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Effect of Organic and Chemical Fertilizer Application on Soil Properties Under Indian Mustard (*Brassica juncea* L.) in Inceptisols of Gird Region of Central India

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Abstract

This study was conducted to evaluate the effects of organic [FYM, vermicompost, and PSB (seed treatment)] and inorganic (urea, DAP, and MOP) nutrient applications on soil properties and economic returns under Indian mustard in the Inceptisols of the Gird Region, Central India. The experiment comprised eight treatments, each replicated three times, arranged in a randomized block design (RBD). Results indicated that the soil was slightly saline, and soil pH, electrical conductivity (EC), and soil organic carbon (SOC) were not significantly affected by the treatments. In contrast, the availability of N, P, K, and S improved significantly with different fertilizer combinations, with the highest values observed under T4 - 75% RDF + FYM @ 4 Mg ha^{-1} + vermicompost @ 1 Mg ha^{-1} + PSB (seed treatment) — compared to initial soil levels. Economic analysis revealed that the maximum net returns (Rs. 74,438 ha^{-1}) were achieved under T4, followed closely by T1 (100% RDF), both of which were significantly higher than the other treatments. However, the highest benefit-to-cost (B:C) ratio (3.92) was recorded under T1, surpassing all other treatments. Overall, the study demonstrated that integrated application of organic and inorganic fertilizers significantly improved soil properties, crop growth, yield attributes, yield, quality, and economic returns of mustard.

Keywords: Nutrients status, Farmyard manure, Mustard, B:C ratio

Introduction

Currently with rapidly growing India's population, the demand for edible oil increases. But, productivity of oilseed crops majorly mustard remains suboptimal that may largely due to its cultivation in marginal and rainfed regions. Use of poor-quality groundwater is also one of major challenges in enhancing yields in these areas, results in low soil moisture availability and poor nutrient status may due to enhanced salts contents in rainfed areas (Sheoran *et al.,* 2021). So, seed hardening, a pre-sowing treatment involving seed hydration, which aids seedling establishment under moisture-deficient conditions. Additionally, treating seeds with phosphate-solubilizing bacteria (PSB) has shown further improvements in germination and early growth by converting insoluble soil phosphorus in stressed environment into usable form that increases nutrients availability (Gupta *et al.,* 2023, Singh *et al.,* 2024).

Another significant constraint for growing of oilseed crops is the imbalanced and inadequate use of fertilizers, which leads to nutrient depletion and declining soil fertility. This issue is particularly evident in intensively cropped areas, where improper nutrient management has skewed the NPK balance and contributed to soil degradation (Hadiyal *et al.,* 2017). Solely, reliance on chemical fertilizers may result in unsustainable yields and deteriorated soil health. Conversely, integrating organic sources like farmyard manure (FYM) and biofertilizers alongwith chemical fertilizers can manage long-term productivity of soil.

Organic manures, such as FYM, not only supply nutrients but also improve soil structure and boost microbial activity. While inorganic fertilizers offer rapid availability of nutrient, they are often expensive and, when overused, can negatively impact soil health, reduce microbial populations, and cause environmental pollution and may causes salts accumulation in soil surface (Prasad *et al.,* 2010) that may hinder plant growth. Hence, combining organic and inorganic nutrient sources is considered essential for maintaining both crop yield, input-output ratio and soil quality.

Although organic amendments like FYM may have a higher cost per nutrient unit, they enhance soil properties and improve overall crop performance. Vermicompost, another effective organic input, has gained popularity due to its balanced nutrient profile, including macro- and micronutrients, along with growth-enhancing substances such as enzymes, vitamins, and beneficial microbes (Shroff and Devesthali, 1992). Studies suggest that integrating FYM and vermicompost with chemical fertilizers leads to higher nutrient-use efficiency, better crop economics, and sustained yields (Verma *et al.,* 2005). Research indicates that consistent use of either chemical or organic inputs alone is insufficient for maintaining long-term productivity. Integrated Nutrient Management (INM) offers a sustainable alternative that promotes soil fertility restoration, stable yields, and reduced environmental risks (Vijaya Sankar Babu *et al.*, 2007, Pal and Pathak, 2016). INM practices also align with national goals of food and nutritional security, as they enhance nutrient availability, enhances yield that improves B: C ratio, and ensure agricultural sustainability (Swarup, 2010).

Given the importance of maintaining soil health and crop economics, the present study was conducted in semi-arid region during the *Rabi* season of 2023–24 at the College of Agriculture Farm, Gwalior. The objective was to evaluate the impact of integrated use of organic and inorganic fertilizers on soil characteristics and the economic performance of Indian mustard in Inceptisols of Gird region of Central India. FYM and vermicompost were included as key organic components due to their proven ability to enhance soil fertility by improving nutrients availability on long term basis and helps in increasing net returns in semi-arid areas (Arbad and Ismail, 2011, Kumar *et al.*, 2014).

Material and Methods

Study location and treatment details

The experiment was carried out at the research farm of the Department of Soil Science, College of Agriculture, R.V.S.K.V.V., Gwalior, situated in the Gird agro-climatic zone at 26°13′ N latitude, 76°10′ E longitude, with an elevation of 197 meters above mean sea level. The experimental area covered 621 m² and consisted of well-managed plots with uniform topography, gentle slopes, and proper drainage. The region experiences a semi-arid, subtropical climate, with summer temperatures reaching up to 45°C and winter minimum temperatures around 1–2°C. The site receives an average annual rainfall of about 730 mm. The soil is classified as Typic Ustochrepts of alluvial origin with a sandy clay loam texture. Initial soil properties included a pH of 7.40, electrical conductivity (EC) of 0.29 dS m^{-1}, and organic carbon content of 0.45%. Available nutrients were measured as nitrogen (206.0 kg ha^{-1}), phosphorus (10.04 kg ha^{-1}), potassium (239.0 kg ha^{-1}), and sulfur (8.9 kg ha^{-1}).

The study comprised eight treatments, each replicated three times, arranged in a randomized block design (RBD). Recommended dose of fertilizers (RDF) via inorganic (Urea, DAP and MOP) and organic [FYM, vermicompost and PSB (seed treatment)] sources was applied. The farmyard manure (FYM) and vermicompost was applied (dry weight basis) before sowing of mustard crop. Urea was applied as N source (two equal split doses) in all the treatments. After field preparation, Indian mustard variety RVM-2 was sown in *Rabi,* 2023-24 and the package of practices recommended by university was adopted for cultivation of crop. Composition of N, P and K in FYM and vermicompost used are shown in Table 1.

The soil samples were collected after the harvest of mustard crop from the following

Table 1. Composition of N, P & K in FYM and Vermi compost used in the experiment

S.No	Particulars	N (%)	P (%)	K (%)
1	FYM	0.5	0.25	0.5
2	Vermicompost	2	1	1.5

treatments- T_1: 100% RDF (Urea+ SSP+ MOP), T_2: 75% RDF + FYM @ 4 Mg ha^{-1}, T_3: 75% RDF + Vermicompost @ 1 Mg ha^{-1}, T_4: 75% RDF + FYM @ 4 Mg ha^{-1}+ Vermicompost @ 1 Mg ha^{-1}+ PSB (Seed treatment), T_5: 50% RDF + FYM @ 8 Mg ha^{-1}, T_6: 50% RDF + Vermicompost @ 2 Mg ha^{-1}, T7: 50% RDF + FYM @ 4 Mg ha^{-1}+ Vermicompost @ 1 Mg ha^{-1}+ PSB (Seed treatment) and T8: FYM @ 8 Mg ha^{-1}+ Vermicompost @ 2 Mg ha^{-1}+ PSB (Seed treatment).

Sample collection, preparation and analysis

At crop harvest, soil samples from a depth of 0–15 cm were collected from each plot following standard procedures and placed in polythene bags. In the laboratory, the samples were air-dried, gently crushed using a wooden roller, passed through a 2 mm sieve, and stored for subsequent analysis.

Soil pH and electrical conductivity (EC) were determined using the glass electrode method in a 1:2 soil-to-water suspension, following the procedure described by Piper (1950). Soil organic carbon (SOC) was estimated by the wet oxidation method using chromic acid, as outlined by Walkley and Black (1934). Available nitrogen was quantified using the Kjeldahl distillation technique according to Subbiah and Asija (1956). Phosphorus availability was measured following the method of Olsen *et al.* (1954), whereas potassium content was determined based on the procedure described by Jackson (1973). The available sulphur in soil was assessed using the turbidimetric technique developed by Chesnin and Yien (1951).

Economics of treatments

Cost of cultivation

The cost incurred as per the treatment was calculated considering price of seed, fertilizers, weeding, herbicides etc. Cost of cultivation from different treatments was calculated considering added cost due to seeds of crop, fertilizers, herbicides and other inputs involving cultural practices.

Gross return

The gross returns (Rs. ha^{-1}) were calculated based on the Indian mustard seed and straw from each treatment and local market prices.

Net return

To identify the most economically viable treatment, a detailed economic analysis was conducted for each treatment based on net returns (Rs ha^{-1}). This analysis considered the current market prices of inputs, services, and crop produce, enabling the recommendation of the most profitable option.

Net return (Rs ha^{-1}) = Gross return (Rs ha^{-1}) -Total cost of cultivation (Rs ha^{-1})

B:C Ratio

The benefit-cost ratio was worked out on the basis of gross return and cost of cultivation

$$\text{Benefit:cost ratio (B:C)} = \frac{\text{Gross return (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs ha}^{-1}\text{)}}$$

Statistical analysis

The data collected from various observations were statistically analyzed following the procedure outlined by Cochran and Cox (1963).

Results and Discussion

Initial soil properties

A clayey loamy soil in texture with soil pH and EC (7.40 and 0.29 dSm^{-1}, respectively) before starting of experiment. Soil organic carbon (SOC) before the start of experiment was 0.45%. Soil having available nitrogen (206.0 kg ha^{-1}), phosphorus (10.04 kg ha^{-1}), potassium (239.0 kg ha^{-1}) and sulphur (8.9 kg ha^{-1}) before initiation of this experiment those helps to examined the comparable results during the study.

Soil pH, EC and SOC

The data presented in Table 2 indicated that soil

Table 2. Effect of organic and chemical fertilizer application on soil pH, electrical conductivity (EC) and soil organic carbon (SOC)

Treatments	pH	EC (dSm^{-1})	SOC (%)
T_1- 100% RDF (Urea + SSP + MOP)	7.71	0.28	0.33
T_2- 75% RDF + FYM @ 4 Mg ha^{-1}	7.70	0.27	0.37
T_3- 75% RDF + Vermicompost @ 1 Mg ha^{-1}	7.69	0.27	0.35
T_4- 75% RDF + FYM @ 4 Mg ha^{-1} + Vermicompost @ 1 Mg ha^{-1} + PSB (seed treatment)	7.68	0.26	0.38
T_5- 50% RDF + FYM @ 8 Mg ha^{-1}	7.68	0.26	0.39
T_6- 50% RDF + Vermicompost @ 2 Mg ha^{-1}	7.69	0.25	0.36
T_7- 50% RDF + FYM @ 4 Mg ha^{-1} + Vermicompost @ 1 Mg ha^{-1} + PSB (seed treatment)	7.66	0.25	0.38
T_8- FYM @ 8 Mg ha^{-1} + Vermicompost @ 2 Mg ha^{-1} + PSB (seed treatment)	7.65	0.25	0.40
S.Em+	0.05	0.012	0.03
LSD (p=0.05)	NS	NS	NS

pH and electrical conductivity (EC) ranged from 7.65 to 7.71 and 0.25 to 0.27 dS m^{-1}, respectively, and were not significantly affected by the different nutrient management practices, consistent with findings by Mohammad *et al.* (2004), Przybysz *et al.* (2014), Ali and Al-Kalil (2015), and Alkhader and Rayyan (2015). The highest soil pH and EC (7.71 and 0.27 dS m^{-1}, respectively) were recorded under T1 - 100% RDF (Urea + SSP + MOP) - compared to other treatments. The reduction in soil pH and EC with the use of organic manures may be attributed to the gradual release of hydrogen ions through the addition of organic matter, as also reported by Mossie *et al.* (2024), Wabela *et al.* (2024), and Prashar *et al.* (2025). Soil organic carbon (SOC) increased under different nutrient management practices, likely due to enhanced root growth contributing more organic residues to the soil, which upon decomposition increased SOC content (Meena *et al.*, 2018). SOC ranged from 0.33 to 0.40% and was not significantly affected by the treatments, with the highest value (0.40%) observed in T8 - FYM @ 8 Mg ha^{-1} + Vermicompost @ 2 Mg ha^{-1} + PSB (seed treatment).

Available N

The data on available soil N, obtained after the harvest of mustard, was influenced by different doses of organic and chemical fertilizer also reported by Navghare *et al.* (2023), Sahu *et al.* (2024), Sharma *et al.* (2024). The data are presented in Fig. 1. The available soil N was found significantly higher under all treatments as compared to T8 (FYM @ 8 Mg ha^{-1} + Vermicompost @ 2 Mg ha^{-1} + PSB) also reported by Pramanik *et al.* (2020). The significantly higher available soil N was recorded under T4-75% RDF + FYM @ 4 Mg ha^{-1} + Vermicompost @ 1 Mg ha^{-1} + PSB (seed treatment) (228 kg ha^{-1}) which was found significant than other treatment but found at par with the treatment T1-100% RDF (Urea + SSP + MOP) (219 kg ha^{-1}) and the minimum available nitrogen (178 kg ha^{-1}) was recorded with T8- FYM @ 8 Mg ha^{-1} + Vermicompost @ 2 Mg ha^{-1} + PSB.

Available P

The available soil phosphorus (P) after mustard harvest was influenced by the application of different combinations of organic and inorganic fertilizers, as also reported by Navghare *et al.* (2023), Sahu *et al.* (2024), and Sharma *et al.* (2024). The data are presented in Fig. 2. Available soil P was significantly higher under all treatments compared to T8 - FYM @ 8 Mg ha^{-1} + Vermicompost @ 2 Mg ha^{-1} + PSB. The highest available P (16.56 kg ha^{-1}) was recorded under T4 - 75% RDF + FYM @ 4 Mg ha^{-1} + Vermicompost @ 1 Mg ha^{-1} + PSB (seed treatment) - which was significantly greater than most treatments and statistically comparable to T1 - 100% RDF (Urea + SSP + MOP), which recorded 15.75 kg ha^{-1}. The lowest available P (11.40 kg ha^{-1}) was observed under T8. These findings are in agreement with previous reports by Arafa *et al.* (2011), Singh *et al.* (2015), Sarhan and El-Gayed (2017), and Meshram *et al.* (2024).

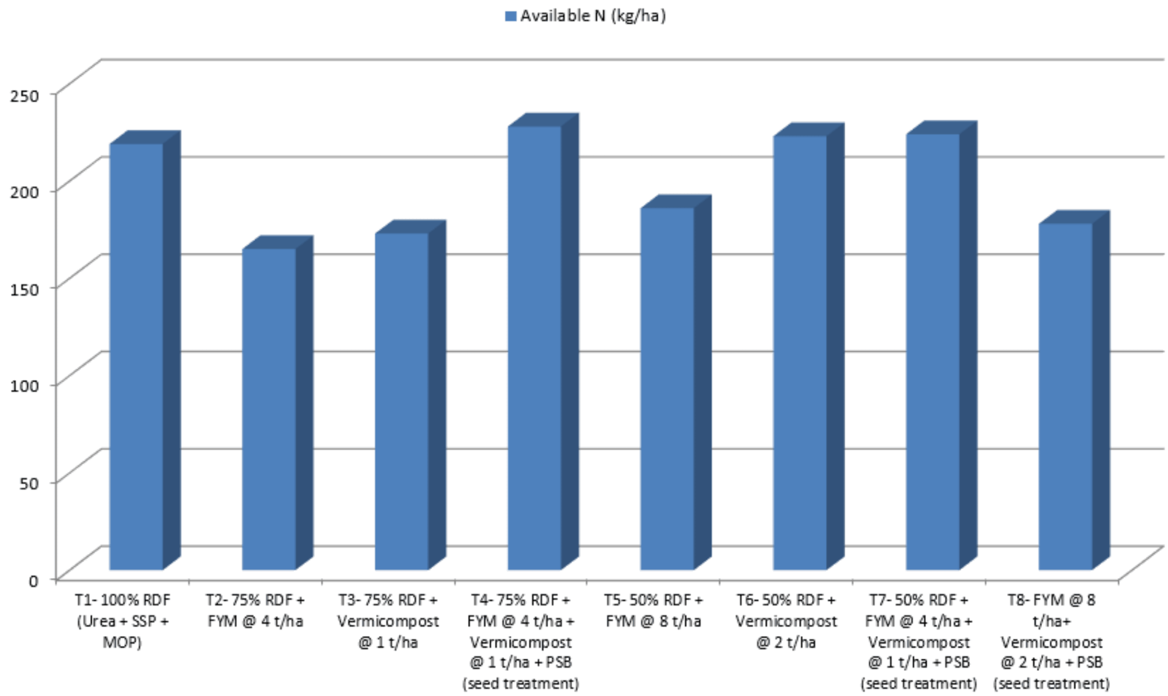

Fig. 1 Effect of organic and chemical fertilizer application on available N content in soil after harvest of crop

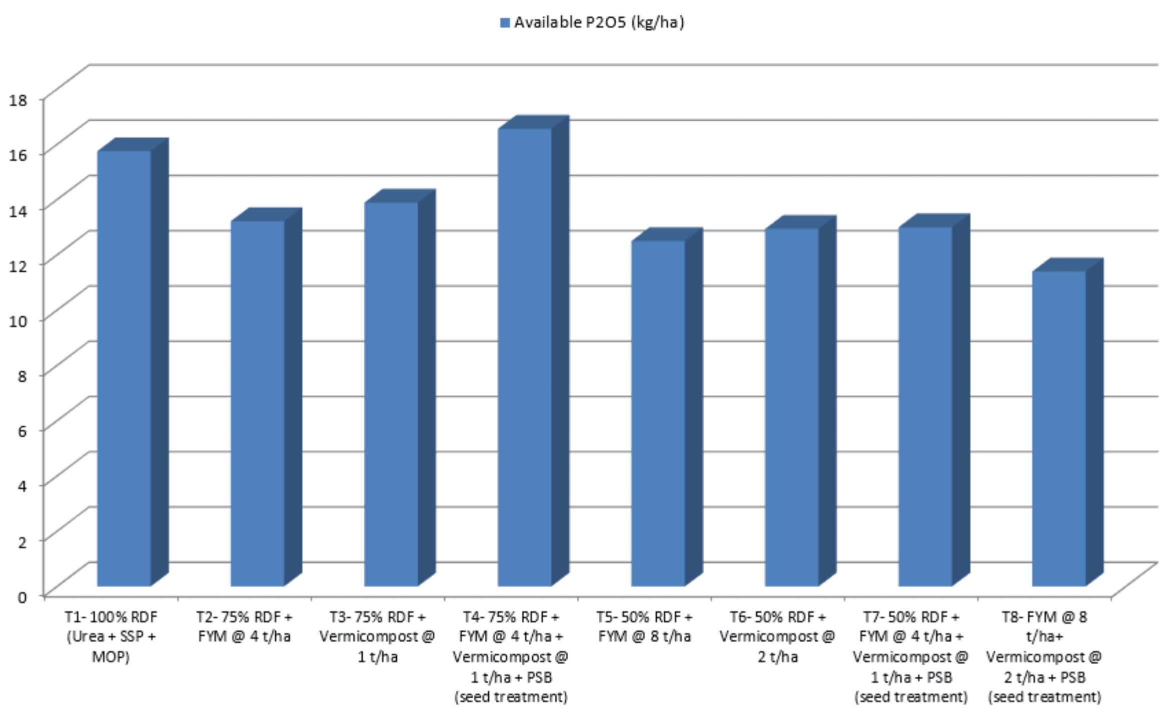

Fig. 2 Effect of organic and chemical fertilizer application on available phosphorus content in soil after harvest of crop

Available K

The available soil potassium (K) after mustard harvest was affected by the application of various organic and inorganic fertilizers, as also reported by Navghare *et al.* (2023), Sahu *et al.* (2024), and Sharma *et al.* (2024). The data are presented in Fig. 3. Available soil K was significantly higher under all treatments compared to T8 - FYM @ 8 Mg ha^{-1} + Vermicompost @ 2 Mg ha^{-1} + PSB - consistent with the observations of Pramanik *et al.* (2020). The highest available K (231 kg ha^{-1}) was recorded under T4 - 75% RDF + FYM @ 4

Mg ha^{-1} + Vermicompost @ 1 Mg ha^{-1} + PSB (seed treatment) - which was significantly greater than most treatments and statistically comparable to T1 - 100% RDF (Urea + SSP + MOP), which recorded 224 kg ha^{-1}. The lowest available K (159 kg ha^{-1}) was observed under T8.

Available S

The data on available sulphur in soil after harvest of mustard, as influenced by different treatments of organic and chemical fertilizer also reported by Navghare *et al.* (2023), Sahu *et al.* (2024), Sharma *et al.* (2024). The data, presented in Fig. 4, indicated that available soil sulphur (S) was significantly higher under all treatments compared to T8 — FYM @ 8 Mg ha^{-1} + Vermicompost @ 2 Mg ha^{-1} + PSB. Similar trends have been reported by Pramanik *et al.* (2020). The maximum available sulphur (11.4 kg ha^{-1}) after harvest was recorded under T4 - 75% RDF + FYM @ 4 Mg ha^{-1} + Vermicompost @ 1 Mg ha^{-1} + PSB (seed treatment) - which was significantly higher than most treatments and statistically comparable to T1 - 100% RDF (Urea + SSP + MOP), which recorded 11.3 kg ha^{-1}. The lowest available sulphur (7.10 kg ha^{-1}) was observed under T8. However, the addition of organic and chemical fertilizer reduced dose of RDF and showed a lower residual soil fertility compared to that of 100% RDF, and this might be due to greater uptake of nutrients as well as less addition of fertilizer nutrients to the soil. Similar results had been reported by Arafa *et al.* (2011), Singh *et al.* (2015), Sarhan and El-Gayed (2017), Meshram *et al.* (2024).

Economics

Net returns

The data on net returns of mustard presented in Table 3. The data reveals that the net returns of mustard was increased significantly with different treatments of organic and chemical fertilizer. Net returns of mustard were found significantly higher under all treatments as except to T_8. The highest net returns from mustard were recorded under T4 - 75% RDF + FYM @ 4 Mg ha^{-1} + Vermicompost @ 1 Mg ha^{-1} + PSB (seed treatment) - amounting to Rs. 74,438 ha^{-1}, which was significantly greater than most other treatments and statistically comparable to T1 - 100% RDF (Rs. 71,775 ha^{-1}). The lowest net returns (Rs. 40,694 ha^{-1}) were observed under T8 - FYM @ 8 Mg ha^{-1} + Vermicompost @ 2 Mg ha^{-1} + PSB (seed treatment). The relatively lower cost associated

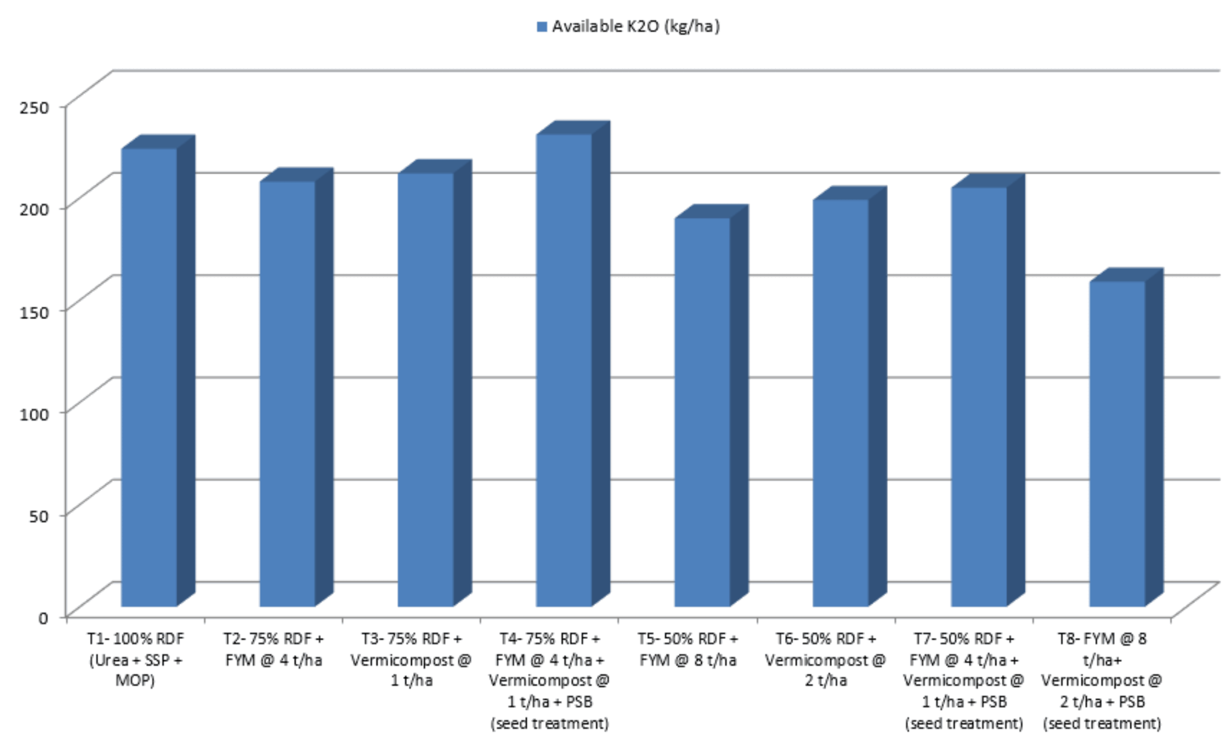

Fig. 3 Effect of organic and chemical fertilizer application on available potassium content in soil after harvest of crop

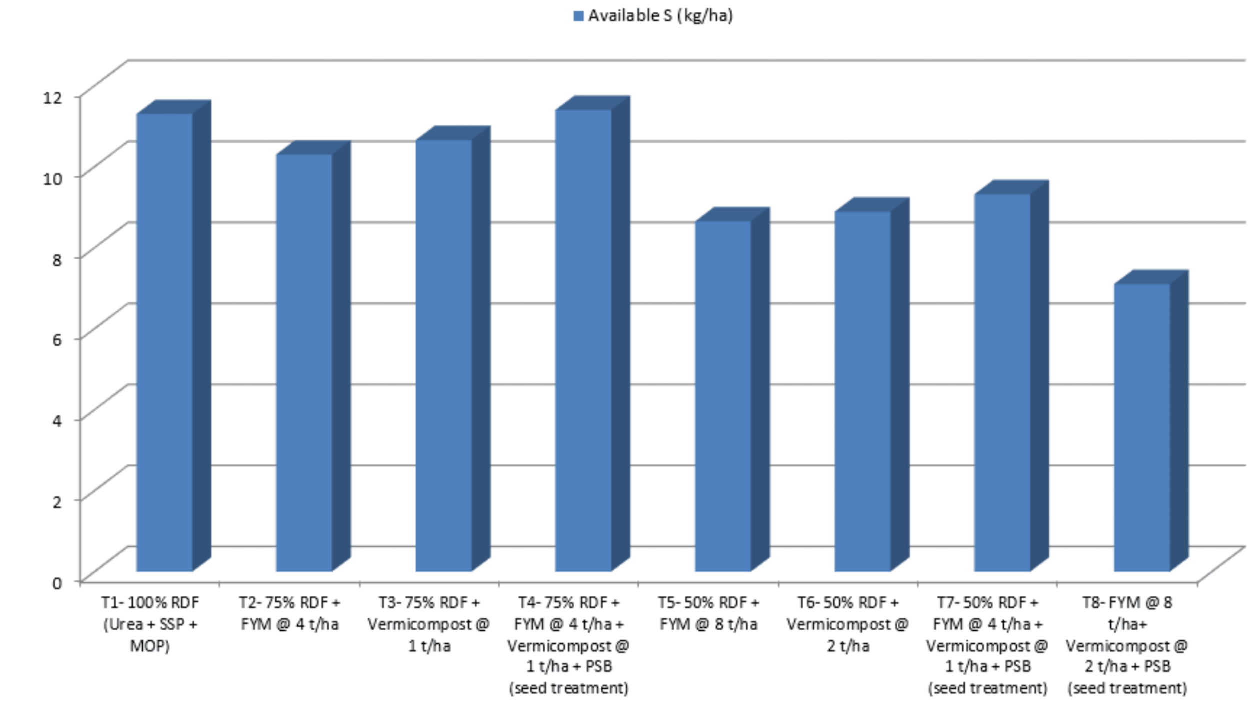

Fig. 4 Effect of organic and chemical fertilizer application on available sulphur content in soil after harvest of crop

Table 3. Effect of organic and chemical fertilizer application on net returns and B:C ratio of mustard

Treatments	Net returns (Rs ha^{-1})	B:C ratio
T_1- 100% RDF (Urea + SSP + MOP)	73732	3.92
T_2- 75% RDF + FYM @ 4 Mg ha^{-1}	53337	2.21
T_3- 75% RDF + Vermicompost @ 1 Mg ha^{-1}	50322	2.08
T_4- 75% RDF + FYM @ 4 Mg ha^{-1} + Vermicompost @ 1 Mg ha^{-1} + PSB (seed treatment)	74438	2.46
T_5- 50% RDF + FYM @ 8 Mg ha^{-1}	56609	1.92
T_6- 50% RDF + Vermicompost @ 2 Mg ha^{-1}	61036	2.07
T_7- 50% RDF + FYM @ 4 Mg ha^{-1} + Vermicompost @ 1 Mg ha^{-1} + PSB (seed treatment)	63344	2.14
T_8- FYM @ 8 Mg ha^{-1} + Vermicompost @ 2 Mg ha^{-1} + PSB (seed treatment)	40694	1.01
S.Em+	2816	0.09
LSD (p=0.05)	8539	0.28

with T4 contributed to higher net returns compared to other treatments. Similar results have been reported by Hadiyal *et al.* (2017), Thaneshwar *et al.* (2017), Dhruw *et al.* (2017), Saini *et al.* (2017), Kumar *et al.* (2018), Kumar *et al.* (2018a), Yadav *et al.* (2023), and Sharma *et al.* (2024) in mustard.

B:C ratio

The data on B:C ratio of mustard presented in Table 3. The data reveals that the B:C ratio of mustard was increased significantly with different treatments of organic and chemical fertilizer. The B:C ratio of mustard was found significantly higher under all treatments. The significantly higher B:C ratio of mustard was recorded under T1- 100% RDF (3.92) which was found significant than other treatment but found at par with the treatment T4-75% RDF + FYM @ 4 Mg ha^{-1} + Vermicompost @ 1 Mg ha^{-1} + PSB (seed treatment) (2.46). The costs associated with these treatments were relatively lower compared to the additional income generated, resulting in higher net returns than other treatments. Similar observations have been reported by Hadiyal *et al.* (2017), Thaneshwar *et al.* (2017), Dhruw *et al.* (2017), Saini *et al.* (2017), Kumar *et al.* (2018), Kumar *et al.* (2018a), Yadav *et al.* (2023), and Sharma *et al.* (2024) in mustard. The lowest benefit-to-cost (B:C) ratio (1.01) was recorded under T8 — FYM @ 8 Mg ha^{-1} + Vermicompost @ 2 Mg ha^{-1} + PSB (seed treatment).

Conclusion

Based on the findings of this study, it can be concluded that the combined use of organic and inorganic fertilizers markedly enhanced soil fertility and economic returns of Indian mustard grown on slightly saline soils in the Gird region of Central India. Soil pH, EC, and SOC, however, showed only non-significant changes. The highest available N, K, and S in the soil were achieved with the application of 75% RDF along with Farmyard Manure (FYM) at 4 t ha^{-1}, Vermicompost at 1 t ha^{-1}, and Phosphate Solubilizing Bacteria (PSB) as a seed treatment (T4). Furthermore, the maximum available soil P and the highest benefit-to-cost (B:C) ratio were observed under 100% RDF (T1). These results emphasize that integrating organic amendments with chemical fertilizers is effective and underscores the need for policies promoting sustainable nutrient management.

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