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Evaluation of the role of vermicompost, biofertilizer, and phosphorus fertilizer in enhancing the sustainability of growth indicators of potato and improving soil fertility

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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. Before maturity, plant height, number of stems per plant, leaf area, chlorophyll index (SPAD) units, and dry weight of the shoot system were measured. Results showed that the highest values of these indicators were obtained from the high level of vermicompost treatment (V2), which recorded 51.35 cm, 2.59 stems/plant, 4871 cm²/plant, 54.99 SPAD units, and 5.55 Mg, respectively. Similarly, the biofertilizer treatment B2 gave values of 51.50 cm, 2.37 stems/plant, 4522 cm²/plant, 53 SPAD units, and 5.2 Mg, respectively.

Keywords: biofertilizer, phosphorus, potato, soil fertility, vermicompost

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} (Feodous et al., 2020). It also improves soil fertility and water-holding capacity (Haque et al., 2025).

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 (Abdul-Patho and Al-Momori, 2020; Magahed et al., 2024.

Phosphorus is considered an essential nutrient for root development and tuber formation. A study by Zewide and Kassa (2021) 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 (Mhadsh, 2024). Therefore, this study aimed to evaluate

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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**).

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-})		nill
	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

Vegetative Growth Indicators of the Studied Traits

Plant height (cm).

On April 5, 2025, with the onset of maturity signs, the height of ten randomly selected plants from each experimental unit was measured using a measuring tape, and the mean was calculated.

Number of main stems (stem/plant)

The number of main stems of ten randomly selected plants per experimental unit was counted and averaged.

Leaf area (cm²/plant):

Three plants were randomly sampled from the ridges of each experimental unit, and the number of leaves was counted. Nine standard leaves were then taken, from which leaf discs were cut using a cork borer (totaling 45 discs). Both discs and leaves were oven-dried at 70°C until constant weight. The leaf area was calculated using the ratio method based on the dry weight of discs and leaves, following the equation described by Watson and Watson (1953).

4. Chlorophyll content in leaves (SPAD units).

Measured using a Chlorophyll Meter (SPAD-502), and recorded as the average of ten readings from the middle rows of each experimental unit before the flowering stage.

5. Dry weight of the vegetative growth (Mg ha^{-1}).

Ten plants were randomly harvested from the middle rows of each experimental unit. Samples were oven-dried at 70°C until constant weight (Al-Sahaf, 1989). The average was calculated and then expressed per hectare.

Percentage of dry weight of vegetative growth = (Dry weight / Fresh weight) × 100

Results and Discussion

Effect of vermicompost, biofertilizer (Biohealth), and phosphorus levels on potato growth indicators.

Plant height (cm).

The results of statistical analysis (**Table 2**) indicated that all factors of the study significantly affected plant height. Vermicompost significantly increased plant height, with the highest value recorded at V2 (51.35 cm) compared to V0 and V1 (49.79 and 47.53 cm, respectively). Similarly, biofertilizer significantly affected this trait, with the highest value at B2 (51.50 cm) compared to B0 and B1 (47.03 and 50.14 cm). Phosphorus also showed a significant effect, with the highest value at P2 (51.60 cm) compared to P1 (47.51 cm).

Table 2: Effect of Vermicompost and Biohealth Fertilizer and Phosphorus Levels on Potato Plant Height (cm)

Phosphorus Fertilizer P	Biohealth Fertilizer	Vermicompost V			P*B	average P
	B_0	V0	V1	V2		
P1	B_1	43.25	44.50	45.89	44.54	
	B_2	46.51	48.93	49.93	48.45	47.51
	B_0	48.00	49.73	50.86	49.53	
P2	B_1	44.63	51.20	52.73	49.52	
	B_2	50.81	51.69	53.00	51.83	51.60
		52.00	52.73	55.70	53.47	
LSD		P*B*V = 6.43			P*B= 1.57	P= 1.35
P*V						
P1		45.92	47.72	48.89	LSD:P*V=2.30	
P2		49.14	51.87	53.81		
B*V					Average B	
B_0		43.94	47.85	49.31	47.03	
B_1		48.66	50.31	51.46	50.14	
B_2		50.00	51.23	53.28	51.50	
LSD		LSD:B*V= 1.55			LSD:B=1.15	
Average V		47.53	49.79	51.35	----	
LSD		V=1.20			----	

Regarding two-way interactions, the combination of biofertilizer and phosphorus (B2P2) recorded the highest value (53.47 cm). The interaction between vermicompost and biofertilizer (B2V2) also produced a high value (53.81 cm), while the lowest was at (P1V0) (45.92 cm).

The three-way interaction (B2V2P2) resulted in the highest plant height (55.70 cm), which did not differ significantly from (B2V2P1) (50.86 cm). The lowest plant height was recorded at the control treatment (B0V0P1), which was 43.25 cm.

Number of main stems (stem/plant)

The statistical analysis (**Table 3**) showed that all studied factors (vermicompost, biofertilizer, and phosphorus) and their interactions significantly affected the number of main stems. The highest value was observed at V2 (2.59 stems/plant) compared to V0 and V1 (1.58 and 2.13 stems/plant). Biofertilizer showed the highest value at B2 (2.37 stems/plant) compared to B0 and B1 (1.80 and 2.13 stems/plant)..

Phosphorus significantly increased this trait, with the highest value recorded at P2 (2.33 stems/plant) compared to P1 (1.86 stems/plant). For two-way interactions, the highest value was at (B2P2) (2.68 stems/plant) compared to (B0P1) (1.66 stems/plant). The vermicompost × phosphorus interaction (V2P2) gave the highest number of stems (2.92 stems/plant), while the lowest was at (V0P1) (1.42 stems/plant)

The vermicompost × biofertilizer interaction showed the highest value at (B2V2) (3.07 stems/plant) compared to the lowest at (B0V0) (1.35 stems/plant).

Finally, the three-way interaction (B2V2P2) showed the highest number of main stems (3.52 stems/plant), which did not differ significantly from (B1V2P2) (2.85 stems/plant). The lowest value was at the control treatment (B0V0P1), which recorded 1.30 stems/plant.

Leaf area (cm²/plant):

The results of the statistical analysis in **Table 4** indicated that the application of vermicompost had a significant effect on increasing the leaf area (cm²/plant) of potato. The highest value was obtained from treatment V2, which reached 4871 cm²/plant,

Table 3: Effect of Vermicompost, Biohealth Fertilizer, and Phosphorus Levels on Number of Main Stems per Potato Plant (stem plant^{-1})

Phosphorus Levels P	Biohealth Fertilizer	Vermicompost V			P*B	avarage P
		V0	V1	V2		
P1	B_0	1.30	1.79	1.90	1.66	
	B_1	1.43	1.98	2.23	1.88	1.86
	B_2	1.55	2.00	2.63	2.06	
P2	B_0	1.40	2.05	2.41	1.95	
	B_1	1.89	2.41	2.85	2.39	2.33
	B_2	1.95	2.52	3.52	2.68	
LSD		P*B*V = 0.96			P*B= 0.25	P= 0.40
P*V						
P1		1.42	1.92	2.25	LSD:P*V=0.33	
P2		1.74	2.35	2.92		
B*V					avarage B	
B_0		1.35	1.92	2.15	1.80	
B_1		1.66	2.20	2.54	2.13	
B_2		1.75	2.29	3.07	2.37	
LSD		LSD:B*V= 0.67			LSD:B=0.18	
V		1.58	2.13	2.59	----	
LSD		V=0.22			----	

Table 4: Effect of Vermicompost, Biohealth Fertilizer, and Phosphorus Levels on Leaf Area per Potato Plant (cm² plant⁻¹)

Phosphorus Levels P	Biohealth Fertilizer	Vermicompost V			P*B	avarage P
		V0	V1	V2		
P1	B_0	2800	3050	3190	3013	3674
	B_1	3105	3900	4461	3822	
	B_2	3241	4150	5175	4188	
P2	B_0	2930	4330	5230	4163	4542
	B_1	3420	5020	5390	4610	
	B_2	3650	5139	5780	4856	
LSD		P*B*V = 263.51			P*B= 135.45	P= 175.30
P*V						
P1		3048	3700	4275	LSD:P*V=0.33	
P2		3333	4829	5466		
B*V					avarage B	
B_0		2865	3690	4210	3588	
B_1		3265	4460	4925	4215	
B_2		3445	4644	5477	4522	
LSD		LSD:B*V= 210.39			LSD:B=115.65	
avarage V		3191	4264	4871	----	
LSD		V=195.53			----	

compared with treatments V0 and V1, which recorded 4264 and 3191 cm²/plant, respectively. The application of biofertilizer (Biohealth) also significantly increased this trait, with the highest value recorded under treatment B2 (4522 cm²/plant) compared with treatments B1 and B0, which recorded 4215 and 3588 cm²/plant, respectively. Similarly, phosphorus fertilizer significantly affected this trait, with the highest value obtained from treatment P2 (4542 cm²/plant) compared with treatment P1 (3674 cm²/plant) . The two-way interactions of the studied factors also had a significant effect on this trait. The interaction between biofertilizer and phosphorus fertilizer recorded the highest value at treatment B2P2 (4856 cm²/plant), whereas the lowest value was observed at treatment B0P1 (3013 cm²/plant). Likewise, the interaction between vermicompost and phosphorus fertilizer significantly increased leaf area, with the highest value obtained under treatment V2P2 (5466 cm²/plant), compared with the lowest value at treatment V1P0 (3048 cm²/plant). In addition, the interaction between vermicompost and biofertilizer significantly increased the leaf area per plant, with the highest value recorded at treatment V2B2 (5477 cm²/plant), compared with the lowest value at treatment V0B0 (2865 cm²/plant). Furthermore, the three-way interaction of vermicompost, biofertilizer, and phosphorus fertilizer also significantly affected this trait. The highest value was recorded at treatment V2B2P2 (5780 cm²/plant), which did not differ significantly from treatment V2B2P1 (5175 cm²/plant). In contrast, the lowest leaf area was observed at the control treatment, which recorded 2800 cm²/plant.

Chlorophyll content index (SPAD unit).

The results of the statistical analysis in **Table 5** showed that all studied factors significantly affected this trait. Vermicompost application had a significant effect on chlorophyll content index (SPAD unit), with the highest value recorded under treatment V2 (54.99 SPAD) compared with treatments V0 and V1, which recorded 47.42 and 51.57 SPAD, respectively. Biofertilizer application also significantly increased chlorophyll content, with the highest value observed under treatment B2 (53.61 SPAD), compared with treatments B1 and B0, which recorded 52.26 and 48.12 SPAD, respectively.

Phosphorus fertilizer at half and full recommended rates significantly increased the chlorophyll index, with the

Table 5: Effect of Vermicompost, Biohealth Fertilizer, and Phosphorus Levels on Leaf Chlorophyll Content (SPAD Units)

Phosphorus Levels P	Biohealth Fertilizer	Vermicompost V			P*B	avarage P
		V0	V1	V2		
P1	B_0	44.31	44.89	45.93	45.04	49.40
	B_1	47.20	50.75	54.63	50.86	
	B_2	48.53	52.39	56.00	52.30	
P2	B_0	45.00	51.75	56.85	51.20	53.25
	B_1	49.30	54.43	57.25	53.66	
	B_2	50.21	55.25	59.29	54.91	
LSD		P*B*V = 10.45			P*B= 0,95	P= 2.17
P*V						
P1		46.68	49.34	52.18	LSD:P*V=2.63	
P2		48.17	53.81	57.79		
B*V					avarage B	
B_0		44.65	48.32	51.39	48.12	
B_1		48.25	52.59	55.94	52.26	
B_2		49.37	53.82	57.65	53.61	
LSD		LSD:B*V= 2.35			LSD:B=1.10	
avarage V		47.42	51.57	54.99	----	
LSD		V=1.69			----	

highest value obtained under treatment P2 (53.25 SPAD) compared with treatment P1 (49.40 SPAD). The two-way interaction between biofertilizer and phosphorus fertilizer had a significant effect on leaf chlorophyll content of potato, with the highest value recorded at treatment B0P1 (54.91 SPAD), while the lowest value was observed at treatment B2P2 (45.04 SPAD).

Similarly, the interaction between vermicompost and phosphorus fertilizer significantly increased the chlorophyll index, with the highest value obtained under treatment V2P2 (57.79 SPAD), compared with the lowest value at treatment V0P1 (46.68 SPAD). The two-way interaction between vermicompost and biofertilizer also significantly increased chlorophyll index, with the highest value observed at treatment V2B2 (57.65 SPAD), compared with the lowest value at treatment V0B0 (44.65 SPAD).

The three-way interaction showed that the control treatment recorded the lowest chlorophyll index value (44.31 SPAD), while the highest value was obtained at treatment V2B2P2 (59.29 SPAD), which did not differ significantly from treatment V2B1P2 (57.25 SPAD).

Dry weight of vegetative growth (Mg/ha).

The results of the statistical analysis in **Table 6** indicated that all studied factors (vermicompost, biofertilizer, phosphorus fertilizer, and their interactions) had a significant effect on increasing the dry weight of vegetative growth (Mg/ha). Vermicompost application significantly increased this trait, with the highest value recorded under treatment V2 (5.55 Mg/ha) compared with treatments V0 and V1, which recorded 4.97 and 4.12 Mg/ha, respectively. Biofertilizer (Biohealth) application also significantly increased this trait, with the highest value obtained at treatment B2 (5.21 Mg/ha), compared with treatments B1 and B0, which recorded 4.94 and 4.50 Mg/ha, respectively.

Phosphorus fertilizer application also significantly increased dry weight, with the highest value recorded under treatment P2 (full recommended rate), which reached 5.24 Mg/ha, compared with treatment P1 (half recommended rate), which recorded 4.52 Mg/ha. The two-way interactions also significantly affected dry weight. The highest value was obtained under treatment B2P2 (5.46 Mg/ha), while the lowest was at treatment B0P1 (3.96 Mg/ha). Similarly, the interaction between vermicompost and phosphorus fertilizer significantly increased dry weight, with the highest value at treatment V2P2 (6.04 Mg/ha) compared with the lowest at treatment V0P1 (3.98 Mg/ha).

The interaction between vermicompost and biofertilizer also significantly increased dry weight, with the highest value recorded at treatment V2B2 (6.00 Mg/ha) compared with the lowest at treatment V0B0 (3.94 Mg/ha). Furthermore, the three-way interaction of vermicompost, biofertilizer, and phosphorus fertilizer significantly increased this trait, with the highest value recorded under treatment V2B2P2 (6.27 Mg/ha), while the lowest value was observed at the control treatment V0B0P1 (3.88 Mg/ha).

It is observed from Tables 2, 3, 4, 5, and 6 that the studied factors significantly enhanced all growth indicators of potato crop, including plant height, number of main stems, leaf area, chlorophyll index, and dry weight of the vegetative biomass. Vermicompost is considered a source of organic fertilizer added to potato-cultivated soil, influencing several vegetative growth indicators as shown in the above tables. These decomposed organic fertilizers derived from vermicompost improve soil properties, particularly fertility, which enhances plant growth, especially root development, leading to increased root activity and nutrient absorption from the soil solution. This positively reflects on plant growth. The reason may also be attributed to the fact that organic matter resulting from

Table 6: Effect of Vermicompost, Biohealth Fertilizer, and Phosphorus Levels on Dry Weight of Shoot Biomass (µg plant^{-1})

Phosphorus Levels P	Biohealth Fertilizer	Vermicompost V			P*B	avarage P
		V0	V1	V2		
P1	B_0	3.88	3.85	4.17	3.96	4.52
	B_1	3.97	4.67	5.29	4.64	
	B_2	4.10	5.06	5.73	4.96	
P2	B_0	4.00	5.25	5.86	5.03	5.24
	B_1	4.31	5.39	6.00	5.23	
	B_2	4.50	5.62	6.27	5.46	
LSD		P*B*V = 1.77			P*B= 0.29	P= 0.33
P*V						
P1		3.98	4.52	6.06	LSD:P*V=2.63	
P2		4.27	5.42	6.04		
B*V					avarage B	
B_0		3.94	4.55	5.01	4.50	
B_1		4.14	5.03	5.65	4.94	
B_2		4.27	5.34	6.00	5.21	
LSD		LSD:B*V= 0.67			LSD:B=0.20	
avarage V		4.12	4.97	5.55	----	
LSD		V=0.44			----	

the decomposition of vermicompost provides a suitable seedbed, which accelerates germination in fewer days compared to control treatments. Due to the higher soil temperature around the tubers and the ability of vermicompost-amended soil to retain adequate moisture, tuber initiation is enhanced. The use of vermicompost also leads to an increase in chlorophyll content as a result of balanced nutrition and improved nutrient uptake, particularly of iron and magnesium, both of which are essential for chlorophyll biosynthesis. Moreover, vermicompost reduces the impact of environmental stresses on plant growth by increasing tolerance to salinity or drought, thereby sustaining photosynthesis efficiently for longer periods, which contributes to greater dry matter accumulation and biomass growth. These findings are in agreement with Panwar and Singh (2022) and Tibebu (2023(.

Furthermore, vermicompost improves soil environment, aeration, and water-holding capacity, creating ideal growth conditions for potato roots. It also decreases soil bulk density and enhances organic matter content, leading to increased microbial activity and improved photosynthetic performance of plants (Al-Maamori et al., 2023). Vermicompost is also characterized by containing natural plant hormones such as auxins, cytokinins, and gibberellins, which are produced by active microorganisms during the biodegradation process in the digestive tract of earthworms. These hormones stimulate cell division and elongation, enhancing root and shoot development and accelerating overall plant growth. In addition, vermicompost is rich in beneficial microorganisms that fix nitrogen and decompose complex organic compounds, thereby improving soil fertility and sustaining crop growth indicators as presented in the above tables (Rehman et al., 2023; Jubier & Jabbar, 2023).

The application of the biofertilizer (Biohealth) also increased crop growth indicators. This may be attributed to its unique composition containing humic acids, seaweed extracts, and beneficial microorganisms such as *Trichoderma* fungi and *Bacillus* bacteria. This integrated mixture stimulates root growth, enhances plant health and productivity in multiple ways. It improves soil structure, increases water retention, and activates microbial activity in the rhizosphere, thereby enhancing photosynthesis and accelerating nutrient uptake. These microorganisms also strengthen plant resistance to biotic and abiotic stresses while increasing nutrient availability through mobilization of unavailable forms, which positively reflects on potato vegetative growth indicators. Moreover, it acts as a bio-organic stimulant with a significant impact on plant growth, development, and yield improvement. These findings are consistent with Idan & Oleiwi (2023) and Jubier & Ali (2023).

The reason may also be attributed to the role of biofertilization in enhancing the availability of macro- and micronutrients, in addition to organic acids, carbon compounds, and growth regulators, which collectively promote vegetative growth. This includes an increase in dry weight of the vegetative biomass, which in turn improves all vegetative growth indicators such as plant height, leaf area, and chlorophyll index. These results are in agreement with Al-Thamri (2023) and Humi Tech (2025). Application of Biohealth resulted in a significant increase in all growth indicators, and the addition of phosphate fertilizer also significantly enhanced growth indicators. This may be due to its role in increasing cell division in meristematic tissues, as phosphorus is an essential element and a major component of most living cells, participating in physiological functions of the plant through enhancing amino acid synthesis, which reflects positively on plant height, leaf area, chlorophyll index, and ultimately on dry biomass (Harine et al., 2017).

Phosphorus also plays a key role in stimulating cell division, cell enlargement, and metabolite translocation, mainly through the synthesis of energy compounds (ATP), which are vital for plant metabolism. Interaction of the studied factors also contributed to enhanced membrane permeability, photosynthesis, and root growth, either indirectly by increasing the efficiency of applied fertilizers, or directly by improving all physiological processes of the plant. These results agree with Ghanem (2025). Furthermore, phosphate fertilization improves the availability of other nutrients, including phosphorus in the soil solution, thereby contributing to significant increases in most physiological and morphological traits of plants. This reflects positively on plant height, number of main stems, leaf area, chlorophyll index, and dry weight of vegetative biomass in potato (Maharsh, 2024). The presence of phosphorus combined with elevated temperature provided by vermicompost and biofertilizer helped in establishing an efficient root system capable of nutrient uptake. The increased application rates also regulated plant hormone activities, controlled meristematic cell division, and enhanced physiological processes, which positively reflected on all vegetative growth indicators. These findings are in line with Al-Moussawi (2023) and Ghanem (2025).

Conclusions

The study results indicated that the application of vermicompost and biohealth fertilizer combined with appropriate phosphorus levels enhanced potato growth characteristics, including plant height, number of main stems, leaf area, chlorophyll content, and dry shoot biomass. The findings confirmed that organic and biofertilizers can improve soil fertility and sustainably increase crop productivity.

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