

Assessment of Vermicompost, Biofertilizer and Inorganic Fertilizer Application for Improving Soil Fertility in Sandy Loam Soils of Rajasthan

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Abstract

The study evaluated the impact of vermicompost, biofertilizer, and inorganic fertilizers on soil fertility in sandy loam soil under Rajasthan's semi-arid conditions. The initial soil was slightly alkaline (pH 8.5), non-saline (EC 0.69 dS m⁻¹), low in available nitrogen (81 kg ha⁻¹) and organic carbon (0.25%), and moderate in phosphorus, potassium, sulfur, and micronutrients. After cropping, significant improvements in soil properties were observed under organic treatments. Vermicompost treatment (T₄) recorded the highest electrical conductivity (0.26 dS m⁻¹), organic carbon (0.33%), sulfur (29.63 ppm), and copper (0.44 ppm). The combined application of vermicompost and biofertilizer (T₅) resulted in the highest available nitrogen (119.28 kg ha⁻¹), zinc (0.67 ppm), iron (4.70 ppm), and manganese (3.08 ppm). Treatment T₃ showed the highest soil pH and available phosphorus, while the control treatment retained the highest available potassium. Overall, vermicompost improved soil organic carbon and micronutrient availability, whereas biofertilizer enhanced nitrogen content. The combined application of vermicompost and biofertilizer proved most effective in improving soil fertility and nutrient status under semi-arid conditions.

Keywords: Fertilizers; Manures; Nutrients; Soil fertility; Sesame

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Introduction

Sesamum indicum L., is one of the most significant and ancient oilseed crops grown worldwide belonging to the family Pedaliaceae. Often referred to as Sesame, Til, or Gingelly, and valued for its high-quality edible oil, nutritional richness, and adaptability to diverse agro-climatic conditions. Particularly in semi-arid areas like western Rajasthan, sesame plays a major role in India's agricultural economy and makes a big contribution to both local consumption and export revenue [1]. With an output of roughly 8.66 lakh tonnes from an area of over 19.47 lakh hectares, India is the world's top producer of sesame. Nonetheless, India's average sesame yield of 413 kg ha⁻¹ is still less than the global average of roughly 535 kg ha⁻¹ [2].

The relatively low productivity of sesame in India can be attributed to several factors, including traditional farming practices, cultivation under rain fed conditions, and the predominance of marginal and sub-marginal soils with poor fertility status. In addition, limited use of balanced fertilizers and inadequate nutrient management practices further restrict crop productivity [1]. Among the various factors influencing crop performance, soil fertility and soil health are key determinants of sustainable agricultural productivity. The application of mineral fertilizers plays an important role in meeting the nutrient requirements of crops and improving yield; however, excessive or unbalanced use of chemical fertilizers can adversely affect soil physical

structure, nutrient balance, and microbial activity over time [3]. In this context, the incorporation of organic amendments has gained increasing attention as a sustainable strategy for improving soil fertility and maintaining soil health. Organic manures such as farmyard manure, compost, vermicompost, and green manures contribute to the gradual release of nutrients, enhance soil organic matter content, improve soil structure, and stimulate beneficial microbial activity. These benefits ultimately lead to improved nutrient availability and better crop growth while minimizing environmental degradation.

Previous studies have demonstrated the positive impact of organic amendments on soil properties. For instance, Abdurrahman et al. [4] reported that the application of compost significantly reduced soil pH (from 9.75 to 8.22), electrical conductivity (from 12.35 to 2.25 dS m⁻¹), and exchangeable sodium percentage (from 44.75 to 6.61%), thereby improving soil quality. Similarly, Rainder and Mandeep [5] observed that the application of organic manures, either alone or in combination with nitrogen fertilizers, increased the availability of phosphorus, potassium, and DTPA-extractable micronutrients such as Zn, Fe, Mn, and Cu in the soil. Other studies have indicated that compost-based fertilizers can reduce soil salinity and pH while increasing the concentrations of essential

nutrients such as nitrogen, phosphorus, calcium, and magnesium [6].

Efficient recycling of organic residues through farmyard manure (FYM), compost, vermicompost, and green manure is considered an effective approach for improving soil fertility and sustaining crop productivity [7]. Furthermore, the use of biofertilizers can enhance nutrient availability through biological processes such as nitrogen fixation and phosphate solubilization, thereby improving the soil-plant nutrient cycle [8]. In recent years, vermicompost has emerged as a promising organic amendment due to its high nutrient content, improved microbial activity, and presence of plant growth-promoting substances. It not only supplies essential macro- and micronutrients but also improves soil physical and biochemical properties, thereby enhancing crop productivity [9].

Despite the recognized benefits of organic amendments, the comparative effects of organic and inorganic fertilizers on soil fertility dynamics after sesame cultivation under semi-arid conditions are still not sufficiently explored. In particular, limited studies have investigated the changes in soil physico-chemical properties following sesame harvest under different nutrient management practices in Rajasthan. Therefore, the present study was undertaken to evaluate the effects of organic and inorganic fertilizer treatments on soil

fertility and to assess the changes in soil physico-chemical properties after harvesting sesame under semi-arid conditions of Rajasthan.

2. Materials and methods

2.1 experiment site

The study was conducted during 2017–2019 at the Department of Botany, University of Rajasthan, Jaipur, India (26°53'19.2" N, 75°48'53.3" E). The crop was sown in July under natural field conditions. During the cropping period, the maximum temperature ranged from 28 to 35 °C, while the minimum temperature varied between 20 and 30 °C.

2.2 soil sampling and chemical analysis

Soil samples were collected from the experimental site at the Department of Botany, University of Rajasthan, Jaipur, India. Plastic pots with a capacity of 1 kg were used for conducting the experiment. The soil texture was classified as sandy loam. Prior to sowing, soil samples were analyzed for their physico-chemical properties [Table 1]. Parameters including pH, electrical conductivity (EC), water holding capacity, organic carbon, total nitrogen, available phosphorus, potassium, sulfur, and micronutrients (zinc, iron, copper, and manganese) were determined using standard analytical methods [10].

Physico-chemical Properties	Value	Dept. of Agri. & Crop. Ministry of Agri. GOI *(DL-MPL)
Soil texture	Sandy loam	-
pH	8.5	6.5-8.5
WHC (%)	36	-
EC (mS/cm)	0.69	0.2
Macronutrients		
Organic carbon (%)	0.25	0.5-0.75
N (kg per hectare)	81	280-560
P (kg per hectare)	26	10-24.6
K (kg per hectare)	238	108-280
S (ppm)	22.72	8-30
Micronutrients		
Zinc (ppm)	1.08	0.4-1.2
Iron (ppm)	4.76	2.5-4.5
Copper (ppm)	0.28	≥0.20
Manganese (ppm)	2.19	≥2.0

Table 1: Experimental soil properties before cropping of *Sesamum indicum* plant

*Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India

DL- Desired limit, MPL-Maximum permissible limit

2.3 experiment design and treatment

The experiment was conducted using plastic pots containing 1 kg of soil, arranged in a completely randomized design (CRD) with five treatments and four replicates [Fig. 1]. The study included two chemical fertilizers, urea and diammonium phosphate (DAP), one organic amendment (vermicompost), and one biofertilizer (Azotobacter). All treatments were applied according to standard procedures [11] and recommendations provided by the Rajasthan Agricultural Research Institute, Durgapura, Jaipur.

The treatments were designated as T₁–T₅: T₁ (control, sandy loam soil without amendment); T₂ (urea applied in two split

doses, at sowing and one month after sowing); T₃ (DAP applied as a basal dose prior to sowing); T₄ (vermicompost applied 15 days before sowing); and T₅ (biofertilizer (Azotobacter) applied along with vermicompost 15 days before sowing).

Sesame (*Sesamum indicum* L.) seeds (variety ‘Super Sona-51’) were sown in July during the 2017–2019 cropping seasons [Figs. 1 and 2]. The crop was harvested in October at physiological maturity, indicated by the yellowing of leaves. After harvest, soil samples were collected randomly from ten pots per treatment at a depth of 0–15 cm. The samples were air-dried, sieved, and stored in polyethylene bags for further analysis.



Figure 1. Pot experiment illustrating early seedling growth under varying fertilizer treatments.



Figure 2. Comparative plant growth under five fertilizer treatments (T1–T5).

2.4 data analysis

Statistical analyses were performed using R software (version 3.5). Differences among treatments were evaluated using one-way analysis of variance (ANOVA). Where appropriate, pairwise comparisons between treatment means were conducted using the t-test. Standard error of the mean ($SEm \pm$) and critical difference (CD) values were calculated using OPSTAT software. Statistical significance was determined at the 5% probability level ($p \leq 0.05$).

3. Results

3.1 effect on physical and chemical properties of soil:

The physico-chemical properties of soil, including pH, electrical conductivity (EC), water holding capacity, macronutrients (organic carbon, available nitrogen, phosphorus, and potassium), and micronutrients (zinc, iron, copper, manganese, and sulfur), were analyzed before and after crop cultivation [Tables 1 and 2].

Prior to sowing, the soil was characterized as sandy loam with a pH of 8.5, indicating a slightly alkaline nature, and an EC of 0.69 dS m^{-1} . The water holding capacity was recorded as 36% [Table 1]. Among macronutrients, organic carbon (0.25%) and available nitrogen (81 kg ha^{-1}) were found to be low compared to standard ranges. Available phosphorus (26 kg ha^{-1}) was within the normal range, while potassium (238 kg ha^{-1}) was in the medium range. Sulfur content (22.72 ppm) was within the adequate range.

Micronutrient analysis revealed that zinc (1.08 ppm) was within the sufficient range, while iron (4.76 ppm) was slightly above the sufficient level. Copper (0.28 ppm) and manganese (2.19 ppm) were also within acceptable limits [Table 1].

Table 2. Changes in Soil Physico-Chemical Properties after Cropping Under Different Fertilizer Treatments

Treatments	pH	EC	OC (%)	N (Kg/hect)	P (Kg/hect)	K (Kg/hect)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
T1 (Control)	8.08±0.29	0.18±0.03	0.22±0.04	76.74±1.76	34.66±4.61	298.33±48.56	22.63±4.21	0.54±0.13	4.05±0.21	0.26±0.06	2.76±0.52
T2 (N Fertilizer)	8.1±0.24	0.25±0.08	0.25±0.01	102.75±2.45**	35.33±6.42	287.66±58.82	25.73±7.73	0.6±0.08	4.29±0.59	0.32±0.08	2.54±0.12
T3 (NP Fertilizer)	8.27±0.38	0.25±0.11	0.31±0.005	103.69±2.99**	37.33±6.42	298±33.64	28.2±6.75	0.58±0.15	3.75±0.56	0.30±0.04	3.08±0.51
T4 (Vermicompost)	8.06±0.21	0.26±0.06	0.33±0.01*	91.28±2.08**	35±11.78	255.66±22.94	29.63±9.15	0.65±0.05	4.49±0.42	0.44±0.21	2.85±0.96
T5 (Biofertilizer)	8.04±0.43	0.23±0.04	0.29±0.01	119.28±6.76**	32.33±2.51	258.33±17.55	20.53±0.11	0.67±0.15	4.70±0.43	0.41±0.29	3.08±0.83
SEm±	0.16	0.038	0.012	2.13	4.07	22.78	3.15	0.07	0.23	0.08	0.33
CD	NS	NS	0.037	6.80	NS	NS	NS	NS	NS	NS	NS

Level of significance: ***= $p \leq 0.001$, **= $p \leq 0.01$, *= $p \leq 0.05$, NS=Not significant

Here, EC: Electrical conductivity, N: Nitrogen, P: Phosphate, K: Potash, S: Sulfur, Zn: Zinc, Fe: Iron, Cu: Copper, Mn: Manganese
Following harvest of the sesame crop, variations in soil properties were observed across treatments [Table 2]. Soil texture remained unchanged across treatments. Soil pH was highest in T₃ (8.27 ± 0.38), followed by T₂ (8.10 ± 0.24), and lowest in T₅ (8.04 ± 0.43) [Fig. 3]. Electrical conductivity was highest in T₄ (0.26 ± 0.06 dS m⁻¹) and lowest in T₁ (0.18 ± 0.03 dS m⁻¹), with all values remaining within permissible limits [Fig. 4].

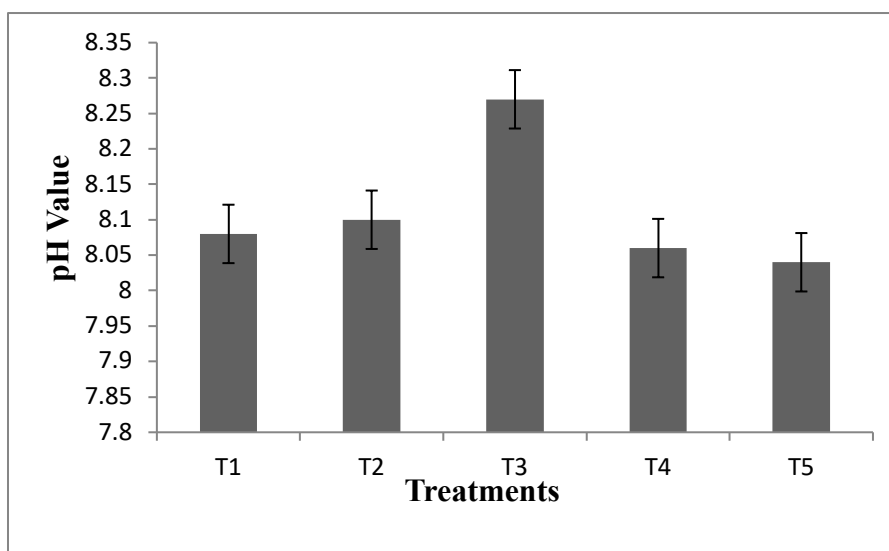


Fig 3: Effect of various fertilizer treatments on pH of soil after harvesting of sesame plant.

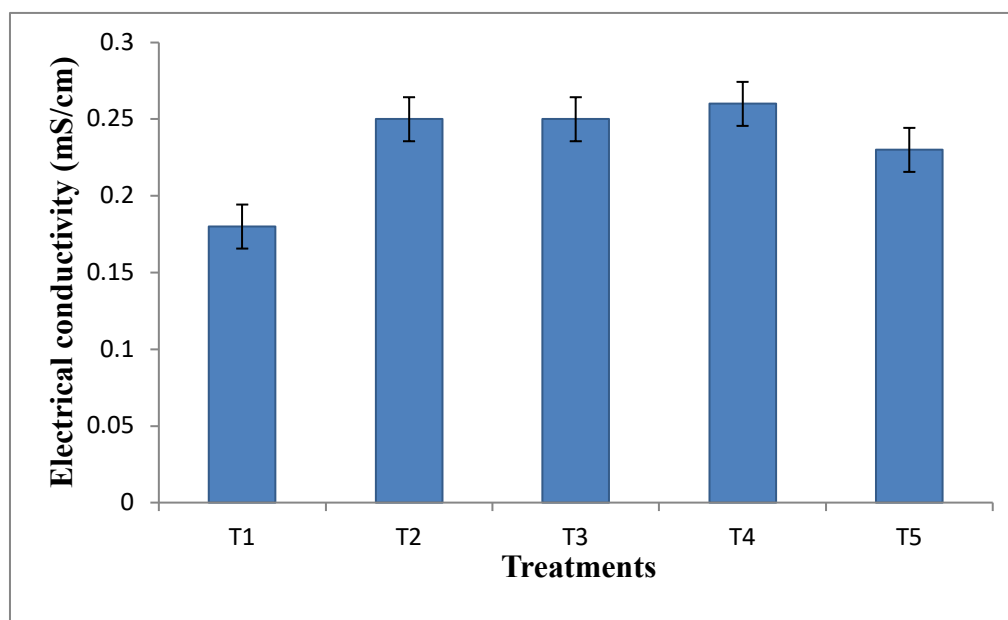


Fig 4: Effect of various fertilizer treatments on electrical conductivity of soil after harvesting of sesame plant.

Organic carbon content was highest in T₄ ($0.33 \pm 0.01\%$), followed by T₃ ($0.31 \pm 0.005\%$), T₅ ($0.29 \pm 0.01\%$), T₂ ($0.25 \pm 0.01\%$), and lowest in T₁ ($0.22 \pm 0.04\%$) [Fig. 5]. Available nitrogen was significantly higher in T₅ ($119.28 \pm 6.76 \text{ kg ha}^{-1}$), followed by T₃, T₂, and T₄, while the lowest value was recorded in T₁ ($76.74 \pm 1.76 \text{ kg ha}^{-1}$) [Fig. 6].

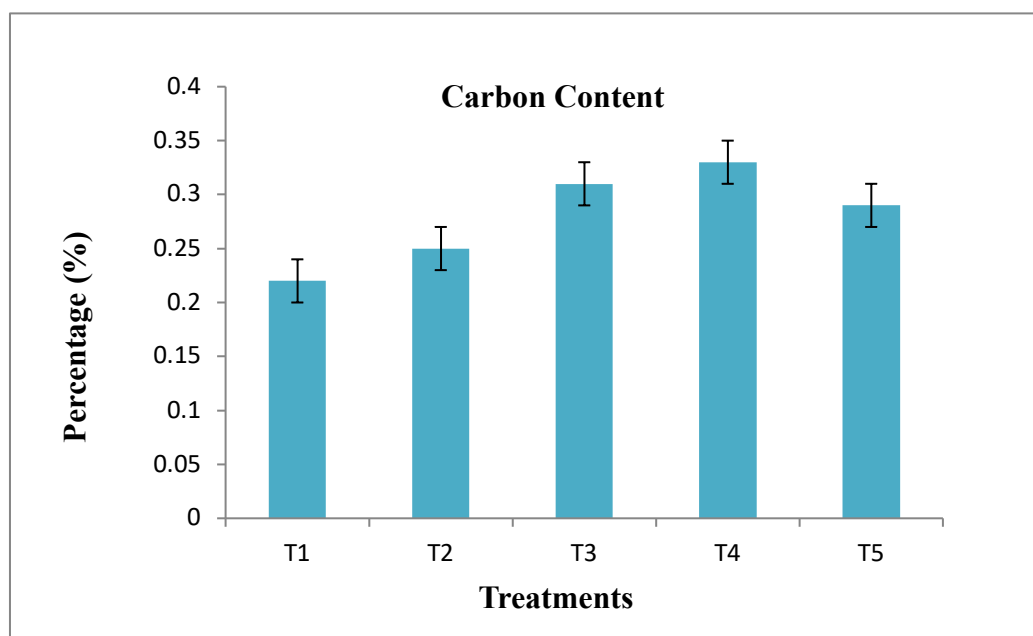


Fig 5: Effect of various fertilizer treatments on carbon content of soil after harvesting of sesame plant.

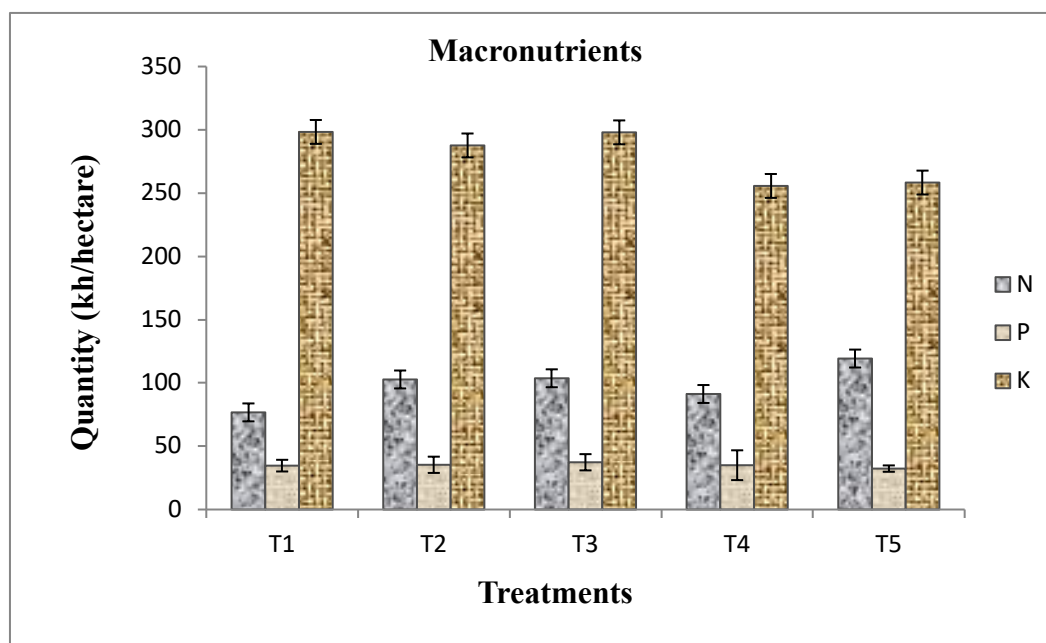


Fig 6: Fertilizers effect on N, P, K of soil after harvesting of sesame plant.

Available phosphorus was highest in T₃ ($37.33 \pm 6.42 \text{ kg ha}^{-1}$), whereas the lowest value was observed in T₅ ($32.33 \pm 2.51 \text{ kg ha}^{-1}$). Available potassium was highest in the control (T₁: $298.33 \pm 48.56 \text{ kg ha}^{-1}$) and lowest in T₄ ($255.66 \pm 22.94 \text{ kg ha}^{-1}$). Sulfur content was highest in T₄ ($29.63 \pm 9.15 \text{ ppm}$) and lowest in T₅ ($20.53 \pm 0.11 \text{ ppm}$) [Table 2; Fig. 7].

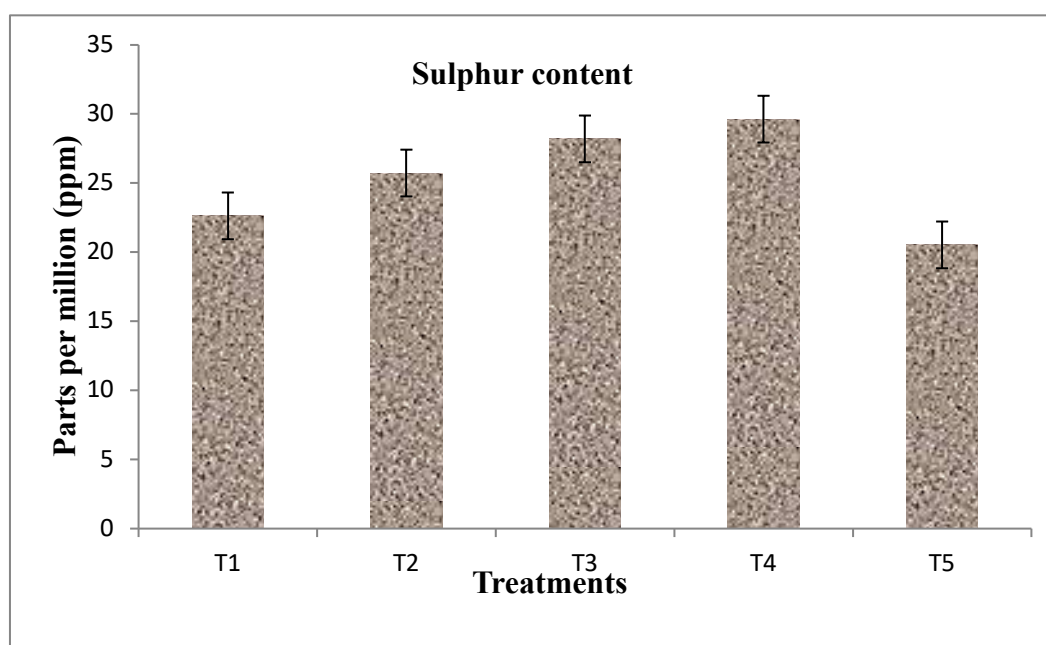


Fig 7: Fertilizers effect on sulfur status of soil after harvesting of sesame plant.

Among micronutrients, zinc content was highest in T₅ ($0.67 \pm 0.15 \text{ ppm}$) and lowest in T₁ ($0.54 \pm 0.13 \text{ ppm}$). Iron content was also highest in T₅ ($4.70 \pm 0.43 \text{ ppm}$) and lowest in T₃ ($3.75 \pm 0.56 \text{ ppm}$). Copper was highest in T₄ ($0.44 \pm 0.21 \text{ ppm}$) and lowest in T₁ ($0.26 \pm 0.06 \text{ ppm}$). Manganese content was highest in T₅ and T₃ (3.08 ppm) and lowest in T₂ ($2.54 \pm 0.12 \text{ ppm}$) [Table 2; Fig. 8].

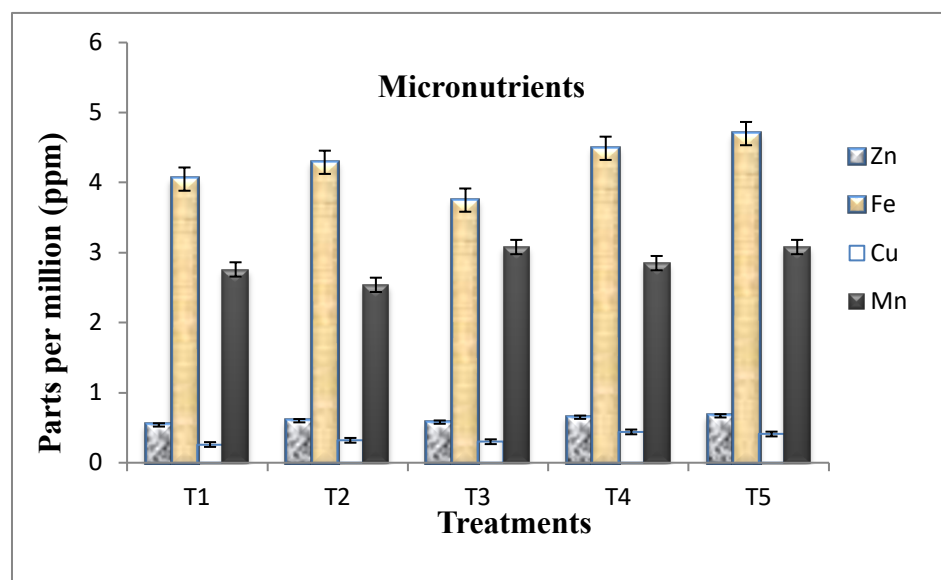


Fig 8: Fertilizers effect on micronutrients status of soil after harvesting of sesame plant.

4. Discussion

Fertilizers and organic amendments have been widely used to enhance crop productivity and soil fertility. Oilseed crops, in particular, play a significant role in the Indian economy by contributing to edible oil production as well as food and fodder resources. Therefore, maintaining soil health is essential, and soil pH is a key factor influencing nutrient availability and overall biochemical processes in soil. In the present study, soil pH showed a slight increase under inorganic fertilizer treatments, whereas the application of vermicompost and biofertilizers resulted in a reduction of alkalinity. These findings are consistent with earlier reports indicating that chemical fertilizers, particularly NPK, may increase soil pH [12–13]. In contrast, organic amendments such as compost, biofertilizers, and humic substances tend to reduce soil pH slightly, although often non-significantly [3,14]. This reduction may be attributed to the production of organic acids during decomposition.

Electrical conductivity (EC), an indicator of soluble salts and nutrient availability, was highest in the vermicompost treatment, suggesting improved nutrient availability. However, the differences were statistically non-significant. Previous studies have similarly reported that moderate application of organic fertilizers does not contribute to soil salinity and may enhance nutrient dynamics without adverse effects [15–16].

Soil organic carbon (SOC) is a critical indicator of soil fertility. Continuous application of chemical fertilizers without organic inputs has been reported to reduce SOC levels [17–19]. In contrast, integrated use of organic manures, such as farmyard manure (FYM), along with nitrogen fertilizers improves SOC through the addition of organic matter and its subsequent mineralization. In the present study, vermicompost application increased SOC compared to control, although values remained below recommended levels. Biofertilizers showed limited direct impact on SOC, which is consistent with findings that their primary role lies in enhancing nutrient uptake rather than carbon accumulation [20–22].

Nitrogen availability was highest in biofertilizer treatments, likely due to enhanced microbial activity and biological nitrogen fixation by organisms such as *Azotobacter* and other plant growth-promoting rhizobacteria [23–26]. Vermicompost, characterized by a low C:N ratio, facilitates rapid decomposition and nutrient release [27], although it alone was insufficient to raise nitrogen levels to recommended standards. Phosphorus availability was highest in DAP-treated soils, reflecting the direct input of readily available phosphorus [28]. Lower phosphorus levels in organic treatments may be attributed to increased plant uptake and gradual nutrient release [29]. Organic amendments, however, play a crucial role in solubilizing native phosphorus through organic acid production.

Potassium levels were found to be higher in control soils and lower in fertilized treatments, likely due to increased plant uptake under enhanced growth conditions [30]. While chemical fertilizers increased the availability of certain nutrients, they may adversely affect soil properties over time, including pH and calcium balance [31–32]. In contrast, organic amendments improved nutrient availability and soil buffering capacity.

Micronutrient availability (Zn, Fe, Mn, and Cu) showed slight improvement with vermicompost and biofertilizer application, possibly due to enhanced microbial activity and mineralization processes [33–35]. Organic amendments also contribute to sulfur availability through gradual oxidation and release of sulfate ions. Similar findings have been reported by Abdel-Aal et al. [36], who observed increased availability of macro- and micronutrients following organic amendments. Additionally, phosphate-solubilizing bacteria improve nutrient availability by modifying soil pH [37].

Despite improvements in certain parameters, most soil properties did not show significant changes over the short experimental period. This may be attributed to the relatively short duration and moderate application rates. Long-term studies have demonstrated that integrated nutrient management, combining organic and inorganic inputs, significantly enhances soil fertility, including N, P, K, and soil organic matter [38–39]. Continuous use of inorganic

fertilizers alone may degrade soil structure and fertility over time [40], whereas vermicompost and other organic amendments improve soil physical, chemical, and biological properties [41–42]. Overall, the findings suggest that integrated use of organic and inorganic fertilizers is essential for sustainable soil health and crop productivity, particularly under semi-arid conditions.

5. Conclusion

The study demonstrated that vermicompost application, particularly in combination with biofertilizers, improved key indicators of soil fertility under semi-arid conditions of Rajasthan. Vermicompost alone (T₄) resulted in higher values of organic carbon, electrical conductivity (EC), sulfur, and copper, whereas the combined application of vermicompost and biofertilizer (T₅) enhanced soil nitrogen and micronutrient availability (Zn, Fe, and Mn). These findings suggest that integrated use of vermicompost and biofertilizers is an effective approach for improving soil organic carbon and nitrogen status, thereby enhancing overall soil health and supporting sesame productivity in sandy loam, slightly alkaline soils with low organic carbon content.

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7. Author contributions

KK carried out the experiment, sample collection and analysis, MRH Sample collection and experiment, A did the Data analysis and manuscript writing, GNM worked on a field experiment and helped in sample collections. SPC reviewed and revised the manuscript. All authors read and approved the final manuscript.

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9. Conflict of interest

Authors do not have any conflict of interest to declare.

10. Data availability

The authors confirmed that, the data supporting the finding of the present study are available within the article.

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