The Effect of Humic Acid, Vermicompost Addition, and Foliar Iron Application on the Sustainability of Certain Quality properties and Tuber Yield in Potato (Solanum tuberosum L.)

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Abstract

A field experiment was conducted of potato cultivation in one of the agricultural fields located in Al-Diblah area, Babylon Governorate. The site is characterized by flat topography with potato, with a silty clay loam soil texture. The study aimed to investigate the effect of humic acid, vermicompost, and foliar iron application on the availability of certain nutrients, growth, and yield of potato. Three factors were studied: the first was the application of humic acid at three levels (0, 25, 50) kg ha^{-1}, denoted as H0, H1, and H2 respectively. The second factor was vermicompost application at levels of (0, 10, 20) tons ha^{-1}, denoted as F0, F1, and F2 respectively. The third factor was foliar application of iron at two levels (0 , 5) ml L^{-1}, denoted as I0 and I1 respectively. The experiment included 18 treatment combinations, each replicated three times, resulting in 54 experimental units arranged in a split-split plot design within a randomized complete block design (RCBD). Humic acid at 50 kg ha^{-1} significantly improved most quality traits of potato tubers, including dry matter percentage, starch, and protein content, as well as achieving the highest tuber yield at 34.34 mg ha^{1}. The interaction between humic acid and vermicompost H2F2 led to the highest values in growth parameters and quality traits, with dry matter, starch, and protein contents reaching 18.50% , 14.23%, and 14.55% respectively, along with a maximum yield of 44.12 mg ha^{1} and an average of 7.43 tubers per plant.

Keywords: Dry Matter, Humic Acid, Potato, Protein, Starch, Vermicompost, Sustainability .

Introduction

Humic acid is one of the key components of humus, containing active groups such as carboxyl, phenol, and amine groups. Humic acid has a positive effect on nutrient absorption by roots as it increases the availability of macronutrients, particularly nitrogen, phosphorus, and potassium. It is considered one of the natural chelates that can potentially replace synthetic chelates (4). Humic acid also affects plant growth by stimulating enzymatic reactions, increasing the permeability of cell membranes, promoting cell division and elongation, increasing the quantity of plant enzymes, and activating vitamins within the cells (11). The addition of humic acid to the soil has led to improvements in plant growth, nutrient absorption, and crop yield. This, in turn, reduced the amount of mineral fertilizers added to the soil, decreasing costs and mineral fertilizer pollution without affecting the

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yield.Vermicompost is an organic fertilizer rich in both macro and micronutrients essential for plant nutrition. It also supports beneficial soil microbes, such as nitrogen-fixing bacteria and phosphate-solubilizing fungi, in addition to releasing growth hormones (auxins, gibberellins,andcytokinins). Vermicompost is water-soluble and easily absorbed by plants, making it suitable for direct application to the soil (7). Iron plays an essential role in the structure and activity of many important plant enzymes, including nitrogenases, and acts as a cofactor in chlorophyll synthesis, despite not being a component of chlorophyll itself (5) (9.(

Material and Methods

Prepare samples:

The experimental site was selected in one of the private fields used for potato cultivation, located in Al-Diblah area, Babylon Governorate, approximately 20 km from the city center. The site is characterized by flat topography and silty clay loam soil. Several random soil samples were taken from the field at a depth of 0 –30 cm. The soil samples were mixed to obtain a composite sample, air-dried, ground, and sieved through a sieve with a 2 mm mesh size. Table 1 presents the results of the physical and chemical analysis of the field soil before planting.

Afield experiment was conducted according to a split-split plot design, which included three factors. The first factor was the addition of humic acid at three levels: (0, 25, 50) kg ha^{-1}, denoted as H0, H1, and H2, respectively. The second factor was foliar iron application, with two levels: no spraying and spraying, denoted as I0 and I1, respectively. The third factor was the addition of vermicompost at three levels: (0, 10, 20) tons ha^{-1}, denoted as F0, F1, and F2, respectively. This resulted in 18 treatment combinations, each replicated three times, yielding a total of 54 experimental units.

The fertilizer recommendations for potato cultivation were followed as suggested by (3), which included 240 kg ha^{-1} of urea (N) and 400 kg ha^{-1} of potassium sulfate (K.(

-1Percentage of Dry Matter in Tubers(%)

Dry matter was estimated by taking 100 grams of tubers, cutting them into small pieces, and drying them in an electric oven at 70°C until weight stabilization (6). The percentage of dry matter was calculated using the following formula:

Percentage of Dry Matter=(Dry Weight of Tubers/Fresh Weight of Tuber)×100

-2Percentage of Starch in Tubers(%)

The starch percentage was calculated using the formula provided in (1), as follows:

%Starch=17.55+0.89×(%Dry Matter−24.18 (

-3Percentage of Protein in Tubers(%)

The protein percentage was calculated based on the dry weight of the tubers (1) using the following formula:

Protein Percentage Based on Dry Weight=Nitrogen Percentage in Tubers×6.25.

-4Tuber yield (megagrams ha-1(

After the crop showed signs of maturity, yield and its components were calculated for each experimental unit separately. After removing tubers from the two middle beds of each experimental unit, they were randomly weighed and the yield per plant was calculated, along with the yield per experimental unit and its percentage per

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hectare, according to(8)using the following equation:

Experimental unit yield = yield per plant x number of plants in the experimental unit.

Table 1: Chemical and physical properties of the soil before cultivation

Values	Units	Traits
3.73	dsm^{-1}	Electrical conductivity
7.71	------	Soil pH
0.63	%	Organic matter
23.55	Cmol kg	Exchange capacity CEC
4.13	g kg^{1}-soil	Gypsum
Positive and negative dissolved ions		
10.50	mmolL^{-1}	Calcium
6.35		Magnesium
8.25		Sodium
0.75		Potassium
12.25		Sulfate
14.00		Chloride
4.65		Bicarbonate
Nill		Carbonate
Available elements		
26.40	mg kg^{-1}	Nitrogen
7.89		Phosphorus
159.89		Potassium
-----		Iron
Soil separators		
225	Gkg^{-1} soil	Sand
475		Silt
300		Clay
Clay Loam		Texture
1.33	Mg m^{-3}	Bulk Density

Results and Discussion

Percentage of Dry Matter in Tubers

The statistical analysis results presented in Table 2 indicate that the study factors humic acid, vermicompost, and foliar iron application significantly affected the percentage of dry matter in the tubers. The addition of humic acid led to a significant increase in the dry matter percentage, with the highest value observed in the H2 treatment at 17.22%, compared to the H0 and H1 treatments, which had values of 16.75% and 15.92%, respectively, showing increases of 2.80% and 8.16%, respectively.

The addition of vermicompost also significantly increased the dry matter percentage, with the highest value in the F2 treatment at 17.72%, compared to the F0 and F1 treatments, which had values of 16.74% and 15.42%, respectively, showing increases of 5.8% and 14.9%, respectively. Foliar iron application significantly increased the dry matter percentage, with the highest value observed in the I1 treatment at 15.80%, showing an increase of 9.90.%

It can be observed from the table that the interactions between the study factors

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significantly affected the dry matter percentage in the tubers. The highest value was found in the interaction between humic acid and iron spraying H2I1, which reached 17.7%, compared to the lowest value in the H0I0 interaction at 14.71 %. Additionally, the interaction between vermicompost and foliar iron resulted in a significant increase in the dry matter percentage, with the highest value at 18.50% in the H2F2 treatment, compared to the lowest value at 14.84 % in the H0F0 treatment, which was also significantly different from the H1F1 treatment, which had a value of 17.61%.

Moreover, the interaction between humic acid and vermicompost resulted in a significant increase in the dry matter percentage, with the highest value in the H2F2 treatment at 18.50 %, which did not differ significantly from the H1F2 treatment at 17.85%. The lowest value for dry matter percentage was found in the control treatment H0F0, which had a value of 15.05%.

Table 2: The Effect of Humic Acid, Vermicompost, and Iron Foliar Spray on the Percentage of Dry Matter in Potato Tubers.

average I	I*H	Vermicompost			Humic acid H	Iron spray I
		F_2	F_1	F_0		
15.80	14.71	15.29	14.55	14.30	H_0	With out I_0
	16.04	16.04	16.30	14.89	H_1	
	16.64	17.85	16.75	15.33	H_2	
17.37	17.12	18.36	17.22	15.80	H_0	With I_1
	17.46	18.75	17.63	16.00	H_1	
	17.77	19.15	18.00	16.20	H_2	
LSD : I	LSD : I*H	LSD : I*H*F=3.17			LSD	
0.77	0.59				I*F	
LSD : I*F=1.85		16.69	15.86	14.84	I_0	
		18.50	17.61	16.00	I_1	
average H					H*F	
15.92		16.83	15.88	15.5	H_0	
16.75		17.85	16.96	15.45	H_1	
17.22		18.50	17.38	15.77	H_2	
LSD : H=0.25		LSD : H*F= 1.30			LSD	
--------------		17.72	16.74	15.42	average F	
--------------		LSD :F= 0.40			LSD	

Starch Percentage in Tubers(%)

The statistical analysis results presented in Table 3 indicate that the study factors humic acid, vermicompost, and foliar iron application, as well as their interactions significantly affected the quality trait of the potato crop, specifically the percentage of starch in the tubers. The addition of humic acid led to a significant increase in the starch

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percentage, with the highest value observed in the H2 treatment at 13.12%, compared to the H0 and H1 treatments, which had values of 12.62% and 11.92%, respectively, showing increases of 7.3% and 9.6%, respectively.

The addition of vermicompost also significantly increased the starch percentage in the tubers, with the highest value at 14.23% in the F2 treatment, compared to the F0 and F1 treatments, which had values of 12.35% and 11.10 %, respectively, showing increases of 15.2 % and 28.1%, respectively. Foliar iron application had a significant effect on increasing the starch percentage, with the highest value at 13.22% in the I1 treatment, compared to the I0 treatment, which had a value of 11.91%, showing an increase of 10.99 .%

It can also be observed from the table that the interactions between the study factors, such as humic acid addition with foliar iron application and vermicompost addition with foliar iron application, significantly affected the starch percentage in the tubers. The highest value was observed in the H2F1 treatment at 13.65 %, compared to the H0I0 treatment, which had a value of 11.58%.

Moreover, the interaction between vermicompost and foliar iron application significantly affected the starch percentage, with the highest value in the F2I1 treatment at 15.2 %. The lowest value for starch percentage was observed in the F0I0 treatment at 10.66%. Additionally, the interaction between humic acid and vermicompost significantly increased the starch percentage, with the highest value at 14.79% in the H2F2 treatment, which did not differ significantly from the H1F2 treatment at 14.40%. The lowest value for starch percentage in the tubers was observed in the H0F0 treatment, with a value of 10.65%.

Table 3: Effect of Humic Acid, Vermicompost, and Iron Foliar Spray Application on the Starch Percentage in Tuber

average I	I*H	vermicompost F_2	F_1	F_0	Humic acidH	Iron spray I
11.91	11.08	12.39	10.55	10.30	H_0	With out I_0
	12.05	13.71	11.73	10.37	H_1	
	12.59	14.25	12.57	10.95	H_2	
13.22	12.84	14.63	12.89	11.00	H_0	With I_1
	13.18	15.10	13.00	11.44	H_1	
	13.65	15.33	13.41	12.20	H_2	
LSD : I	LSD : I*H	LSD : I*H*F=2.75			LSD	
0.71	1.35				I*F	
LSD : I*F=1.24		13.45	11.62	10.66	I_0	
		15.02	13.10	11.55	I_1	
average H					H*F	
11.96		13.51	11.72	10.65	H_0	
12.62		14.40	12.37	11.09	H_1	
13.12		14.79	12.99	11.58	H_2	
LSD : H =0.30		LSD : H*F= 0.54			LSD	
--------------		14.23	12.35	11.10	average F	
--------------		LSD :F= 0.36			LSD	

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Percentage of Protein in Tubers

The statistical analysis results presented in Table 4 indicate that all study factors humic acid, vermicompost, foliar iron application, and their interactions significantly affected the percentage of protein in the tubers. The addition of humic acid led to a significant increase in the protein percentage, with the highest value observed in the H2 treatment at 12.58%, compared to the H0 and H1 treatments, which had values of 11.90% and 11.30%, respectively, showing increases of 5.7% and 11.3%, respectively.

It can also be observed from the table that the addition of vermicompost had a significant effect on the protein percentage in the tubers, with the highest value at 13.28% in the F2 treatment, compared to the F0 and F1 treatments, which had values of 11.9 % and 10.31%, respectively, showing increases of 11.5% and 28.8%, respectively. Additionally, foliar iron application significantly affected the protein percentage in the tubers, with the highest value at 12.80% in the I1 treatment, compared to the I0 treatment (no foliar iron), which had a value of 10.85%, showing an increase of 17.9%.

Furthermore, the interactions between the study factors also significantly influenced the protein percentage in the tubers. The interaction between humic acid and foliar iron application led to a significant increase in the protein percentage, with the highest value at 13.18% in the H2I1 treatment, compared to the lowest value at 9.60% in the H0I0 treatment. The interaction between vermicompost and foliar iron application also significantly increased the protein percentage, with the highest value at 14.73% in the F2I1 treatment, compared to the lowest value at 9.75% in the F0I0 treatment.

The interaction between humic acid and vermicompost also significantly increased the protein percentage, with the highest value at 14.55% in the H2F2 treatment, followed by 13.20% in the H1F2 treatment. The lowest value was observed in the control treatment H0F0, with a protein percentage of 10.03%. The triple interaction between humic acid, vermicompost, and foliar iron application had a significant effect on the protein percentage in the tubers, with the highest value at 15.29% in the H2F2I1 treatment, which did not differ significantly from the 14.70% observed in the H1F2I1 treatment. The lowest value for the triple interaction was observed in the H0F0I0 treatment, with a protein percentage of 9.33%, followed closely by 9.93% in the H1F0I0 treatment.

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Table 4: Effect of Humic Acid, Vermicompost, and Iron Foliar Spray on Protein Percentage in Tubers.

average I	I*H	Vermicompost			Humic acid H	Iron spray I
		F_2	F_1	F_0		
10.85	9.60	9.97	9.51	9.33	H_0	With out I_0
	10.98	11.69	11.33	9.93	H_1	
	11.97	13.81	12.10	10.00	H_2	
12.80	12.46	14.22	12.43	10.73	H_0	With I_1
	12.81	14.70	12.89	10.85	H_1	
	13.18	15.29	13.25	11.00	H_2	
LSD : I	LSD : I*H	LSD : I*H*F=2.33			LSD	
0.87	1.25				I*F	
LSD : I*F=0.92		11.82	10.98	9.75	I_0	
		14.73	12.85	10.84	I_1	
average H					H*F	
11.30		12.09	10.97	10.03	H_0	
11.90		13.20	12.11	10.39	H_1	
12.58		14.55	12.68	10.50	H_2	
LSD : H =0.37		LSD : H*F= 1.10			LSD	
--------------		13.28	11.91	10.31	average F	
--------------		LSD :F= 0.53			LSD	

Tubers Yield (Microgram per Hectare(

The statistical analysis results presented in Table 5 indicate that all the study factors humic acid, vermicompost, foliar iron application, and their interactions significantly affected the tuber yield (in micrograms per hectare) of the potato crop. The addition of humic acid led to a significant increase in the tuber yield, with the highest value observed in the H2 treatment at 34.34 micrograms per hectare, compared to the H0 and H1 treatments, which had values of 31.58 and 26.88 micrograms per hectare, respectively. This represents an increase of 8.73% and 27.75%, respectively.

The addition of vermicompost also significantly increased the tuber yield, with the highest value at 39.39 micrograms per hectare in the F2 treatment, compared to the F1 and F0 treatments, which had values of 29.66 and 25.42 micrograms per hectare, respectively. These values represent increases of 32.8% and 54.9%, respectively. Additionally, foliar iron application resulted in a significant increase in the tuber yield, with the highest value at 35.34 micrograms per hectare in the I1 treatment, compared to the I0 treatment (no foliar iron), which had a value of 26.52 micrograms per hectare, reflecting an increase of 33.3%.

The interactions between the study factors also significantly affected the tuber yield. The interaction between humic acid and foliar iron application led to a significant increase in the tuber yield, with the highest value at 38.58 micrograms per hectare in the H2I1 treatment, compared to the lowest value at 22.12

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micrograms per hectare in the H0I0 treatment, reflecting a 74.4% increase.

Table 5: Effect of Humic Acid, Vermicompost, and Iron Foliar Spray on Tuber Yield (Mg ha^{-1}.(

average I	I*H	Vermicompost			Humic acid H	Iron spray I
		F_2	F_1	F_0		
26.52	22.12	24.90	21.90	19.53	H_0	With out I_0
	27.36	33.38	26.89	21.81	H_1	
	30.10	38.43	28.30	23.59	H_2	
35.34	31.64	43.50	31.42	20.00	H_0	With I_1
	35.81	46.35	33.69	27.39	H_1	
	38.58	49.82	35.73	30.20	H_2	
LSD : I	LSD : I*H	LSD : I*H*F=6.85			LSD	
2.85	3.75				I*F	
LSD : I*F=4.65		32.23	25.70	21.64	I_0	
		46.55	33.61	25.86	I_1	
average H					H*F	
26.88		34.20	26.67	19.77	H_0	
31.58		39.86	30.29	24.60	H_1	
34.34		44.12	32.01	26.90	H_2	
LSD : H=2.51		LSD : H*F=			LSD	
--------------		39.39	29.66	25.42	average F	
--------------		LSD :F= 3.36			LSD	

As observed from the results in Tables 2, 3, 4, and 5, the effects of the study factors humic acid, vermicompost, and foliar iron application significantly influenced the qualitative traits, including the percentage of dry matter, starch, and protein in potato tubers. The addition of humic acid leads to the stimulation of enzymes and plant hormones, improves soil fertility, and increases nutrient availability. This could be attributed to the fact that humic acid enhances root growth and weight, as well as the dry weight of the vegetative parts. This, in turn, improves soil water retention and increases the plant's nutrient uptake, which results in enhanced growth. These effects are reflected in the higher dry matter, protein, and starch content in the tubers. These findings align with the work of (13.(

The increase in nutrient availability, particularly the macronutrients and micronutrients, due to humic acid application, facilitates nutrient absorption by the plant. This allows the plant to maintain a healthy root system capable of absorbing nutrients efficiently, promoting the development of a healthy vegetative system. Through carbon metabolism, the plant produces various compounds needed for its growth, which are then transported to the tubers for storage. Therefore, the availability of nutrients contributes to the increased percentage of starch and protein in potato tubers. The protein content in the tubers is influenced by the

concentration of nutrients, while the starch content depends on the dry matter weight of the tubers. All of these effects are attributed to the fact that humic acids, including humic acid, increase the permeability of cell membranes and facilitate the movement and transfer of nutrients to all plant parts (10)(12.(
The addition of vermicompost also resulted in an increase in the release of humic acids, which improved nutrient availability, making it easier for the plant to absorb essential nutrients. Vermicompost, as both a material and an organic fertilizer, helps the plant overcome stress, increases the leaf area, and enhances nutrient absorption. Consequently, this leads to an increase in the storage materials, tuber weight, and size, resulting in better nutrient uptake by the tubers, which is reflected in the increased starch and protein content. f (5) (2.(
Furthermore, the combined effect of humic acid, vermicompost, and foliar iron application significantly increased both the total yield and the number of potato tubers. The addition of humic acid improves both the quantity and quality of crop yields by affecting cellular mechanisms such as respiration, metabolism, carbon fixation, protein synthesis, water absorption, nutrient uptake, and enzymatic activities. These mechanisms play a crucial role in increasing the number and yield of potato tubers.

Conclusion

Adding vermicompost at a level of 20 mg kg-1 led to a significant increase in most growth indicators of potato crop and qualitative characteristics including the percentage of dry matter, protein , starch and tuber yield.

References

[1] A.O.A.C. 1970. OVVicial Methods Analysis 11th ed. Washington,D.C.Association oV OVVicial Analytical Chemists. P.1015.
2]Al-Amri, Zeinab Ali Hussein Marhoon. 2022. Role of Bentonite, Perlite, and Vermicompost in Improving Some Physical and Chemical Properties of Desert Soil and in Growth and Yield of Potato (Solanum tuberosum L.). Master's Thesis, College of Agriculture, University of Baghdad.
[3]Al-Fadhli, Jawad Taha Mahmoud. 2006. Effect of Organic and Inorganic Fertilization on Growth and Yield of Potato. Master's Thesis, Department of Soil Science and Water Resources, College of Agriculture, University of Baghdad.
[4]Ali, Noor Al-Din Shawqi and Abdul Wahab Abdul Razzaq Shaker. 2018. Organic Fertilization and Its Role in Sustainable Agriculture. Dar Al-Kutub Al-Ilmiyah for Printing, Publishing, and Distribution, Baghdad, Iraq.
[5]Al-Mamouri, Marwa Alwan. 2020. Effect of Iron Spraying and Humic Acid Addition on Some Growth Traits and Yield of Wheat (Triticum aestivum L.). Master's Thesis, College of Agriculture, Al-Qasim Green University.
[6]Al-Sahaf, Fadel Hussein. 1989. Applied Plant Nutrition. Dar Al-Hikma Printing Press, Ministry of Higher Education and Scientific Research, University of Baghdad.
[7]Al-Shibli, Hassan Habib Hussein. 2022. Effect of Bacillus subtilis Bacteria, Earthworm

Compost, and Phosphate Fertilizer on the Activity of Alkaline Phosphatase Enzyme, Biomass, Growth, and Yield of Cauliflower. Master's Thesis, College of Agriculture, University of Al-Qadisiyah.

[8]Al-Tamimi, Muhammad Salal Aliwi, and Dhi Muhammad Matar Al-Jadi. 2018. The Effect of Adding Poultry Waste and Organic Acid Spraying on Potato Yield and Some of Its Components. Karbala Journal of Agricultural Sciences. Proceedings of the Third Agricultural Scientific Conference, March 5-6. College of Agriculture, University of Karbala.

[9]Hamada, Iyad Ahmed, and Noor Al-Din Mohamed Mahawish. 2024. Foliar Fertilization: Basics and Applications. University of Tikrit, College of Agriculture.

[10]Mohsen, Taleb Khairi. 2019. Effect of Humic Acids Addition, Foliar Application of Amino Acids, and Nitrogen Fertilizer Levels on Growth and Yield of Potato (Solanum tuberosum L.). Master's Thesis, University of Baghdad, College of Agriculture.

[11]Ouda, Marwan Mahmoud. 2024. Effect of Humic Acid Addition on the Chemical Behavior of Zinc and Boron in Calcareous Soil and on the Growth and Yield of Sunflower. Ph.D. Thesis, College of Agricultural Engineering Sciences, University of Baghdad.

[12]Sarhan, Taha Zubeir. 2008. Effect of Bio-fertilizers, Animal Residues, and Urea on Growth and Yield of Potato Variety (Desiree) (Solanum tuberosum L.). Ph.D. Thesis, College of Agriculture and Forestry, University of Mosul, Ministry of Higher Education and Scientific Research, Iraq.

[13]Trevisan, S; O. Francoso; S. Quaggiotti; and S. Nardi .2010.Humic Substances biological activity of plant soil ,Interface from Environmentala spects to molecular factors .plant. signal Beha Behav. 6(5) :635-643.

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