Journal homepage
www.ajas.uoanbar.edu.iq
Anbar Journal of Agricultural Sciences
(University of Anbar – College of Agriculture)

EFFECT OF SPRAYING WITH BEETROOT EXTRACT AND POTASSIUM SULFATE ON SOME VEGETATIVE, CHEMICAL, AND FRUIT CHARACTERISTICS OF STRAWBERRY PLANT, VARIETY RUBY GEM

H. H. Al-Omrani [1]* **R. M. Hamad [2]** **N. T. Abd [3]**

[1] Faculty of Agriculture, University of Al- Qadisiyah. Iraq.
[2] Faculty of Agriculture, University of Anbar. Iraq.
[3] Center of Desert Studies University of Anbar.

***Correspondence to:** H. H. Al-Omrani, Faculty of Agriculture, University of Al-Qadisiyah, Iraq.
Email: hussein.h.abood@qu.edu.iq

Article info

Received: 2024-11-28
Accepted: 2025-01-06
Published: 2025-06-30

DOI-Crossref:
10.32649/ajas.2025.186612

Cite as:
Al-Omrani, H. H., Hamad, R. M., and Abd, N. T. (2025). Effect of spraying with beetroot extract and potassium sulfate on some vegetative, chemical, and fruit characteristics of strawberry plant, variety ruby gem. Anbar Journal of Agricultural Sciences, 23(1): 235-247.

Abstract

The experiment was carried out in one of private nurseries in Diwaniyah Governorate, Iraq, for 2022 agricultural season to study the effect of spraying with beetroot root extract in concentrations (0, 10, 20 ml l^{-1}), potassium sulfate in concentrations (0, 1.5, 3 gm l^{-1}) and the interaction between them on some vegetative, chemical and fruit Quality of strawberry plant., Factorial experiment was conducted according to randomized complete block design (RCBD) with three triplicates and compared between treatments by using the least significant differences (LSD) at 0.05 level. Interaction between treatments were also statistically significant; however, the B_2K_2 treatment yielded the most significant increases in leaf area, relative chlorophyll, Concentration of nitrogen in leaf nitrogen, phosphorus, potassium, iron, fruit size and weight, substance dry matter percentage and the total soluble solids in fruits amounted to 17.15%, 80.48 cm^2 $leaf^{-1}$, 63.30 SPAD unit, 2.19%, 0.232%, 1.74%, 198.00 mg kg^{-1}, 34.28 gm $fruit^{-1}$, 49.61 cm^3, 13.94%, respectively.

Keywords: Strawberry, Beetroot Extract, Potassium Sulfate.

تأثير الرش بمستخلص جذور الشوندر وكبريتات البوتاسيوم في بعض الصفات الخضرية والكيميائية والثمرية لنبات الفراولة صنف Robygem

حسين حميد عبود العمراني [1]* رسمي محمد حمد الدليمي [2] نور طه عبد [3]

[1] كلية الزراعة، جامعة القادسية.

[2] كلية الزراعة، جامعة الانبار.

[3] مركز دراسات الصحراء، جامعة الانبار.

*المراسلة الى: حسين حميد عبود العمراني، كلية الزراعة، جامعة القادسية، العراق.

البريد الالكتروني: hussein.h.abood@qu.edu.iq

الخلاصة

نفذت التجربة في أحد المشاتل الاهلية في محافظة الديوانية للموسم الزراعي 2022 لدراسة تأثير الرش بمستخلص جذور الشوندر بالتراكيز (0، 10، 20 مل لتر$^{-1}$) بكبريتات البوتاسيوم بالتراكيز (0، 1.5، 3 غم لتر$^{-1}$) والتداخل بينهما في بعض الصفات الخضرية والكيميائية والثمرية لنبات الفراولة. اجريت تجربة عاملية وفق تصميم القطاعات العشوائية الكاملة (RCBD) وبثلاث قطاعات وتمت المقارنة بين المعاملات باستعمال اختبار أقل فرق معنوي L.S.D عند مستوى احتمال 0.05. أظهرت النتائج ان الرش بكبريتات البوتاسيوم ومستخلص جذور الشوندر بصوره مفردة ادى الى زيادة معنوية في جميع الصفات المدروسة وكذلك التداخل بين العاملين حيث سجلت المعاملة B_2K_2 أعلى زيادة معنوية في النسبة المئوية للمادة الجافة للورقة ومساحة الورقة والكلوروفيل النسبي والنتروجين والفسفور والبوتاسيوم والحديد في الأوراق ووزن الثمرة وحجمها والنسبة المئوية للمواد الصلبة الذائبة الكلية في الثمار بلغت 17.15%، 80.48 سم^2 ورقة$^{-1}$، 63.30 Spad، 2.19%، 0.232%، 1.74%، 198.00 ملغم كغم$^{-1}$، 34.28 غم ثمرة$^{-1}$، 49.61 سم^3، 13.94% على التوالي.

كلمات مفتاحية: الفراولة، مستخلص الشوندر، كبريتات البوتاسيوم.

Introduction

Strawberry is a perennial herbaceous crop, it is belong to rosacea family, specifically the Fragaria genus and species Fragaria × ananassa. There are few tiny fruits as significant as this one, and it grows all around the globe. Its spread is due to its ability to adapt to different environmental conditions, high nutritional value, and the speed of its entry into growth and production (7). The genus *Fragaria* includes about 45 wild and farmed species, believed to be native to alps and the Massif-Central regions in France, from where they spread to the rest of Europe and North Asia (6). Strawberry cultivation's cultivation area in 2021 was approximately 389,665 hectares, and its global production rate was about 9.175 million tons. It is widely used in over 63 nations (13). Strawberry cultivation in Iraq is relatively recent (14), and most of the strawberries eaten in Iraq come from neighboring nations because their cultivation is restricted to scientific experiment stations, a few family gardens, and tiny agricultural areas (29).

The strawberry plant has a shallow and medium-spreading root system. The fruit is rich in minerals, fibers, vitamins, proteins, carbs, and phenolic compounds like anthocyanins and others, and it also has a high nutritional and medicinal value. Notably, Shillik fruits contain a lot of vitamin C, a substance that reduces inflammation. Fruits, which are rich in antioxidants, can help prevent cancer, heart disease, high blood pressure, and other long-term health problems (15, 16, 26, 28 and 33).

Fertilization is essential for many plants, but strawberries are particularly important. Foliar fertilization makes up for deficiencies in some essential components and nutrients, which boosts the plant's efficiency in meeting quality and aesthetic standards for fruit production. Studies have proven that adding chemical fertilizers in large quantities causes increased environmental pollution and health damage to humans and animals (30).

The extract of the roots of the beetroot contains antioxidants due to the presence of Betalain, phenolic acids, saponins, alkaloids, steroids, triterpenes, catechin, flavonoids and nutrients calcium, phosphorus, iron, vitamins, vitamin B and folic acid. The roots of the beetroot are considered a functional food because its valuable active components such as minerals, amino acids, phenolic acid, flavonoids, betaxanthin, and betacyanin contain a large number of bioactive elements (8 and 31).

Potassium impacts many essential plant functions, including respiration, photosynthesis, transpiration, and stomatal opening and shutting (1) Plants need potassium in large quantities, even though it is not included in any organic compound. It is one of the mobile elements within the plant and moves when needed within the plant tissues. Hence, the lower or older leaves and the young leaves are the first to show indications of their deficit (4). Its high concentration and mobility inside the plant make potassium the ideal monovalent cation for enzyme activation. Fertilization with potassium must consistently include its addition because it is vital to plant nutrition. It increases the synthesis of ATP (plant energy) and multiple oxidative phosphorylation and is crucial for structure (9). Protein synthesis, essential for fruit enlargement, plays a significant role in stomatal movement, stabilizes pH, and allows cells to expand (11). In addition to its function in protein metabolism, potassium is a vital enzyme activator. It has an effect on the amount of water in the leaves as well as their chlorophyll formation (12). This study was conducted on apricot trees, a Royal variety, in which potassium humate was used. Also, in a study in which foliar spraying with potassium sulfate at a concentration of 1 gm was used, it significantly increased the characteristics of vegetative growth and the content of N, P, K, and chlorophyll in the leaves and increased the weight of the fruit and the percentage of dissolved solids of strawberry fruits (27).

The study aims to determineIs to study the effect of using beetroot root extract and potassium sulfate under protected environment conditions and to demonstrate the effect of their interactions on the growth and production of strawberry plants.

Materials and Methods

This study was conducted in one of private nurseries in Diwaniyah Governorate for the period from 12/1/2021 to 6/1/2022 The diameter of each anvil is (15 cm) and it contains 1 -2 pairs of true leaves, with similar in terms of growth. The anvils were placed on wooden terraces and placed inside plastic tunnels with a height of 75 cm and the distance between one plant and another was 25 cm. The taken plants were treated with a fungicide and insecticide as a preventive measure for the plants. Fertilization operations were carried out with NPK fertilizer, which included the use of the following fertilizers 20-20-20 and watering according to the needs of the plants by dissolving (3 gm l^{-1}) of fertilizer as a fertilizer recommendation for each anvil. The Randomized Complete Block Design (R.C.B.D.) was used to conduct the factorial experiment with three components. There were a total of nine treatments across three sectors in the experiment, with three plants per unit. This brought the grand total of plants utilized in the experiment to 81. We used the L.S.D. test at the 5% confidence level to compare means after statistical analysis of the data (3). The data were analyzed using the Genstat program. The research included a study of two factors: the first factor was spraying with potassium sulfate at concentrations (0, 1.5 and 3 gm L^{-1}) and the second factor was spraying with an extract of beetroot roots, which was prepared after heating every half kilogram with a liter of distilled water to the boiling point (100°C) and then used according to the concentrations (0, 10, 20 ml L^{-1}). spraying process was carried out at three times (1/1, 1/15, and 1/30) in the early morning of each appointment.

Studied attributes:

Leaf dry weight percentage (%)

Leaf area (cm^2 leaf $^{-1}$)

Vegetation food (SPAD unit $leaf^{-1}$) An on-the-go SPAD-502 chlorophyll meter from MIMOLTA CO. LTD. JAPAN was used to get a rough reading of the leaf chlorophyll concentration while we were out in the field.

Nitrogen N%: Nitrogen was estimated using the Micro Kjeldahl device, as mentioned in (17).

Phosphorus P%: An 80 D UV-VIS Spectrophotometer operating at 662 nm measured phosphorus in solutions containing ammonium molybdate and ascorbic acid (23).

Potassium K%: Potassium was estimated using a flame photometer, as mentioned in (10).

Iron Fe mg. L^{-1}: Estimated using the Atomic Absorption Spectrophotometer as mentioned in (5).

Fruit weight (gm $fruit^{-1}$)

Fruit size (cm^3 $fruit^1$)

Total dissolved solids (TSS %)

This characteristic was measured using a manual refractometer. Five ripe, homogeneous fruits from each experimental unit were cut into slices and crushed in an earthen jar. After filtering the juice with cotton cloth, an average of two readings was taken to reduce the error.

Results and Discussion

Leaf dry weight percentage (%): Results in table 1 showed that there are a significant differences between the two factors and their interaction. Spraying treatment with beetroot extract B_2 (20 ml l^{-1}) recorded the highest average percentage of leaf dry matter, amounting to 15.09%, while the treatment without spraying recorded B_0 (0 at a concentration of (0 ml l^{-1}) lowest percentage was 10.69%. Spraying with potassium sulfate, as treatment K_2 (3 gm L^{-1}) recorded significant differences in the percentage of dry matter of the leaf, amounting to 14.17%, while the treatment without spraying K_0 (0 gm L^{-1}) recorded the lowest percentage, amounting to. 12.56%. It was noted that the interaction between the factors that there was a significant effect, as treatment B_2K_2 (bean root extract at a concentration of 20 ml L^{-1} + potassium sulfate at a concentration of 3 gm L^{-1}) gave the highest values, reaching 17.15%, and the measurement treatment B0K0 recorded the lowest value, amounting to 10.32%.

Table 1: Effect of spraying with beetroot extract and potassium sulfate on the percentage of strawberry leaf dry matter (%).

Beet root extract B	Potassium sulfate			Average B
	K_0	K_1	K_2	
B_0	10.32	10.50	11.24	10.69
B_1	13.24	13.66	14.12	13.67
B_2	14.13	13.99	17.15	15.09
Average K	12.56	12.72	14.17	
K*B =0.80		K = 0.46	B = 0.46	L.S.D

Leaf area (cm^2 leaf^{-1}): It is clear from the results of Table 2 that there is a significant effect of the research factors on this trait, as the spray treatment with beetroot extract B_2 gave the largest leaf area, amounting to 73.86 cm^2 leaf^{-1}, superior to the unsprayed treatment B_0, which gave the lowest leaf area, 44.28 cm^2 leaf^{-1}. We note the superiority of the potassium sulfate K_2 treatment over rest of the treatment for this factor also gave it the highest leaf area, which amounted to 63.73 cm^2 leaf^{-1}, while the measurement treatment K_0 gave it the lowest leaf area, which amounted to 52.93 cm^2 leaf^{-1}. It was also observed that there was a significant effect between the study factors when they interacted in this characteristic, when treatment B_2K_2 gave the highest leaf area of 80.48 cm^2 leaf^{-1}, superior to the rest of the treatments, while treatment B_0K_0 gave the lowest leaf area of 40.96 cm^2 leaf^{-1}.

Table 2: Effect of spraying with beetroot extract and potassium sulfate on leaf area of strawberry plants (cm^2 leaf^{-1}).

Beet root extract B	Potassium sulfate			Average B
	K_0	K_1	K_2	
B_0	40.96	44.22	47.66	44.28
B_1	50.85	54.71	63.03	56.20
B_2	66.97	74.12	80.48	73.86
Average K	52.93	57.68	63.73	
K*B = 1.272		K = 0.735	B = 0.735	L.S.D

Chlorophyll (SPAD unit leaf^{-1}): Results of Table 3 Showed significant differences for the two factors and the interaction between them, as spraying with treatment beetroot extract was significantly superior to the treatment without spraying B_0, as treatment B_2 recorded the highest value, amounting to 61.26 Spad unit. In contrast, the treatment without spraying, B_0, recorded the lowest value, reaching 42.69 Spad unit. As for foliar spraying with potassium sulfate, there were significant differences between the K_2 treatment, with the highest value reaching 56.65 Spad unit, while the treatment without Potassium sulfate, K_0 recorded spray recorded the lowest value, amounting to 47.71 Spad unit. The interaction coefficients Between treatments showed a significant differences between the study factors showed significant differences, as the B_2K_2 treatment gave the highest value, amounting to 63.30 Spad unit, with a significant difference for all transactions, while the measurement treatment B_0K_0 gave the lowest value, amounting to 30.99 Spad unit.

Table 3: Effect of spraying with beetroot extract and potassium sulfate on relative chlorophyll of strawberry leaf (SPAD unit leaf^{-1}).

Beet root extract B	Potassium sulfate			Average B
	K_0	K_1	K_2	
B_0	30.99	47.44	49.63	42.69
B_1	53.03	54.67	57.00	54.90
B_2	59.10	61.37	63.30	61.26
Average K	47.71	54.49	56.65	
K*B =1.130		K = 0.652	B = 0.652	L.S.D

Nitrogen concentration in leaves (%): According to Table 4 the nitrogen concentration in the leaves is significantly increased by using the highest nitrogen concentration in leaves was in treatment B_2 and reached to 2.39%, while the treatment with the lowest nitrogen percentage was in treatment B0 and reached to 1.67%. above, the highest rate of nitrogen concentration 2.19% was achieved by spraying with potassium sulfate K_2, whereas the lowest concentration 1.92% was achieved by treatment K_0. While plants in the interaction treatment B_0K_0 recorded the lowest percentage of nitrogen at 1.47%, treatment B_2K_2 recorded the highest percentage of nitrogen at 2.19% when sprayed with beetroot extracts and potassium sulfate, according to the significant binary interaction of the study factors.

Table 4: Effect of spraying with beetroot extract and potassium sulfate on percentage of nitrogen in strawberry leaves (%).

Beet root extract B	Potassium sulfate			Average B
	K_0	K_1	K_2	
B_0	1.47	1.68	1.87	1.67
B_1	2.01	2.10	2.19	2.10
B_2	2.29	2.36	2.52	2.39
Average K	1.92	2.05	2.19	
K*B = 0.04		K = 0.02	B = 0.02	L.S.D

Phosphorus concentration in leaves (%): Table 5 shows that the phosphorus concentration was dramatically altered by spraying with levels concentration of beetroot extract B. Treatment B_2 had the maximum concentration of 0.214 percent, while treatment B_0 had the lowest content of 0.167 percent. Spraying with potassium sulfate at K_2 tratment therapy with potassium sulfate K_2 had the greatest concentration and the most noticeable effect. Treatment K_0 had the lowest concentration, at 0.178%, while the concentration reached 0.196%. The interaction treatment B2K2 showed a significant increase in the phosphorus concentration in the leaves, as it recorded the highest content (0.232%), while the control treatment B0K0 recorded the lowest content in the phosphorus concentration in the leaves (0.196%).

Table 5: Effect of spraying with beetroot extract and potassium sulfate on percentage of phosphorus in strawberry leaves (%).

Beet root extract B	Potassium sulfate			Average B
	K_0	K_1	K_2	
B_0	0.163	0.166	0.171	0.167
B_1	0.176	0.181	0.185	0.181
B_2	0.196	0.213	0.232	0.214
Average K	0.178	0.187	0.196	
K*B =0.005		K =0.003	B =0.003	L.S.D

Potassium concentration in leaves (%): Results in Table 6 showed that beetroot extract significantly affected potassium content, as treatment B2 showed the highest potassium content in leaves at a concentration of 1.69%, while treatment B0 produced the lowest at 1.47%. Regarding potassium sulfate, treatment K2 achieved the best potassium content at a concentration of 1.63%, while treatment K0 achieved the lowest rate at 1.55%. As for the interaction treatment B2K2, it recorded the highest potassium content in leaves at 1.74% compared to the control treatment B0K0, which recorded the lowest potassium content at 1.43%.

Table 6: Effect of spraying with beetroot extract and potassium sulfate on percentage of potassium in strawberry leaves (%).

Beet root extract B	Potassium sulfate			Average B
	K_0	K_1	K_2	
B_0	1.43	1.45	1.51	1.47
B_1	1.57	1.60	1.63	1.60
B_2	1.65	1.68	1.74	1.69
Average K	1.55	1.58	1.63	
K*B = 0.014		K = 0.008	B = 0.008	L.S.D

Iron concentration in leaves (mg kg^{-1} dry matte): Results of Table 7 showed that beetroot extract had a significant effect on increasing the iron concentration in strawberry leaves, B_2 Treatment the highest rate, amounting to 195.36 mg kg^{-1}, while treatment B_0 gave the lowest iron content, amounting to 163.92 mg $kg^{-1.}$ For the treatment, spraying with potassium sulfate K_2 gave the highest Concentration of iron, amounting to 189.11 mg kg^{-1}, while treatment K_0 gave the lowest Concentration of iron, amounting to 173.35 mg kg^{-1}. The binary interaction showed a significant effect in increasing Iron concentration in strawberry leaves, and the B_2K_2 treatment gave the highest concentration of 198.00 mg kg^{-1} compared to the treatment B_0K_0, which recorded the lowest iron concentration in the leaves of 144.89 mg kg^{-1}.

Table 7: Effect of spraying with beetroot extract and potassium sulfate on iron concentration in strawberry leaves (mg kg^{-1} dry matte).

Beet root extract B	Potassium sulfate			Average B
	K_0	K_1	K_2	
B_0	144.89	167.05	179.83	163.92
B_1	182.67	185.83	189.50	186.00
B_2	192.50	195.58	198.00	195.36
Average K	173.35	182.82	189.11	
K*B =2.69		K = 1.55	B = 1.55	L.S.D

Fruit weight (g $fruit^{-1}$): Table 8 shows a significant differences in fruits fresh weight after spraying with beetroot extract. The highest Was 32.39 g $fruit^{-1}$ was achieved by spraying treatment B_2, while the lowest rate was 17.40 g fruit-1 by treatment B_0. The rate of increase in average fresh fruit weight was greatest (27.19 g $fruit^{-1}$) in the K_2 spraying treatment with potassium sulfate and lowest (22.69 g $fruit^{-1}$) in the K_0 treatment. There was also a significant interaction between the two study factors in increasing fresh weight, and treatment B_2K_2 was characterized by giving the highest average fruit weight of 34.28 g $fruit^{-1}$, while treatment B_0K_0 gave the lowest rate of this trait of 15.64 g $fruit^{-1}$.

Table 8: Effect of spraying with beetroot extract and potassium sulfate on the fruit weight of strawberry plants (g $fruit^{-1}$).

Beet root extract B	Potassium sulfate			Average B
	K_0	K_1	K_2	
B_0	15.64	17.26	19.31	17.40
B_1	22.46	25.41	27.98	25.29
B_2	29.96	32.94	34.28	32.39
Average K	22.69	25.21	27.19	
K*B =0.49		K =0.49	B =0.49	L.S.D

Fruit size (cm^3 $fruit^{-1}$): Table 9 indicate there was a significant effect of beetroot extract on fruit size of strawberry plant. B_2 treatment recorded the highest average fruit size, amounting to 46.62 cm^3 $fruit^{-1}$, compared to treatment B_0, which gave the lowest size, amounting to 28.94 cm^3. $Fruit^{-1}$ Treatment with potassium sulfate also increased the average size of the fruit in treatment K_2 as the highest size was recorded at 40.99 cm^3 $fruit^{-1}$, compared to the average fruit size of the plants in the mentioned K_0 treatment, which recorded the lowest size, which was 35.09 cm^3 $fruit^{-1}$. As for the interaction between the two study factors, it showed the significant effect of the fruit size characteristic, as the highest significant average of 49.61 cm^3 $fruit^{-1}$ was recorded when spraying with the B_2K_2 interference treatment compared to the B_OK_0 control treatment, which recorded the lowest strawberry fruit size of 26.06 cm^3 $fruit^{-1}$.

Table 9: Effect of spraying with beetroot extract and potassium sulfate on the fruit size of strawberry plants (cm^3 $fruit^{-1}$).

Beet root extract B	Potassium sulfate			Average B
	K_0	K_1	K_2	
B_0	26.06	28.35	32.40	28.94
B_1	35.55	38.48	40.95	38.33
B_2	43.66	46.61	49.61	46.62
Average k	35.09	37.81	40.99	
K*B = 0.42		K = 0.24	B = 0.24	L.S.D

Total dissolved solids (TSS %): Results of Table 10 showed that the percentage of total soluble solids in the fruits of the strawberry plant was significantly affected by spraying with beetroot extract and potassium sulfate, as the spraying treatment with Beetroot extract B_2 achieved the highest percentage of total soluble solids, 12.56%, compared to the average recorded by the treatment B_0 For the trait, it reached 7.35%, and the spraying treatment with potassium sulfate K_2 at a concentration of 3 gm l^{-1} recorded a significant effect on the average total dissolved solids in the fruits which amounted to 10.78%, while the K_0 treatment recorded the lowest percentage, amounting to 8.92%. factors, treatment B_2K_2 recorded the highest percentage of total soluble solids in the fruits when sprayed with beetroot extracts and potassium sulfate, which recorded 13.94%, compared to the control plants B_0K_0, which recorded the lowest percentage, amounting to 6.73%.

Table 10: Effect of spraying with beetroot extract and potassium sulfate on the total soluble solids of strawberry fruits (%).

Beet root extract B	Potassium sulfate			Average B
	K0	K1	K2	
B0	6.73	7.17	8.14	7.35
B1	8.89	9.75	10.26	9.63
B2	11.14	12.60	13.94	12.56
Average k	8.92	9.84	10.78	
K*B =0.28		K = 0.16	B = 0.16	L.S.D

Spraying with beetroot extract had improved the vegetative growth characteristics of the leaves, represented by the percentage of dry matter of the leaf, the area of the leaf, the relative chlorophyll content of the leaf, the nutritional elements (N, P, K, and Fe) of the leaf, and the fruiting characteristics of the weight of the fruit, the size of the fruit, and the percentage of dissolved solids. This may be because the beanroot roots contain potassium, phosphorus, calcium, magnesium, and iron, which have an essential role in increasing the metabolic activities of the plant including potassium, which works to activate the enzymes that synthesize amino acids and proteins, and also helps in the Metabolic of chlorophyll, which is necessary for the process of photosynthesis and the formation of proteins, sugars, and the energy compounds ATP, which It leads to increased vegetative growth. Perhaps because beetroot roots contain antioxidants, vitamins A and C, proteins, carbohydrates, and pigments derived from betalain, which includes the red-purple betacyanin betanin and the yellow betaxanthin fucoxanthin, and these are consistent with (19, 21, 22 and 25).

The reason behind this is its involvement in various growth processes, including cell division stimulation, enzyme activation that promotes plant part growth, and an increase in the efficiency of photosynthesis. This is achieved by increasing the leaves' area and the number of carbohydrates and proteins built into plant tissues (2). Along with the impact of this acid on the plant's metabolic activities and the activation of enzymes involved in chlorophyll production a key component of photosynthesis and the formation of sugars, proteins, and energy compounds all of which contribute to the expansion of the plant and the observed vegetative growth traits (21). Moreover, this leads to moral superiority in all studied traits (19). Since potassium improves photosynthesis and cell division, it stands to reason that it would lead to superiority in all traits examined. Raising both their quantity and size (18). As a bonus, it facilitates the movement of carbs to various locations within the plant.

Additionally, potassium helps attract water into the cell vacuole by generating mild osmosis. Stomatal mobility in leaves is one of the cell's functions. Since potassium increases protein metabolism and activates several physiological processes, it is reasonable to assume that it functions in plant development and growth (32). because of this, the proportion of total dissolved solids, chlorophyll, vegetative growth, leaf area, and metabolism increased, leading to larger and heavier fruits (24).

Conclusions

From the results presented in Tables 1-10, we noticed that beetroot extract at a concentration of 20 ml L^{-1} (B_2) and spraying with potassium sulfate at a concentration of 3 g L^{-1} (K_2) gave significant superiority in the studied traits, and the best results were the B2K2 intervention treatment.

Recommendations: From the above, we can recommend the following:

1. Use concentrations of 20 ml l-1 of beetroot extract and 3 g l of potassium sulfate, individually or in combination, to record the best results.
2. Conducting other experiments on other varieties and fruit trees to determine the direct and indirect effects of the study factors of spraying with beetroot root extract and potassium sulfate on plant growth.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

Author 1: methodology, writing—original draft preparation, Author 2 and Author 3 writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The study cooperated with the College of Agriculture and the Agricultural Secondary School in Diwaniyah.

Informed Consent Statement:

No Informed Consent Statement.

Data Availability Statement:

No Data Availability Statement.

Conflicts of Interest:

The authors declare no conflict of interest.

Acknowledgments:

The authors would like to thank the Director of the Agricultural Secondary School in Diwaniyah and the Dean of the College of Agriculture, University of Anbar, for their valuable assistance in conducting this research.

Disclaimer/Journal's Note:

The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of AJAS and/or the editor(s). AJAS and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

References

1. Abdel-Al, K. A., Samira, A. F. Hassan, Y. M. Hafez, and M. M. Salem. (2013). Essentials of plant physiology. Faculty of Agriculture - Kafr El-Sheikh University.
2. Abu Zeid, Al-Shahat Nasr. (2000). Plant hormones and agricultural applications. Second edition. Arab House for Publishing and Distribution. Cairo Egypt
3. Al-Mohammadi, S. M., and Al-Mohammadi, F. M. (2012). Statistics and experimental design. Dar Osama for publishing and distribution. Amman, Jordan, 376.
4. Ali, N. S. (2012). The Guide to Plant Nutrition. Translator. part One.
5. Al-Sahhaf, F. H. (1989). Soilless farming systems. Ministry of Higher Education and Scientific Research. Baghdad University, 47-45.
6. Al-Saidi, I. H. M. (2000). Small fruit production. House of Books and Publishing, University of Mosul. Iraq. p. 306.
7. Al-Saidi, I. H. M. (2015). Shalek production (strawberries - strawberries). Tigris Library, Iraq. p. 155.
8. Besbas, M. E. A., and Takácsné, M. H. (2024). Evaluation of bioactive substances in different parts of the root in beetroot (Beta vulgaris ssp. esculenta var. rubra). Acta Agraria Debreceniensis, (1): 33-38.
9. Chen, Y., De Nobili, M., and Aviad, T. (2004). Stimulatory effects of humic substances on plant growth. Soil organic matter in sustainable agriculture, 161-168.
10. Cresser, M. S. and J. W. Parsons .1979. Sulphuric-Perchloric acid digestion of plant material for the determination of nitrogen, phosphorus, potassium, calcium and magnesium. Analytica Chimica Acta, 109(2), 431-436.
11. Dell, B., and Huang, L. (1997). Physiological response of plants to low boron. Plant and soil, 193: 103-120. https://doi.org/10.1023/A:1004264009230.
12. Devlin, R. M., and F. H. Withham. (2011). Plant Physiology. Translated by: Sharaqi, Muhammad Mahmoud, Abdel Hadi Khader, Ali Saad Eddin Salama, and Nadia Kamel. Arab House for Publishing and Distribution, third edition. Cairo Egypt.

13. FAO, FAOSTAT-Food and Agriculture Organization Corporate Statistical Database. (2021). FAO Online Database.
14. Franco, S. U. S. (2009). Agency for International development (USAID). The Production of Strawberries in Iraq, 1-10.
15. Giampieri, F., Alvarez-Suarez, J. M., and Battino, M. (2014). Strawberry and human health: Effects beyond antioxidant activity. Journal of agricultural and food chemistry, 62(18): 3867-3876. https://doi.org/10.1021/jf405455n.
16. Giampieri, F., Tulipani, S., Alvarez-Suarez, J. M., Quiles, J. L., Mezzetti, B., and Battino, M. (2012). The strawberry: Composition, nutritional quality, and impact on human health. Nutrition, 28(1): 9-19. https://doi.org/10.1016/j.nut.2011.08.009.
17. Jackson, M. (1958). Soil chemical analysis prentice Hall. Inc., Englewood Cliffs, NJ, 498(1958): 183-204.
18. Jundia, H. (2003). Physiology of fruit trees. -Arab House for Publishing and Distribution. The Egyptian Arabic Republic.
19. Kadam, V. D., Shinde, S. J., and Satav, D. C. (2018). Effect of different spacing and fertilizer levels on yield and economics of beetroot (Beta vulgaris L.). Journal of Pharmacognosy and Phytochemistry, 7(6): 31-35.
20. Lateef, M. A. A., Fadhil, N. N., and Mohammed, B. K. (2021). Effect of Spraying with Cal-Boron and Potassium Humate and Maturity Stage on Fruit Quantity, Quality Characteristics of Apricot Prunus Armeniaca L. cv." Royal". In IOP Conference Series: Earth and Environmental Science, 910(1): p. 012038. DOI: 10.1088/1755-1315/910/1/012038.
21. Martin, J. W. (2012). Impact of marine extracts applications on cv. Syrah grape (Vitis vinifera L.) yield components, harvest juice quality parameters, and nutrient uptake. California Polytechnic State University.
22. Mudgal, D., Singh, S., and Singh, B. R. (2022). Nutritional composition and value added products of beetroot: A review. Journal of Current Research in Food Science, 3(1): 1-9.
23. Nelson, D. W., and Sommers, L. E. (1982). Total carbon, organic carbon, and organic matter. Methods of soil analysis: Part 2 chemical and microbiological properties, 9: 539-579. https://doi.org/10.2134/agronmonogr9.2.2ed.c29.
24. Oudah, N. A., and Saleh, S. A. A. (2024). Using some treatments to improve vegetative growth characteristics of three grape cultivars. Anbar Journal of Agricultural Sciences, 22(2): 1477-1488. https://doi.org/10.32649/ajas.2024.185687.
25. Patkai, G. Y., Barta, J., and Varsanyi, I. (1997). Decomposition of anticarcinogen factors of the beetroot during juice and nectar production. Cancer Letters, 114(1-2): 105-106. DOI: 10.1016/S0304-3835(97)04636-3.
26. Savini, G., Neri, D., Zucconi, F., and Sugiyama, N. (2005). Strawberry growth and flowering: an architectural model. International journal of fruit science, 5(1): 29-50. https://doi.org/10.1300/J492v05n01_04.
27. Sharma, K., Mirza, A., and Dahiya, A. (2023). Influence of Plastic Mulch Colors and Application of Potassium Sulphate on Strawberry cv. Camarosa in Polyhouse.

J Food Chem Nanotechnol, 9(1): 141-147. https://doi.org/10.17756/jfcn.2023-s1-018.

28. Szajdek, A., and Borowska, E. J. (2008). Bioactive compounds and health-promoting properties of berry fruits: a review. Plant foods for human nutrition, 63: 147-156. https://doi.org/10.1007/s11130-008-0097-5.
29. Taha, Sh. M. (2004). Response of four varieties of Shalik to environmental conditions in the Kurda Rah field, Erbil. Zanco Magazine, 16(5): 1-8.
30. Taiz, L., and Zeiger, E. (2010). Plant Physiology. 5th ed. Sinauer Associates, Inc., Publishers Sunderland, Massachusetts.
31. Thiruvengadam, M., Chung, I. M., Samynathan, R., Chandar, S. H., Venkidasamy, B., Sarkar, T., ... and Simal-Gandara, J. (2024). A comprehensive review of beetroot (Beta vulgaris L.) bioactive components in the food and pharmaceutical industries. Critical Reviews in Food Science and Nutrition, 64(3): 708-739. https://doi.org/10.1080/10408398.2022.2108367.
32. Wang, M., Zheng, Q., Shen, Q., and 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.
33. Zhao, Y. (2007). Berry fruit: value-added products for health promotion. CRC press.