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Effect of Adding Vermicompost and Nitrogen Fertilization Levels on Nitrogen and Phosphorus Concentration in Wheat (Tritium Aestivum L.) using Remote Sensing Devices

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ABSTRACT: This study aimed to determine the effect of vermicompost on nitrogen concentration in wheat, the effect of vermicompost levels on soil nitrogen content, and the effect of interaction on soil and plant nitrogen concentration. A field experiment was conducted in Al-Muthanna Governorate, in the Al-Dahra area, during the 2025-2026 winter season. The experiment was designed according to a randomized complete block design (RCBD). It included three levels of vermicompost (0, 2, and 4 tons ha-1, designated V1, V2, and V3, respectively) and four levels of nitrogen fertilizer (0, 25, 50, and 100% of the recommended fertilization, designated N1, N2, N3, and N4, respectively). Available soil nitrogen was estimated at flowering and harvesting stages, as were plant nitrogen concentrations at flowering and harvesting stages, total bacterial counts, and available soil phosphorus at both stages. Flowering and harvesting. The results showed the effect of adding vermicompost on increasing nitrogen availability in the soil. Level V3 resulted in a significant increase in the average available nitrogen in the soil during the flowering and harvesting stages. Adding vermicompost also affected the nitrogen concentration in plants during the flowering and harvesting stages. Level V3 resulted in a significant increase in the average nitrogen concentration in plants during these stages. Adding vermicompost also affected the phosphorus availability in the soil. Level V3 resulted in a significant increase in the average available phosphorus in the soil during the flowering and harvesting stages. Adding vermicompost also affected the total bacterial count in the soil. Adding nitrogen compost at 50% of the recommended fertilizer level also increased nitrogen availability in the soil. Level N3 resulted in a significant increase in the average available nitrogen in the soil during the flowering and harvesting stages. And harvesting. The addition of nitrogen fertilizer also affected the increase in nitrogen concentration in plants during the flowering and harvesting stages. The N3 level showed a significant advantage in the average nitrogen concentration in plants during these stages. Furthermore, the application of nitrogen fertilizer at 50% of the recommended fertilizer level increased phosphorus availability in the soil. The N3 level showed a significant advantage in the average available nitrogen in the soil during the flowering and harvesting stages. The addition of nitrogen fertilizer also increased the total number of bacteria in the soil. The interaction between vermicompost and nitrogen fertilizer resulted in a significant increase in available nitrogen in the soil at harvest, nitrogen concentration in plants during flowering, nitrogen concentration in plants at harvest, and available phosphorus in the soil at both flowering and harvesting.

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INTRODUCTION

Vermicompost is considered one of the most important natural organic fertilizers that has received increasing attention in modern agricultural studies. This is due to its ability to improve certain chemical, physical, and biological properties of the soil. It contributes to improving the soil's water retention capacity and reducing compaction. It is also a rich source of macro and micronutrients, in addition to containing vital components and compounds that can contribute to improving soil properties, increasing nutrient availability, promoting plant growth, and increasing productivity. Worm fertilizer is distinguished by its high content of macro and micro mineral nutrients. Furthermore, it contains hormones and enzymes that have played a significant and vital role in enhancing the chemical and physiological properties of many plants and increasing their content of many medically and therapeutically important compounds (Elissen *et al.*, 2023).

Vermicompost plays a vital role in sustainable agriculture due to its numerous positive effects. It improves soil vitality by increasing the density and number of microorganisms in the soil. This is especially true of bacteria and algae, which fix nitrogen and increase the availability of macro and micronutrients in the soil, as well as secreting growth promoters (Mazyad *et al.*, 2020). It also improves vegetative growth and plant health because it contains essential elements, such as nitrogen, phosphorus, potassium, calcium, magnesium, iron, zinc, copper, and manganese. In addition, it secretes growth-regulating substances like auxin, gibberellins, and cytokinins. Furthermore, it improves the physical properties of the soil by increasing porosity and permeability, enhancing aeration, and improving its chemical and biological properties. In addition, worm fertilizer contains high levels of antibiotics, vitamins, hormones, enzymes, and amino acids that promote plant growth and development (Al-Shablawi, 2022).

Nitrogen fertilization is considered an important method for addressing low crop productivity and improving plant growth. Nitrogen is involved in many vital processes within the plant, such as regulating the activity of plant hormones like cytokines, which play a crucial role in increasing cell division in meristematic cells. This, in turn, leads to an increase in both shoot and root growth. Nitrogen is also involved in the synthesis of nucleic acids (RNA and DNA). Furthermore, nitrogen contributes to the formation of energy-transporting compounds, adenosine diphosphate and adenosine triphosphate (ATP and ADP). In addition, it is involved in the synthesis of amino acids, enzymes, chlorophyll, and proteins, which leads to an increase in leaf area, which is considered the plant's food factory (Naghimish, 2017).

The application of nitrogen fertilizers enhances the availability of essential macronutrients required for plant development and supports critical physiological functions within plant tissues, thereby improving overall soil fertility. However, the indiscriminate or excessive application of nitrogen fertilizers can disrupt the ecological balance of the soil and affect the nutrient availability within the rhizosphere (Bronson, 2004).

Wheat (Triticum aestivum L.) is one of the most important staple crops in the world, contributing approximately 20% of human food needs (El-Fouly et al., 2011). The area cultivated with wheat for the 2025 winter season was estimated at 7,050,000 dunams, representing a 13.8% decrease compared to the previous season. The total cultivated area was estimated at 8,177,000 dunams. The average yield per dunam, calculated from the total cultivated area, reached 621.1 kg for the 2025 season, a 3.0% decrease compared to 640.1 kg in the previous season (Directorate of Agricultural Statistics, 2025).

Remote sensing technologies represent modern tools in precision agriculture (Al-Shujairy et al., 2025), that accurately assess crop nutritional needs. Among the most prominent of these affordable tools is the Green Seeker device, which enhances fertilizer management by providing farmers with site-specific, precise nitrogen fertilization recommendations (Crain et al., 2012).

The current study aims to investigate the effects of vermicompost addition and nitrogen fertilization levels on nitrogen and phosphorus concentrations in wheat (Triticum aestivum L.) using remote sensing techniques.

MATERIALS AND METHODS

4.1 Experimental Location:

The field experiment was conducted in Al-Muthanna Governorate/Al-Dahra District, at latitude (45°15'38'544) and longitude (46°575'31°22) during the 2025–2026 growing season. The soil was clay. The necessary agricultural operations were carried out on the soil, including perpendicular plowing, harrowing, leveling, and dividing the field into three sections, with a distance of 1

meter between each section. Each section contained 12 experimental units, each measuring 2×3 meters. The distance between the experimental units was 50 cm, for a total of 36 experimental units.

All fertilization treatments were applied before planting, while nitrogen fertilizer was applied according to the study levels. The application was done in two installments. The first installment, according to the treatments, was applied one month after planting. The second installment was for treatments N2 and N3 only, after readings were taken with a Green Seeker device one month after the first application. The percentage of vegetation cover was obtained using a portable Green Seeker device for measuring vegetation cover. Manufactured by Trimble Navigation Limited (California, USA). Based on the Normalized Difference Vegetation Index (NDVI) (Longchamps *et al.*, 2011; Al Salman and Al-Gharawi, 2019).

On November 15, 2025, wheat (*Triticum aestivum* L.) Baghdad variety was planted with 10 rows per experimental unit and with a distance of 20 cm between the rows. Weeding was done whenever necessary, and the experimental units were watered with equal amounts of water according to the needs of the plants.

4.2 Studied Characteristics

Available nitrogen in the soil at the flowering and harvesting stages was estimated by extraction with 2 M potassium chloride solution using a microKieldahl apparatus. The pH was raised using MgO, and the nitrate ion was reduced using a Devardian alloy, following the method employed by Bremmner (Page *et al.*, 1982).

Available phosphorus in the soil at the flowering and harvesting stages was extracted using 0.5 N sodium bicarbonate (NaHCO3) at pH 8.5. The color was then altered using ammonium molybdate and ascorbic acid. Phosphorus concentration was determined using a spectrophotometer at a wavelength of 882 nm according to the Olsen method (Page *et al.*, 1982).

The nitrogen concentration in the plant at the flowering and harvesting stages of the digested samples was estimated by adding 10 M sodium hydroxide using a microKieldahl apparatus. Micro Kjeldhal and titration with 0.05 N sulfuric acid as described in (Haynes, 1980).

Phosphorus concentration in plants during the flowering and harvest stages was estimated for the ammonium molybdate digested samples using a spectrophotometer at a wavelength of 880 nm (Haynes, 1980).

Total bacterial counts in soil samples were estimated using the dilution and plate counting method. 10 g of soil was weighed and placed in a bottle containing 9 ml of sterile distilled water. The mixture was shaken well for 10 minutes, and then 10 ml was transferred to another bottle containing 90 ml of sterile distilled water. The drying process continued to obtain a series of decile dilutions (10^{-1} and 10^{-7}). One ml of each of the dilutions (10^{-5}, 10^{-6}, and 10^{-7}) was transferred to Petri dishes containing nutrient agar. The bacteria incubated the plates upside down in the incubator at a temperature of 28°C, then the plates were removed to count the growing colonies. After that, the growing colonies were counted according to the method of Black (1965).

4.3 Experimental Design:

The experiment was designed according to a randomized complete block design (RCBD) with three replications. The treatments were randomly distributed among the experimental units, resulting in a total of 36 experimental units. The treatments included the following:

Factor 1: Worm fertilizer at three levels (0, 2, and 4 tons ha^{-1}).

Factor 2: Nitrogen fertilization at four levels (0, 25, 50, and 100% of the fertilizer recommendation).

4.4 Statistical Analysis:

The data were statistically analyzed using Analysis of Variance (ANOVA) according to the Randomized Complete Block Design (R.C.B.D), and the means were compared using the Least Significant Difference (LSD) test at a probability level of 0.05 using the GENSTAT program (Al-Rawi and Khalaf Allah, 2000).

RESULTS AND DISCUSSION:

5.1 Available nitrogen in the soil (mg N kg^{-1}) at the flowering stage:

The results in Table (1) indicate that the addition of vermicompost significantly affected the concentration of available nitrogen in the soil at the flowering stage. Level V3 achieved the highest amount of available nitrogen in the soil, reaching 22.87 mg N/kg^{-1}, representing a 26.98% increase compared to the control treatment V1, which averaged 18.01 mg N/kg^{-1}. This may be attributed to the role of vermicompost in improving soil pH and increasing nutrient availability. Furthermore, the organic acids produced from the decomposition of the added vermicompost by microorganisms in the rhizosphere compete for adsorption surfaces due to their content of active groups that reduce nutrient binding on fixation surfaces. Consequently, this increases the availability of essential nutrients in the soil, including nitrogen. vermicompost also improves some of the physical, chemical, and biological properties of the soil as a result of its decomposition and the release of nutrients, consistent with Lazcano and Dominguez (2011).

Nitrogen fertilization significantly increased available soil nitrogen during the flowering stage. N3 level recorded the highest amount of nitrogen in the soil, reaching 22.34 mg N/kg^{-1}, representing a 16.71% increase compared to the control treatment N1, where available soil nitrogen was 19.14 mg N/kg^{-1}. This superiority of N3 may be attributed to more efficient nitrogen management. N3 level received a second application of nitrogen fertilizer, based on GreenSeeker readings. This resulted in a more consistent nitrogen application rate with the plant's needs during the flowering stage, thus utilizing excess nitrogen and maintaining a higher level of available nitrogen compared to N4 level, where the entire amount was applied at once. This single application could have increased the likelihood of nitrogen loss from the soil or increased uptake by the plant.

Table (1) indicated that there were no significant differences in the interaction between the levels of vermicompost and nitrogen fertilizer at different levels of ready nitrogen concentration in the soil at the flowering stage.

Table (1) Effect of vermicompost and nitrogen fertilizer and the interaction between them on the concentration of available nitrogen in the soil during the flowering stage (mg N kg^{-1} soil).

Vermicompost	Nitrogen Fertilizer				Mean
	N1	N2	N3	N4	
V1	17.07	17.70	19.03	18.23	18.01
V2	19.80	2 .87	23.13	21.53	21.58
V3	20.57	23.67	24.87	22.40	22.87
Mean	19.14	21.08	22.34	20.72	
L.S.D$_{0.05}$	V		N		V×N
	0.58		0.67		N.S

5.2 Available nitrogen in the soil mg N kg^{-1} soil at harvest stage:

The results in Table (2) indicate that the addition of vermicompost significantly affected the soil's available nitrogen concentration at harvest. Team V3 achieved the highest available nitrogen content in the soil, reaching 18.14 mg N kg^{-1}, representing a 27.56% increase compared to the control treatment V1, which averaged 14.22 mg N kg^{-1}. This may be attributed to the enrichment of the soil with beneficial microorganisms such as bacteria and fungi, which play a crucial role in nitrogen fixation and increasing its availability in the soil. Vermicompost also contributes to the activation of existing soil microorganisms, improving soil structure and increasing its water retention capacity. This facilitates the availability of essential nutrients for plant growth (Devi and Khwairakpam, 2020). These results are consistent with those of Esmaielpour *et al.* (2020) and Tith (2021).

Different levels of nitrogen fertilization significantly affected nitrogen concentration values at harvest. N3 level resulted in the highest amount of nitrogen in the soil, averaging 17.62 mg N kg^{-1} soil, representing a 17.62% increase. This was compared to the control treatment N1, where the available nitrogen in the soil was 14.98 mg N kg^{-1} soil. This difference may be attributed to the fact that the remaining available nitrogen in the soil, represents the balance between nitrogen applied, nitrogen absorbed

by the plant, and nitrogen that may be lost from the soil. Therefore, N3 can be higher than N4 despite a lower amount of fertilizer applied, due to the efficient timing of the second application (as measured by the GreenSeeker device, Naser *et al.*, b 2020).

The results indicate significant differences in the interaction between vermicompost and nitrogen fertilizer at different levels. The interaction treatment V3N3 showed a significant advantage, yielding the highest average of 19.63 mg N kg^{-1} soil, while the lowest average available nitrogen in the soil was obtained with the non-added treatment V1N1, which yielded 13.20 mg N kg^{-1} soil. This may be attributed to the synergistic effect of nitrogen addition with its mineral component and the decomposition of organic matter in the vermicompost. This leads to increased nitrogen release and its conversion into forms available to plants, thus increasing soil nitrogen levels after harvest (Sheoran, 2015).

Table (2) Effect of vermicompost, nitrogen fertilizer, and their interaction on soil nitrogen concentration at harvest (mg N kg^{-1} soil).

Vermicompost	Nitrogen Fertilizer				Mean
	N1	N2	N3	N4	
V1	13.20	14.03	15.00	14.66	14.22
V2	15.60	17.16	18.23	17.00	17.00
V3	16.16	19.20	19.63	17.56	18.14
Mean	14.98	16.80	17.62	16.41	
$L.S.D_{0.05}$	V		N		V×N
	0.44		0.51		0.88

5.3 Percentage of Nitrogen Concentration in Plants at the Flowering Stage:

Table (3) shows that adding different levels of vermicompost significantly affected the percentage of nitrogen concentration in plants at the flowering stage. Level V3 achieved the highest nitrogen concentration in plants, at 2.57%, representing a 37.43% increase compared to the V1 treatment (no vermicompost added), which achieved 1.87%. The increase in the percentage of nitrogen concentration in plants may be attributed to the role of vermicompost in improving the physical and chemical properties of the soil and increasing the availability of essential nutrients for plants. This, in turn, raises the concentration of these elements in the plant, as vermicompost is an organic material that stimulates and encourages the reproduction and growth of microorganisms. These microorganisms play an important role in fixing atmospheric nitrogen and increasing phosphorus availability, which is reflected in the increased concentration of phosphorus in plant tissues (Devi and Khwairakpam, 2020).

Nitrogen fertilization resulted in significant differences in the percentage of nitrogen concentration in plants. N3 level significantly outperformed N4, yielding the highest nitrogen concentration with an average of 2.45%, representing a 20.09% increase. This is compared to the control level, N1, which yielded an average of 2.04%. This difference may be attributed to the fact that nitrogen fertilization increased nitrogen availability and supply to the plant, leading to increased absorption and accumulation in plant tissues. N3 outperformed N4 due to the second application at the N3 level aligning with the plant's actual needs, as measured by GreenSeeker readings. This contributed to improved nitrogen uptake and utilization efficiency within the plant (Naser *et al.*, 2020a).

The interaction between vermicompost and nitrogen fertilizer levels significantly affected the percentage of nitrogen concentration in plants. The V3N3 interaction treatment yielded the highest average of 2.85%, which did not differ significantly from several other treatments, including V3N2, V2N3, and V2N2, which achieved averages of 2.71, 2.58, and 2.41%, respectively. The lowest average was 1.85% with the V1N1 interaction treatment. The superiority of V3N3 interaction treatment may be attributed to the complementary effect between vermicompost and nitrogen fertilizer. The combination of these improves nitrogen availability and increases plant utilization, thus raising nitrogen concentration in plant tissues (Erda and Gultekin, 2017).

Table (3) Effect of Vermicompost and Nitrogen Fertilizer Levels and the Interaction Between Them on the Percentage of Nitrogen Concentration in the Plant During the Flowering Stage.

Vermicompost	Nitrogen Fertilizer				Mean
	N1	N2	N3	N4	
V1	1.85	1.85	1.93	1.86	1.87
V2	2.06	2.41	2.58	2.33	2.34
V3	2.21	2.71	2.85	2.49	2.57
Mean	2.04	2.32	2.45	2.23	
$L.S.D_{0.05}$	V		N		V×N
	0.02		0.03		0.05

5.4 Percentage of Nitrogen Concentration in Plants at Harvest.

The results in Table (4) indicate that the addition of different levels of vermicompost significantly affected the percentage of nitrogen concentration in plants at harvest. Level V3 achieved the highest average nitrogen concentration in plants, with an average of 2.11%, representing a 24.11% increase. This is compared to the treatment without vermicompost, V1, which achieved 1.70%. This may be attributed to the role of vermicompost in releasing nutrients and making them available in the soil solution within the root zone, thus facilitating their absorption by the plant. Furthermore, the compost contains organic acids and natural chelates, which contain active groups that contribute to reducing nutrient binding on fixation surfaces, thereby increasing the availability and quantity of nutrients necessary for plant growth (Yuvaraj *et al.*, 2020).

Nitrogen fertilization resulted in significant differences in the percentage of nitrogen concentration in plants. N3 level significantly outperformed N4 level, yielding the highest average nitrogen concentration at 2.08%, representing an 18.85% increase. This is in contrast to the N1 level (no nitrogen application), which yielded an average of 1.75%. This difference may be attributed to the fact that the N3 level provided an adequate amount of nitrogen to meet the plant's needs, thus enhancing its absorption, utilization, and accumulation in plant tissues. Conversely, the increased nitrogen at the N4 level may exceed the plant's requirements, leading to reduced utilization efficiency and resulting in a lower nitrogen concentration.

The interaction between vermicompost and nitrogen fertilizer levels significantly affected the percentage of nitrogen concentration in plants. V3N3 interaction treatment resulted in the highest average nitrogen concentration at 2.34%, while V1N1 interaction treatment yielded the lowest average nitrogen concentration at 1.62%. This may be attributed to the complementary roles of vermicompost and nitrogen fertilizer in providing nitrogen to plants. Vermicompost contributed to improving soil environment and increasing nutrient availability. Meanwhile, nitrogen fertilizer provided a readily available source of nitrogen, leading to its availability in the root zone and improved absorption and accumulation in plant tissues. Consequently, the nitrogen concentration in plants increased at harvest.

Table (4) Effect of vermicompost levels, nitrogen fertilizer, and their interaction on the percentage of nitrogen concentration in plants at harvest.

Vermicompost	Nitrogen Fertilizer				Mean
	N1	N2	N3	N4	
V1	1.62	1.66	1.79	1.74	1.70
V2	1.83	1.97	2.13	1.88	1.95
V3	1.82	2.25	2.34	2.02	2.11
Mean	1.75	1.96	2.08	1.88	

L.S.D$_{0.05}$	V	N	V×N
	0.05	0.06	0.11

5.5. Total Soil Bacterial Counts CFU×10^6 gm of Soil:

Table (5) shows that adding different levels of vermicompost significantly affected the total soil bacterial count. Level V3 achieved the highest total soil bacterial count, with an average of 21.35 CFU×10^6 gm of Soil, compared to the control V1 (no additive), which had an average of 8.85 CFU×10^6 gm of Soil. The increase in total soil bacterial counts may be attributed to the addition of vermicompost. However, organic additives play an important role in increasing microbial populations because they contain many essential nutrients that microorganisms need for growth and cell building (Noni *et al.*, 2021).

The application of different levels of nitrogen fertilizer significantly affected the total bacterial count in the soil. Level N3 resulted in the highest total bacterial count, averaging 19.92 CFU×10^6 gm of Soil. Conversely, the lowest total bacterial count was recorded at level N1, averaging 11.80 CFU×10^6 gm of Soil. This may be attributed to the fact that a moderate level of nitrogen fertilization, coupled with targeted application based on Greenseeker readings, provided better synchronization between nitrogen availability and plant requirements. This enhanced root growth and secretion, and supported bacterial activity and reproduction.

The results also showed no significant differences in the interaction between vermicompost and nitrogen fertilization on the total bacterial count in the soil.

Table (5) Effect of vermicompost and nitrogen fertilizer levels and their interaction on the total bacterial count (CFU×10^6 gm of Soil).

Vermicompost	Nitrogen Fertilizer				Mean
	N1	N2	N3	N4	
V1	5.90	7.55	12.42	9.43	8.85
V2	13.53	18.55	22.33	17.66	18.02
V3	15.89	23.40	25.01	21.11	21.11
Mean	11.80	16.50	19.92	16.06	
L.S.D$_{0.05}$	V		N		V×N
	2.16		2.49		N.S

5.6 Available Phosphorus in the Soil (mg P kg^{-1}) at the Flowering Stage.

Table (6) indicates that the addition of vermicompost significantly affected the concentration of available phosphorus in the soil at the flowering stage. Level V3 achieved the highest amount of available phosphorus in the soil, reaching 6.51 mg P kg^{-1}, representing an increase of 23.76%. This is compared to the control treatment V1, which averaged 5.26 mg P kg^{-1}. This may be attributed to the continued decomposition and mineralization of organic matter, leading to the release of phosphorus and increasing its availability in the soil. Furthermore, the role of microorganisms in dissolving certain minerals, such as phosphates, and converting phosphorus into forms more readily available to plants (Hadis *et al.*, 2019).

Nitrogen fertilization significantly increased available soil phosphorus during the flowering stage. N3 level showed the highest soil phosphorus content, reaching 6.32 mg P kg^{-1}, representing a 14.07% increase compared to N1 control, where available soil phosphorus was 5.54 mg P kg^{-1}. The superiority of the N3 level in increasing soil phosphorus concentration may be attributed to the balanced application of nitrogen fertilizer, which improved soil fertility and increased nutrient availability. It also stimulated microbial activity and organic matter decomposition, contributing to increased solubility of phosphorus compounds and reduced fixation, thus leading to a higher concentration of available phosphorus in the soil. However, at the higher nitrogen

level, no additional increase in available phosphorus was observed. This may be due to increased plant phosphorus consumption or a relative imbalance in nutrient composition. This aligns with Bronson's (2004) findings, which explained that balanced management of nitrogen fertilization increases the availability of nutrients and improves soil fertility, while excessive addition may lead to an imbalance of elements.

The results indicate significant differences in the interaction between vermicompost and nitrogen fertilization at different levels. The interaction treatment V3N3 showed significant superiority, yielding the highest average phosphorus availability in the soil at 6.95 mg P kg^{-1}. Conversely, the lowest average available phosphorus in the soil was observed in the non-added treatment V1N1, which yielded 5.00 mg P kg^{-1}. This may be attributed to the complementary effect between vermicompost and nitrogen fertilization. Vermicompost provided organic matter, microorganisms, and organic acids, which contributed to increased phosphorus solubility and reduced fixation. Meanwhile, the appropriate level of nitrogen fertilizer created favorable conditions for microbial activity and decomposition of organic matter, leading to increased phosphorus availability in the soil. This aligns with the findings of Al-Ubaidi (2020).

Table (6) Effect of vermicompost and nitrogen fertilizer and the interaction between them on the concentration of available phosphorus in the soil during the flowering stage (mg P kg^{-1}soil).

Vermicompost	Nitrogen Fertilizer				Mean
	N1	N2	N3	N4	
V1	5.00	5.24	5.47	5.31	5.26
V2	5.78	6.25	6.55	5.93	6.13
V3	5.85	6.89	6.95	6.36	6.51
Mean	5.54	6.13	6.32	5.87	
$L.S.D_{0.05}$	V		N		V×N
	0.13		0.16		027

5.7 Available Phosphorus in the Soil (mg P kg^{-1}) at Harvest.

Table (7) indicate that the addition of vermicompost significantly affected the concentration of available phosphorus in the soil at harvest. V3 achieved the highest amount of available phosphorus in the soil, reaching 6.21 mg P kg^{-1}, representing a 20.58% increase. This is compared to the control treatment V1, which averaged 5.15 mg P kg^{-1}. This is attributed to the continued decomposition of the vermicompost components by soil microorganisms and the formation of organic acids. This contributes to the dissolution of some phosphorus-containing compounds and their release into the soil solution. Furthermore, it reduces the adsorption and precipitation of phosphorus and chelates some positive ions, thus increasing the availability of phosphorus in the soil. Nitrogen fertilization significantly affected soil phosphorus availability at harvest. N3 level was higher, with an average of 6.08 mg P kg^{-1}, representing a 13.43% increase. This was compared to N1 control treatment, where soil phosphorus availability was 5.36 mg P kg^{-1}. This may be attributed to the fact that this level of nitrogen fertilization provided a favorable nutritional condition for the plant. This contributed to improved root system growth and increased root efficiency in utilizing nutrients. Furthermore, increasing nitrogen to N4 level further enhanced plant growth and nutritional requirements, potentially leading to increased phosphorus uptake and absorption from the soil.

The results indicated significant differences in the interaction between vermicompost and nitrogen fertilization at different levels. The interaction treatment V3N3 showed a significant advantage, yielding the highest average of 6.63 mg P kg^{-1} soil. Conversely, the lowest average available phosphorus in the soil was observed in the non-apply treatment N1V1, which yielded 4.96 mg P kg^{-1} soil. This may be attributed to the combined effect of vermicompost and nitrogen fertilization. This combination contributed to improving soil properties and increasing phosphorus availability, in addition to the vermicompost's contribution to supplying the soil with phosphorus. This, in turn, led to increased phosphorus availability at harvest (Gemeda, 2024; Habtamu, 2024).

Table (7) Effect of vermicompost, nitrogen fertilization, and their interaction on the concentration of available phosphorus in the soil at harvest (mg P kg^{-1} soil).

Vermicompost	Nitrogen Fertilizer				Mean
	N1	N2	N3	N4	
V1	4.96	5.09	5.39	5.18	5.15
V2	5.50	5.82	6.23	5.70	5.81
V3	5.61	6.43	6.63	6.17	6.21
Mean	5.36	5.78	6.08	5.68	
$L.S.D_{0.05}$	V		N		V×N
	0.05		0.06		0.11

CONCLUSIONS AND RECOMMENDATIONS:

The study concluded that the Appling of vermicompost and minerals nitrogen fertilizer significantly enhanced content nitrogen in the soil and plant and increased numbers of total bacteria in the soil otherwise improved soil health. It is recommended that farmers adopt this integrated approach to sustainably increase wheat productivity and maintain.

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Novelty Statement:

The application of modern organic fertilization methods, particularly vermicomposting, in soils subjected to extreme environmental stresses, especially in central and southern Iraq.

Authors' Contribution (ACF)

Shima Jalil: Carried out research and drafted the manuscript.

Ghanim bahlol noni: Helped in layout of the research. Conceived the idea and supervised, the research and Helped in data collection

Conflict of interest:

The authors have declared no conflict of interest

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