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Effect of Nutrient Management on Physico-chemical Properties of Soil in Indian Mustard

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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

A field experiment was conducted at the IFS Unit Instructional Farm of Banda University of Agriculture & Technology, Banda (UP) during the winter *(rabi*) seasons of 2022-23 and 2023-24. The study aimed to examine the impact of nutrient management on the soil properties of Indian mustard (*Brassica juncea* L.) grown in clay loam soil. Mustard, an essential oilseed crop in India,

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encounters issues like low productivity and diminished soil fertility caused by excessive use of chemical fertilizers. The paper highlights the importance of integrating chemical and organic sources, such as vermicompost. Vermicompost enriched with biofertilizers, especially Azotobacter, PSB, PMB, NPK Consortia, and ZSB demonstrates significant potential in improving the soil conditions for mustard crops. The experiment utilized a split plot design (SPD) with four main factors in the main plot and four levels in the sub-plot, resulting in sixteen treatment combinations, each applied three times. The soil at the experimental site was characterized by a clay loam texture and low levels of organic carbon, available nitrogen, phosphorus, zinc and sulfur, with moderate levels of available potash. The main plot treatments consisted of different fertility levels: 50% RNPKS, 75% RNPKS, 100% RNPKS and 125% RNPKS. Each main plot was further divided into four sub-plots, each with a combination of micronutrients and enriched vermicompost. The results indicated that the treatment of either 125% or 100% RNPKS and 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost ha^{-1} was superior in improving the soil properties for Indian mustard.

Keywords: Organic and inorganic nutrients; biofertilizers; soil fertility; enriched vermicompost.

1. INTRODUCTION

Oilseed crops are grown mainly for their oil-rich seeds, which serve a variety of purposes in food, animal feed, industrial applications, and biofuels. The production of oilseeds is crucial in global agriculture, providing substantial economic and nutritional advantages. India plays a major role in the global oilseed industry, both in terms of production and consumption.In the 2018-19 periods, rapeseed-mustard cultivation covered an estimated global area of 36.59 mha, producing approximately 72.37 mt with an average yield of 1980 kg ha^{-1} [1]. Mustard crop cultivation is pivotal in agriculture, offering substantial economic advantages to farmers as a prominent oilseed crop. It fosters agricultural diversity through crop rotation, enhancing soil health, and mitigating pest and disease cycles. Mustard crops demonstrate adaptability, thriving in various climates, including semi-arid and arid regions, thereby playing a pivotal role in diverse agricultural systems [2-5]. With their high oil and protein content, mustard seeds contribute significantly to food security. The seeds are predominantly processed into mustard oil, renowned for its unique flavor and health benefits, particularly in South Asian cuisine. They also serve as raw materials for condiments like mustard paste and powder. Mustard cake, a byproduct of oil extraction, serves as a valuable protein-rich animal feed. Moreover, mustard plants can enrich soil fertility when used as green manure, mustard oil finds utility in various industrial sectors, including soap manufacturing, lubrication, and biofuel production, showcasing the crop's versatility.

Soil's physical and chemical attributes are vital for its overall fertility and health. Physical characteristics, including texture, structure, porosity, and density, impact water retention, aeration, and root development. Porosity, the space between soil particles, controls water storage and movement, along with gas exchange. Density, representing soil mass per unit volume, affects root growth and microbial life. Chemical properties, such as pH, electrical conductivity, nutrient levels, cation exchange capacity (CEC), and organic material content, are also crucial. Soil pH, indicating acidity or alkalinity, significantly influences nutrient availability and microbial functions. Organic material, derived from plant and animal decay, improves soil structure, water retention, and nutrient recycling.Mustard production in India has shown variability influenced by multiple factors. Imbalanced nutrition is a key constraint to achieving higher mustard productivity, oil content and other soil parameters Lal et al*.* [6]. The low yields of Indian mustard are mainly due to poor nutrient management and plant protection measures, with soils often lacking nitrogen, phosphorus, and sulfur. The deficiency is exacerbated by multiple cropping and high-yielding varieties. Integrating chemical fertilizers with organic manures, like vermicompost, is effective in maintaining soil health, productivity, and stable crop production. Vermicompost, though costlier than chemical fertilizers, enriches the soil with essential nutrients and enhances soil structure by improving soil aggregates Kumawat et al*.* [7]. Achieving the right balance and applying nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) appropriately are crucial for enhancing both the physical and chemical characteristics of the soil in mustard farming. Effective nutrient management is crucial for maintaining soil quality and sustaining high crop production over time Prasad et al. [8], Pal and Pathak, [9].

Nitrogen encourages sturdy plant growth and leaf formation, enriching soil fertility by boosting biomass production and microbial functions. Phosphorus supports root growth, enhances nutrient absorption and encourages the creation of durable organic compounds, which contribute to soil texture and water retention. Potassium improves water usage efficiency, seed and oil quality and the soil's ability to retain nutrients. Sulfur aids in protein creation, nitrogen utilization, and microbial activity in the soil, leading to improved fertility. Collectively, these essential nutrients optimize soil composition, nutrient accessibility, and microbial functions, promoting healthier mustard crops with enhanced yield and quality Meena et al. [10]. Rapeseed-mustard needs substantial nutrients for optimal yield, but inadequate supply often leads to low productivity. Enhancing productivity requires balanced and adequate nutrition from both organic and inorganic sources. Integrating these fertilizers ensures essential nutrient availability and improves soil and crop productivity Thakur et al. [11], Meena et al. [12].

Zinc (Zn) and boron (B) are micronutrients vital for sustaining soil fertility and fostering plant growth of mustard. Despite being needed in small amounts, they exert substantial influence on both the physical and chemical aspects of the soil. Zinc plays a pivotal role by activating enzymes and facilitating protein synthesis in plants, essential for their diverse physiological functions. It also promotes root growth and enhances the efficiency of nutrient absorption, indirectly benefiting soil structure and moisture retention. Halim et al. [13]. Conversely, boron is indispensable for cell wall construction and membrane stability in plants, crucial for their overall development. It regulates the transportation of nutrients within plants and supports carbohydrate metabolism, indirectly affecting soil characteristics by promoting robust plant growth. Additionally, boron aids in the effective utilization of other nutrients like nitrogen and phosphorus, thereby contributing to soil fertility. In essence, sufficient levels of zinc and boron in the soil not only foster plant development but also indirectly improve soil physical attributes such as structure and moisture retention, while optimizing chemical properties through enhanced nutrient uptake and utilization. Using organic fertilizers and managing them properly can provide crops with nutrients for an extended period. Among organic sources, vermicompost is especially beneficial, offering significant amounts of nitrogen and phosphorus Shilpa et al. [14]. Utilizing vermicompost enhances soil physical attributes by improving its structure and capacity for water retention, alongside augmenting soil fertility through the gradual release of vital nutrients and encouragement of microbial activity. Furthermore, vermicompost fosters the proliferation of beneficial microorganisms, which play pivotal roles in nutrient recycling and the breakdown of organic matter. Additionally, vermicompost has the capability to regulate soil pH levels, creating a more favorable environment for plant growth. Combining vermicompost (VC) and bio-fertilizers like Azotobacter, NPK Consortia with fertilizers supports profitable and sustainable production while improving soil's physical, chemical, and biological properties Meena et al. [15]. Keeping above facts in mind an experiment was conduct to know the proper nutrient management practices for enhancing physico-chemical properties of soil of Indian mustard.

2. MATERIALS AND METHODS

The experimental trial was conducted during the winter cropping seasons of 2022-23 and 2023-24 at the IFS unit Instructional Farm, located within the Banda University of Agriculture & Technology, Banda to know the best nutrient management practices for enhancing soil properties of Indian mustard.This unit is situated in the Central plateaus & Hill Region, falling under agro-climatic zone VIII. The experiment employed a split-plot design with three replications with four different fertility levels in main plot viz. 50% RNPKS, 75% RNPKS, 100% RNPKS and 125% RNPKS and four different combination of micronutrients with vermicompost in sub plot viz. 2.5 kg Zn + 0.5 kg B, 5 kg Zn + 1 kg B, 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost, 5 kg Zn + 1 kg B + 250 kg enriched vermicompost. This encompassing 16 treatment combinations viz. 50% RNPKS + 2.5 kg Zn + 0.5 kg B, 50% RNPKS + 5 kg Zn + 1 kg B, 50% RNPKS + 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost, 50% RNPKS + 5 kg Zn + 1 kg B + 250 kg enriched vermicompost, 75% RNPKS + 2.5 kg Zn + 0.5 kg B, 75% RNPKS+ 5 kg Zn + 1 kg B, 75% RNPKS+2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost, 75% RNPKS + 5 kg Zn + 1 kg B + 250 kg enriched vermicompost, 100% RNPKS+ 2.5 kg Zn + 0.5 kg B, 100% RNPKS + 5 kg Zn + 1 kg B, 100%

RNPKS + 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost, 100% RNPKS + 5 kg Zn + 1 kg B + 250 kg enriched vermicompost, 125% RNPKS+ 2.5 kg Zn + 0.5 kg B, 125% RNPKS + 5 kg Zn + 1 kg B, 125% RNPKS+ 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost, 125% RNPKS+ 5 kg Zn + 1 kg B + 250 kg enriched vermicompost.

The experimental site's soil was identified as clay loam with low organic carbon and available nutrients such as nitrogen, phosphorus, zinc, and sulphur, along with moderate levels of available potash. For the study, the 'Giriraj (DRMRIJ-31)' cultivar of Indian mustard was selected as the test crop. Indian mustard seeds were manually sown at a rate of 3 kg per hectare.The recommended quantities of NPKS (90 kg N, 45 kg P_20_5, 30 kg K_20, and 25 kg S) were applied using Urea, di-ammonium phosphate, muriate of potash, and sulphur bentonite. Zinc and boron were applied via zinc sulphate monohydrate and disodium octaborate tetrahydrate. 500 kg vermicompost is treated by 1 litre of each bacteria namely Azotobacter + NPK consortia + PSB + PMB +ZSB. In both years of the seasons, the mustard crop received fertilizer application with half of the nitrogen dosage applied alongside full doses of phosphorus, potassium, and sulphur during sowing as the basal dose in experimental plots. Furthermore, zinc sulphate monohydrate, disodium octaborate tetra hydrate and enriched vermicompost were also administered to the crop based on treatmentspecifications in corresponding plots. Following this, the remaining half of the nitrogen dosage was applied to the mustard crop during the first irrigation in both years, according to the respective plots.

RNPKS- Recommended doses of NPKS

Recommended Doses of 100% NPKS - (90 kg N, 45 kg P_20_5, 30 kg K_20, and 25 kg S)

Enriched vermicompost preparation - 500 kg vermicompost is treated by 1 litre of each bacteria namely Azotobacter + NPK consortia + Phosphate Solubilising Bacteria + Potassium Mobilising Bacteria + Zinc Soulbilising Bacteria.

3. RESULTS AND DISCUSSION

3.1 Soil pH

The pH of the soil post-harvest exhibited a tendency to decrease as a result of the combined application of organic manures alongside chemical fertilizers. Table 1 presents information related to the chemical properties of soil, indicating that the soil pH ranges from 7.12 to 7.75, which is either lower or similar to the initial value of soil pH. The analysis revealed that neither the main plot nor the sub-plot treatments had a significant effect on soil pH. However, the main plot treatment with 125% RNPKS (M_4) exhibited the lowest pH values, followed by 100% RNPKS (M_3). This trend was consistent in the sub-plot treatment involving the use of 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost (S_3) across both years of the experiment. Furthermore, the interaction between main plot and sub-plot treatments also did not significantly affect soil pH in either year of the experiment. This decline in soil pH could potentially be attributed to the oxidation of sulphur and the breakdown of vermicompost. Comparable findings were observed by Yadav et al*.* [16], Kansotia et al*.* [17] and Chandan et al*.* [18].

3.2 Electrical Conductivity

The data indicated an increase in soil electrical conductivity (EC) within the mustard field compared to the initial measurement of 0.17 dS m^{-1} (Table 1). Both main and sub-plot treatments had no significant impact on soil EC throughout the experiment's duration (Table 1). Generally, the combined application of various fertility levels and micronutrients with enriched vermicompost had a more pronounced effect on soil EC compared to individual applications. Post-harvest of Indian mustard, EC ranged from 0.16 to 0.17 dS m^{-1} in the first year and 0.17 to 0.18 dS m^{-1} in the second year. Consistently, the treatments with 125% RNPKS (M_4) and 100% RNKS (M_3) showed the lowest EC values in both years. Furthermore, the sub-plot treatments employing 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost (S_3) exhibited the lowest EC values in both years. Furthermore, the interaction between main plot and sub-plot treatments also did not significantly affect soil EC in either year of the experiment.

3.3 Organic Carbon

The data indicated an increase in soil organic carbon (OC) within the mustard field compared to the initial measurement of 0.44% (Table 1). Table 1 presents information on soil organic carbon (OC) in both years. Soil organic carbon content increased with the integrated use of different fertility levels and micronutrients with enriched vermicompost compared to alone applications. The analysis of the data revealed that neither the main plot nor the sub-plot treatments significantly affected soil organic carbon levels in both year of experiment. However, the main plot treatment with 125% RNPKS (M_4) exhibited higher OC values, followed by 100% RNPKS (M_3), which was

Table 1. Effect of main plot and sub plot treatments on soil pH, soil EC and organic carbon of post harvest soil of Indian mustard

Treatment	Soil pH		Soil EC (dsm^{-2})		Soil OC (%)	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Main plot treatments						
M_1 – 50% RNPKS	7.65	7.27	0.17	0.18	0.44	0.45
M_2 - 75% RNPKS	7.65	7.20	0.17	0.18	0.45	0.47
M_3 -100% RNPKS	7.58	7.19	0.16	0.17	0.45	0.47
M_4 - 125%NPKS	7.57	7.12	0.16	0.17	0.46	0.47
SEM± for MPT	0.15	0.16	0.01	0.00	0.01	0.01
C.D. (0.05)	NS	NS	NS	NS	NS	NS
Sub plot treatments						
S_1-2.5 kg Zn + 0.5 kg B	7.75	7.30	0.17	0.18	0.44	0.45
S_2-5 kg Zn + 1 kg B	7.71	7.26	0.17	0.18	0.45	0.46
S_3-2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost	7.49	7.19	0.16	0.17	0.46	0.47
S_4-5 kg Zn + 1 kg B + 250 kg enriched vermicompost	7.50	7.21	0.17	0.18	0.46	0.47
SEM± for SPT	0.13	0.14	0.00	0.00	0.01	0.01
C.D.(0.05)	NS	NS	NS	NS	NS	NS
Interaction(MXS)	NS	NS	NS	NS	NS	NS
Initial value	7.80		0.17		0.44	

Table 2. Effect of main plot and sub plot treatments on Bulk density, Particle densityand porosity of post harvest soil of Indian mustard

Treatment	Bulk density (Mg m^{-3})		Particle density (Mg m^{-3})		Porosity (%)	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Main plot treatments						
M_1 – 50% RNPKS	1.33	1.32	2.64	2.63	49.773	49.810
M_2 - 75% RNPKS	1.32	1.32	2.63	2.63	49.886	49.905
M_3 -100% RNPKS	1.32	1.31	2.63	2.62	49.886	49.962
M_4 - 125%NPKS	1.31	1.30	2.62	2.61	50.000	50.192
SEM± for MPT	0.01	0.00	0.01	0.01	0.331	0.332
C.D. (0.05)	NS	NS	NS	NS	NS	NS
Sub plot treatments						
S_1-2.5 kg Zn + 0.5 kg B	1.32	1.32	2.62	2.62	49.465	49.713
S_2-5 kg Zn + 1 kg B	1.32	1.31	2.62	2.61	49.484	49.751
S_3-2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost	1.31	1.31	2.61	2.60	49.789	49.827
S_4-5 kg Zn + 1 kg B + 250 kg enriched vermicompost	1.32	1.31	2.61	2.61	49.502	49.770
SEM± for SPT	0.00	0.00	0.01	0.01	0.308	0.310
C.D. (0.05)	NS	NS	NS	NS	NS	NS
Interaction(MXS)	NS	NS	NS	NS	NS	NS
Initial value	1.33		2.64		49.379	

consistent with the trend observed in the sub-plot treatment involving the application of 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost (S_3) across both years of the experiment. Pathak et al. [19], Chandan et al. [18], Tomar et al. [20] and Kansotia et al. [17] also found that the combined application of nutrients contributes to the enhancement of organic carbon levels. Additionally, the interaction between main plot and sub-plot treatments did not significantly influence soil organic carbon levels in either year of the experiment.

3.4 Bulk Density

The data indicated a decrease in bulk density of soil within the mustard field compared to the initial measurement of1.33 Mg m^{-3} (Table 2). Table 2 presents information on bulk density of soil in both years. Bulk density decreased with the integrated use of different fertility levels and micronutrients with enriched vermicompost compared to alone applications. The analysis of the data revealed that neither the main plot nor the sub-plot treatments significantly affected the bulk density of soil in both year of experiment. However, the main plot treatment with 125% RNPKS (M_4) exhibited lower bulk density values, followed by 100% RNPKS (M_3), which was consistent with the trend observed in the sub-plot treatment involving the application of 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost (S_3) across both years of the experiment. Pathak et al. [19], Saha et al. [21] and Singh et al. [22] also found that the combined application of organic and inorganic nutrients contributes to lower the bulk density of soil. Additionally, the interaction between main plot and sub-plot treatments also did not significantly influence bulk density of soil in either year of the experiment.

3.5 Particle Density

The data indicated a decrease in particle density of soil within the mustard field compared to the initial measurement of2.64 Mg m^{-3} (Table 2). Table 2 presents information on particle density of soil in both years. Particle density decreased with the integrated use of different fertility levels and micronutrients with enriched vermicompost compared to alone applications. The analysis of the data revealed that neither the main plot nor the sub-plot treatments significantly affected the particle density of soil in both year of experiment. However, the main plot treatment with 125% RNPKS (M_4) exhibited lower particle density values, followed by 100% RNPKS (M_3), which was consistent with the trend observed in the sub-plot treatment involving the application of 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost (S_3) across both years of the experiment. Pathak et al. [19], Santhey et al. [23] and Singh et al. [24] also found that the combined application of organic and inorganic nutrients contributes to lower the particle density of soil. Additionally, the interaction between main plot and sub-plot treatments also did not significantly influence particle density of soil in either year of the experiment.

3.6 Porosity

The data indicated an increasein porosity of soil within the mustard field compared to the initial measurement of49% (Table 2). Table 2 presents information on porosity of soil in both years. Porosity increased with the integrated use of different fertility levels and micronutrients with enriched vermicompost compared to alone applications. The analysis of the data revealed that neither the main plot nor the sub-plot treatments significantly affected the porosity of soil in both year of experiment. However, the main plot treatment with 125% RNPKS (M_4) exhibited higher particle density values, followed by 100% RNPKS (M_3), which was consistent with the trend observed in the sub-plot treatment involving the application of 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost (S_3) across both years of the experiment. Additionally, the interaction between main plot and sub-plot treatments also did not significantly influence porosity of soil in either year of the experiment.

4. CONCLUSION

It is conclude that the treatment combination of either 125% or 100% RNPKS and 2.5 kg Zn + 0.5 kg B + 500 kg enriched vermicompost gave best respond related to soil physico-chemical properties (Soil pH, Soil EC, Soil OC, Bulk density, Particle density and porosity) of Indian mustard.

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 writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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