Kirkuk University Journal for Agricultural Sciences
ISSN:2958-6585
https://kujas.uokirkuk.edu.iq

RESEARCH ARTICLE
https://doi.org. 10.58928/ku26.17228

Response of the Strawberry Plant Variety "Rubygem" to the Addition of Vermicompost and Foliar Application With Potassium and Boron

Naji Isam Hussein[1] **Shukri Haji Salih**[1]
Dept. Hort. Coll. Agric. Engi. Sci. University of Duhok, IRAQ
*Corresponding Author: naji.isam@uod.ac.

Received:07/11/2025 **Revised: 06/01/2026** **Accepted: 07/05/2026** **Published:21/06/2026**

ABSTRACT

This experience was conducted in Horticultural orchards at the University of Duhok, College of Agricultural Engineering Sciences, which is situated in Sumel City, Duhok Governorate, Kurdistan region of Iraq during growing season of 2025., to investigate the effects of three dosages of liquid vermicompost (0, 50 and 100 ml plant-1) and three doses of foliar potassium spray (0, 1 and 2 g L-1) and boron (0, 20 and 40 mg L-1) on the contents of the leaves and the increase in yield of the field-grown strawberry variety "Rubygem." The following parameters were noted throughout the experiment: leaf protein content percentage, Zn (mg kg -1), length of flowering period (Day), juice density (g cm-3), total yield (kg h-1), distorter fruits percentage, fruit anthocyanins content (mg 100 gm-1 fruit flesh weight), glucose (g 100 g-1 on fresh weight). The data were collected and organized according to factorial randomized complete block design with four replications, then the data were analyzed by SAS program, treatment means was compared for statistical significance using Duncan's Multiple Range Test at a $p<0.05$ probability level, addition of vermicompost, potassium and boron rates, especially at (100 ml plant-1 vermicompost, 2 g L-1 potassium and 20 and 40 mg L-1 boron) resulted in a significant increase in most of the studied parameters. High rates of interaction between vermicompost, potassium, and boron produced leaf protein content percentage (13.048 %), Zn (41.488 mg kg -1), length of flowering period (94.750 Day), juice density (1.308 g cm-3), hectare yield (8800.816 kg h-1), distorter fruits percentage (24.585 %), fruit anthocyanin content (24.811mg 100 gm-1 fruit flesh weight) and glucose (1.925 g 100 g-1 on fresh weight).

***Keywords*:** Strawberry, Vermicompost, Potassium oxide, Boric acid.

INTRODUCTION

The strawberry (*Fragaria × ananassa* Duch.) is a member of the Rosaceae family, encompassing over 100 genera and 2,500 species. It is one of the most significant crops with diminutive fruits, following grapes, cultivated worldwide in diverse environments due to the availability of many adapted cultivars and capacity to thrive in diverse environmental conditions, [1]. The global strawberry market showed strong growth, with estimates placing its value around $95.02 billion in 2024 to $105.52 billion in 2025 [2]. The strawberry plant is a universally esteemed fruit crop, distinguished by its alluring fragrance, vivid red hue, succulent texture, and outstanding nutritional value. It is a substantial source of vitamins, antioxidants, flavonoids, and phenolic compounds, which enhance its significant commercial and dietary value [3]. Growing organic strawberries is beneficial since it offers a healthy, clean, and chemical-free food supply that is especially appealing to kids. Ensuring sufficient plant nutrition, however, is one of the major obstacles in organic farming. Consequently, a lot of research has been done to improve the effectiveness of several organic sources, like vermicompost, farm manure, and various Biofertilizers, for use in organic strawberry growing [4].Vermicompost has become one of the best organic fertilizers and soil conditioners. In addition to being a source of macro and micronutrients, vermicompost—the stable, humus-rich byproduct of the vermicomposting process involving earthworms—is also a storehouse of helpful microorganisms, plant growth hormones, and humic compounds. By enhancing soil structure, water-holding capacity, and microbial activity, its application creates a rhizosphere that is conducive to plant growth [5]. Research has repeatedly shown that applying vermicompost to strawberries promotes vegetative development, fruit yield, and metrics including ascorbic acid concentration and total soluble solids (TSS) [6].

While healthy soil serves as the basis for plant growth, it is crucial to precisely manage essential nutrients during crucial growth phases. Two such elements that are essential to the production and quality of strawberries are potassium (K) and boron (B). For photosynthesis, sugar translocation, and fruit growth, potassium is an essential osmotic regulator and enzyme activator. Improved fruit size, firmness, color, and sugar content are all closely correlated with enough K intakes [7]. Potassium has a considerable function in maintaining cell turgor, stimulates its elongation and boosting protein and carbohydrate synthesis [8].Despite being needed in small levels, boron is essential for a number of physiological processes, such as fruit set, pollen tube growth, cell wall synthesis and integrity, and glucose metabolism. Even temporary boron deficit can result in poor fruit set, deformed fruits, and large output losses [9]. As a heavy non-metal micronutrient, boron is crucial to fruit production. The plant absorbs it as boric acid (H_3BO_3) for the translocation of sugar; boron is required for plant reproduction and pollen grain germination. In addition to its role in the transport of carbohydrates through membranes as the borate sugar complex, boron also aids in the production of fruit. Using growth regulators and trace nutrients, erratic efforts have been made to increase strawberry output and quality [10].

The availability of macro and micronutrients is crucial for plant growth since their absence causes a major imbalance in yield and growth. Some of these components are present in the soil in significant amounts, but the plant's access to these nutrients barely meets its requirements for normal growth [11].

It has been demonstrated that foliar fertilization is an effective way to provide these essential nutrients, particularly during times of high demand like flowering and fruit development. By overcoming soil-related limitations like PH fixation or immobilization, it enables the quick repair of nutritional deficits. We hypothesize that the synergistic effect of a vermicompost-amended rhizosphere and timely foliar potassium and boron nutrition will unlock superior plant performance, yield, and fruit quality in strawberry [12]. Therefore, the present study is designed to evaluate the following goals:

1. To assess the effects of vermicompost and foliar potassium and boron application, both separately and in combination, on strawberry plant vegetative growth.
2. To evaluate how they affect the mineral content of leaves of strawberry plants.
3. To ascertain how they affect the criteria of fruit quality and total yield of plants.

Materials and Methods

This experience was conducted in horticultural orchards at the University of Duhok, College of Agricultural Engineering Sciences, which is situated in Sumel City, Duhok Governorate, Kurdistan region of Iraq during growing season of 2025. Situated between latitude 36° 51' 38.077" N and longitude 42° 52' 02.998" E, this location is 535 meters above sea level. The field climate under study is semi-arid, with hot, dry summers and wet, cold winters. The Rubygem cultivar strawberry plants under investigation were chosen from the College of Agricultural Engineering Sciences' orchard. They were uniform in growth, crown diameter, and vigor, and they were sprayed with fungicide prior to treatments. The remaining leaves were joined prior to planting, and runners were removed once a week. The irrigation system used drip irrigation, with one dripper per plant, and the plants are two years old. The soil type is clay loam. Ten randomly selected samples of the strawberry field soil were gathered from different parts of the field at a depth of 0 to 25 cm. The samples were well mixed, allowed to air dry, and then put through a 2 mm sieve before being examined by the College of Agricultural Engineering Sciences. The strawberry field soil's physical and chemical characteristics (clay 49.7%, silt 35.2%, sand 15.1%, total N 1.242%, available P 2.013 ppm, available K 2.151 ppm), with a planting distance of 40 by 75 cm, were determined. Next, a fungicide (Kriptanol SL) was used to sterilize the field's soil. The study was conducted during growing season of 2025 to determine the impact of liquid vermicompost (total organic matter 20%, total nitrogen 1%, organic nitrogen 1%), foliar spraying potassium (pure potassium oxide) and boron (boric acid -17% Boron) on the contents in leaves and the increase in yield of strawberries (*Fragaria* × *ananassa* Duch.) cv. "Rubygem" grown in field conditions. Thus, three elements are included in the experiment: As stated by [6], the first one involves treating the strawberry plants with three levels of liquid vermicompost (0, 50, and 100 ml plant^{-1}) twice (8/3/2025, 1/4/2025), with intervals applied per season (in spring) on the ground surrounding each plant. According to [13], the second factor is plants sprayed with potassium oxide (K2O) (0, 1, and 2 g L^{-1}) three times (13/3/2025, 3-16/4/2025). The third factor is that plants are sprayed with boric acid (H3BO3) (0, 20, and 40 mg L^{-1}) three times (17/3/2025), (6-20/4/2025), As stated by [14], (beginning of each growth, flowering, and fruiting commenced), and Tween-20, which is added to solutions as a wetting agent at a concentration of 0.1%. The treatment means were compared using the Duncan Multiple Range Test at the significant level of 5%, and the data were analyzed using the SAS program [15]. The experimental units were set up as factorial experiment 3×3×3 in RCBD, with 5 plants for each experimental unit and 27 experimental units with 135 plants for each replication, totaling 540 plants. These data were registered.

Leaf protein content percentage: The following formula was used to calculate the protein % in strawberry leaves, According to [16].
Protein percentage = Nitrogen percentage x 6.25
Zn (mg kg $^{-1}$): The following formula was used to calculate Zn in strawberry leaves, According to [17].
Zn (mg kg^{-1}) = C × V × DF / W
Length of flowering period (Day): estimated the duration of the plant's blossoming from the beginning to the last day.
Juice density (g cm^{-3}): juice for the same volume / Water weight (g) for the same volume (cm^{3}), Complying with [18].
Total yield (kg h^{-1}): Total yield per plant × (10000 m^{2}) / Area of one plant
Distorter fruits percentage: Weight of distorter fruits / Total weight of the experimental unit × 100
Fruit anthocyanin content (mg 100 gm^{-1} fruit flesh weight): The following formula is used to compute the total anthocyanin, as stated by [19].
Anthocyanin (mg 100 ml^{-1}): Absorbance at 520 × volume composed of the color-measuring extracts × total volume / 98.2 × weight of sample.
Glucose (g 100 g^{-1} on fresh weight): The following formula was used to calculate Glucose in fruits, According to [20].
Glucose (g 100 g^{-1} FW) = (C HPLC × V total × D / W sample × 1000) × 100

Results

Leaf protein content percentage

The data in table (1) show that the leaf protein content by adding vermicompost dosages of 100 and 50 ml plant^{-1} had a substantial impact on the leaf protein content % of strawberry plants, in contrast to the control treatment. In comparison to the values of other treatments, the same table demonstrated a considerable impact of potassium foliar spray on the plant's leaf protein content %. Table 1 show that the "Rubygem" cultivar's leaf protein content % was significantly impacted by boron spraying by 20 mg L^{-1} spraying was superior.

The results showed that the interaction of vermicompost + potassium in table 1 had a significant impact on the percentage of leaf protein content. The highest percentage of leaf protein content was found in the interactions of 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium, as opposed to the value that was fixed at the other treatments. When compared to other interaction treatments, the combination of 100 ml plant^{-1} vermicompost + 40 mg L^{-1} boron and 100 ml plant^{-1} vermicompost + 20 mg L^{-1} boron yielded the highest values (12.570%, 12.479%) for leaf protein content percentage. The "Rubygem" plant's leaf protein content percentage was strongly impacted by the composition of potassium and boron, as shown in table 1. However, the interaction of 2 g L^{-1} potassium + 40 mg L^{-1} boron produced the highest range (12.521%) when compared to all other interactions.

Regarding the experiment factor interactions, the results showed that the interactions of 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium + 20 mg L^{-1} boron confirmed the highest percentage of leaf protein content (13.048%), while the interactions of 0 ml plant^{-1} vermicompost + 1 g L^{-1} potassium + 0 mg L^{-1} boron confirmed the lowest value (9.858%).

Table (1) Response of leaf protein content percentage of the strawberry plant to the addition of vermicompost and foliar application with potassium and boron

Vermicompost ml plant^{-1}	Potassium g L^{-1}	Boron mg L^{-1}			Vermicompost *Potassium	Vermicompost
		0	20	40		
0	0	10.808bc	11.130a-c	12.306ab	11.415ab	11.516b
	1	9.858c	10.956a-c	12.095ab	10.970b	
	2	12.672ab	11.459a-c	12.358ab	12.163a	
50	0	11.530a-c	12.161ab	12.353ab	12.015ab	12.053ab
	1	11.323a-c	12.166ab	12.050ab	11.846ab	
	2	11.514a-c	12.469ab	12.913ab	12.298a	
100	0	11.506a-c	12.025ab	12.639ab	12.057ab	12.203a
	1	11.111a-c	12.364ab	12.780ab	12.085ab	
	2	12.066ab	13.048a	12.292ab	12.469a	
Vermicompost * Boron	0	11.113c	11.182bc	12.253ab	Potassium	
	50	11.456a-c	12.265ab	12.439a		
	100	11.561a-c	12.479a	12.570a		

Potassium * Boron	0	11.281bc	11.772a-c	12.433a	0	11.829ab
	1	10.764c	11.829a-c	12.308ab	1	11.634b
	2	12.084ab	12.326ab	12.521a	2	12.310a
Boron		11.376b	11.975a	12.421a		

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple ranges test at significant level of 5%.

Leaf zinc content (mg kg^{-1})

The findings in table 2 shows that, in contrast to the control treatment, the dosage of vermicompost 100 ml plant^{-1} considerably affected the leaf zinc content (mg kg^{-1}) on the strawberry plants. When compared to the values of other treatments, the same table demonstrated a significant effect of potassium foliar spray on the leaf zinc content (mg kg^{-1}), with the application of 1 and 2 g L^{-1} being superior to the control. Table 2 shows that the "Rubygem" cultivar's leaf zinc concentration (mg kg^{-1}) was not significantly affected by boron spraying. Table 2 vermicompost + potassium interaction showed a significant impact on leaf zinc content (mg kg^{-1}). The results showed that the combination of 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium produced the highest leaf zinc content (mg kg^{-1}) when compared to the value fixed at the other treatments. In comparison to other interaction treatments, the combination of 100 ml plant^{-1} vermicompost + 20 mg L^{-1} boron produced the highest value (40.490 mg kg^{-1}) of leaf zinc content (mg kg^{-1}). The "Rubygem" plant's leaf zinc content (mg kg^{-1}) was strongly impacted by the mix of potassium and boron, as shown in table 2. However, compared to all other interactions, the combination of 2 g L^{-1} potassium and 20 mg L^{-1} boron produced the highest range (38.493 mg kg^{-1}).

Regarding the experiment factor interactions, the results showed that the interactions of 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium + 20 mg L^{-1} boron confirmed the maximum leaf zinc content (mg kg^{-1}) (41.488 mg kg^{-1}), while the interactions of 0 ml plant^{-1} vermicompost + 0 g L^{-1} potassium + 20 mg L^{-1} boron confirmed the lowest value (24.935 mg kg^{-1}).

Table (2) Response of leaf zinc content (mg kg^{-1}) of the strawberry plant to the addition of vermicompost and foliar application with potassium and boron

Vermicompost ml plant^{-1}	Potassium g L^{-1}	Boron mg L^{-1}			Vermicompost *Potassium	Vermicompost
		0	20	40		
0	0	26.833e-g	24.935g	28.003d-g	26.590d	31.782c
	1	35.710a-d	31.069b-g	36.864a-c	34.547bc	
	2	28.203c-g	35.324a-e	39.100ab	34.209bc	
50	0	26.135fg	31.688b-g	37.925ab	31.916c	34.655b
	1	38.648ab	26.707e-g	38.087ab	34.481bc	
	2	40.015ab	38.666ab	34.029a-f	37.570ab	
100	0	38.203ab	41.213a	39.371ab	39.595a	39.602a
	1	38.716ab	38.770ab	37.685ab	38.390ab	
	2	39.534ab	41.488a	41.444a	40.822a	
Vermicompost * Boron	0	30.249d	30.442d	34.656b-d	Potassium	
	50	34.932b-d	32.354cd	36.680a-c		
	100	38.817ab	40.490a	39.500ab		
Potassium * Boron	0	30.390c	32.612bc	35.099a-c	0	32.700b
	1	37.691a	32.182bc	37.545a	1	35.806a
	2	35.917ab	38.493a	38.191a	2	37.534a
Boron		34.666a	34.429a	36.945a		

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple ranges test at significant level of 5%.

Length of flowering period (day)

Table 3 shows that, in contrast to the control treatment, the dose of vermicompost 100 ml plant^{-1} had a significant impact on the length of blooming period (day) on the strawberry plants. In comparison to the values of the other treatments, the same table demonstrated a substantial effect of potassium foliar spray on the length of the blooming period (day) especially at 2 g L^{-1}. Table 3 shows that boron spraying had no discernible effect on the "Rubygem" cultivar's blooming period (day).

Table 3 showed that the combination of vermicompost and potassium had a significant impact on the length of the flowering period. The results showed that the combination of 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium produced the longest flowering period (day) when compared to the value fixed at the other treatments. In comparison to other interaction treatments, the combination of 100 ml plant^{-1} vermicompost + 40 mg L^{-1} boron produced the largest value (92.833 days) for the length of blooming period (day) due to the vermicompost and boron interaction. The duration of the blooming period (day) of the "Rubygem" plant was considerably affected by the composition of potassium and boron, as shown in table 3. However, the interaction of 2 g L^{-1} potassium + 40 mg L^{-1} boron produced the highest range (92.167 days) when compared to all other interactions.

Regarding the experiment factors' interactions, the results showed that the interactions of 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium + 40 mg L^{-1} boron confirmed the longest flowering period (day) (94.750 days), while the interactions of 0 ml plant^{-1} vermicompost + 0 g L^{-1} potassium + 0 mg L^{-1} boron confirmed the lowest value (82.250 days).

Table (3) Response of length of flowering period (day) of the strawberry plant to the addition of vermicompost and foliar application with potassium and boron

Vermicompost ml plant^{-1}	Potassium g L^{-1}	Boron mg L^{-1}			Vermicompost *Potassium	Vermicompost
		0	20	40		
0	0	82.250h	82.500gh	83.750f-h	82.833d	86.528b
	1	85.250e-h	90.500a-e	85.250e-h	87.000c	
	2	92.500a-d	86.500d-h	90.250a-f	89.750a-c	
50	0	87.250b-h	85.500e-h	86.750c-h	86.500c	88.278b
	1	86.500d-h	89.500a-f	89.000a-g	88.333bc	
	2	88.250a-h	90.250a-f	91.500a-e	90.000a-c	
100	0	93.500ab	88.000b-h	93.000a-d	91.500ab	92.194a
	1	93.000a-d	91.750a-e	90.750a-e	91.833ab	
	2	91.750a-e	93.250a-c	94.750a	93.250a	
Vermicompost * Boron	0	86.667c	86.500c	86.417c	Potassium	
	50	87.333c	88.417bc	89.083bc		
	100	92.750a	91.000ab	92.833a		
Potassium * Boron	0	87.667bc	85.333c	87.833bc	0	86.944c
	1	88.250bc	90.583ab	88.333bc	1	89.056b
	2	90.833ab	90.000ab	92.167a	2	91.000a
Boron		88.917a	88.639a	89.444a		

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple ranges test at significant level of 5%.

Juice density (g cm^{-3})

Table 4 shows that, in contrast to the control treatment, the dose of vermicompost 100 ml plant^{-1} had a substantial impact on the strawberry plants' juice density (g cm^{-3}). According to the same data, there was no discernible effect of potassium foliar spray on strawberry fruit juice density (g cm^{-3}). Table 4 shows that the strawberry "Rubygem" cultivar's juice density (g cm^{-3}) was significantly affected by boron spraying when compared to the control especially spraying at 40 mg L^{-1}.

Table 4 vermicompost + potassium interaction showed a significant impact on juice density (g cm^{-3}). The results showed that the combination of 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium had the highest juice density (g cm^{-3}) when compared to the values recorded at the other treatments. Juice density (g cm^{-3}) has been greatly boosted by the interaction between vermicompost and boron; the combination of 100 ml plant^{-1} vermicompost + 40 mg L^{-1} boron produced the highest value (1.158 g cm^{-3}) when compared to the control treatment. The juice density (g cm^{-3}) of the "Rubygem" plant was considerably impacted by the composition of potassium and boron, as shown in table 4. However, the interaction of 2 g L^{-1} potassium + 40 mg L^{-1} boron produced the largest range (1.113 g cm^{-3}) in comparison to all other interactions.

In terms of the experiment factor interactions, the results revealed that the interactions of 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium + 40 mg L^{-1} boron confirmed the highest juice density (g cm^{-3}) (1.308 g cm^{-3}), as the interactions of 0 ml plant^{-1} vermicompost + 1 g L^{-1} potassium + 0 mg L^{-1} boron confirmed the lowest value (0.953 g cm^{-3}).

Table (4) Response of juice density (g cm^{-3}) of the strawberry plant to the addition of vermicompost and foliar application with potassium and boron

Vermicompost ml plant^{-1}	Potassium g L^{-1}	Boron mg L^{-1}			Vermicompost *Potassium	Vermicompost
		0	20	40		
0	0	1.015c-e	1.078bc	1.080bc	1.058bc	1.041b
	1	0.953e	1.053 b-d	1.073bc	1.026c	
	2	1.068 b-d	1.093bc	0.960e	1.040bc	
50	0	1.055 b-d	0.985de	1.078bc	1.039bc	1.044b
	1	1.070bc	1.040 b-d	1.068 b-d	1.059bc	
	2	0.950e	1.078bc	1.073bc	1.033bc	
100	0	1.063 b-d	1.100bc	1.063 b-d	1.075b	1.099a
	1	1.055 b-d	1.080bc	1.103b	1.079b	
	2	1.065 b-d	1.055b-d	1.308a	1.143a	
Vermicompost * Boron	0	1.012d	1.074b	1.038b-d	Potassium	
	50	1.025cd	1.034b-d	1.073b		
	100	1.061bc	1.078b	1.158a		
Potassium * Boron	0	1.044bc	1.054bc	1.073ab	0	1.057a
	1	1.026c	1.058bc	1.081ab	1	1.055a
	2	1.028c	1.075ab	1.113a	2	1.072a
Boron		1.033c	1.062b	1.089a		

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple ranges test at significant level of 5%.

Total yield (kg ha^{-1})

In contrary to the control treatment, the inclusion of vermicompost 100 and 50 ml plant^{-1} had a substantial impact on the strawberry plants' total production (kg ha^{-1}), as shown in table 5. In regard to the results of other treatments, the same table suggested a substantial impact of potassium foliar spray on the total yield (kg ha^{-1}) spraying with 2 g L^{-1} was more effected. Table 5 demonstrates that the "Rubygem" cultivar's total yield (kg ha^{-1}) had no significant impact by boron spraying.The results revealed that the vermicompost + potassium interaction in table 5 had a major effect on hectare yield (kg ha^{-1}). In comparison to the control, the highest total yield (kg ha^{-1}) was found in the interactions of 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium.

The interaction involving vermicompost and boron has greatly enhanced total yield (kg ha^{-1}); the combination of 100 ml plant^{-1} vermicompost + 20 mg L^{-1} boron achieved the highest value (7152.972 kg ha^{-1}) if compared to other interaction treatments. The composition of potassium and boron, as can be seen in table 5, had a significant impact on the total yield (kg ha^{-1}) of the "Rubygem" plant. But the interaction of 1 g L^{-1} potassium + 20 mg L^{-1} boron and 2 g L^{-1} potassium + 40 mg L^{-1} boron produced the maximum ranges (6039.698 and 6143.787 kg ha^{-1}) in comparison to the control. The maximum total yield (kg ha^{-1}) (8800.816 and 8689.265 kg.ha^{-1}) was confirmed from the interactions of 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium + 40 mg L^{-1} boron and 100 ml plant^{-1} vermicompost + 0 g L^{-1} potassium + 20 mg L^{-1} boron, contrary to the interactions of 0 ml plant^{-1} vermicompost + 0 g L^{-1} potassium + 0 mg L^{-1} boron confirmed the lowest value (1910.609 kg ha^{-1}).

Table (5) Response of total yield (kg ha^{-1}) of the strawberry plant to the addition of vermicompost and foliar application with potassium and boron

Vermicompost ml plant^{-1}	Potassium g L^{-1}	Boron mg L^{-1}			Vermicompost *Potassium	Vermicompost
		0	20	40		
0	0	1910.609j	2656.382ij	3405.846g-i	2657.612f	3792.204c
	1	3723.452g-i	5553.105c-e	2564.218ij	3946.925e	
	2	5752.272cd	4273.411e-h	4290.545e-h	4772.076cd	
50	0	4463.955d-g	4291.653e-h	4105.615f-h	4287.074de	4624.016b
	1	5401.781c-f	6033.358bc	4451.566d-g	5295.568bc	
	2	4455.165d-g	3073.052h-j	5340.000c-f	4289.406de	
100	0	6450.768bc	8689.265a	5762.624cd	6967.552a	6733.143a
	1	5328.495c-f	6532.631bc	5704.731cd	5855.285b	
	2	7091.937b	6237.020bc	8800.816a	7376.591a	
Vermicompost * Boron	0	3795.444de	4160.966cd	3420.203e	Potassium	
	50	4773.633c	4466.021cd	4632.394c		
	100	6290.400b	7152.972a	6756.057ab		
Potassium * Boron	0	4275.110d	5212.433bc	4424.695d	0	4637.413c
	1	4817.909cd	6039.698a	4240.172d	1	5032.593b
	2	5766.458ab	4527.828cd	6143.787a	2	5479.357a
Boron		4953.159a	5259.986a	4936.218a		

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple ranges test at significant level of 5%.

Distorted fruits percentage

There are notable variations amongst the treatments, as table 6 illustrates. The proportion of deformed fruits was dramatically reduced by increasing the amount of vermicompost; strawberry plant dosages with 100 ml plant^{-1} vermicompost recorded the lowest percentage of damaged fruits (12.385%) compared to the control group, which had the highest percentage (19.754%). Additionally, Table 6 showed that potassium at a concentration of 1 g L^{-1} produced the lowest proportion of deformed fruits (15.860%), while the control group recorded the greatest percentage (18.156%). Table 6 data collection showed that the boron spraying had the lowest percentage of deformed fruits (15.913% and 16.756%) at 20 mg L^{-1} and 40 mg L^{-1}, whereas the control group had the greatest proportion (18.031%). Table 6 suggested that the interactions between potassium and vermicompost had an impact on the distorted fruit percentage values. The proportion of discolored fruits was highest at 0 ml plant^{-1} vermicompost + 2 g L^{-1} potassium and lowest at 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium. Table 6 makes it evident that the interactions between vermicompost and boron caused notable variations in the proportion of deformed fruits. In comparison to the control (19.186%), it was found that 100 ml plant^{-1} vermicompost + 40 mg L^{-1} boron recorded the lowest values (11.363%) and a significant influence on deformed fruits. The combination of 1 g L^{-1} potassium + 40 mg L^{-1} boron was the most effective way to reduce the percentage of distorted fruits when compared to 0 g L^{-1} potassium + 0 mg L^{-1} boron.
Table 6 showed the effects of three factors on the percentage of strawberry distorted fruits. The interactions of 100 ml plant^{-1} vermicompost + 1 g L^{-1} potassium + 40 mg L^{-1} boron and 100 ml plant^{-1} vermicompost + 2 g L^{-1} potassium + 20 mg L^{-1} boron produced the lowest significant value of distorted fruits percentage (9.063% and 9.318%), while 0 ml plant^{-1} vermicompost + 0 g L^{-1} potassium + 40 mg L^{-1} boron produced the highest value (24.585%).

Table (6) Response of distorted fruits percentage of the strawberry plant to the addition of vermicompost and foliar application with potassium and boron

Vermicompost ml plant^{-1}	Potassium g L^{-1}	Boron mg L^{-1}			Vermicompost *Potassium	Vermicompost
		0	20	40		
0	0	19.220b-e	18.880c-e	24.585a	20.895ab	19.754a
	1	17.045c-f	15.983d-g	17.698 c-e	16.908cd	

	2	21.293a-d	18.798 c-e	24.288ab	21.459a	
50	0	22.110a-c	16.270d-g	17.978 c-e	18.786a-c	18.560a
	1	24.325ab	17.790 c-e	13.683e-h	18.599a-c	
	2	17.853 c-e	18.550 c-e	18.485 c-e	18.296bc	
100	0	14.445e-h	15.625d-g	14.290e-h	14.787de	12.385b
	1	15.158e-g	12.000f-h	9.063h	12.073ef	
	2	10.833gh	9.318h	10.738gh	10.296f	
Vermicompost * Boron	0	19.186bc	17.887c	22.190a	Potassium	
	50	21.429ab	17.537c	16.715c		
	100	13.478d	12.314d	11.363d		
Potassium * Boron	0	18.592a	16.925ab	18.951a	0	18.156a
	1	18.843a	15.258bc	13.481c	1	15.860b
	2	16.659ab	15.555bc	17.837ab	2	16.684ab
Boron		18.031a	15.913b	16.756ab		

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple ranges test at significant level of 5%.

Fruit anthocyanin content (mg 100 gm^{-1} fruit flesh weight)

As compared to the 50 ml plant⁻¹ and control treatment, the use of vermicompost 100 ml plant⁻¹ considerably affected the fruit anthocyanin content (mg 100 gm^{-1} fruit flesh weight) on the strawberry plants, as shown data in table 7. According to the same findings, fruit anthocyanin concentration (mg 100 gm^{-1} fruit flesh weight) was significantly influenced by potassium foliar spray, with 2 g L⁻¹ being the most effective. Table 7 shows that the "Rubygem" cultivar's fruit anthocyanin concentration (mg 100 gm^{-1} fruit flesh weight) was not significantly affected by boron spraying.

Fruit anthocyanin content (mg 100 gm^{-1} fruit flesh weight) significantly changed by the interaction of vermicompost + potassium in table 7. The results showed that the highest fruit anthocyanin content (mg 100 gm^{-1} fruit flesh weight) was present from the interactions of 100 ml plant⁻¹ vermicompost + 2 g L⁻¹ potassium, compared to the value obtained at the other treatments. Compared to other interaction treatments, the combination of 100 ml plant⁻¹ vermicompost + 40 mg L⁻¹ boron produced the highest value (20.569 mg 100 gm-1 fruit flesh weight) for the vermicompost and boron interaction. The "Rubygem" plant's fruit anthocyanin content (mg 100 gm^{-1} fruit flesh weight) had a major effect by the composition of potassium and boron, as shown in table 7. Nonetheless, compared to all other interactions, the combination of 2 g L⁻¹ potassium and 40 mg L⁻¹ boron produced the highest range (21.054 mg 100 gm^{-1} fruit flesh weight).

In terms of the experiment factor interactions, the results showed that the interactions of 100 ml plant⁻¹ vermicompost + 2 g L⁻¹ potassium + 40 mg L⁻¹ boron confirmed the highest fruit anthocyanin content (mg 100 gm^{-1} fruit flesh weight) (24.811 mg 100 gm^{-1} fruit flesh weight), while the interactions of 50 ml plant⁻¹ vermicompost + 1 g L⁻¹ potassium + 20 mg L⁻¹ boron confirmed the lowest value (12.736 mg 100 gm^{-1} fruit flesh weight).

Table (7) Response of fruit anthocyanin content (mg 100 gm^{-1} fruit flesh weight) of the strawberry plant to the addition of vermicompost and foliar application with potassium and boron

Vermicompost ml plant^{-1}	Potassium g L^{-1}	Boron mg L^{-1}			Vermicompost *Potassium	Vermicompost
		0	20	40		
0	0	14.852b-d	19.257a-d	13.021cd	15.710c	17.826ab
	1	16.063b-d	20.132a-d	16.989a-d	17.728a-c	
	2	21.871ab	17.263a-d	20.987a-c	20.040a-c	
50	0	15.859b-d	14.832b-d	16.734a-d	15.808c	16.106b
	1	15.208b-d	12.736d	19.186a-d	15.710c	
	2	16.185b-d	16.846a-d	17.365a-d	16.799bc	
100	0	21.464ab	20.234a-d	19.725a-d	20.474ab	19.466a
	1	15.635b-d	16.551b-d	17.171a-d	16.453bc	

	2	18.738a-d	20.864a-d	24.811a	21.471a	
Vermicompost * Boron	0	17.595ab	18.884ab	16.999ab	Potassium	
	50	15.751b	14.804b	17.762ab		
	100	18.613ab	19.216ab	20.569a		
Potassium * Boron	0	17.392ab	18.107ab	16.493b	0	17.331ab
	1	15.635b	16.473b	17.782ab	1	16.630b
	2	18.931ab	18.324ab	21.054a	2	19.437a
Boron		17.319a	17.635a	18.443a		

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan's multiple ranges test at significant level of 5%.

Glucose (g 100 g^{-1} on fresh weight)

In contrast to the control and 50 ml $plant^{-1}$ vermicompost treatments, the addition of 100 ml vermicompost considerably affected the glucose (g 100 g^{-1} on fresh weight) content on the strawberry plants, as shown in table 8 data. In comparison to control treatments, the same table demonstrated a substantial impact of potassium foliar spray on the glucose content (g 100 g^{-1} on fresh weight) recorded 1.752 g 100 g^{-1} on fresh weight as compare to control value. Table 8 shows that the "Rubygem" cultivar's glucose content (g 100 g^{-1} on fresh weight) was not significantly affected by boron spraying.

The results showed that the interaction of vermicompost + potassium in table 8 had a significant impact on the amount of glucose (g 100 g^{-1} on fresh weight). The highest amount of glucose (g 100 g^{-1} on fresh weight) was found in the interactions of 100 ml $plant^{-1}$ vermicompost + 2 g L^{-1} potassium, as opposed to the value that was fixed at the other treatments. The interaction between vermicompost and boron has greatly enhanced the amount of glucose (g 100 g^{-1} on fresh weight); the combination of 100 ml $plant^{-1}$ vermicompost + 40 mg L^{-1} boron produced the highest value (1.780 g 100 g^{-1} on fresh weight) compared to the control. The "Rubygem" plant's glucose content (g 100 g^{-1} on fresh weight) was significantly altered by the composition of potassium and boron, as shown in table 8. However, the combination of 2 g L^{-1} potassium and 40 mg L^{-1} boron produced the highest ranges (1.778 g 100 g^{-1} on fresh weight) in relation to the control.

Regarding the experiment factor interactions, the results showed that the interactions of 100 ml $plant^{-1}$ vermicompost + 2 g L^{-1} potassium + 40 mg L^{-1} boron confirmed the highest glucose (g 100 g^{-1} on fresh weight) content (1.925 g 100 g^{-1} on fresh weight), while the interactions of 0 ml $plant^{-1}$ vermicompost + 0 g L^{-1} potassium + 0 mg L^{-1} boron confirmed the lowest value (1.590 g 100 g^{-1} on fresh weight).

Table (8) Response of glucose (g 100 g^{-1} on fresh weight) of the strawberry plant to the addition of vermicompost and foliar application with potassium and boron

Vermicompost ml $plant^{-1}$	Potassium g L^{-1}	Boron mg L^{-1}			Vermicompost *Potassium	Vermicompost
		0	20	40		
0	0	1.590d	1.698b-d	1.738b-d	1.675b	1.687b
	1	1.720b-d	1.678b-d	1.733b-d	1.710b	
	2	1.680b-d	1.673b-d	1.675b-d	1.676b	
50	0	1.638cd	1.665b-d	1.663b-d	1.655b	1.708b
	1	1.705b-d	1.673b-d	1.808a-c	1.728b	
	2	1.818ab	1.668b-d	1.735b-d	1.740b	
100	0	1.690b-d	1.698b-d	1.718b-d	1.702b	1.759a
	1	1.770a-c	1.733b-d	1.698b-d	1.733b	
	2	1.828ab	1.770a-c	1.925a	1.841a	
Vermicompost * Boron	0	1.663c	1.683bc	1.715a-c	Potassium	
	50	1.720a-c	1.668bc	1.735a-c		

	100	1.763ab	1.733a-c	1.780a		
Potassium * Boron	0	1.639b	1.687ab	1.706ab	0	1.677b
	1	1.732ab	1.694ab	1.746a	1	1.724ab
	2	1.775a	1.703ab	1.778a	2	1.752a
Boron		1.715a	1.695a	1.743a		

Means within a column, row and their interactions followed with the same letters are not significantly different from each other according to Duncan’s multiple ranges test at significant level of 5%.

Discussion

The results of the study clearly demonstrate that applying vermicompost, potassium, and boron individually and together significantly increases the mineral content, yield, and fruit quality of strawberry "Rubygem" leaves. The highest quantity of vermicompost (100 ml plant^{-1}) usually had the most obvious positive impacts, often in combination with potassium (2 g L^{-1}) and boron (40 mg L^{-1}).

Vermicompost multifarious involvement in soil health and plant nutrition explains its exceptional performance. Vermicompost is a rich source of humic chemicals, macro and micronutrients, and beneficial microorganisms that improve strawberry plant development, quality, and yield [21]. It improves soil structure, boosts water-holding capacity, and enhances nutrient availability and uptake [22 and 23]. Because the enhanced rhizosphere environment promoted better nitrogen metabolism and micronutrient assimilation, this explains the notable rise in strawberry leaf protein and zinc content. Better vegetative growth, a requirement for increased output, was directly correlated with the better nutritional condition. The significant increase in hectare production with the best-integrated treatments serves as proof of this. The longer flowering period, which offers a longer window for fruit set and development, was probably caused by vermicompost's role in encouraging root development and plant vigor [24 and 25]. Researchers concluded that the application of vermicompost to the plants shown an increase in nitrogen in the leaves, which was evidence of improved biological nitrogen fixation. The dissolved nutrient made the nutrient more accessible for the plant to absorb, and the enzyme complex created [26]. Strawberry fruits have higher levels of sweetness (fructose, glucose, and total sugars) because vermicompost can make micronutrients readily available to plants [27].

Potassium used topically was equally important. Potassium is an essential regulator of many physiological processes, such as osmoregulation, enzyme activation, and the transport of photosynthesis, which helps to improve the nutrient content of strawberry leaves and the transport of sugar [28]. The role of Potassium in sugar production and translocation into the fruits is directly responsible for the notable rise in juice density and glucose content upon application [29]. Additionally, because potassium is a key component in photosynthesis, translocation and sugar biosynthesis, stomata adjustment and anion cation equilibrium, plant water relations, osmotic regulation, root growth, cell and vegetative growth of plants, and other processes, it is known to improve fruit firmness, quality, and coloration, which is consistent with the observed higher juice density [30]. Potassium is a key component in photosynthesis, translocation and sugar biosynthesis, stomata adjustment and anion cation equilibrium, plant water relations, osmotic regulation, root growth, plant cell and vegetative growth, fruit quality and marketable yield, total yield, enhancing the efficiency of nutrient utilization, especially nitrogen, and playing additional roles in plant defense and tolerance to biotic and abiotic stress [31 and 32].

One important conclusion is that using vermicompost, potassium, and boron significantly reduced the percentage of deformed fruits. Boron shortages during flower growth and fruit set are frequently associated with fruit malformation in strawberries. Boron increases transport sugar to the flower bud, giving it energy and producing longer pollen tubes that improve fertilization [33 and 34]. The foliar treatment of boron and the soil application of vermicompost, a source of accessible boron and a medium that enhances the uptake of other nutrients like potassium, guaranteed a sufficient supply of this vital element during the crucial flowering phase. This reduced distortion by promoting effective fertilization and the growth of well-formed fruits [34].

The availability of sugars carried by boron, which is up-regulated by abiotic stressors and particular nutrients, may have an impact on the notable increase in fruit anthocyanins [36]. The enhanced plant health and metabolic activity, fueled by an ideal nutrition supply, probably promoted the phenylpropanoid pathway, resulting in increased anthocyanin formation, while the high glucose content supplied the required substrate [37]. Boron's physiological pattern and role in protein metabolism, translocation of sugar during enhancement of the plant flowering and fruiting stages, synthesis of pectin, re-synthesis of adenosine triphosphate (ATP), and maintaining the proper water relation within the strawberry plant are some of the reasons why boron foliar application helps to increase flowering period. It also plays a major role in pollination, fruit set, and yield per plant [38].

Conclusion

In conclusion, the combination of foliar-applied potassium and boron with soil-applied vermicompost produces a synergistic effect that maximizes the physiological performance of the strawberry plant "Rubygem." improves fruit development, nutrient availability and uptake. Consequently, the applying of 100 ml plant^{-1} vermicompost in addition to foliar sprays of 2 g L^{-1} potassium and 40 mg L^{-1} boron is advised in order to maximize strawberry production and quality.

Acknowledgments

This experience was conducted in horticultural orchards at the University of Duhok, College of Agricultural Engineering Sciences. Additionally, every parameter was measured in the College of Agricultural Engineering Sciences laboratory at the University of Duhok in Iraq. Many thanks to the laboratory personnel for supplying the facilities, needs, and equipment.

References

[1]. Singh R, RR Sharma, SK Tyagi. (2007) Pre-harvest foliar application of calcium and boron influence physiological disorders, fruit yield and quality of strawberry. Sci. Hort.;112:215-220. DOI:10.1016/j.scienta.2006.12.019

[2]. Processing strawberry global market report (2025). The business research company, ID: 5980538, 175 Pages

[3]. Giampieri, F, Alvarez-Suarez, J. M., & Battino, M. (2014). Strawberry and human health: Effects beyond antioxidant activity. Journal of agricultural and food chemistry, 62(18), 3867-3876. DOI: 10.1021/jf405455n

[4]. Negi, Y. K., Sajwan, P., Uniyal, S., & Mishra, A. C. (2021). Enhancement in yield and nutritive qualities of strawberry fruits by the application of organic manures and biofertilizers. Scientia Horticulturae, 283, 110038. DOI:10.1016/j.scienta.2021.110038

[5]. Lim, S. L., Wu, T. Y., Lim, P. N., & Shak, K. P. Y. (2015). The use of vermicompost in organic farming: overview, effects on soil and economics. Journal of the Science of Food and Agriculture, 95(6), 1143-1156. https://doi.org/10.1002/jsfa.6849

[6]. Abdulkadhim, S., & Hussein, R. (2023). Effect of vermicompost and bio-chemical fertilizers on yield traits of strawberry plants (*Fragaria x ananassa*) Rubygem cultivar. Euphrates journal of agricultural science, 15(2), 375-386.

[7]. Trejo-Téllez, L. I., Gómez-Trejo, L. F., & Gómez-Merino, F. C. (2023). Biostimulant effects and concentration patterns of beneficial elements in plants. Beneficial Chemical Elements of Plants: Recent Developments and Future Prospects, 58-102. DOI:10.1002/9781119691419.ch4

[8]. Vago, I., Tolner, L., & Loch, J. (2009). Effect of chloride anionic stress on the yield amount and some quality parameters of strawberry (*Fragaria X ananassa* Duch). Cereal Research Communications, 37, 81-84. DOI: 10.1556/CRC.37.2009.

[9]. Bons, H. K., & Sharma, A. (2023). Impact of foliar sprays of potassium, calcium, and boron on fruit setting behavior, yield, and quality attributes in fruit crops: a review. Journal of Plant Nutrition, 46(13), 3232-3246. DOI:10.1080/01904167.2023.2192242

[10]. Verma, S., Dwivedi, A. K., & Tripathi, D. V. (2022). Effect of gibberellic acid and boron on growth, yield and yield attributory traits in strawberry (*Fragaria x ananassa* Duch.) under North Gangetic Plains. Yield and Yield Attributory Traits In Strawberry (*Fragaria X Ananassa* Duch.) Under North Gangetic Plains (August 14, 2022). DOI:10.2139/ssrn.4189998

[11]. Arunkumar, K., Varghese, M. J., Sudhakar, S., Marimuthu, R., Paul, P. K., Ashiba, A., & Abishek, R. (2022). Foliar application of calcium and boron on yield and quality attributes of strawberry. Pharma Innovation, 11(4), 2054-7.

[12]. Kumar, L., Bairwa, H. L., Mahawer, L. N., Meena, S. C., Kaushik, R. A., & Choudhary, R. C. (2021). Response of foliar spray of iron, zinc and boron in strawberry (*Fragaria× ananassa* Duch.) cv. winter dawn.

[13]. Nakro, A., Bamouh, A., El Khatib, O., & Ghaouti, L. (2022). Effect of potassium source and dose on yield and quality of strawberry fruit. American Journal of Plant Sciences, 13(9), 1196-1208.DOI: 10.4236/ajps.2022.139081

[14]. Agheli, M., Pakkish, Z. & Mohammadrezakhani, S. (2025). The effect of boron and vitamin C foliar application on the yield and quality of strawberry fruit.Jurnal of plant process and function, Iranin society of plant physiology, Volume 14, Issue 65 (vol. 14, no. 65. 35 – 48. DOI: 10.22034/14.65.35

[15]. SAS Institute. (2015). Base SAS 9.4 procedures guide. SAS Institute

[16]. Mariotti F. Tomé D. & Mirand P.P (2008). Converting nitrogen into protein-beyond 6.25 and Jones' factors. Critical reviews in food sci. and nut.; 48(2): 177-184. DOI: 10.1080/10408390701279749

[17]. Prom-u-thai, C., & Rerkasem, B. (2023). Comparison between Acid Digestion (ICP-OES) and X-ray Fluorescence (XRF) Spectrometry for Zinc Concentration Determination in Rice (Oryza sativa L.). Foods, 12(5), 1044. https://doi.org/10.3390/foods12051044

[18]. FAO: General standard for fruit juices and nectars; Codex Alimentarius Commission. (2005), www.codexalimentarius.org/.../standards/.../CXS_247.

[19]. Ranganna, S. (2011) Handbook of Analysis and Quality Control for Fruit and Vegetable Products. 2nd edition, New Delhi, McGrow-Hill.

[20]. Zhang, Z., Tian, R., Wan, J., Wang, Y., & Li, H. (2025). Combined analysis of metabolomics and transcriptomics reveals the effects of sugar treatment on postharvest strawberry fruit quality. BMC Plant Biology, 25(1), 882. DOI:10.1186/s12870-025-06919-7

[21]. Kilic, N., Dasgan, H. Y., & Gruda, N. S. (2023). A novel approach for organic strawberry cultivation: Vermicompost-based fertilization and microbial complementary nutrition. Horticulturae, 9(6), 642. https://doi.org/10.3390/horticulturae9060642

[22]. Tang, X., Li, Y., Fang, M., Li, W., Hong, Y., & Li, Y. (2024). Effects of different water storage and fertilizer retention substrates on growth, yield and quality of strawberry. Agronomy, 14(1), 205. https://doi.org/10.3390/agronomy14010205

[23]. Mufty, R. K., & Taha, S. M. (2021, November). Response two strawberry cultivars (fragaria X ananassa duch.) for foliar application of two organic fertilizers. In IOP Conference Series: Earth and Environmental Science (Vol. 910, No. 1, p. 012033). IOP Publishing. doi: 10.58928/ku23.14311

[24]. Trejo-Téllez, L. I., & Gómez-Merino, F. C. (2014). Nutrient management in strawberry: Effects on yield, quality and plant health. Strawberries: Cultivation, antioxidant properties and health benefits, 239-267.

[25]. Ali, H. O., & Bani, S. H. S. (2024). Effect of planting dates, chilling periods and N/P foliar spray on flowering traits of strawberry (Fragaria× ananassa Duch) cv. Robygem in a hydroponic system. Journal of Kirkuk University for Agricultural Sciences, 15(4). https://doi.org.10.58928/ku25.16129

[26]. Joshi, R., Singh, J., & Vig, A. P. (2015). Vermicompost as an effective organic fertilizer and biocontrol agent: effect on growth, yield and quality of plants. Reviews in Environmental Science and Bio/Technology, 14(1), 137-159. Http://dx.doi.org/10.1007/s11157-014-9347-1

[27]. Nyoro, A. G. (2023). Evaluation of Vermicompost-inorganic Fertilizer Combination on Growth, Yield and Quality of Strawberry (Doctoral dissertation, University of Nairobi).

[28]. Wang, M., Zheng, Q., Shen, Q., & Guo, S. (2013). The critical role of potassium in plant stress response. International Journal of Molecular Sciences, 14(4), 7370-7390. https://doi.org/10.3390/ijms14047370

[29]. Tohidloo, G., Souri, M. K., & Eskandarpour, S. (2018). Growth and Fruit Biochemical Characteristics of Three Strawberry Genotypes under Different Potassium Concentrations of Nutrient Solution. Open Agriculture, 3(1). DOI:10.1515/opag-2018-0039

[30]. Malekzadeh, M. R., Esmaeilizadeh, M., & Roosta, H. R. (2024). Optimizing strawberry growth and fruit quality through fertigation frequency and foliar application of potassium sulfate. Journal of Soil Science and Plant Nutrition, 24(2), 3042-3055. DOI:10.1007/s42729-024-01729-6

[31]. Yildrim E., Karlidag H., Turan M., (2009). Mitigation of salt stress in strawberry by foliar K, Ca and Mg nutrient supply. Plant Soil Environ, 55(5), 213-221. Http://dx.doi.org/10.17221/383-PSE

[32]. Marschner H., Marschner's (2012) mineral nutrition of higher plants. Third Edition, Academic Press, London.Https://doi.org/10.1016/C2009-0-63043-9

[33]. Álvarez-Herrera, J. G., Jaime-Guerrero, M., & Fischer, G. (2025). The Effect of Boron on Fruit Quality: A Review. Horticulturae, 11(8), 992. https://doi.org/10.3390/horticulturae11080992

[34]. Ahmed, A. S., Sattar, A. G., Hussein, H. K., & Khurshed, D. N. (2023). Effect of Humic acid and potassium sulfate spraying on growth and yield of strawberry (*Fragaria x ananassa* Duch.). Journal of Kirkuk University for Agricultural Sciences, 14(3). DOI:10.58928/KU23.14326

[35]. Singh, J., Singh, M., Jain, A., Bhardwaj, S., Singh, A., Singh, D. K.,.. & Dubey, S. K. (2013). An introduction of plant nutrients and foliar fertilization: a review. Precision farming: a new approach, New Delhi: Daya Publishing Company, 252-320. DOI:10.13140/RG.2.1.1629.3844

[36]. Mohamed, M. H., Petropoulos, S. A., & Ali, M. M. E. (2021). The application of nitrogen fertilization and foliar spraying with calcium and boron affects growth aspects, chemical composition, productivity and fruit quality of strawberry plants. Horticulturae, *7*(8), 257. https://doi.org/10.3390/horticulturae7080257

[37]. Jaakola, L. (2013). New insights into the regulation of anthocyanin biosynthesis in fruits. Trends in Plant Science, 18(9), 477-483. https://doi.org/10.1016/j.tplants.2013.06.003

[38]. Barker, A. V., & Pilbeam, D. J. (Eds.). (2015). Handbook of plant nutrition. CRC press.

Https://doi.org/10.1201/b18458

استجابة صنف نبات الفراولة "روبي جيم" لإضافة السماد الدودي والتسميد الورقي بالبوتاسيوم والبورون

ناجي عصام حسين[1] **شكري حجي صالح**[1]

[1] قسم البستنة، كلية علوم الهندسة الزراعية،جامعة دهوك، دهوك، العراق.

الخلاصة

أجريت هذه التجربة في حقول قسم البستنة - كلية علوم الهندسة الزراعية - جامعة دهوك الواقعة في مدينة سميل، محافظة دهوك، إقليم كردستان، العراق، خلال موسم النمو لعام 2025، لدراسة تأثير ثلاث مستويات من السماد الدودي السائل (0، 50 و 100 مل نبات-1) وثلاثة تراكيز من الرش الورقي بالبوتاسيوم (0، 1 و 2 غم لتر-1) والبورون (0، 20 و 40 ملغم لتر-1) على المحتويات في أوراق الفراولة وحاصل نبات الشليك صنف "روبي جيم" المزروعة في ظروف الحقل. وقد تم دراسة الصفات التالية طوال التجربة. نسبة البروتين في الأوراق، الزنك (ملغم كغم -1)، طول فترة الإزهار (يوم)، كثافة العصير (غم سم -3)، إجمالي المحصول (كغم لهكتار -1)، نسبة الثمار المشوهة، محتوى الأنثوسيانين في الثمار (ملغم 100 غم -1 وزن الطازج الثمرة)، الجلوكوز (غم 100 غم - 1 على الوزن الطازج). تم استخدام التجربة العاملية ضمن تصميم القطاع العشوائية اربع مكررات. اجريت التحليل الإحصائي باستخدام برنامج ***SAS*** مع اختبار دنكن متعدد النطاق ($p \le 0.05$). إضافة السماد الدودي والبوتاسيوم والبورون ، وخاصة عند (100 مل نبات-1 سماد دودي و 2 غم لتر-1 بوتاسيوم و 20 و 40 ملغم لتر-1 بورون) وأدى ذلك إلى زيادة كبيرة في معظم المعايير المدروسة. أدى التفاعل بين السماد الدودي والبوتاسيوم والبورون بمعدلات عالية إلى إنتاج نسبة البروتين في الأوراق (13.048%)، الزنك (41.488 ملغم كغم -1)، طول فترة الإزهار (94.750 يوم)، كثافة العصير (1.308 غم سم -3)، إنتاج الهكتار (8800.816 كغم لهكتار -1)، نسبة الثمار المشوهة (24.585%)، محتوى الأنثوسيانين في الثمار (24.811 ملغم 100 غم -1 وزن الطازج الثمرة) والجلوكوز (1.925 غم 100 غم - 1 على الوزن الطازج).

الكلمات المفتاحية: الشليك ، السماد الدودي، أكسيد البوتاسيوم ، حمض البوريك.