Journal of Tekirdag Agricultural Faculty
Tekirdağ Ziraat Fakültesi Dergisi

Mayıs/May 2026, 23(3)
Başvuru/Received: 15/06/25
Kabul/Accepted: 14/05/26
DOI: 10.33462/jotaf.1710816

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http://jotaf.nku.edu.tr/

ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effects of Nano-NPK Foliar Spray Application and Organic Waste Sources on Growth, Yield, and Nutrient Uptake of Broad Bean (*Vicia faba* L.)

Haneen Shartoh SHARQI[1*], Malath A. HAMED[2], Bassam R. SARHEED[3]

Abstract

A field experiment is carried out in silty loam soil through the 2023 season in Ramadi, located in Al-Anbar Governorate (110 km west of Baghdad), Iraq, to assess the impact of applying three organic waste types (control—no addition, poultry waste, sheep waste, and litter of domestic cats) applied at a rate of 3 Mg ha^{-1} as well as spraying three concentrations of nano NPK fertilizers (0, 2, and 4 g L^{-1}). Furthermore, it aims to assess the individual and interactive effects between these wastes and NPK content in seeds, as well as the growth and yield of broad beans (*Vicia faba* L.). The factorial experiment utilizes a randomized complete block design (RCBD) with three replicates. The results indicate that poultry waste exhibited superiority by achieving the highest values of 62.72 cm for plant height, leaves per plant of 70, protein concentration in seeds of 45.56 g kg^{-1}, and total seed yield of 1.546 ton ha^{-1}. Meanwhile, sheep waste outperformed in terms of phosphorus and potassium concentrations in seeds 0.1527%, 45.92 g kg^{-1}, respectively, along with the number of pods per plant 16.07 pods per plant, Furthermore, the results showed that utilizing NPK fertilizer with 4 g L^{-1} concentrations showed a superior effect with plant height of 54.78 cm, leaves number of 67.7, nitrogen and potassium concentrations of 40.45 and 43.01 g kg^{-1}, respectively, as well as pods per plant number of 16.79. On the other hand, utilizing a 2 g L^{-1} concentration of NPK fertilizer has increased the seed yield significantly, achieving 1.449 ton ha^{-1}.

Keywords: Poultry waste, Sheep waste, Cats litter, Nano fertilizers, Broad bean, Responsible Consumption and Production

[1]***Sorumlu Yazar/Corresponding Author:** Haneen Shartoh Sharqi, University of Anbar, Upper Euphrates Research Center for Sustainable Development, Anbar, Iraq. E-mail: ag.haneen.shartoh@uoanbar.edu.iq OrcID: 0000-0002-1005-8674
[2]Malath A. Hamed, University of Anbar, College of Basic Education-Haditha, General science Department, Anbar, Iraq. E-mail: ag.malath.hamid@uoanbar.edu.iq OrcID: 0000-0002-2051-3116
[3]Bassam R. Sarheed, University of Anbar, College of Agriculture, Soil Sciences and Water Resources Department, Anbar, Iraq. E-mail: ag.bassam.ramadhan@uoanbar.edu.iq OrcID: 0000-0003-1335-5161
Atıf/Citation: Sharqi, H. S., Hamed, M. A., Sarheed, B. R. (2026). Effects of nano-npk foliar spray application and organic waste sources on growth, yield, and nutrient uptake of broad bean (*Vicia faba* L.). *Journal of Tekirdag Agricultural Faculty,* 23(3): 911-922.

1. Introduction

Numerous statistics indicate that the global population by 2050 is expected to reach roughly 10 billion, necessitating securing food for this growth, which is a critical objective of the sustainable development goals (FAO, 2017). To achieve these goals, critical steps should be considered, such as focusing on sustainable agriculture and boosting productivity without damaging the environment by reducing greenhouse gas emissions, which in turn reduces pollution. Consequently, alternative strategies should be considered, such as promoting organic farms and fertilizers and increasing public awareness towards the recycling of organic wastes (Wanyenze et al., 2023). In a study conducted by (Bayramoğlu, et al., 2025), confirmed that organic farming, including the use of organic fertilizers, achieved high productivity and improved the qualities and characteristics of agricultural soils, thus ensuring their economic and environmental sustainability by increasing productivity.

Vast of arable lands, particularly in Al-Anbar Governorate, are situated in arid and semi-arid regions, which are known for extreme weather conditions such as extremely high temperatures of 45 to 50 °C during the summer and significantly low precipitation rate, reaching most of 150mm, which in turn increasing the oxidation process and effecting organic materials in the soil as well as the growth of the natural vegetations. Consequently, it is essential to improve these soils by adding organic materials, which enhance the physical, chemical, and biological properties, as well as the fertility of these soils, improving the productivity of vegetation. Furthermore, increasing the organic matter in the soil enhances root growth and soil structure by ensuring aggregate stability, which in turn enhances the aeration mechanism, improving the soil-air-water relationship. Chemically, organic matter enhances soil cation exchange (CEC) and nutrient retention capacities and protects soil from erosion induced by wind and water (Ayoola and Makinde, 2009). Thus, valuable research has focused on organic waste from different sources to enhance some of these properties in soils, which, in turn, would yield more crops (Hirzel, et al., 2007). Jasim and Mhanna (2014) investigated the impact of including poultry and cattle waste on soil. The findings showed a significant increase in growth parameters, yield, and qualitative traits of faba bean compared to unfertilized control treatments.The findings showed that cattle waste has significantly increased the growth parameters, yield, as well as some qualitative traits (Hanoon, et al., 2020), which are the same results obtained by utilizing organic fertilizer at various levels, as reported by Al-Leela, et al. (2019). Likewise, board bean (Vicia faba L.) growth, yield and qualitative traits significantly increased with the adoption of organic amendments in study expedited by Mohamed (2022) and Maruf (2021). El-Yazal (2020) used two forms of organic fertilizers (poultry and farm manure) in different levels (4 and 8 tons ha^{-1}). The results suggested that the use of animal manure increased significantly plant growth and yield, especially at the ratio 8 tons ha^{-1}.

Over the past few decades, researchers have been shifting their attention to more efficient and effective fertilization strategies especially using nanomaterials (substances with particle sizes ranging from 1 to 100 nm in at least one dimension). Nanomaterials exhibit unique physical and chemical characteristics, enabling them to be absorbed and penetrate the plant cell effectively. The nanomaterials' unique small size and higher surface area enable them to enhance the plant metabolic activities, which in turn increase the productivity of crops (Madlala, et al., 2024). Furthermore, it ensures that plants and soil have a continuous nutrient supply (Çetin et al.,2020), enhancing the plants' growth and eliminating the soil pollution induced by excessive fertilizer utilization. Additionally, the utilization of macronutrient fertilized, specifically NPK, showed a significant improvement in both photosynthesis and respiration, which are considered essential processes in plant life. Hussein, et al. (2024) investigated the utilization of organic fertilizer, namely cattle manure, at different ratios ranging from 0-40 tons ha^{-1}and different concentrations of nano fertilizers ranging from 0-40 mg L^{-1} on the board bean's growth, yield, and qualitative traits. The findings showed that combining organic fertilizers with spraying of nano fertilizers has significantly enhanced these traits, which are the same findings obtained by Kamel (2025) after combining NPK and organic fertilizers. Furthermore, they significantly enhance plant height, branch and pod number, pod weight, and other qualitative traits. Mfouapon et al. (2024) reported a significant increase in growth parameters, yield, and qualitative traits of common bean (*Phaseolus vulgaris* L.) when evaluating the effect of organic fertilizer (poultry manure) at an application rate of 2.5 tons ha^{-1}.

In a study conducted by Sharqi et al. (2025), it was found that adding sheep waste at several levels and spraying with organic acids gave significant results in the content of major and minor nutrients in fenugreek seeds, as this content increased with the increase in the level of addition.

Broad bean (*Vicia faba* L.) is considered a strategic crop cultivated for its pods or seeds, whether fresh or dry and is widely used in various culinary applications. Nutritionally, it is mostly significant for its high protein content and also contains carbohydrates, oils, minerals (especially calcium and iodine), fiber and essential vitamins A, B_1 and B_2 (FAO, 2023). Fig (3): Broad Bean used as a green fertilizer crop because of his capacity to stunted bacterial soil that has led by Rhizobia species through biological nitrogen fixations (Hala, 2007). Cultivated in the Middle East, broad bean is widely consumed but is also used to formulate animal feed. Additionally, it serves as a green organic fertilizer in nutrient-deficient soils, owing to its biological impact through the activity of Rhizobia bacteria (Chafi and Bensoltane, 2009).

Given the significance of organic waste in influencing both the quantity and quality of yield, the aim of this study is to compare the impact of various organic waste types along with the foliar NPK fertilizers on nutrient uptake and their impact on the total yield of broad beans, as well as the nutrient content of its seeds.

2. Materials and Methods

During the 2023 growing season, a field experiment is carried out at agricultural research fields in Ramadi District, Al-Anbar Governorate. The soil physical and chemical properties are depicted in *Table 1*. The soil of the experimental field was classified as silty loam according to the soil texture triangle after determining the percentages of sand, silt, and clay using the hydrometer method. Soil pH was determined in a 1:1 soil–water suspension using a digital pH meter, while electrical conductivity (EC) was measured in the soil extract using an EC meter. Organic matter content was determined by the Walkley and Black (1934) wet oxidation method.

Table 1. The physical and chemical characteristics of the raw soil

Parameter	Value	Units
Available Potassium	90.8	
Available Phosphorus	10.3	mg kg^{-1}
Available Nitrogen	8.96	
CEC	16.1	cmol kg^{-1} soil
Soil pH 1:1	7.36	
Organic Matter	4.4	%
Electrical Conductivity (EC)	2.48	(dS m^{-1})
Dissolved Cations and Anions *		
$SO_4^{=}$	10.84	
$HCO_3^{=}$	4.66	
$CO_3^{=}$	1.8	
Cl^{-}	5.99	(mmol L^{-1})
K^{+}	6.6	
Na^{+}	2.88	
Mg^{++}	7.64	
[illegible]	[illegible]	
Soil Texture	Silty loam	
Soil Separates		
Clay	180	
Silt	196	gm kg^{-1} soil
Sand	624	

* Estimated in saturated soil paste extract

Available nitrogen in the soil was determined using the Kjeldahl method, available phosphorus was determined using the Olsen extraction method and measured spectrophotometrically, whereas available potassium was measured using a flame photometer after ammonium acetate extraction. Bulk density was determined using the core method, and soil particle density was measured using the pycnometer method. All analyses were carried out according to standard procedures described by Day et al. (1965), Hille (2013), and Knudsen et al. (1982).

A moldboard plow was utilized to plow the experimental field with two perpendicular passes to a 20–30 cm depth. The soil was then leveled and divided into furrows measuring 0.7 × 6 m each, with a total area of 4.2 m^2 per furrow. To prevent treatment interference, 1.5 m wide gaps were left between furrows and experimental blocks. Phosphorus was applied at 80 kg P ha^{-1} as triple superphosphate (20% P) in a single dose during land preparation. Utilizing urea (46%), the nitrogen fertilizer was applied with a rate of 40 kg N ha^{-1} in two split doses, the first does after seedling emergence and the second one at the branching stage, coinciding with the early formation of flower buds.

A factorial experiment utilizing a randomized complete block design (RCBD) with three replicates was carried out. The first factor represented sources of decomposed organic matter (chicken waste [A1], sheep waste [A2] and cat waste [A3]) at 3 ton ha^{-1} and a non-amendment control treatment (A0). The poultry, sheep, and cat wastes were collected separately and subjected to aerobic decomposition for 90 days, during which water and nitrogen (1%) were periodically added, along with continuous turning, until full decomposition was achieved (AL-Mehadee and Sarheed, 2021). *Table 2* presents some properties of the added organic materials. The treatments were incorporated into the top 30 cm of the soil while considering the moisture content of each type of organic waste. The second factor involved the application of NPK fertilizer (20N:20P_2O_5:20K_2O) at three concentrations: 0 g L^{-1} (B0), 2 g L^{-1} (B1), and 4 g L^{-1} (B2).

Table 2. The properties of the organic waste utilized in the study

Studied Traits	Units	Poultry Waste (A1)	Sheep Waste (A2)	Cat Waste (A3)
pH	---	5.5	6.4	6.8
EC	ds m^{-1}	7.7	13.80	14.28
C:N	---	16:1	18:1	22:1
OM	%	56	58	43
N		28.66	16.08	16.25
P	g kg^{-1}	20.84	15.08	12.86
K		168.4	68.6	203.2

Broad bean (*Vicia faba* L.) seeds were sown on October 20, 2022, in furrows measuring 0.7 × 6 m (area of 4.2 m^2 per furrow). A spacing of 1.5 m was maintained between furrows and experimental blocks, with 25 cm between planting hills at a depth of 4–5 cm. Each hill was sown with three seeds, which were later thinned to two plants after full emergence. A 20 cm buffer zone was left at both ends of each furrow. Irrigation was performed using surface irrigation when 50% of the available soil water had been depleted, based on the gravimetric approach to determine soil moisture levels.

Crop maintenance, including manual weeding, was carried out as necessary. On June 1, 2023, which is the end of the experiment, plant samples were obtained from the central rows of each individual experimental unit. Five plants were randomly selected per unit to assess the plant height (cm), leaves number (leaves per plant), nitrogen, phosphorus, and potassium concentrations in seeds (%), pods number (per plant), and total yield (ton ha^{-1}). Plant samples (broad bean seeds) were oven dried at 70°C, ground and digested using a wet digestion method with nitric and perchloric acids according to Jones (2001). Total nitrogen was determined by the Kjeldahl method according to AOAC (2005). Phosphorus was determined calorimetrically using the molybdenum blue method with a spectrophotometer, and potassium was measured using a flame photometer as described by Keeney (1982).

The study data are analyzed utilizing analysis of variance (ANOVA) based on a randomized complete block design (RCBD). Statistical analyses are carried out utilizing GenStat software, and treatment means are compared utilizing the least significant difference (LSD) test at a 5% significance level.

3. Results and Discussion

3.1. Plant height (cm)

Table 3 illustrates the impact of organic waste source application, nano NPK fertilizer spraying, and their interaction on plant height. The addition of organic poultry wastes (poultry litter, liquid and dry wastes) significantly improved the tendency and characteristics of plant height (72.50 to 62.72 cm), compared to control treatment (no adding an organic waste) that had a minimum plant height 44.12 cm with corresponding increase in plant height was 42.15%. The results also showed that there was a marked effect of nano NPK fertilizer levels on plant height. Sample B2 (4 g L^{-1}) achieved the highest plant height of 54.78 cm significantly higher than Sample B1 (2 g L^{-1}), that recorded 52.99 cm. The comparisons of both treatments to the control (B0) while in this treatment, the plant height is 50.08 cm. In addition, nano NPK fertilization with organic waste sources in general had a significant effect on plant height. The highest value (65.05 cm) was recorded when poultry waste was combined with nano NPK fertilizer at 4 g L^{-1} (B2), compared to the control treatment (41.10 cm), reflecting a 58.27% increase.

Table 3. The effect of organic waste type and nano NPK fertilizer on plant height (cm).

Type of organic waste*	Nano Fertilizer Spraying			Mean
	B0	B1	B2	
A0	41.10 f	45.01 ef	46.25 def	44.12 c
A1	60.60 ab	62.50 a	65.05 a	62.72 a
A2	49.65 cde	50.85 cde	52.45 cd	50.98 b
A3	48.95 cde	53.60 c	55.35 bc	52.63 b
Mean**	50.08 b	52.99 ab	54.78 a	
LSD $_{0.05}$		A=3.756	B=3.252 A*B=6.505	

* A0: control, A1: Poultry Waste, A2: Sheep Waste, A3: Cat Waste. B0: control NPK concentration=0, B1: NPK concentration=2 g L^{-1}, B2: NPK concentration=4 g L^{-1}.
** Means followed by the same letter within each column or row are not significantly different at $P \leq 0.05$ according to the LSD test.

3.2. Number of leaves (leaves per plant)

All sources of organic waste significantly increased the number of leaves per plant (*Table 4*). The highest number of leaves (70.0 leaves per plant) occurred with the application of poultry waste, followed by sheep waste (57.8 leaves per plant), and cat waste wetting (53.0 leaves per plant). The lowest number of leaves per plant (40.0) was found in the control treatment.

Table 4. The effect of organic waste type and nano NPK fertilizer on the number of leaves (leaves per plant)

Type of organic waste	Nano Fertilizer Spraying			Mean
	B0	B1	B2	
A0	22.5 i	43.5 gh	54.0 def	40.0 d
A1	49.0 efg	76.0 ab	85.0 a	70.0 a
A2	47.5 fg	58.5 cde	67.5 bc	57.8 b
A3	35.0 h	59.5 cd	64.6 c	53.0 c
Mean**	50.0 c	59.3 b	67.7 a	
LSD $_{0.05}$		A=4.46	B= 3.46 A*B=9.93	

* A0: control, A1: Poultry Waste, A2: Sheep Waste, A3: Cat Waste. B0: control NPK concentration=0, B1: NPK concentration=2 g L^{-1}, B2: NPK concentration=4 g L^{-1}.
** Means followed by the same letter within each column or row are not significantly different at $P \leq 0.05$ according to the LSD test.

Control was 50 leaves per plant, highest mean leaf counted at 67.7 leaves/plant in nano NPK fertilizer concentration (4 g L^{-1}) by treatment B2 with significant difference from Control as analysed by statistical analysis for yield attributes that indicates the degree of effect by NPK fertilizers.

So and Wong108 found a strong interaction of organic waste sources with fertilization nano NPK. The maximum number of leaves (85.0 leaves per plant) was obtained when poultry waste was added in combination with nano NPK at 4 g L^{-1} (B2), while the lowest leaf count value, 21.5 leaves per plant was determined for control treatment (without organic wastes, without foliar spraying).

The increased height and number of leaves produced by plants due to organic wastes application may be related to its ability in reducing soil pH that is a factor affecting nutrient availability and plant uptake. Furthermore, this effect is probably influenced by the nutrient content of organic fertilizers (*Table 2*) either through macronutrients and/or micronutrients. When taken up by plant roots, these nutrients get incorporated into the plants and directly increase growth, increase photosynthetic efficiency, and combine to form different nutrient-rich complexes within the plant leading it to develop better overall. Additionally, organic acids induced by organic fertilizers may contribute to the dissolution of phosphate rock, thereby increasing the phosphorus availability and uptake by plants. These findings align with findings reported by Barakat et al. (2012) and Gomaa et al. (2010) explaining the crucial role of organic matters in promoting vegetative growth, leading to increased plant height, number of branches, and leaves.

On the other hand, applying nano NPK fertilizer has led to considerable increases in plant height, leaf size, and number due to the presence of nitrogen, which enhances plant growth by improving meristematic tissue activity and cell division. Furthermore, it increases the plant light interception, content of chlorophyll, and the leaf's specific weight, enhancing the ability of the plant to capture light energy more effectively, turning it into dry matter. Moreover, it synthesizes amino acids (such as tryptophan), which is a precursor to the biosynthesis of auxins, where the latter has a critical effect on both cell division and expansion (Loddo and Gooding, 2012). This study's findings align with those reported by Alhasan (2020) and Aziz and Zrar (2021).

3.3. Protein concentration in seeds (%)

Table 5 shows the impact of various types of organic wastes and nano NPK fertilizer on seed Protein concentrations. The results showed a significant increase in Protein concentrations induced by the organic wastes compared to the control treatment. Furthermore, poultry waste achieved the highest Protein concentration of 45.56%, which is a 98.51% enhancement compared to the control treatment, where the Protein concentration was 22.95%. Additionally, both sheep waste and cat waste showed significant improvements in nitrogen concentration, recording 43.37% and 38.31%, respectively, with increases of 88.97% and 66.92% compared to the control. The impact of nano NPK fertilizer concentrations on seed Protein concentration is carried through statistical analysis, revealing a significant improvement in nitrogen concentration, which reaches 40.45% with 4 g L^{-1} concentration (B2). Meanwhile, the 2 g L^{-1} concentration (B1) has recorded a Protein concentration of 37.94%, which is lower than B1 by 6.61%. Both B1 and B2 surpassed the control treatment, which, in this case,

Table 5. The effect of organic waste type and nano NPK fertilizer Protein concentration in seeds (%)

Type of organic waste	Nano Fertilizer Spraying			Mean
	B0	B1	B2	
A0	16.33 h	25.68 g	26.83 g	22.95 d
A1	43.22 cd	44.98 bc	48.49 a	45.56 a
A2	41.15 de	43.11 cd	45.84 b	43.37 b
A3	36.33 f	37.98 f	40.62 e	38.31 c
Mean**	34.26 c	37.94 b	40.45 a	
$LSD_{0.05}$	A=1.398	B= 1.211	A*B=2.422	

* A0: control, A1: Poultry Waste, A2: Sheep Waste, A3: Cat Waste. B0: control NPK concentration=0, B1: NPK concentration=2 g L^{-1}, B2: NPK concentration=4 g L^{-1}.

** Means followed by the same letter within each column or row are not significantly different at $P \leq 0.05$ according to the LSD test.

was 34.26%, by 18.06% and 10.74, respectively. Finally, there is a significant interaction between organic waste type and nano NPK fertilizer, recording the highest Protein concentration of 48.49% (B2) with an NPK concentration of 4 g L^{-1}. Meanwhile, the lowest Protein concentration was recorded in the control treatment, reaching a concentration of 16.33%.

3.4. Phosphorus concentration in seeds (%)

Table 6 shows the effect of organic waste type and nano NPK fertilizer on the phosphorus in seeds. No significant differences were observed among poultry waste (A1, 0.1500%), sheep waste (A2, 0.1527%), and cat waste (A3, 0.1517%), as these treatments shared the same statistical group.

On the other hand, according to statistical analysis, the nano NPK fertilizer has significantly increased the phosphorus concentration, particularly with 2 g L^{-1} concentration (B1), recording the highest increment

(0.160%), which is 20.75% higher than the control treatment (B0), where in the latter the phosphorus concentration was 0.1325%.

For the interaction effect, the highest phosphorus concentration was obtained from A2B1 (0.175%), which did not differ significantly from A1B1 (0.170%), A3B0 (0.165%), A2B2 (0.163%), and A0B2 (0.160%). The lowest value was recorded in A0B0 (0.115%), which did not differ significantly from A2B0 (0.120%) and A1B0 (0.130%).

Table 6. effect of organic waste type and nano NPK fertilizer on phosphorus concentration in seeds (%)

Type of organic waste	Nano Fertilizer Spraying			Mean
	B0	B1	B2	
A0	0.115 e	0.150 bcd	0.160 abc	0.1417 a
A1	0.130 de	0.170 ab	0.150 bcd	0.1500 a
A2	0.120 e	0.175 a	0.163 abc	0.1527 a
A3	0.165 abc	0.145 cd	0.145 cd	0.1517 a
Mean**	0.1325 b	0.160 a	0.1545 a	
LSD $_{0.05}$	A=0.0123	B=0.0106	A*B=0.0213	

* A0: control, A1: Poultry Waste, A2: Sheep Waste, A3: Cat Waste. B0: control NPK concentration=0, B1: NPK concentration=2 g L^{-1}, B2: NPK concentration=4 g L^{-1}.
** Means followed by the same letter within each column or row are not significantly different at P ≤ 0.05 according to the LSD test.

3.5. Potassium concentration in seeds (g kg^{-1})

Table 7 illustrates the effect of organic waste source application, nano NPK fertilizer spraying, and their interaction on potassium concentration in seeds. For all organic waste types, there was a significant increment in potassium concentration, recording the highest concentration of 45.92 g kg^{-1} with sheep waste, which is 56.72% higher than the control treatment, where in the latter; the potassium concentration was 29.30 g kg^{-1}. Moreover, both poultry and cat wastes recorded a significant potassium concentration of 42.12 g kg^{-1} and 41.67 g kg^{-1}, showing an improvement of 43.75% and 42.21%, respectively, compared to the control treatment. Additionally, applying nano NPK fertilizer has significantly increased the potassium concentration in seeds, recording the highest potassium concentration of 43.01 g kg^{-1} after applying 4 g L^{-1} of nano NPK fertilizer (B2). Meanwhile, applying 2 g L^{-1} concentration (B1) has increased the potassium concentration in seeds, recording 39.62 g kg^{-1}, which is lower than B2 by 8.55%. Compared to the control treatment (B0), B2 and B1 showed a considerable increase of 17.48% and 8.22%, respectively, compared to the control treatment, where the latter recorded a potassium concentration of 36.61 g kg^{-1}. Finally, there is a significant interaction between organic waste types and nano NPK concentration, reaching the highest potassium concentration of 49.20 g kg^{-1} by integrating cat waste and 4 g L^{-1} of nano NPK (B2). On the other hand, the lowest potassium concentration of 26.75 g kg^{-1} was achieved when using only 4 g L^{-1} nano NPK without organic waste addition.

The higher potassium concentration observed in broad bean seeds under the treatment combining cat litter waste with 4 g L^{-1} NPK fertilizer can be explained by the improvement in soil fertility and the greater availability of nutrients following the decomposition of organic residues. The addition of organic matter is known to increase the soil's cation exchange capacity, which helps retain potassium ions in the soil and limits their loss through leaching, thereby enhancing their uptake by plants. In addition, the integration of organic amendments with mineral fertilizers often results in a complementary effect that promotes nutrient uptake efficiency and stimulates plant growth. The variation in the impact of different organic waste sources on yield and nutrient composition may be related to differences in their chemical characteristics, mineralization rate, and C:N ratio, all of which affect the release and availability of nutrients in the soil. Furthermore, the application of NPK fertilizer at both 2 and 4 g L^{-1} improved the nutrient content of seeds, likely due to the balanced supply of essential macronutrients that support plant metabolic processes and facilitate the translocation of nutrients to developing seeds.

Table 7. The effect of organic waste type and nano NPK fertilizer on potassium concentration in seeds (g kg⁻¹)

Type of organic waste	Nano Fertilizer Spraying			Mean
	B0	B1	B2	
A0	33.75 e	27.40 f	26.75 f	29.30 c
A1	32.35 e	44.80 bc	49.20 a	42.12 b
A2	43.40 c	47.75 a	46.60 ab	45.92 a
A3	46.95 ab	38.55 d	49.50 a	41.67 b
Mean**	36.61 c	39.62 b	43.01 a	
LSD 0.05	A=1.693	B= 1.466	A*B= 2.932	

* A0: control, A1: Poultry Waste, A2: Sheep Waste, A3: Cat Waste. B0: control NPK concentration=0, B1: NPK concentration=2 g L^{-1}, B2: NPK concentration=4 g L^{-1}.
** Means followed by the same letter within each column or row are not significantly different at P ≤ 0.05 according to the LSD test.

The results showed that utilizing organic wastes has improved nitrogen, phosphorus, and potassium concentrations in broad bean seeds due to their role in improving soil properties and binding essential mineral nutrients through active functional groups such as humic and fulvic acids, which is also proved by Hussein et al (2024), where the latter concluded that applying organic waste with irrigation water has significantly increased the concentration of NPK in broad seed. This is due to the intense application of NPK fertilizers, which in turn enhances the availability of nutrients and plant uptake, and these findings were proved by El-Azizy and Habib (2021) and Menajid, et al. (2021) after applying the NPK fertilizers on broad bean and sunflower, respectively.

3.6. Number of pods per plant

Table 8 shows the effect of applying different organic wastes and nano NPK fertilizers on the number of pods per plant. The results indicate that utilizing all types of organic wastes has significantly increased the pods number per plant, reaching its highest value of 16.07 when sheep waste is utilized, which is a 54.22% improvement compared to control treatment, where in the latter produces the lowest number of pod per plant of 10.42. Another improvement was achieved by utilizing poultry waste, reaching a number of pods per plant of 13.73, which is 31.76 higher than the control treatment. The results also revealed that utilizing nano NPK fertilizer concentration has significantly increased the pods' number, reaching its highest value of 16.79 (62.22%improvement compared to the control treatment) after applying the 4 g L^{-1} concentration (B2), followed by 2 g L^{-1} concentration (B1) with 10.35 pods per plant. A significant interaction was observed between organic waste sources and nano NPK fertilization on the number of pods per plant, with the highest pod count (21.65 pods per plant) recorded when sheep waste was combined with nano NPK at 4 g L^{-1} (B2), whereas the lowest value of 7.60 was observed in the control treatment (no organic waste, no foliar spraying).

Table 8. The effect of organic waste type and nano NPK fertilizer on the number of pods per plant

Types of organic waste	Nano Fertilizer Spraying			Mean
	B0	B1	B2	
A0	7.60 h	9.90 g	13.75 d	10.42 c
A1	11.70 e	13.90 d	15.60 c	13.73 b
A2	19.05 b	7.50 h	21.65 a	16.07 a
A3	7.75 h	10.10 fg	16.15 c	11.33 c
Mean**	11.52 b	10.35 c	16.79 a	
LSD 0.05	A=0.935	B= 0.810	A*B= 1.619	

* A0: control, A1: Poultry Waste, A2: Sheep Waste, A3: Cat Waste. B0: control NPK concentration=0, B1: NPK concentration=2 g L^{-1}, B2: NPK concentration=4 g L^{-1}.
** Means followed by the same letter within each column or row are not significantly different at P ≤ 0.05 according to the LSD test.

3.7. Total yield (Mg ha⁻¹)

Table 9 shows a significant increase in total yield with poultry and cat waste application compared to the control treatment. Poultry waste recorded the highest total yield (1.546 Mg ha^{-1}), representing a 24.67% increase compared to the control, where the latter had the lowest yield (1.240 Mg ha^{-1}). Additionally, cat waste significantly improved, recording a total yield of 1.294 Mg ha^{-1}, which is 4.35% higher than the control.

Statistical analysis also showed that nano NPK fertilizer concentrations have a significant effect on total yield. The 2 g L^{-1} concentration (B1) resulted in the highest yield (1.499 Mg ha^{-1}), significantly surpassing the 4 g L^{-1} concentration (B2), which recorded 1.346 Mg ha^{-1}, reflecting an 11.36% increase. Both treatments significantly outperformed the control (B0), which had the lowest total yield (1.172 Mg ha^{-1}), with increases of 27.90% and 14.84%, respectively. A significant interaction was also noted between organic waste sources and nano NPK fertilization. The highest total yield (2.072 Mg ha^{-1}) was recorded when poultry waste was combined with nano NPK at 2 g L^{-1} (B1); meanwhile, the lowest yield (1.122 Mg ha^{-1}) was observed in the control treatment (no organic waste, no foliar spraying). The increment in total seed yield can be attributed to the cumulative effect of growth indicators and pod number as a result of applying organic wastes. Organic waste has improved the physical and biological characteristics of the soil, enhancing nutrient availability and supply through decomposition (Adekiya and Agbede, 2009), as reflected in the growth traits of the crop (*Table 3-7*). These findings are consistent with Shaaban and Okasha (2007) and El-Desuki et al. (2010). Additionally, the humic acids produced during organic waste decomposition enhance membrane permeability, facilitating and accelerating nutrient absorption through both roots and leaves. These nutrients are then transported to the photosynthetic sites (leaves), contributing to biomass accumulation in seeds, improving vegetative growth, and reducing nutrient competition among pods, ultimately increasing pod number per plant (Katkat et al., 2009). These findings align with the findings obtained by Aziz and Zrar (2021), Sabh and Shallan (2008), Sarheed et al. (2020), Shafeek, et al. (2013), Sharqi et al. (2024). The role of nano NPK fertilizers, particularly nitrogen, in enhancing leaf photosynthesis efficiency contributed to increased vegetative growth and canopy expansion. Consequently, it enhances both nutrient uptake capacity and assimilated accumulation, incrementing pod number per plant (Hassan and Nasser, 2023).

Table 9. The effect of organic waste type and nano NPK fertilizer on total yield (Mg ha⁻¹)

Type of organic waste	Nano Fertilizer Spraying			Mean
	B0	B1	B2	
A0	1.122 de	1.450 bc	1.147 cde	1.240 b
A1	1.392 cd	2.072 a	1.173 cde	1.546 a
A2	0.905 e	1.205 cde	1.715 b	1.275 b
A3	1.268 cd	1.268 cd	1.348 cd	1.294 b
Mean**	1.172 b	1.499 b	1.346 a	
LSD $_{0.05}$	A=0.1855	B= 0.1606	A*B= 0.3213	

* A0: control, A1: Poultry Waste, A2: Sheep Waste, A3: Cat Waste. B0: control NPK concentration=0, B1: NPK concentration=2 g L^{-1}, B2: NPK concentration=4 g L^{-1}.

** Means followed by the same letter within each column or row are not significantly different at P ≤ 0.05 according to the LSD test.

4. Conclusions

This study investigates the impact of applying various organic wastes and nano NPK fertilizer on broad (*Vicia faba* L.) beans' growth, yield, and mineral content of broad bean seeds. The findings showed that both sheep and poultry wastes have significantly enhanced soil fertility, nutrient availability, and plant growth. Meanwhile, nano NPK fertilizer has significantly improved seed nutrient content and total yield, particularly in the concentration of 2 g L^{-1}, where the highest yield (2.072 Mg ha^{-1}) was achieved after combining the latter with poultry waste.

In light of these results, this study suggests that farmers should take into consideration utilizing organic wastes to enhance soil fertility and productivity. Furthermore, for obtaining ideal nutrient uptake and yield, this study suggests the utilization of nano NPK fertilizer at a concentration of 2 g L^{-1}. Moreover, this study suggests achieving sustainable practices by combining organic wastes and nano fertilizer, enhancing productivity and minimizing environmental damage. Finally, a long-term study should be considered to assess the impact of organic-inorganic fertilization, as well as large-scale application from an economic perspective, to obtain sustainable and efficient crop production.

The increase in potassium content in broad bean seeds under the treatment of cat litter waste combined with 4 g L^{-1} of NPK fertilizer may be attributed to the improvement of soil fertility and nutrient availability resulting from the decomposition of organic residues. Organic matter enhances the cation exchange capacity of the soil and reduces potassium losses, thereby increasing its availability for plant uptake. Moreover, the combined application of organic and mineral fertilizers creates a synergistic effect that improves nutrient absorption and plant growth. Differences among organic waste sources may be related to variations in their chemical composition, decomposition rate, and C:N ratio, which influence nutrient release and plant availability. The positive effect of both 2 and 4 g L^{-1} NPK fertilizer concentrations on seed nutrient content may be due to the balanced supply of essential macronutrients that enhance plant metabolism and nutrient translocation to seeds.

Acknowledgment

This work supported by the Faculty of Agriculture, University of Anbar.

Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

Authors declare that there is no conflict of interest.

Authorship Contribution Statement

Concept: Sharqi, H. S.; Design: Sharqi, H. S.; Data Collection or Processing: Sharqi, H. S.; Statistical Analyses: Sarheed, B. R.; Literature Search: Hamed, M. A.; Writing, Review and Editing: Sharqi, H. S.

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