

Effect of Vermicompost, Biofertilizer, and Phosphorus on Nutrient Sustainability in Soil

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Abstract:

A field experiment was conducted in one of the fields of Babylon Province during the 2024–2025 season to cultivate potato crop (cv. Bureish) in a silty loam soil, with the aim of evaluating the role of biofertilizer, vermicompost, and phosphorus fertilizer in enhancing the sustainability of potato growth indicators. The experiment included three factors: the first factor was the addition of vermicompost at three levels (0, 10, and 20 Mg ha⁻¹), denoted as V0, V1, and V2, respectively. The second factor was the addition of biofertilizer (Biohealth) at three levels (0, 4, and 8 kg ha⁻¹), while the third factor was phosphorus fertilizer at two levels only 50 kg ha⁻¹, representing half the recommended dose, and 100 kg ha⁻¹, representing the full recommended dose), denoted as P1 and P2, respectively. Thus, the total number of experimental units was 54. The results showed that all the study factors and their interactions significantly affected the availability of nitrogen, potassium, and phosphorus in the soil after harvest. The addition of vermicompost v2 significantly increased available nitrogen to 42.98 mg N kg⁻¹soil, available phosphorus to 30.45 mg P kg⁻¹soil, available potassium to 203.49 mg K kg⁻¹soil, and available phosphorus to 23.32 mg kg⁻¹ soil. The addition of biofertilizer also significantly increased the availability of these elements in the soil after harvest. The treatment with biofertilizer B2 was the most effective, gave the highest levels of available nitrogen (38.52 mg N kg⁻¹soil), available potassium (192.74 mg K kg⁻¹soil), and available phosphorus (23.32 mg K kg⁻¹soil). phosphate content in the soil (mg/kg). The addition of phosphate fertilizer had a significant effect, with treatment P2 showing the highest available nitrogen (31.83 mg N kg⁻¹soil) and available phosphorus (24.34 mg P kg⁻¹soil). The results also showed that the interaction between treatments had a significant effect. The bi- interaction (B2P2, V2P2, and V2B2) was the most effective, recording the highest available nitrogen, potassium, and phosphorus content in the soil after harvest. Regarding the three-treatment interaction, treatment V2B2P2 was the most effective, recording the highest available nitrogen (52.72 mg N kg⁻¹soil), available phosphorus (38.15 mg P kg⁻¹soil), and available potassium (225.77mg K kg⁻¹soil).

Keywords: Vermicompost, phosphorus, bio fertilizer, potato, soil fertility.

Introduction

Improving the quality and yield of potato crop, and its reflection on the qualitative traits under sustainable agriculture, can be achieved through biological nutrient inputs that play a pivotal role in enhancing these traits and reducing dependence on harmful chemical fertilizers. Among these inputs, vermicompost

is produced from the decomposition of biomass with the aid of earthworms and contains easily absorbable nutrients such as nitrogen, phosphorus, and potassium, in addition to enzymes and plant-available compounds, along with the stimulation of intensive microbial activity. Vermicompost has been reported to increase potato yield from

22 to 36 t ha⁻¹ [5]. It also improves soil fertility and water-holding capacity [7].

Biofertilizer, on the other hand, is a material containing beneficial microorganisms such as *Azospirillum* and *Azotobacter*, which promote plant growth through nitrogen fixation, phosphorus solubilization, and the production of plant hormones. It also reduces the activity of harmful microbes and enhances nutrient availability in the soil, thereby facilitating nutrient absorption and translocation into tubers, which in turn increases the percentage of dry matter, starch, and protein, and ultimately improves tuber yield and number [12].

Phosphorus is considered an essential nutrient for root development and tuber formation. A study by [15] revealed that the integration of organic and biofertilizers with phosphorus according to recommendations significantly contributed to increasing potato productivity. Phosphorus also activates more than 90 enzymes that play an important role in nutrient availability and energy compound formation, which positively affects potato quality traits and yield [12]. Therefore, this study aimed to evaluate the interaction of the three factors (vermicompost, biofertilizer, and phosphorus) and their role in improving quality traits such as dry matter, starch, and protein, given the scarcity of studies linking these inputs, and their potential impact on increasing tuber yield and number in potato crop.

Materials and Methods

A field experiment was conducted during the autumn season of 2024 to cultivate potato crop, cultivar Burrish, in one of the fields in Babylon Province, on a silty loam soil. The aim was to study the effect of vermicompost, biofertilizer (Biohealth), and phosphorus on improving the qualitative traits of potato under a sustainable farming system. Three factors were studied:

First factor: Application of vermicompost at three levels (0, 10, and 20 Mg ha⁻¹), symbolized as V0, V1, and V2.

Second factor: Application of biofertilizer (Biohealth) at three levels (0, 4, and 8 kg ha⁻¹), symbolized as B0, B1, and B2.

Third factor: Application of phosphorus fertilizer at half and full recommended rates (50 and 100 kg ha⁻¹), symbolized as P1 and P2, respectively.

Thus, the total number of experimental units was 54. Before planting, random soil samples were taken from the depth of 0–30 cm, mixed, and sieved through a 2 mm mesh. These samples were used to determine the chemical, physical, and biological properties of the soil before planting (Table 1).

Studied Traits

Samples were randomly taken from the center of each experimental unit, air-dried, and then dried in an electric oven at 65°C until a stable weight was reached. Afterward, they were ground in an electric mill in the laboratory. A 0.2 g sample of the plant material was placed in a conical flask, and 3 ml of concentrated sulfuric acid was added. The mixture was left overnight, and the solution turned black. The following day, 1 ml of a 1:1 mixture of concentrated sulfuric acid and concentrated perchloric acid was added. The digestion process was carried out by placing the mixture on a heat source (hot plate) for 25–35 minutes to complete the digestion process, until the solution became clear. The solution was then left to cool and diluted with distilled water. Finally, it was quantitatively transferred into 50 ml plastic containers according to [4].

Available Nitrogen Concentration(%)

Nitrogen was determined by distillation using a microkjeldal apparatus after adding sodium

hydroxide (10 M) and titrating with sulfuric acid (H₂ SO₄) at 0.05 N, according to the method described in [14].

Available Phosphorus Concentration(%)
Phosphorus in tubers was determined using ammonium molybdate and ascorbic acid after adjusting the reaction of the solutions used and

measuring using a spectrophotometer, according to [13]

Available Potassium Concentration(%)
Potassium was determined using a flame photometer, according to the method described in [9].

Table 1. The chemical, physical, and biological properties of the soil before cultivation

Property	Unit	Value
Electrical conductivity (ECe)	dS m ⁻¹	3.95
Soil reaction (pH)	-	7.55
Organic matter	g kg ⁻¹	0.50
Cation exchange capacity (CEC)	cmol(+) kg ⁻¹ soil	29.25
Soluble cations and anions		
Magnesium (Mg ²⁺)	mmol L ⁻¹	7.50
Calcium (Ca ²⁺)		8.45
Potassium (K ⁺)		0.85
Sodium (Na ⁺)		6.80
Sulfates (SO ₄ ²⁻)		10.25
Chlorides (Cl ⁻)		12.70
Bicarbonates (HCO ₃ ⁻)		6.20
Carbonates (CO ₃ ²⁻)		nil
Soil particals		
Sand	g kg ⁻¹	335
Silt		465
Clay		200
Texture	Silty loam	
Biological properties		
Total fungi count	CFU g ⁻¹ soil	1.80 × 10 ³
Total bacteria count		2.75 × 10 ⁶
Bulk density	Mg m ⁻³	1.34

Results and Discussion

Effect of Vermicompost, Biofertilizer, Phosphorus, and Their Interaction on Nutrient Sustainability

1. Nitrogen (mg N kg⁻¹soil)

The results of the statistical analysis (Table 2) indicate that all the study factors and their interactions significantly increased the available soil nitrogen (mg N kg⁻¹soil) after harvest. The addition of Vermicompost significantly increased available soil nitrogen,

with the highest value observed in treatment V2 (42.98 mg N kg⁻¹soil), compared to treatments V1 and V0 (34.65 and 28.18 mg N kg⁻¹soil, respectively). Similarly, the addition of biofertilizer significantly increased available soil nitrogen after harvest, with the highest value observed in treatment B2 (38.52 mg N kg⁻¹soil), while treatment B1 (36.54 mg N kg⁻¹soil) also significantly increased available soil nitrogen. The highest value of available soil nitrogen (NO) was recorded in treatment B0 (30.73 mg N/kg/soil), while the lowest value was observed in the control treatment. The addition of phosphate fertilizer significantly increased soil nitrogen, with the highest value recorded in treatment P2 (38.67 mg N/kg/soil) compared to the lowest value in treatment P1 (31.83 mg N/kg/soil). Bi-interactions also significantly increased soil nitrogen, with the highest value recorded in the B2P2 binary interaction (41.40 mg N/kg/soil) compared to the lowest value in treatment

B0P1 (25.66 mg N/kg/soil). Furthermore, the combination of vermicompost and phosphate fertilizer significantly increased soil nitrogen after harvest, with the highest value recorded in treatment V2P2 (48.45 mg N/kg/soil). The combined effect of Vermicompost and Biohealth fertilizer significantly increased soil nitrogen availability after harvest, with the highest value recorded in the V2B2 treatment (48.01 mg N kg⁻¹ soil), compared to the lowest value in the control treatment (24.60 mg N kg⁻¹ soil, V0B0). The table also shows that the combined effect of Vermicompost, Biohealth, and phosphorus significantly impacted soil nitrogen availability after harvest, with the highest value recorded in the V2B2P2 treatment (52.72 mg N kg⁻¹ soil), while the lowest value was recorded in the control treatment (24.60 mg N kg⁻¹ soil). For treatment V0B0P1, the value was 23.31 mgN/kg⁻¹ soil.

Table 2: Effect of Vermicompost and Biohealth fertilizers on post-harvest available soil nitrogen (mg N kg⁻¹soil) phosphorus levels

phosphate fertilizer P	Biohealth fertilizers	Vermicompost V			P*B	average P
		V ₀	V ₁	V ₂		
P ₁	B ₀	23.31	26.13	27.55	25.66	31.83
	B ₁	28.43	32.72	41.66	34.27	
	B ₂	29.00	34.65	43.30	35.65	
P ₂	B ₀	25.89	36.80	44.75	35.81	38.67
	B ₁	30.31	38.25	47.90	38.82	

	B₂	32.17	39.33	52.72	41.40	
LSD		LSD: P*B *V = 12.85			LSD: P*B	LSD: P
P*V		5.08				3.38
P₁		26.85	31.16	37.50	LSD:P *V =4.90	
P₂		29.45	38.12	48.45		
B*V						معدل B
B₀		24.60	31.46	36.15	30.73	
B₁		29.37	35.48	44.78	36.54	
B₂		30.58	36.99	48.01	38.52	
LSD		LSD: B*V = 5.44			LSD:B = 1.31	
average V	-----	28.18	34.65	42.98	-----	
LSD		LSD: V=4.17			-----	

2. Phosphorus (mg P kg⁻¹soil)

The results of the statistical analysis in Table 3 show that Vermicompost significantly increased post-harvest available soil phosphorus. The highest level was observed in treatment V2, reaching 30.45 mg P kg⁻¹soil, while treatment V1 had a value of 20.25 mg P kg⁻¹soil. The lowest value for post-harvest available phosphorus was observed in treatment V0, at 9.38 mg P kg⁻¹soil. The addition of biohealth fertilizer also significantly increased post-harvest available soil phosphorus, with the highest value observed in treatment B2, reaching 23.32 mg P kg⁻¹soil. While the value of treatment B1 reached 20.58 mg P/kg/soil, the lowest value was in the control treatment B0, which reached 16.17 mg P/kg/soil. The addition of phosphorus fertilizer at half and full

fertilization recommendations led to a significant increase in available soil phosphorus after harvest, with the highest value in treatment P2 reaching 24.34 mg P/kg/soil, compared to the value in treatment P1 at half fertilization, which reached 15.70 mg P/kg/soil. It was also observed that the bi-interactions of the study factors significantly affected the increase in available soil phosphorus after harvest, with the highest value in the bi-interaction treatment between biofertilizer and phosphate fertilizer B2P2 reaching 27.05 mg P/kg/soil, compared to the lowest value in treatment B0P1, which reached 10.51 mg P/kg/soil. The bi-interaction between the fertilizer also led to Vermicompost and phosphate significantly increased soil availability after harvest, with the highest value (36.58 mg P kg⁻¹) observed in

treatment V2P2, compared to the lowest value (7.4 mg P kg⁻¹) in treatment V0P1. The bi-interaction of Vermicompost and biofertilizer also significantly increased soil availability after harvest, with the highest value (35.18 mg P kg⁻¹) observed in the bi-interaction treatment V2B2, while the lowest value (7.87 mg P kg⁻¹) was recorded in treatment V0B0. As can be seen from the table, the triple

interaction of Vermicompost, biofertilizer, and phosphorus significantly impacted soil availability after harvest, with the V2B2P2 treatment gave the highest value. The value of available phosphorus in the soil after harvest was 38.15 mgP kg⁻¹ soil, while the lowest value of available phosphorus in the soil was in the control treatment V0B0P1, which was 6.40 mgP kg⁻¹ soil.

Table 3: Effect of Vermicompost and Biohealth fertilizers on post-harvest soil phosphorus levels (mg P/kg/soil)

phosphate fertilizer P	Biohealth fertilizers	Vermicompost V			P*B	average P
		V ₀	V ₁	V ₂		
P ₁	B ₀	6.40	11.40	13.73	10.51	15.70
	B ₁	7.35	16.70	27.00	17.01	
	B ₂	7.89	18.65	32.20	19.58	
P ₂	B ₀	9.33	21.35	34.79	21.82	24.34
	B ₁	10.79	24.85	36.80	24.15	
	B ₂	14.50	28.52	38.15	27.05	
LSD		LSD: P*B *V = 20.66			LSD: P*B	LSD: P
P*V		5.89				4.47
P ₁		7.21	15.58	24.31	LSD:P *V =3.55	
P ₂		11.54	24.90	36.58		
B*V						معدلB
B ₀		7.87	16.38	24.26	16.17	
B ₁		9.07	20.77	31.90	20.58	
B ₂		11.20	23.58	35.18	23.32	
LSD		LSD: B*V =6.13			LSD:B =1.24	
average V	-----	9.38	20.25	30.45	-----	
LSD		LSD: V= 5.50			-----	

3. Potassium (mg K/kg/soil)

The results of the statistical analysis in Table 4 indicate that all the study factors the addition of Vermicompost and Biohealth fertilizers, phosphorus, and their interactions significantly affected the increase in post-harvest soil potassium (mg K/kg/soil). The addition of Vermicompost led to a significant increase in post-harvest soil phosphorus, with the highest value observed in treatment V2 (203.49 mg K/kg/soil), compared to treatments V1 and V0 (188.52 and 169.81 mg K/kg/soil, respectively). Similarly, the addition of Biohealth fertilizer significantly increased post-harvest soil phosphorus, with the highest value observed in treatment V2. Treatment B2, which reached 192.74 mg K_2 /kg_1 soil, was significantly higher than treatments B1 and B0, which reached 187.35 and 181.75 mg K_2 /kg_1 soil, respectively. The addition of phosphate fertilizer, at either the full or half recommended amount, also significantly increased soil-available potassium after harvest. The highest value was observed in treatment P2, reaching 194.62 mg K_2 /kg_1 soil, compared to the half recommended amount for treatment P1, which reached 179.89 mg K_2 /kg_1 soil. Furthermore, bi-interactions significantly increased soil-available potassium after harvest. The bi-interaction between biofertilizer and phosphate

significantly increased soil-available potassium after harvest, with the highest value for the B2P2 bi-interaction treatment reaching 200.22 mg K_2 /kg_1 soil, compared to the lowest value for treatment B0P1. The soil potassium level reached 173.99 mg K kg^{-1} soil. The bi-interaction between Vermicompost and phosphate fertilizers resulted in a significant increase in post-harvest soil potassium, with the highest value observed in treatment V2P2 (214.22 mg K kg^{-1} soil), compared to the lowest value in treatment V0P1 (162.49 mg K kg^{-1} soil). Similarly, the bi-interaction between Vermicompost and bio-fertilizer also led to a significant increase in post-harvest soil potassium, with the highest value observed in the bi-interaction treatment V2B2 (212.06 mg K kg^{-1} soil), compared to the lowest value in the control treatment V0B0 (165.36 mg K kg^{-1} soil). The table also shows that the tertiary interaction of Vermicompost, Biohealth, and phosphorus may have a significant effect. The treatment significantly affected the sustainability of available potassium in the soil after harvest. The highest value was observed in the triple interaction treatment V2B2P2, reaching 225.77 mg K kg^{-1} soil, while the lowest value of available potassium in the soil after harvest was observed in the triple interaction treatment

(control) VOBOP1, reaching 157.34 mg K kg⁻¹ soil.

Table 4: Effect of Vermicompost and Biohealth fertilizers on post-harvest phosphorus and potassium levels in the soil (mg K kg⁻¹soil).

phosphate fertilizer P	Biohealth fertilizers	Vermicompost V			P*B	average P
		V ₀	V ₁	V ₂		
P ₁	B ₀	157.34	181.43	183.20	173.99	179.89
	B ₁	160.00	185.60	195.73	180.44	
	B ₂	170.13	187.31	198.35	185.26	
P ₂	B ₀	173.35	190.00	205.13	189.49	194.62
	B ₁	177.80	192.15	212.80	194.25	
	B ₂	180.25	194.65	225.77	200.22	
LSD		LSD: P*B *V = 25.83			LSD: P*B	LSD: P
P*V		6.75				4.45
P ₁		162.49	184.78	192.42	LSD:P *V =	
P ₂		177.06	192.26	214.56		
B*V					معدل B	
B ₀		165.35	185.72	194.17	181.75	
B ₁		168.90	188.88	204.26	187.35	
B ₂		175.19	190.98	212.06	192.74	
LSD		LSD: B*V = 13.62			LSD:B = 3.34	
average V	-----	169.81	188.52	203.49	-----	
LSD		LSD: V= 8.52			-----	

Tables 2, 3, and 4 show that the effects of the studied factors—the addition of biofertilizers, Vermicompost, Biohealth fertilizer, and phosphorus at half and full fertilization rates, and their interactions significantly increased the availability and sustainability of nitrogen,

phosphorus, and potassium nutrients in the soil after harvest. The addition of Vermicompost significantly increased the availability of these nutrients in the soil. This may be attributed to the fact that Vermicompost improved the physical properties and fertility of the soil due

to its components (see Table 2). It also plays a significant role in soil water retention and raising soil temperature in winter. Furthermore, the low C:N ratio led to a mineralization process that converted all nutrients into available forms. In the soil, organic acids are released and decomposed by microorganisms, lowering the soil pH and thus increasing the availability of most nutrients, including nitrogen, phosphorus, and potassium. The addition of vermicompost enhances soil fertility, further increasing nutrient availability[3]. Vermicompost, with its humic acids, particularly humic acid, plays a role in releasing these elements, especially potassium, from certain minerals present in the soil. This occurs by replacing potassium ions with hydrogen ions produced during the decomposition of these organic acids. Therefore, adding organic acids to the soil increases the amount of available nutrients after harvest, including major nutrients. The continued activity of microorganisms in decomposition processes, releasing organic acids, and lowering the soil pH throughout the growing season (the entire crop growth period) further increases the availability of these nutrients. Moreover, this acid has a good storage capacity for nutrients like nitrogen. Phosphorus and potassium [1]. Adding Biohealth fertilizer also increased the availability of nitrogen, phosphorus, and potassium in the soil after harvest, due to the

microorganisms, bacteria, and microbiomes it contains. Biohealth and bacteria play a significant role in increasing the efficiency of ready-made and added fertilizers. Biohealth also improves all vital plant activities, including the production of enzymes and amino acids, which play a significant role in increasing the availability of various nutrients, especially nitrogen, phosphorus, and potassium, and increasing their availability in the soil through increased root secretions of organic acids. Therefore, adding this biohealth fertilizer plays a significant and broad role in the secretion of some enzymes and plant hormones, which play a significant role in increasing the availability of these nutrients [8].

The bacteria contained in this fertilizer also activate nitrogen-fixing bacteria, which fix atmospheric nitrogen and increase its availability. This is crucial for root growth and increases the availability of macronutrients such as nitrogen, phosphorus, and potassium in the soil. Furthermore, Biohealth fertilizer plays a significant role in releasing substances that promote plant growth, leading to better growth and root spread in the soil. This facilitates the absorption of nutrients from the soil and the plant, thus increasing their availability. The addition of Biohealth fertilizer, along with the high percentage of humic acid it contains, increases cell membrane permeability,

photosynthesis, and root growth. It also indirectly enhances the efficiency of available and added fertilizers, or directly improves all vital plant functions, thereby increasing the availability of nitrogen, phosphorus, and potassium in the soil [2,10]. It should be noted that adding phosphate fertilizer at half or full nutrient recommendations... It played a significant role in increasing the availability of nitrogen, phosphorus, and potassium nutrients in the soil after harvest. The addition of this fertilizer, along with the components of Vermicompost and bio-fertilizer, led to increased solubility of these fertilizers and the release of most available nutrients in the soil, including nitrogen. Nitrogen has an acidic effect in the rhizosphere after its addition to the soil, and nitrification occurs with the presence of urease enzyme, affecting the soil pH and thus increasing the availability of these nutrients in the soil [12]. Furthermore, the interaction of the study's factors significantly increased the availability of these nutrients in the soil after harvest, providing a complete and balanced nutrient system that increased soil productivity and fertility of nutrients, including nitrogen, phosphorus, and potassium. This also had a positive role in promoting plant growth and increasing bacterial metabolic activity, leading to the development of a large root system. With an increased respiration rate, CO₂ production increases, which combines with water to form

acid. The carbonic acid that begins to diffuse towards the minerals bearing these nutrients in the rhizosphere. These results are consistent with those found by [3,6]. The interaction of these study factors led to an increase in root mass. The phosphorus released through both vermicompost and Biohealth fertilizers, over time, contributes to the development of a large root system that releases H⁺, which in turn contributes to the release of these nutrients from the soil after harvest. Furthermore, the addition of certain enzymes and organic acids also stimulates root growth [11]. The combined effect of these factors, particularly the vermicompost, resulted in increased availability of these nutrients in the soil. The biological factor that positively impacted the availability of these nutrients with half and full fertilizer recommendations for added phosphorus is consistent with several studies, including [3,6].

Conclusions:

- 1- The study showed that adding Vermicompost at a level of 20 Mg ha⁻¹ contributed to increasing nutrient availability, reflecting the role of organic fertilizers in building a balanced and sustainable agricultural system.
- 2- The treatment with Biohealth fertilizer at a level of 8 kg ha⁻¹ demonstrated its effectiveness in activating microorganisms and

assessing the availability of macronutrients, which supported the plant's nutrient absorption efficiency and increased its productivity within a safe environmental framework.

3- The results of phosphate fertilization showed that applying half the recommended fertilizer amount of 20 kg (50 kg p ha⁻¹) with organic and bio-treatments resulted in an increase in nutrient availability.

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