and it requires a temperature of 15-25 °C for its best growth, grows from medium to sandy loam soils (Prashad, 2017). The oil content of Indian mustard ranges from 37% to 49%, and the composition includes 38–57% erucic acid, 4.7–13% linolenic acid, 27% oleic acid, and 10–12% linoleic acid (Kumar *et al.*, 2019). The cultivation area for mustard in India spans approximately 8.06 million hectares, yielding a production of 11.75 million tonnes with a productivity of 1458 kg/ha, Rajasthan ranks first in cultivated area and production of Mustard in India whereas Gujarat ranks first in productivity (MoA & FW, 2023). The crop is predominantly grown in the Indo-Gangetic plains and north-western India, where continuous cereal-based rotations, inadequate organic matter inputs and imbalanced fertilization have intensified multi-nutrient deficiencies, particularly of nitrogen, phosphorus, sulphur and micronutrients.

Conventional reliance on mineral fertilizers alone has improved productivity but often at the cost of declining soil health, reduced nutrient-use efficiency and plateauing yield responses, underscoring the need for more sustainable nutrient strategies. INM combines organic manures,

bio-fertilisers and chemical fertilisers in a synergistic way to optimise crop nutrient supply enhance soil health and sustain productivity over the long term (Devkota *et al.*, 2020) ^[5]. Recent studies across Indian mustard-growing regions demonstrate that INM enhances root growth, photosynthetic efficiency and yield attributes (silique number, seeds per silique and thousand-seed weight), leading to significant gains in seed yield and oil content compared with sole chemical fertilization. Integrated use of organic and inorganic fertilizers not only ensures availability of all the essential plant nutrients but also improves the soil chemical, biological properties and crop productivity ((Thakur *et al.*, 2009; Meena *et al.*, 2015) ^[21, 10]. Application of vermicompost or FYM in conjunction with recommended NPK doses consistently improves soil organic carbon, aggregate stability, cation-exchange capacity and the availability of macro- and micronutrients, thereby strengthening nutrient cycling and resilience to abiotic stress.

The foothill zone of Dehradun in Uttarakhand represents an important but relatively less studied niche for mustard cultivation, characterized by sandy clay loam soils, variable rainfall and frequent late sowing after rice-based systems. Yield potentials of the crop, can be realized by balanced and efficient use of organic and inorganic sources of nutrient (Meena *et al.*, 2016) ^[9]. Under these conditions, yield instability and declining factor productivity are closely linked to imbalanced fertilization and minimal recycling of organic residues. Site-specific INM options that integrate FYM, vermicompost and biofertilizers with regionally optimized fertilizer doses therefore hold considerable potential to enhance nutrient-use efficiency, restore soil fertility and narrow the yield gap of Indian mustard in this agro-ecological situation. Against this background, the present investigation on “Quantifying Synergistic Effects of Organic-Inorganic Nutrient Combinations on Morpho-Physiological Traits, Productivity and Soil Fertility Restoration in *Brassica juncea* L.” was undertaken to quantify the effects of selected INM treatments on crop growth, yield formation and post-harvest soil nutrient dynamics, with the broader goal of developing environmentally sound and economically viable nutrient management recommendations for the region.

Methodology

A field experiment was carried out at the instructional farm of School of agriculture and allied Sciences, Doon Business School, Dehradun during the Rabi season 2021-22. Dehradun is located at the foot of the Himalayas and the climate is moderate which depends upon the altitude. It is situated at 33°13' N altitude and 77°51' E longitudes with an average elevation of 682 m above sea level with the average annual rainfall of 2073 mm. Wide range of temperature is observed in summer temperature reach upto 40° with hot wind called loo blows over north India and in winter temperature ranges from 1°C which can reach below freezing during severe cold. The soil of the experimental site contains 0.62% organic carbon, 215.6 kg/ha Available Nitrogen, 14.4 kg/ha Available Phosphorus and 118.8 kg/ha Available Potassium, 6.4 pH and 0.64 electrical conductivity. The experiment was laid out in the Randomized complete block design with three replications and twelve treatments. The variety Java super 30 was used with a spacing of 30 x15 cm. The treatment details are as follows:-

S. No	Treatment
1.	Control (T ₁)
2.	100% RDF: 80:40:40 (NPK) (T ₂)
3.	100% RDF: + Azotobacter (T ₃)
4.	FYM @ 4 t/ha (T ₄)
5.	Vermi compost @2 t/ha (T ₅)
6.	FYM @ 4 t/ha + Azotobacter (T ₆)
7.	Vermi compost @ 2 t/ha + Azotobacter (T ₇)
8.	50% RDF + FYM @ 4 t/ha (T ₈)
9.	50% RDF + Vermi compost @ 2 t/ha (T ₉)
10.	50% RDF + FYM @ 2 t/ha + Azotobacter (T ₁₀)
11.	50% RDF + Vermicompost @ 1 t/ha Azotobacter (T ₁₁)
12.	50% RDF + Azotobacter (T ₁₂)

Results and Discussion

The integrated nutrient management treatments significantly influenced the growth, yield attributes and yield of the India mustard.

Plant height was significantly influenced by different nutrient management treatments at all growth stages (30, 60, 90 DAS and at harvest). 50% RDF + Vermicompost @ 1 t/ha Azotobacter produced significantly highest plant height 27.1 cm, 78.6 cm, 96.4 cm respectively at 30, 60, 90 DAS, which was higher than all other treatments and control. At harvest, the tallest plant height (147.6 cm) was recorded with treatment 50% RDF + Vermicompost @ 1 t/ha Azotobacter, which was superior to all other treatments. Control recorded the lowest plant height (123.8 cm). The highest plant height that was recorded with integrated Nutrient Combinations with biofertilizers may be attributed to improved nutrient availability, better root growth, and improve microbial activity results in sustained nutrient supply throughout the crop growth period. These findings also report with earlier studies reporting enhanced plant height due to combined application of inorganic fertilizers with organic manures and biofertilizers study by Ghosh *et al.*, (2004) ^[6] and Meena *et al.*, (2018) ^[12].

Dry matter accumulation showed a significant increase in crop growth. The significantly higher dry matter production 58.1 g/plant was recorded with treatment 50% RDF + Vermicompost @ 1 t/ha Azotobacter, which was at par with a treatments 50% RDF + FYM @ 2 t/ha + Azotobacter (55.5 cm) and 50% RDF + Vermi Compost @ 2 t/ha (55.1 cm). Control recorded the lowest dry matter accumulation (46.5 g/plant). Integrated use of vermicompost and Azotobacter increases nutrient mineralization, nitrogen fixation, and nutrients uptake efficiency, resulting in greater photosynthetic activity and biomass accumulation. Similar enhancement in dry matter production under integrated nutrient management has been reported by Yadav *et al.*, (2017) ^[23] and Meena *et al.*, (2019) ^[13]. Maximum root length (26.4 cm) and root dry weight (13.0 g) were recorded with 50% RDF + Vermicompost @ 1 t/ha Azotobacter, which was significantly higher to all other treatments also at par with treatments 50% RDF + FYM @ 2 t/ha + Azotobacter and 50% RDF + VERMI COMPOST @ 2 t/ha. Control plots showed the lowest root length (17.0 cm) and root dry weight (5.6 g) followed by RDF alone. The improved root growth under Organic and Inorganic Nutrient Combinations with Azotobacter treatments may be resulted to better soil physical conditions due to organic amendments, increased microbial population, and enhanced availability of nutrients in the rhizosphere. Vermicompost improves soil porosity and

moisture retention, while *Azotobacter* enhances nitrogen availability, promoting vigorous root development. These observations related with the study reported significant improvement in root growth parameters with combined use of organic manures and biofertilizers Arancon *et al.*, (2005) ^[1] and Swarup *et al.*, (2000) ^[20].

The result for all yield attributes viz Siliquae per plant, Siliquae length (cm), Seeds per siliquae and 1000 seed weight recoded significantly higher with treatment 50% RDF + Vermicompost @ 1 t/ha *Azotobacter* which were also at par with treatment 50% RDF + FYM @ 2 t/ha + *AZOTOBACTER*. This is due to the synergy among these different organic and inorganic nutrient sources which improved soil structure, microbial activity and nutrient availability at critical reproductive stages as earlier reported by Yadav *et al.*, (2016) ^[22] and Meena *et al.*, (2017) ^[11].

Application of 50% RDF + Vermicompost @ 1 t/ha *Azotobacter* produce significantly higher seed yield (2872.2 Kg/ha) among all other treatments which was at par with treatment 50% RDF + FYM @ 2 t/ha + *Azotobacter* (2573.4 Kg/ha). This may be explained by the availability of sufficient and balanced nutrients, which raises photosynthesis and causes more photosynthate to be produced and moved from leaves to other plant parts. The findings are consistent with Das *et al.*, (2021) ^[4]. Lowest grain yield was produced by control treatment (1354.2 Kg/ha) followed by treatment 50% RDF + *Azotobacter* (1575.0 Kg/ha). Biological yield was recorded statically higher with treatment 50% RDF + Vermicompost @ 1 t/ha *Azotobacter* (6543.5 Kg/ha) from all other treatments and lowest biological yield was recorded in control treatment (6205.8 Kg/ha) followed by RDF alone (7074.2 Kg/ha).

Table 1: Plant height (30, 60, 90 DAS and at harvest) as affected by different treatments

Treatments	Plant height			
	30 DAS	60 DAS	90 DAS	Harvest
Control (No Fertilizer)	20.4	62.4	86.6	123.8
100% RDF: 80:40:40 (NPK)	23.8	66.9	93.9	134.1
RDF+ <i>Azotobacter</i>	22.5	67.2	92.5	136.7
FYM @ 4 t/ha	21.6	67.5	93.3	136.9
Vermi Compost @2 t/ha	22.5	68.1	93.9	136.5
FYM @ 4 t/ha + <i>Azotobacter</i>	20.5	68.6	94.5	139.7
Vermi Compost @ 2 t/ha + <i>Azotobacter</i>	20.6	68.7	94.4	139.8
50% RDF + FYM @ 4 t/ha	20.7	69.7	95.5	140.0
50% RDF + Vermi Compost @ 2 T/ha	21.7	71.6	95.5	142.9
50% RDF + FYM @ 2 t/ha + <i>Azotobacter</i>	25.1	72.7	95.6	145.1
50% RDF + VERMICOMPOST @ 1 t/ha <i>Azotobacter</i>	27.1	78.6	96.4	147.6
50% RDF + <i>Azotobacter</i>	20.5	65.2	93.7	135.5
S.Em±	0.5	1.2	0.9	0.6
CD (P=0.05)	1.6	3.6	2.7	1.9

Table 2: Dry matter (g), root length (cm), root dry weight (g) and days to maturity as affected by different treatments

Treatments	Dry matter (g)	Root length (cm)	Root dry weight (g)	Days to maturity
Control (No Fertilizer)	46.5	17.0	5.6	126.0
100% RDF: 80:40:40 (NPK)	51.4	20.9	6.9	125.0
RDF+ <i>Azotobacter</i>	52.5	21.3	7.0	125.0
FYM @ 4 t/ha	53.2	21.2	7.2	125.0
Vermi Compost @2 t/ha	53.0	22.3	7.2	125.0
FYM @ 4 t/ha + <i>Azotobacter</i>	54.1	22.3	7.8	125.3
Vermi Compost @ 2 t/ha + <i>Azotobacter</i>	54.2	22.7	8.1	124.7
50% RDF + FYM @ 4 t/ha	54.3	23.8	8.8	124.0
50% RDF + Vermi Compost @ 2 T/ha	55.1	24.4	10.5	124.0
50% RDF + FYM @ 2 t/ha + <i>Azotobacter</i>	55.5	24.5	12.1	124.0
50% RDF + VERMICOMPOST @ 1 t/ha <i>Azotobacter</i>	58.1	26.4	13.0	124.0
50% RDF + <i>Azotobacter</i>	50.2	20.6	6.2	125.0
SEm±	1.1	0.8	0.6	0.6
CD (P=0.05)	3.3	2.2	1.7	1.7

Table 3: Siliquae/plant, Siliquae length (cm), root dry weight (g) and days to 50% flowering as affected by different treatments

Treatments	Siliquae/plant	Siliquae length (cm)	Seeds/siliquae	1000 seed weight (g)	Seed yield (kg/ha)	Biological yield (kg/ha)	Straw yield (kg/ha)
Control (No Fertilizer)	184.7	3.43	7.33	4.00	1354.2	6205.8	4851.6
100% RDF: 80:40:40 (NPK)	186.1	4.30	10.00	3.99	1860.3	7074.2	5213.9
RDF+ <i>Azotobacter</i>	186.0	4.47	10.33	4.04	1922.7	7205.1	5282.3
FYM @ 4 t/ha	181.9	4.60	10.67	4.03	1941.6	7221.5	5279.9
Vermi Compost @2 t/ha	189.1	4.70	11.00	3.97	2079.8	7748.2	5668.4
FYM @ 4 t/ha + <i>Azotobacter</i>	192.6	4.87	11.33	4.02	2183.3	7966.4	5783.1
Vermi Compost @ 2 t/ha + <i>Azotobacter</i>	193.8	5.00	11.33	4.01	2194.4	8013.4	5819.0
50% RDF + FYM @ 4 t/ha	198.7	5.13	11.67	3.99	2321.0	8196.3	5875.4
50% RDF + Vermi Compost @ 2 T/ha	202.3	5.27	12.00	3.95	2428.1	8222.7	5794.6
50% RDF + FYM @ 2 t/ha + <i>Azotobacter</i>	203.2	5.33	12.67	4.04	2573.4	8690.9	6117.5
50% RDF + VERMICOMPOST @ 1 t/ha <i>Azotobacter</i>	205.2	5.73	14.00	4.06	2872.2	8958.1	6085.9
50% RDF + <i>Azotobacter</i>	181.7	3.70	8.67	3.99	1575.0	6543.5	4968.6
SEm±	1.0	0.17	0.58	0.01	110.9	67.4	134.5
CD (P=0.05)	3.1	0.49	1.69	0.03	325.2	197.8	394.5

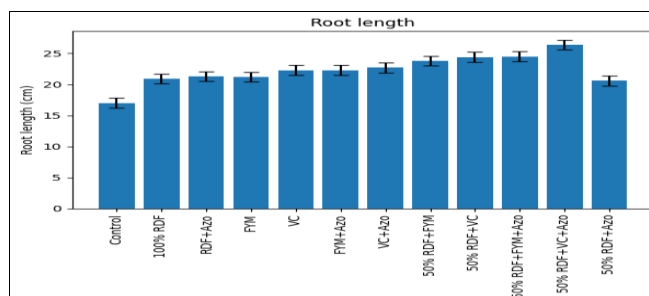


Fig 1: Root length (cm) of the *Brassica juncea* L. as affected by various nutrient management treatment

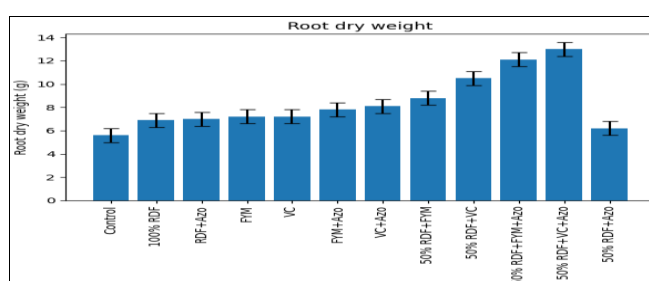


Fig 2: Root dry weight (g) of the *Brassica juncea* L. as affected by various nutrient management treatment

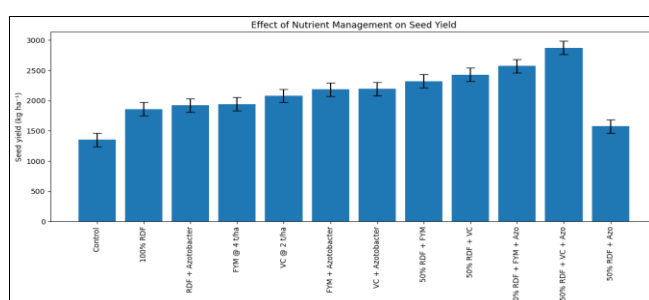


Fig 3: Seed yield (kg/ha) as affected by the different nutrient management treatment

Conclusion

The present study clearly showed that combining organic and inorganic nutrient sources is more effective than using chemical fertilizers alone for Indian mustard cultivation. The use of 50% recommended fertilizers along with vermicompost (1 t/ha) and Azotobacter improved plant growth, root development, yield traits, and final productivity while also enhancing soil nutrient status and soil health. This approach helps reduce chemical fertilizer dependence and supports sustainable crop production. Therefore, integrated nutrient management can be recommended as an economical and eco-friendly nutrient strategy for improving mustard yield and maintaining long-term soil fertility under foothill conditions.

Abbreviations used

RDF – recommended dose of fertilizer

FYM- Farmyard manure

DAS- Days after sowing

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