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Enhancing Nutritional Value and Antioxidants in Blackberry by Foliar Potassium Sulfate and Phenylalanine Under Soilless Cultivation

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ABSTRACT

The aim of this study to enhance the nutritional value and antioxidants in the leaves and fruits of blackberry plants by cultivating them using soilless conducted at Research Station of the College of Agricultural Engineering Sciences-University of Baghdad in the 2023–2024 seasons. Three factors included the first factor: cultivation in organic media of local and imported plant waste: The media included licorice root waste (C3) and coconut husk waste (C2), compared to field soil (C1). The second factor was Folior application of potassium sulfate (S) in concentrations (0, 2.5, 5) g.l^{-1} and the third factor was foliar applicates with amino acid phenylalanine (A) in concentrations (0, 100, 200) mg. l^{-1} in factorial experiment as a completely randomized design (R.C.B.D) with three replications. The results indicated the superiority of the treatment with licorice residue medium and phenylalanine at a concentration of 200 mg.l^{-1} with 2.5 g.l^{-1} of potassium sulfate ($C_3A_2S_1$) with the highest concentration of total carotene in the leaves (13.33 mg 100g^{-1}) and the highest concentration of phenols, anthocyanin, and DPPH in the fruits (198.26, 534.5 mg100g^{-1}, 89.41%) respectively. The treatment $C_3A_1S_2$ excelled with the highest concentration of total carotene and folic acid in the fruits (0.81, 2.62 mg 100g^{-1}) respectively.

Key words: anthosanins, organic media, total phenols.

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INTRODUCTION

The blackberry (*Rubus fruticosus* L.) is a small fruit plant that belongs to the family Rosaceae and the genus Rubus. Several varieties of this genus have been developed in breeding and improvement and have properties such as texture, shape, size, flavor, color, yield, maturity, and nutritional value. It's fruits are popular in the world market for their sweet taste, flavor and nutritive value (Subbiah et al., 2021). Blakberry is receiving attention of the researchers recently for its nutritional and industrial values such as low in calories and fat, copious source of vitamins nutrient and fiber, and high in water content, potassium, carbohydrates and simple sugar. While blackberry is not rich in protein as a common fruit, it does contain significant amount of protein as compared to other fruits, and is also contains some bioactive compounds such as flavonoid, phenol, anthocyanins, tannin, antioxidants etc. (Okatan, 2020, Vega et al. 2021, Zia-Ul-Haq et al., 2014) It been indicated that blackberry has tremendous health benefits such as cancer and cardiovascular disease prevention, anti-diabetic, anti-obesity, anti-diarrhea, anti-memory-impaired, and anti-inflammatory effects. Moreover, it exhibits fascinating biological activity towards esophageal, colon, and oral cancers. It is an interesting topic for health and nutrition research and development both for its therapeutic properties and commercial interests (Gil-Martínez et al., 2023, Manzoor et al., 2022) .Memete et al. (Memete et al.,2023) observed that the plant has a high antioxidant activity in the presence of large amounts of anthocyanins and phenols in a study performed in seven blackberry cultivars, among them the Thorn free. The

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anthocyanin found in the blackberry was cyanidin-3-glucoside, with an overall anthocyanin content 329.26 mg g-1 dry weight. Thorn free variety with total phenolic content 1687.14 mg100 g-1 dry weight and antioxidant content among the eight blackberry varieties was significantly different, and also its antioxidant content proved to be more than the other varieties. The blackberry crop faces many problems depending on the production areas such as slow or rampant vegetative, diseases and insect infestation, and reduction in quality and quantity of fruit yield. In recent years, the cultivated areas have increased, and despite this increase and demand, the scientific knowledge about the plant's requirements for nutrients is still recent and developing. Due to the importance of potassium for physiological processes, several studies have been conducted on various blackberry cultivars showing the physiological effect of potassium addition (pereira et al., 2015). It is one of the main essential nutrients necessary for plant growth and development and is one of the essential macronutrients involved in many physiological and biochemical functions, the most important of which are related to protein synthesis from amino acids and the activation and transport of most enzymes and important plant hormones, including those related to energy transfer, ATP synthesis, starch, proteins, and sugars, thus stimulating the photosynthesis process. It also works to transport sugars and proteins to their storage sites within the plant, from the upper parts to the roots and vice versa, in addition to its essential role in controlling stomata and reducing biotic and abiotic stress on the plant (Ortel et al., 2024, Sardans and Penuelas. 2021, Gaurat et al. 2020) mentioned in an experiment conducted on four blackberry cultivars using four levels of potassium K_2O (10, 20, 30, 40 g plant-1) that the level of 20 g plant-1 plant gave the best economic efficiency in production. Recently, there has been an increased interest in using natural and safe materials in terms of improving fruit quality and enhancing their marketability. Studies have shown that amino acids are essential components for protein synthesis, and phenylalanine is one of the most important aromatic amino acids, as it links primary and secondary metabolism in plants and is the basic building block for proteins and a precursor for a number of essential plant compounds involved in growth and defense against various stresses (Kumar and Verma. 2024 , Oosalo et al., 2024, Adams et al., 2019 , Lee et al.,2024). Increasing stressors on global food security and ecosystems, over the growing human population, stand before the world today. This has prompted the need to implement sustainable agricultural systems such as soilless culture technology, which is seen as having a promising potential to be a viable alternative to conventional soil-based agriculture due to its many advantages. These benefits are reduced land and water requirements, recycling 85 to 90% of irrigation water on the farm, efficient nutrient management, year-round production of high-quality crops, disease and pest control, and low labor. (Bihari et al., 2023, Ghorbel et al., 2021). The study aimed to enhance and increase the content of antioxidant compounds in the leaves and fruits of the blackberry plant by treating them with potassium sulfate and phenylalanine and cultivating them in organic media in a soilless agricultural system.

MATERIALS AND METHODS

The experiment was conducted at the Research Station A, College of Agricultural Engineering Sciences at the University of Baghdad - Al-Jadriyah for two consecutive seasons, 2023/2024,at protected place covered with sarain in pots with the aim of studying the nutritional value and antioxidants of the leaves and fruits of thornless blackberry plants (Thornfree) Foliar application with potassium sulfate and phenylalanine grown in soilless culture systems with sustainable organic media (imported and local). Saplings aged one year with as uniform growth as possible and free from disease and insect infestation were selected. A factorial experiment was designed according to a randomized complete block design(RCBD)involving the following factors:

- Foliar application of potassium sulfate (Ahmed et. al., 2023) at concentrations of S0 0, S1 2.5, and S2 5 g L^{-1}
- Foliar application of the amino acid phenylalanine (A) at concentrations (Khadam

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et al.,2020.) of A0 0 ,A1 100, and A2 200 mg L^{-1};

- Cultivation in soilless systems using organic media derived from plant residues, designated as factor (C): field soil + peat moss in a 1:2 ratio (control treatment), (C1), coconut husk residues (imported coco peat) + peat moss in a 1:2 ratio (C2), and local licorice root residues + peat moss in a 1:2 ratio (C3). A drip irrigation system was employed to supply the plants with water and nutrients. The plants grown in the tested media were provided with a modified nutrient solution based on Cooper's standard formula for macro- and micronutrients, as outlined Fertigation was used to deliver the nutrient solution through the irrigation system, with nutrient concentrations adjusted according to the different plant growth stages (vegetative, flowering, and fruiting). This approach was based on scientific principles and designed to be applicable for practical use by farmers and producers.

Foliar application treatments with potassium sulfate and phenylalanine commenced in mid-March and continued throughout the growing season. The sprays were applied at 20-day intervals, with a three-day gap between the applications of the two factors.

The following Parameters were studied:

- Concentration of phenols and flavonoids (mg. $100g^{-1}$ fresh weight) for leaves and fruits.
- Total carotene (mg 100g $^{-1}$fresh weight) for leaves and fruits.
- DPPH % radical scavenging activity in leaves and fruits.
- Folic acid, vitamin C, and total anthocyanin concentration (mg $100g^{-1}$ fresh weight) for fruits.

Table 1. Some chemical and physical properties of the planting soil, Coconut Substrate and licorice root Substrate

Properties		**Soil**	**Substrate** **Coconut**	**licorice**	**Unit**
EC 1:1		0.86	2.0	1.3	dsm^{-1}
PH		7.2	6.9	7.43	-------
Available Nitrogen (N)		24.30	1.52	1.83	
Available Phosphorus (P)		5.25	0.72	0.48	mg kg^{-1} soil
Available Potassium (K)		70.60	2.45	1.38	
Organic Matter (O M)		15.8	30.4	25.6	g kg^{-1} %
Soluble Calcium (Ca^{+2})		4.30	0.38	0.49	meq L^{-1}
Magnesium (Mg^{+2})		2.67	0.28	0.36	
Soil Separates	Sand	672	-----------		
	Silt	28	-----------		g kg^{-1} soil
	Clay	20	-----------		
Soil Texture		Sand			------

RESULTS AND DISCUSSION

Table (2) indicates that the study factors had a significant effect on them. The three-way interaction treatment $C_2A_2S_1$ excelled by giving the highest total phenolic concentration for leaves without a significant difference from the treatment $C_3A_2S_1$, which gave 575.16 and 568.53 mg 100g fresh weight, respectively, compared to the control treatment, which recorded 442.52 mg $100g^{-1}$ fresh weight. In fruits, the treatment $C_3A_2S_1$, with 198.26 mg 100g fresh weight, significantly outperformed the lowest concentration of 148.39 mg $100g^{-1}$ fresh weight in the treatment $C_1A_1S_0$. As for the two-way interaction effect between phenylalanine spraying treatments and organic media, the results in Table 1 indicated the superiority of the treatment C_3A_2 without a significant difference from the treatment C_3A_1 in the total phenolic concentration of leaves, reaching 559.62 and 558.1 mg $100g^{-1}$ fresh weight, respectively. In fruits, the treatment C_3A_2 recorded the highest total phenolic concentration, reaching 187.63 mg $100g^{-1}$ fresh weight, while the lowest rate was recorded by the treatment C_1A_0 in leaves and

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fruits, which reached 465.77 and 160.25 mg 100g⁻¹ fresh weight, respectively. Regarding the two-way interaction effect between potassium sulfate and organic media, the treatment C_2S_2 showed the highest value for total phenolic concentration in leaves, reaching 555.68 mg $100g^{-1}$ fresh weight. For fruits, the treatment C_3S_2 outperformed, giving 188.99 $mg100g^{-1}$ fresh weight compared to the lowest values in the treatment C_1S_0 in leaves and fruits, which were 474.35 and 154.5 mg $100g^{-1}$fresh weight, respectively. In the results of the two-way interaction between potassium sulfate and phenylalanine, the results in Table (1) indicate the superiority of the treatment A_2S_1 in giving the highest value for total phenols in leaves, reaching 556.33 $mg100g^{-1}$ fresh weight. In fruits, the treatment A_1S_1 excelled by giving 187.62 $mg100g^{-1}$ fresh weight compared to the lowest rate in the treatment A_0S_0 in leaves and fruits, which gave 489.39 and 157.62 mg $100g^{-1}$ fresh weight, respectively. Regarding the individual effect, the saplings growing in the organic medium coco peat C_2 were distinguished by giving the highest value for total phenolic concentration in leaves, which reached 545.11 mg $100g^{-1}$ fresh weight. In fruits, the treatment C_3 gave the highest value, reaching 183.11 mg $100g^{-1}$ fresh weight compared to the lowest value recorded by the control treatment C_1 in leaves and fruits, which reached 488.75 and 168.37 mg $100g^{-1}$fresh weight. As for the individual effect of the foliar spraying treatment with the amino acid phenylalanine, the treatment A_2 gave the highest concentration of total phenols in leaves and fruits, reaching 543.81 and 180.33 mg $100g^{-1}$ fresh weight, respectively, compared to the lowest values in the treatment A_0, which were 503.33 and 167.21 mg $100g^{-1}$ fresh weight. Regarding the spraying of potassium sulfate, the treatment S_2 excelled with the highest concentration of total phenols in leaves, reaching 533.89 mg $100g^{-1}$ fresh weight. In fruits, the same treatment outperformed without a significant difference from the treatment S_1, giving 181.89 and 181.09 mg $100g^{-1}$ fresh weight compared to the lowest value for leaves and fruits in the control treatment S_0, which gave 511.21 and 163.65 mg $100g^{-1}$ fresh weight.

Table 2. Effect of potassium sulfate and phenylalanine foliar application and organic media on total phenolic concentration in the leaves and fruits of blackberry (mg 100 g fresh weight) during the 2023 and 2024 seasons.

C	A	Leaves 2023				Fruit 2024			
		S			CxA	S			CxA
		S_0	S_1	S_2		S_0	S_1	S_2	
	A_0	442.52	468.44	486.35	465.77	150.2	162.27	168.26	160.25
	A_1	475.21	488.27	496.83	525.75	148.39	188.26	177.25	171.3
	A_2	505.32	525.31	510.47	518.47	165.12	182.27	173.31	173.57
C_1	A_0	515.37	524.44	537.44	486.77	154.14	168.3	175.35	165.93
C_2	A_1	532.26	553.29	564.29	549.95	169.38	186.4	178.48	178.09
C_3	A_2	538.38	575.16	565.32	546.62	166.51	180.42	192.41	179.78
	A_0	510.27	516.51	528.63	513.7	168.51	175.48	182.35	175.45
	A_1	535.21	548.41	556.24	559.62	176.3	188.18	194.23	186.24
	A_2	546.36	568.53	559.41	558.1	174.26	198.26	190.38	187.63
L.S.D 0.05			11.83		6.83		6.77		3.91
C			C × S		C		C × S		C
C_1		474.35	494.01	497.89	488.75	154.57	177.6	172.94	168.37
C_2		528.67	550.96	555.68	545.11	163.34	178.38	182.08	174.6
C_3		530.61	544.48	548.09	541.06	173.02	187.31	188.99	183.11
L.S.D 0.05			6.83		3.94		3.91		2.26
A			A × S		A		A × S		A
A_0		489.39	503.13	517.47	503.33	157.62	168.68	175.32	167.21
A_1		514.23	529.99	539.12	527.78	164.69	187.62	183.32	178.54
A_2		530.02	556.33	545.07	543.81	168.63	186.98	185.37	180.33
L.S.D 0.05			6.83		3.94		3.91		2.26
S		511.21	529.82	533.89		163.65	181.09	181.34	
L.S.D 0.05			3.94				2.26		

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Table (3) indicate significant effect of the three-way interaction treatment $C_3A_1S_1$, giving the highest concentration in leaves, reaching 362.5 mg $100g^{-1}$ fresh weight. In fruits, the treatment $C_3A_1S_2$ excelled by giving the highest concentration, reaching 96.18 mg $100g^{-1}$ fresh weight, compared to the lowest concentration for leaves and fruits in the control treatment $C_1A_0S_0$, which was 212.8 and 58.33 mg $100g^{-1}$ fresh weight. Regarding the double interaction effect between phenylalanine spraying treatments and organic media on the total flavonoid concentration in leaves, the results showed the superiority of the treatment C_2A_2, reaching 325.7 mg $100g^{-1}$ fresh weight, which did not differ significantly from the treatments C_3A_2 and C_2A_1. In fruits, the treatment C_3A_1 excelled by giving 84.87 mg $100g^{-1}$ fresh weight compared to the lowest value in the treatment C_1A_0 in leaves and fruits, which gave 225.1 and 61.59 mg$100g^{-1}$ fresh weight, respectively. The interaction effect between potassium sulfate and organic media shows that the treatment C_3S_1 excelled with the highest value, reaching 303.6 mg $100g^{-1}$ fresh weight, without significant difference from the treatments C_2S_1 and C_2S_2. In fruits, the treatment C_3S_2 excelled with the highest value, giving 88.25 mg $100g^{-1}$ fresh weight, compared to the lowest values in the treatment C_1S_2, which gave 235.7 and 61.59 mg $100g^{-1}$ fresh weight for leaves and fruits, respectively. Similarly, in the results of the double interaction between potassium sulfate and phenylalanine, the results in Table 3 indicate significant superiority, as the treatment A_2S_1 recorded the highest rate of 327.2 mg $100g^{-1}$ fresh weight without difference from the treatment A_1S_1. In fruits, the treatment A1S2 excelled by giving the highest value of 88.99 mg $100g^{-1}$ fresh weight compared to the lowest rate in leaves and fruits in the treatment A_0S_0, which was 241.3 and 59.76 mg $100g^{-1}$ fresh weight. As for the individual effect of organic media, the treatment C_3 excelled by giving the highest rate of total flavonoid concentration in leaves, reaching 326 mg $100g^{-1}$ fresh weight. In fruits, the treatment C_3 was distinguished by giving the highest concentration, which reached 80.18 mg $100g^{-1}$ fresh weight, compared to the lowest rate in the control treatment C_1 in leaves and fruits, which was 258.3 and 69.99 mg $100g^{-1}$ fresh weight, respectively. Regarding the individual effect of the foliar application treatment with the amino acid phenylalanine, the treatment A_2 was distinguished by the highest concentration for leaves, reaching 307.3 mg $100g^{-1}$ fresh weight, without a significant difference from the treatment A_1 (303.8 mg $100g^{-1}$ fresh weight). For fruits, the treatment A_1 was distinguished by the highest concentration of total flavonoids, recording 78.79 mg $100g^{-1}$fresh weight, without a significant difference from the treatment A_2 (78.67 mg $100g^{-1}$ fresh weight) compared to the lowest values for leaves and fruits in the control treatment A_0, which were 257.4 and 68.38 mg $100g^{-1}$ fresh weight, respectively. As for foliar application potassium sulfate, the treatment S1 excelled with the highest concentration for leaves, giving 303.2 mg. $100g^{-1}$ fresh weight. In fruits, the treatment S_2 excelled with the highest concentration, reaching 82.34 mg $100g^{-1}$ fresh weight, compared to the lowest rate for leaves and fruits in the control treatment S_0, which was 263.3 and 66.6 mg $100g^{-1}$ fresh weight, respectively.

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Table 3. Effect of potassium sulfate and phenylalanine foliar application and organic media on total flavonoid concentration in leaves and fruits (mg 100 g⁻¹ Fresh Weight) in the 2023 and 2024 seasons

C	**A**	**Leaves 2023**			**CxA**	**Fruit 2024**			**CxA**
		S				**S**			
		S_0	**S_1**	**S_2**		**S_0**	**S_1**	**S_2**	
	A_0	212.8	226.7	235.9	225.1	58.33	64.41	73.41	65.38
C_1	A_1	244.4	263.3	289.2	265.6	60.2	74.19	82.37	72.25
	A_2	249.8	284.9	284.4	273	66.25	78.41	72.33	72.33
	A_0	262	280.2	306.9	283	56.54	68.43	79.38	68.12
C_2	A_1	289.6	352.8	325.3	322.6	68.91	80.36	88.43	79.23
	A_2	298.7	343.5	334.8	325.7	76.25	82.36	80.36	79.66
	A_0	249.1	262.1	281	264.1	64.41	72.29	78.23	71.64
C_3	A_1	272.6	362.5	334.7	323.3	70.25	88.19	96.18	84.87
	A_2	290.3	353.3	326.3	323.3	78.23	83.48	90.35	84.02
L.S.D 0.05			15.81		9.13		7.99		4.62
C			C × S		C		C × S		C
C_1		269.8	254.6	235.7	258.3	61.59	72.33	76.04	69.99
C_2		322.3	310.4	283.4	325.5	67.23	77.05	82.72	75.67
C_3		314	303.6	270.7	326	70.96	81.32	88.25	80.18
L.S.D 0.05			9.13		5.27		4.62		2.67
A			A × S		A		A × S		A
A_0		241.3	256.4	274.6	257.4	59.76	68.37	77.01	68.38
A_1		268.9	326.2	316.4	303.8	66.45	80.91	88.99	78.79
A_2		279.6	327.2	315.2	307.3	73.58	81.42	81.01	78.67
L.S.D 0.05			9.13		5.27		4.62		2.67
S		263.3	303.2	302.1		66.6	76.9	82.34	
L.S.D 0.05			5.27				2.67		

The study results, represented in Table (4) show the significant effect of the thee-way interaction factors in increasing the total carotene concentration in leaves. The saplings of the treatment $C_3A_2S_1$ excelled by giving the highest average of 13.33 mg 100g⁻¹ fresh weight, while the average of the control treatment $C_1A_0S_0$ was the lowest in concentration, reaching 6.20 mg 100g⁻¹ fresh weight. As for the effect of the study factors on total carotene in fruits, the treatment $C_3A_1S_2$ excelled the highest average of 0.81 mg 100g⁻¹ fresh weight, while the lowest average was in the treatment $C_1A_1S_0$, reaching 0.32 mg 100g⁻¹ fresh weight. Regarding the interaction effect between the amino acid phenylalanine and organic media, we note the superiority of the interaction treatment C_3A_2, which gave 11.95 mg 100g⁻¹ fresh weight. In fruits, the treatment C_3A_1 stood out by giving the highest total carotene concentration of 0.75 mg 100g⁻¹ fresh weight compared to the lowest average in the control treatment C_1A_0 in leaves and fruits, which gave 7.33 and 0.53 mg 100g⁻¹ fresh weight, respectively. Similarly, regarding the interaction treatment between potassium sulfate and organic media, we note that the interaction C_3S_1 gave the highest concentration for leaves, reaching 11.53 mg100g⁻¹ fresh weight, and the interaction C_3S_2 gave the highest concentration for fruits, reaching 0.76 mg 100g⁻¹ fresh weight, compared to the treatment C_1S_0, which gave the lowest concentration in leaves and fruits, reaching 6.71 and 0.37 mg 100g⁻¹ fresh weight, respectively. As for the interaction between foliar application with potassium sulfate and phenylalanine, we also note the significant effect on total carotene concentration in leaves, as the treatment A_2S_1 recorded the highest value 12.59 mg 100g⁻¹ fresh weight. In fruits, the treatments A_1S_2, A_2S_1, and A_2S_2 gave the same average 0.75 mg 100g⁻¹ fresh weight compared to the control treatment A_0S_0, which had the lowest value in leaves and fruits, reaching 6.75 and 0.47 mg 100g⁻¹ fresh weight, respectively. The results show the significant superiority of the organic media. The treatment C_3 was distinguished by giving the highest concentration for leaves and fruits, reaching 10.46 and 0.71 mg 100g⁻¹ fresh weight, respectively, compared to the

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lowest concentration in the control treatment C_1, which was 8.91 and 0.57 mg $100g^{-1}$ fresh weight, respectively. Similarly, the s foliar application treatment with the amino acid phenylalanine had a significant effect at treatment A_2 in leaves and fruits, reaching 10.89 and 0.68 mg $100g^{-1}$ fresh weight, respectively, compared to (A_0), which had the lowest concentration in leaves and fruits at 8.36 and 0.59 mg $100g^{-1}$ fresh weight, respectively. We also note the superiority of the potassium sulfate foliar application treatment S_2 in leaves and fruits, reaching 10.92 and 0.72 mg $100g^{-1}$ fresh weight, respectively, without a significant difference from S_1 (10.49 and 0.70 mg $100g^{-1}$ fresh weight), and the lowest average for leaves and fruits was in the treatment S_0, which was 7.63 and 0.51 mg $100g^{-1}$ fresh weight, respectively.

Table 4. Effect of potassium sulfate and phenylalanine foliar application and organic media on total carotene concentration in leaves and fruits (mg $100g^{-1}$ fresh weight) in the 2023 and 2024 seasons

C	A	Leaves 2023 S S_0	S_1	S_2	CxA	Fruit 2024 S S_0	S_1	S_2	CxA
C_1	A_0	6.2	7.29	8.5	7.33	0.36	0.58	0.66	0.53
	A_1	6.62	8.46	12.18	9.09	0.32	0.65	0.69	0.55
	A_2	7.32	12.42	11.17	10.3	0.42	0.74	0.68	0.61
C_2	A_0	6.58	9.19	10.62	8.8	0.48	0.66	0.64	0.59
	A_1	7.48	10.41	11.6	9.83	0.52	0.7	0.75	0.66
	A_2	8.52	12.03	10.65	10.4	0.57	0.77	0.8	0.71
C_3	A_0	7.46	9.25	10.11	8.94	0.57	0.68	0.7	0.65
	A_1	8.26	12.02	11.18	10.49	0.66	0.78	0.81	0.75
	A_2	10.22	13.33	12.31	11.95	0.65	0.75	0.78	0.73
L.S.D 0.05			1.62		0.93		0.08		0.046
C			C × S		C		C × S		C
C_1		6.71	9.39	10.62	8.91	0.37	0.66	0.68	0.57
C_2		7.53	10.55	10.96	9.68	0.52	0.71	0.73	0.65
C_3		8.65	11.53	11.2	10.46	0.63	0.74	0.76	0.71
L.S.D 0.05			9.13		5.27		4.62		2.67
A			A × S		A		A × S		A
A_0		6.75	8.58	9.74	8.36	0.47	0.64	0.67	0.59
A_1		7.45	10.3	11.65	9.8	0.50	0.71	0.75	0.65
A_2		8.69	12.59	11.38	10.89	0.55	0.75	0.75	0.68
L.S.D 0.05			0.93		0.54		0.046		0.027
S		7.63	10.49	10.92		0.51	0.70	0.72	
L.S.D 0.05			0.54				0.027		

The results in the Table (5) show the superiority of the three-way interaction treatment $C_3A_2S_2$ in leaves with the highest average of 76.62%. For fruits, the saplings of the three-way interaction treatment $C_3A_2S_1$ excelled with the highest average, giving 89.41%, without a significant difference from the treatment $C_3A_1S_1$, which reached 88.36%, compared to the lowest average in leaves and fruits, which was 63.31 and 72.24%, respectively, in the control treatment $C_1A_0S_0$ and $C_1A_0S_2$ actors, they showed a significant effect between phenylalanine foliar application treatments and organic media on the DPPH percentage. The results indicated the superiority of the treatment C_3A_2 in leaves, reaching 73.57%, and in fruits, the treatment C_3A_1 was distinguished by giving the highest average of 83.65%. The lowest average for leaves and fruits was in the treatment C_1A_0, which gave 66.31 and 73.54%. Similarly, in the double interaction between potassium sulfate and organic media, the treatment C_2S_2 was distinguished in leaves the highest value of 73.61%, while the interaction C_3S_1 gave the highest value 84.33% for fruits compared to the lowest value in the treatment C_1S_0 in leaves and fruits, which gave 63.67 and 74.66%. As for the two-way interaction between potassium sulfate and phenylalanine, the study results show a significant effect of the treatment A_2S_2 in leaves, giving the highest average of 74.41%, while the fruit treatment A_2S_1 gave the highest average of 84.62%. The

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lowest average was in the treatment A_0S_0 in leaves and fruits, which reached 65.42 and 74.94%, respectively. As for the individual effect of the study factors, the results reveal the significant effect of organic media. The treatment C_3 recorded the highest values in leaves and fruits, which were 71.85 and 81.78%, respectively, compared to the lowest values in the control treatment C_1, which were 67.41 and 75.99%, respectively. Regarding the foliar spraying treatment with the amino acid phenylalanine, the treatment A_2 excelled in leaves and fruits with the highest average 71.15 and 80.21%, respectively, and the lowest average was in the control treatment A_0, which was 68.68 and 76.01%. As for the potassium sulfate foliar application treatment, the treatment S_2 recorded the highest rate in leaves, reaching 72.15%, and in fruits, the treatment S_1 was distinguished by the highest rate, reaching 81.05%, compared to the lowest average for leaves and fruits in the control treatment S_0, which was 66.53 and 76.29%.

Table 5. Effect of potassium sulfate and phenylalanine foliar application and organic media on DPPH radical scavenging activity in leaves and fruits (%) in the 2023 and 2024 seasons

C	**A**	**Leaves 2023**			**CxA**	**Fruit 2024**			**CxA**
			S				**S**		
		S_0	**S_1**	**S_2**		**S_0**	**S_1**	**S_2**	
C_1	A_0	63.31	67.19	68.41	66.31	73.16	75.23	72.24	73.54
	A_1	64.38	70.2	69.2	67.93	74.5	78.2	76.62	76.44
	A_2	63.31	69.2	71.51	68.01	76.32	80.22	77.44	77.99
C_2	A_0	65.64	72.2	69.28	69.04	72.26	78.2	74.12	74.86
	A_1	67.26	74.2	76.46	72.64	75.19	80.34	77.39	77.64
	A_2	68.2	72.32	75.11	71.88	78.2	84.23	79.32	80.58
C_3	A_0	67.3	74.42	70.34	70.69	79.39	75.23	84.26	79.63
	A_1	68.22	73.23	72.4	71.28	79.19	88.36	83.4	83.65
	A_2	71.16	72.94	76.62	73.57	78.41	89.41	78.37	82.06
L.S.D 0.05			3.41		1.97		4.74		2.74
C			C × S		C		C × S		C
C_1		63.67	68.86	69.71	67.41	74.66	77.88	75.43	75.99
C_2		67.03	72.91	73.61	71.19	75.21	80.92	76.94	77.69
C_3		68.9	73.53	73.12	71.85	79	84.33	82.01	81.78
L.S.D 0.05			1.97		1.14		2.74		1.58
A			A × S		A		A × S		A
A_0		65.42	71.27	69.34	68.68	74.94	76.22	76.87	76.01
A_1		66.62	72.54	72.68	70.62	76.29	82.3	79.14	79.24
A_2		67.56	71.49	74.41	71.15	77.64	84.62	78.37	80.21
L.S.D 0.05			1.97		1.14		2.74		1.58
S		66.53	71.77	72.15		76.29	81.05	78.13	
L.S.D 0.05			1.14				1.58		

The results, in Table (6) show significant effect of the study factors, as the saplings of the treatment $C_2A_2S_2$ excelled by giving the highest concentration of 56.36 mg. $100g^{-1}$ fresh weight, which did not differ significantly from the average of the treatments $C_2A_2S_1$, $C_3A_1S_1$, $C_3A_1S_2$, and $C_3A_2S_2$, which were 50.23, 52.43, 50.21, and 55.51 mg $100g^{-1}$ fresh weight, respectively, while the average of the control treatment $C_1A_0S_0$ was the lowest in concentration, giving 32.45 mg $100g^{-1}$ fresh weight. Regarding the interaction effect between phenylalanine foliar application and cultivation in organic media, the superiority of the interaction treatment C_2A_2 was observed, recording 51.30 mg $100g^{-1}$ fresh weight without significant difference from the treatments C_3A_2 and C_3A_1, which reached 49.70 and 48.99 mg $100g^{-1}$ fresh weight, respectively, compared to the lowest concentration in the control treatment C_1A_0, which recorded 35.98 mg $100g^{-1}$ fresh weight. Similarly, in the interaction treatment between potassium sulfate and organic media, we note that the interaction C_2S_2 gave the highest average 51.29 mg $100g^{-1}$ fresh weight without significant difference from the treatments C_3S_1 and C_3S_2, which were 48.31 and 49.02 mg$100g^{-1}$ fresh weight, respectively, compared to the treatment C_1S_0, which

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recorded the lowest average of 37.04 mg100g^{-1} fresh weight. The interaction between foliar application with potassium sulfate and phenylalanine also significantly affected vitamin C concentration, as the treatment A_2S_2 recorded the highest value of 52.76 mg100g^{-1} fresh weight without significant difference from the treatment A_2S_1, which reached 49.44 mg 100g^{-1} fresh weight compared to the control treatment A_0S_0, which had the lowest value with an average of 35.39 mg 100g^{-1} fresh weight. The results in Table (6) show significant superiority of the organic media. The treatment C_3 was distinguished by giving the highest concentration without a significant difference from the treatment C_2, which reached 46.67 and 46.35 mg100g^{-1} fresh weight, respectively, compared to the lowest concentration in the control treatment C_1, which was 40.79 mg 100g^{-1} fresh weight. Regarding the spraying treatment with the amino acid phenylalanine, the results show a significant increase in vitamin C concentration at the treatment A_2, which did not differ significantly from the treatment A1, reaching 48.23 and 46.49 mg 100g^{-1} fresh weight, respectively, compared to the treatment A_0, which had the lowest concentration 39.09 mg 100g^{-1} fresh weight. We also note the superiority of the potassium sulfate foliar application treatment S_2, which recorded 47.66 mg 100g^{-1} fresh weight, and the lowest average was recorded by the treatment S_0, which was 40.48 mg 100g^{-1} fresh weight.

Table 6. Effect of potassium sulfate and phenylalanine foliar application and organic media on vitamin c concentration in fruits (mg. 100g^{-1} fresh weight) in 2024 seasons.

C	A	Fruit 2024			
		S			
		S_0	**S_1**	**S_2**	**CxA**
C_1	A_0	32.45	35.30	40.20	35.98
	A_1	38.34	48.25	41.45	42.68
	A_2	40.34	44.33	46.42	43.70
C_2	A_0	35.36	40.34	44.2	39.97
	A_1	42.42	47.65	53.31	47.79
	A_2	47.30	50.23	56.36	51.30
C_3	A_0	38.37	44.28	41.34	41.33
	A_1	44.33	52.43	50.21	48.99
	A_2	45.37	48.22	55.51	49.70
L.S.D 0.05			5.87		3.39
C			C × S		C
C_1		37.04	42.63	42.69	40.79
C_2		41.69	46.07	51.29	46.35
C_3		42.69	48.31	49.02	46.67
L.S.D 0.05			3.39		1.96
A			A × S		A
A_0		35.39	39.98	41.91	39.09
A_1		41.7	49.44	48.32	46.49
A_2		44.34	47.59	52.76	48.23
L.S.D 0.05			3.39		1.96
S		40.48	45.67	47.66	
L.S.D 0.05			1.96		

The results in Table (7) show a significant increase in anthocyanin concentration in the three-way interaction treatment $C_3A_2S_1$, recording the highest concentration without a significant difference from the treatment $C_3A_2S_2$, which reached 534.5 and 520.3 mg 100g^{-1} fresh weight, respectively, compared to the lowest concentration in the control treatment $C_2A_0S_0$, which was 300.3 mg 100g^{-1} fresh weight. As for the two-way interaction effect between phenylalanine foliar application treatments and organic media on the total anthocyanin concentration in fruits, the results showed the superiority of the treatment C_3A_2 with the highest average 497.7 mg 100g^{-1} fresh weight compared to the lowest average in the treatment C_2A_0, which reached 340.3 mg100g^{-1} fresh weight. The interaction between potassium sulfate and organic media significantly affected anthocyanin

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concentration, as the treatment C_3S_1 was distinguished by the highest value without a significant difference from the treatment C_3S_2, which reached 481.1 and 478 m $100g^{-1}$ fresh weight, respectively, compared to the lowest value in the treatment C_2S_0, which reached 347.7 mg$100g^{-1}$ fresh weight. Regarding the results of the interaction between potassium sulfate and phenylalanine, the results indicate the superiority of the treatment A_2S_1 with the highest average without a significant difference from the treatment A_2S_2, which reached 491.6 and 484.8 mg $100g^{-1}$ fresh weight, respectively, compared to the lowest average in the treatment A_0S_0, which was 337 mg $100g^{-1}$ fresh weight.

Table 7. Effect of potassium sulfate and phenylalanine foliar application and organic media on total anthocyanin concentration in fruits (mg. $100g^{-1}$ fresh weight in 2024 season

C	**A**	Fruit 2024			**CxA**
			S		
		S_0	**S_1**	**S_2**	
	A_0	320.5	342.4	395.4	352.7
C_1	A_1	407.5	420.2	480.3	436
	A_2	430.3	502.2	450.4	461
	A_0	300.3	380.2	340.3	340.3
C_2	A_1	376.3	402.6	446.3	408.4
	A_2	366.4	438.3	483.7	429.4
	A_0	390.3	425.3	438.4	418
C_3	A_1	426.3	483.4	475.3	461.7
	A_2	438.4	534.5	520.3	497.7
L.S.D 0.05			16.25		9.38
C			C × S		C
C_1		386.1	421.6	442	416.6
C_2		347.7	407	423.4	392.7
C_3		418.3	481.1	478	459.1
L.S.D 0.05			9.38		5.42
A			A × S		A
A_0		337	382.6	391.4	370.3
A_1		403.4	435.4	467.3	435.4
A_2		411.7	491.6	484.8	462.7
L.S.D 0.05			9.38		5.42
S		384.0	436.6	447.8	
L.S.D 0.05			5.42		

As for the individual effect of the treatments, the results show the significant superiority of organic media in increasing the total anthocyanin concentration in fruits in the treatment C_3, giving the highest average of 459.1 mg $100g^{-1}$ fresh weight compared to the lowest average in the treatment C_2, which was 392.7 mg $100g^{-1}$ fresh weight. The results reveal a significant effect of the phenylalanine foliar application treatment, as the treatment A_2 was distinguished by the highest concentration of 462.7 mg $100g^{-1}$ fresh weight compared to the lowest concentration in the control treatment A_0, which recorded 370.3 mg $100g^{-1}$ fresh weight. As for potassium sulfate foliar application, the treatment S_2 excelled the highest average, giving 447.8 mg $100g^{-1}$ fresh weight compared to the lowest average in the control treatment S_0, which recorded 384 mg $100g^{-1}$ fresh weigh

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Table 8. Effect of potassium sulfate and phenylalanine foliar application and organic media on folic acid concentration in fruits (mg100g^{-1} fresh weight) in 2024 seasons.

C	A	S_0	S_1	S_2	CxA
			Fruit 2024 S		
C_1	A_0	1.24	1.46	1.50	1.40
	A_1	1.4	1.58	1.61	1.53
	A_2	1.38	1.62	1.58	1.53
C_2	A_0	1.18	1.48	1.44	1.37
	A_1	1.3	1.71	1.65	1.55
	A_2	1.42	1.66	1.72	1.60
C_3	A_0	1.45	1.66	1.57	1.56
	A_1	1.62	1.85	2.62	2.03
	A_2	1.58	1.78	2.05	1.8
L.S.D 0.05			**0.20**		**0.12**
C			**C × S**		**C**
C_1		1.34	1.55	1.56	1.49
C_2		1.3	1.62	1.6	1.51
C_3		1.55	1.76	2.08	1.8
L.S.D 0.05			**0.12**		**0.07**
A			**A × S**		**A**
A_0		1.29	1.53	1.5	1.44
A_1		1.44	1.71	1.96	1.7
A_2		1.46	1.69	1.78	1.64
L.S.D 0.05			**0.12**		**0.07**
S		1.40	1.64	1.75	
L.S.D 0.05			**0.07**		

The study results, in Table(8) represented, show the significant effect of the study factors on folic acid concentration, as the saplings of the treatment $C_3A_1S_2$ excelled by recording the highest concentration of 2.62 mg 100g^{-1} fresh weight, while the average of the treatment $C_2A_0S_0$ was the lowest in concentration, recording 1.18 mg 100g^{-1} fresh weight. The results indicated a significant effect of foliar application with phenylalanine and cultivation in organic media, as the saplings of the treatment C_3A_1 were distinguished by the highest average 2.03 mg 100g^{-1} fresh weight compared to the lowest concentration in the treatment C_2A_0, which recorded 1.37 mg 100g^{-1} fresh weight. Similarly, in the interaction treatment between potassium sulfate and cultivation in organic media, we note that the saplings of the treatment C_3S_2 gave the highest average of 2.08 mg 100g^{-1} fresh weight compared to the treatment C_2S_0, which gave the lowest average of 1.30 mg 100g^{-1} fresh weight. The interaction between foliar application with potassium sulfate and phenylalanine also significantly affected folic acid concentration, as the treatment A_1S_2 excelled with the highest value 1.96 mg. 100g^{-1} fresh weight compared to the control treatment A_0S_0, which had the lowest value with an average of 1.29 mg. 100g^{-1} fresh weight. The results show a significant effect of cultivation in organic media. The treatment C_3 stood out by recording the highest average of 1.80 mg 100g^{-1} fresh weight compared to the lowest average in the control treatment C_1, which was 1.49 mg 100g^{-1} fresh weight. Regarding the foliar application treatment with the amino acid phenylalanine, the results shown a significant increase in folic acid concentration at the treatment A_1, which reached 1.70 mg 100g^{-1} fresh weight compared to the treatment A_0, which had the lowest concentration 1.44 mg 100g^{-1} fresh weight. We also note the superiority of the potassium sulfate foliar application treatment S_2, which recorded 1.75 mg 100g^{-1} fresh weight, compared to the lowest value recorded by the treatment S_0, which was 1.40 mg 100g^{-1} fresh weight. The results show that soilless cultivation systems caused a significant increase in most of the studied traits in leaves and fruits. This may be attributed to their advantages in the possibility of controlling nutrient levels and supplying nutrients based

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on plant needs compared to soil-grown plants, as well as providing a better root growth environment (Massa et al., 2020). The root system, which is in direct contact with these nutrients in the growing medium with a suitable pH, absorbs the elements necessary for growth, which are available in an integrated manner from macro and micro elements and amino acids. These play a role in controlling and regulating biochemical and physiological activities and building carbon skeleton compounds in photosynthesis and the subsequent formation of primary and secondary metabolites, as well as the production of ATP energy compounds important in plant vital processes and nucleic acids DNA and RNA necessary for cell division (Hasanuzzaman et al., 2018, Souza et al.,2024). The increase in most of the studied traits in plants growing in organic waste media (coconut husk and licorice residues) may be due to their good physical and chemical properties such as pH (6.5-6.8), electrical conductivity (2.0 ds m^{-1}), bulk density, very high water retention capacity, and their content of a large number of important chemical compounds, vitamins, and elements that make them a nutrient and stimulant (Yahya et at. 2009) Potassium has an effective role in significant superiority as it regulate enzymatic reactions, protein formation, photosynthesis, and water relations by regulating osmotic potential, stomatal opening and closing, and regulating water content through transpiration (Kumar and Verma. 2024, Ali et al., 2020.), Furthermore, the superiority of phenylalanine and the increase in study indicators is because it is an essential amino acid that directly regulate protein synthesis in the plant or metabolism through the phenylpropanoid pathway, thus increasing vegetative growth. The biosynthesis of phenylpropanoids leads to the synthesis of a wide range of secondary compounds (Hyun et al., 2011, Yoo et al., 2013) including total carotene, flavonoids, and total phenols.===

CONCLUSION

=====The results indicate the superiority of plants grown in the licorice residue medium in most of the studied traits. The traits in which the coco peat medium excelled showed no significant difference from the licorice residue medium. This is a positive scientific finding that enables to replace the imported medium (coco peat) with the local medium (licorice residue). The results also indicate no significant differences between the first and second concentrations of potassium sulfate and phenylalanine in improving some of the studied traits and increasing growth, leading to cost savings.\

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

AUTHOR/S DECLARATION

We confirm that all Figures and Tables in the manuscript are original to us. Additionally, any Figures and images that do not belong to us have been incorporated with the required permissions for re-publication, which are included with the manuscript.

AUTHOR'S CONTRIBUTION STATEMENT

All authors made equal contributions to the study design, methodology, experimental work, data analysis, and manuscript writing. All authors reviewed and approved the final version of the manuscript

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تعزيز القيمة الغذائية ومضادات الأكسدة في التوت الاسود بالرش بكبريتات البوتاسيوم والفينيل ألانين تحت الزراعة من دون تربة

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المستخلص

كان هدف هذه الدراسة زيادة القيمة الغذائية ومضادات الأكسدة في اوراق وثمار نبات توت العليق الاسود بزراعته بأنظمة الزراعة من دون تربة في محطة الأبحاث A التابعة لكلية علوم الهندسة الزراعية ـ جامعة بغداد في أالموسمين 2023-2024 وتضمنت ثلاث عوامل العامل الاول الزراعة بأوساط عضوية لمخلفات نباتية محلية ومستوردة وهي مخلفات جذور عرق السوس (C_3) ومخلفات قشور جوز الهند(C_2) قياسا بتربة الحقل(C_1) ، العامل الثاني الرش بكبريتات البوتاسيوم (S) وفق التراكيز (0,2.5,5) غم لتر$^{-1}$ ، العامل الثالث الرش بالحامض الاميني فنيل الانين(A) phenylalanine وفق التراكيز (0,100,200) ملغم لتر$^{-1}$ في تجربة عاملية بتصميم القطاعات الكاملة المعشاة.R.C.B.D وبثلاثة مكررات. اشارت النتائج تفوق معاملة الزراعة في وسط مخلفات عرق السوس والفنيل الانين بتركيز 200ملغم لتر$^{-1}$مع 2.5 غم.لتر$^{-1}$من كبريتات البوتاسيوم ($C_3A_2S_1$) باعلى تركيز في الكاروتين الكلي في الاوراق (13.33 ملغم 100غم$^{-1}$) وباعلى تركيز للفينولات والانثوسانين وDPPH في الثمار (198.26، 534.5 ملغم 100غم$^{-1}$، 89.41%) بالتتابع ، وتفوقت المعاملة $C_3A_1S_2$ باعلى تركيز للكاروتين الكلي وحامض الفولك في الثمار (0.81 ،2.62 ملغم 100غم$^{-1}$) بالتتابع.

الكلمات المفتاحية: انثوسانين، اوساط عضوية، فينولات كلية