International Journal of Biological Engineering and Agriculture
ISSN: 2833-5376
Volume 03 Number 03 (2024)
Impact Factor: 9.51
SJIF (2023): 3.916

www.inter-publishing.com

Article

Response of strawberry to mulching, biofertilizer and calcium spraying and its effect on fruit traits

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Abstract: The experiment was conducted in the agricultural field located in the village of Tunisia / Al-Mahawil District (30 km) north of Babylon province, in a plastic house with an area of 450 m2 and dimensions of 9 x 50 m. to study the effect of the type of coverage, biofertilizer, and calcium spray on the growth and production of the Rubygem cultivar. The experiment was conducted according to the Complete Randomized Blocks Design (CRBD), in a split plot arrangement, with three replicates and with three factors. The first represents mulching type of with three levels, namely (Mulching soil planted with black polyethylene, white polyethylene, and straw. (wheat and barley waste) and is symbolized by the symbol (A1, A2, A3) respectively and were placed in the main plot . As for the sub-plots , the second factor included biofertilizers at four levels that were added to the soil near the plant roots by injection method (the control and Azotobacter bacteria (10 ml. Plant-1) and Mycorrhizas fungi (10 ml. Plant - 1) and a mixture of (Mycorrhizas fungi with Azotobacter bacteria and symbolized by (B0, B3, B2, B1), respectively. The third factor is spraying with calcium at three concentrations (the first is the control treatment and the second is 2.5 (g. L-1) and the third 5 (g. L-1) and symbolized by (C3, C2, C1). The results showed that the black polyethylene mulching treatment was significantly excelled on all traits and both seasons, as follows: number of flowers (30.53, 31.84 flowers . plant-1), average number of opened flowers (29.80, 31.17 flowers . plant-1), average number of set flowers (28.70, 29.99 flowers. Plant-1) Number of fruits (27.65, 28.83 fruits. Plant-1). The results also showed that the biological fertilization treatment (Mycorrhiza + Azotobacter) was significantly excelled on the other treatments and gave the highest values for most of the studied traits, while the triple interaction treatment with black poly Biofertilization (Azotobacter at a concentration of 10 ml. Plant-1 + Mycorrhizae at a concentration of 10 ml. Plant-1) and calcium spraying at a concentration of 5 (g.L-1) and the highest values were recorded for all the studied traits and for both seasons.

Keywords: Ischemic, strawberry, mulching, fruit traits

Citation: Mariam M. Abed Al-Hussien, Ibrahim M. Radhi, Response of strawberry to mulching, biofertilizer and calcium spraying and its effect on fruit traits International Journal of Biological Engineering and Agriculture , 5(4),260-275

Received: 26thJun 2024
Revised: 3rdJul2024
Accepted: 10thJul2024
Published: 17thJul2024

1. Introduction

Strawberry (Strawberry Fragaria × ananassa Duch.) belongs to the order Rosales belonging to the Rosaceae family and under the family Rosoideae and to the genus Fragaria, which includes multiple species up to 45 species. It is a hybrid between Schleck Virginia and Schleck Shelley (Husaini and Neri 2016). The cultivated Strawberry is A beautiful small perennial herbaceous plant whose flowers are often hermaphrodite and sometimes they are only female. Strawberry fruits are one of the important fruits for their nutritional value and distinct flavour. They are rich in mineral elements such as calcium, silicon, iron, copper, zinc and phosphorus. They contain antioxidants and increase their effectiveness. They also contain a high percentage of vasodilating agents. Mulching is considered a means of mulching the heart and small blood vessels, reduces atherosclerosis, and contains phenolic acids and compounds responsible for antioxidant properties that limit the oxidative cause that causes cancer (Bellamy., 2014, Richardson et al., 2019, Basu, 2021, Ikram et al., 2019). It is one of the important agricultural operations in the development and production of Strawberries because it has many advantages, the most important of which are preserving the quality of the fruits and preventing their rotting, protecting the flowers from frost, preserving soil moisture, stimulating the growth of superficial roots, and reducing the growth of the bush. Black and transparent plastic and straw are used for this purpose (Alwan, 2010). Biofertilizers are a safe alternative to chemical fertilization. Specialists have resorted to these alternative fertilizers to improve plant growth and development. Biofertilizers are fertilizers that encourage microorganisms to establish a symbiotic relationship with plants or enhance plant growth by supplying the plant with nutrients. These fertilizers help increase growth and yield. Reducing the amount of mineral fertilizers to a rate of up to (40-50%) works to preserve the environment, the results of which appear directly on the plant and the soil, as it increases the plant's ability to absorb the nutrients and water present in the soil (Pylak et al., 2019 and Reddy et al., 2020). Among these fertilizers are mycorrhizal fungi, which play an important role in fixing phosphorus, and azotobacter bacteria, which are types of bacteria that fix nitrogen, as well as produce some amino acids, vitamins, and some growth regulators, which are obtained from isolating microorganisms and propagating them in appropriate farms (Sharma et al. (2019). Foliar nutrition plays an important role in Strawberry quality and production (Sturm et al., 2003). Carrying out the spraying process at the appropriate stage improves the qualitative and quantitative traits of Strawberry. Calcium is one of macro elements and has many physiological roles in the growth and development of the plant. It is included in the formation of pectin compounds that bind the cell walls, and it is also involved in the formation of the middle lamella, which leads to increasing the hardness of the fruits. It is also one of the important elements that affects the quality of the fruits and the components of the crop and reduces the phenomenon of cracking of the fruits. Also, increasing the calcium content of the fruits is of great importance. In delaying puberty and maturity in fruits (Al-Mohamed et al., 2023)

2. Materials and Methods

The experiment was conducted in the agricultural field located in the village of Tunis / Al-Mahawil District (30 km) north of Babylon province, in a greenhouse with an area of 450 m2 and dimensions of 9*50 m. To study the effect of mulching type , biofertilizer, and calcium spray on the growth and production of the Rubygem cultivar. The experiment was conducted according to the Complete Randomized Blocks Design (CRBD), in a split plot arrangement, and with three replicates. Each replicate includes two terraces, and each terrace contains 18 experimental units. The number of experimental units in one replicate reached 36 experimental units, with 8 seedlings for each experimental unit, with three factors: The first represents the mulching type with three levels, which are (Mulching Soil planted with black polyethylene, white polyethylene, and straw. (Wheat and barley waste). It is symbolized by (a3, a2, a1) and placed in the main panels. Main plots. The secondary panels include Sub-plots. The second factor is biofertilizers at four levels that were added near the roots by injection method of 10 ml for each plant, which are (the control, Azotobacter bacteria, ycorrhizas fungi, and a mixture of (Mycorrhizas fungi with Azotobacter bacteria as a ground addition and are symbolized by (b0, b3, b2, b1), and the third factor is Spraying calcium M at three concentrations (the first was the control treatment, the second was 2.5 (g. liter-1), and the third was 5 (g. Then it was left to sterilize in sunlight (solarization), after which it was smoothed and leveled. It planned the terraces in the form of agricultural terraces, the height of the terrace (15 cm), with six terraces along the length of the greenhouse, noting that the distance between one terrace and another is (75 cm), and It left a space of (2 m) at the beginning and end of the house without cultivation, then I divided each terrace crosswise into 18 units. Experimental, so that the number of experimental units in one replicate (two terraces containing 36 experimental units), and the area of the experimental unit reached 0.9 m2 (length 2.25 m * width 0.4 m) with a distance of 25 cm between one seedling and another. After that, these terraces were covered with white and black polyethylene covers and straw. (Wheat and barley waste) according to the design of the experiment, and the treatments were then distributed randomly among the experimental units.

Rubygem strawberry seedlings were obtained on 10/31/2022 from Turkey through cooperation with Dabana Company and were placed in the canopy. After the damaged seedlings were sorted and the infected ones were excluded, the seedlings were treated with a systemic fungicide (Asdazim 50wp). The active ingredient is Methyl-benzimidazol. Z – Ylcarbamte to combat the types of fungi that cause crown and leaf rot and root rot. At a concentration of 1 g/L solution, the seedlings were also sprayed with the acaricide Vertimic, the active ingredient is Abamectin20%, to prevent mites. They were then planted the next day inside the greenhouse designated for the experiment, according to the random distribution of the treatments after preparation. Drip irrigation system and Mulching terraces with black and white polyethylene covers and straw. All recommended agricultural operations were conducted , as (100) kg/ha of NPK complex fertilizer (18:18:18) was added to the soil after the first irrigation (11/1/2022) of the seedlings, and weeding and hoeing operations were conducted manually (Abdul, 2013)

Table 1. Some chemical, physical and biological traits of the study soil before cultivation.

units	values	Adjective	
-	7.3	Soil reaction degree (pH) 1:1	
$DS.m^{-1}$	3.48	The degree of electrical conductivity (EC) is 1:1	
cmolc/kg	18.5	Cation exchange capacity (CEC)	
$g.kg^{-1}$ soil	8.99	Organic matter	
$Meq\ L^{-1}$	15.8	Calcium	Dissolved positive ions
	11.81	Magnesium	
	1.76	Potassium	
	5.78	Sodium	
	Nill	Carbonate	Dissolved negative ions
	5.65	Bicarbonate	
	7.26	Sulfates	
	21.9	Chlorine	
$mg.kg^{-1}$ soil	25.17	Nitrogen	available elements
	7.21	Phosphorus	
	174.13	Potassium	
	3.82	Iron	
	0.58	Zinc	
$g.kg^{-1}$ soil	540	Sand	Soil separators
	270	Silt	
	190	Clay	
Sandy Loamy		Textile class	
1.62 $Mg.m^{-3}$		Bulk density	
32 spores/1 g.soil		Mycorrhizal fungus (Glomus mosseae) before adding	
(x10113.6) cells/ml		Azotobacter chroococcum before adding	

Studied traits:

Number of flowers (flower plant-1):The number of flowers for all plants in the experimental unit was calculated from the appearance of the first flower until the end of the flowering season. After that, the rate was found by dividing the total number of flowers by the number of plants.

Average number of opened flowers (flower, plant-1):Readings were taken periodically from the beginning of flowering until its end for the plants of the experimental unit (8 plants), and then the average number of total flowers per plant was calculated as follows:

a. Average number of opened flowers/plant = (total number of opened flowers)/8
b. Average number of set flowers (flower.plant-1):The number of flowers set for the plants of the experimental unit (8 plants) was calculated as follows:

The average number of flowers set per plant = (total number of flowers set)/8

Number of fruits (fruit.plant-1): I calculated the number of fruits for all the fairies and divided by the number of plants in the experimental unit for the purpose of extracting the average number of fruits for the experimental unit.

a. Average fruit weight (g): Calculated according to the following equation:
b. Average fruit weight (g) = (one plant for total fruit weight)/(plant x number of fruits)

3. Results

It is clear in Tables 2 and 3 that the three experimental factors had a positive effect, individually or collectively, on the number of flowers of strawberry plant, where the treatment with mulching with white polyurethane and biofertilization (Azotobacter at a concentration of 10 ml. Plant-1 + Mycorrhizae at a concentration of 10 ml. Plant-1) excelled on the treatment. Calcium spraying at a concentration of 5 (mg l-1) significantly increased the number of flowers in both seasons of the study (2022-2023, 2023-2024), and gave the highest average number of flowers amounting to (36.46 and 37.77) flowers . plant-1 for both seasons according to the order when compared to the treatment. Mulching with straw and comparison with biofertilization and calcium recorded (21.19 and 22.50) flowers. Plant-1 for both seasons according to the order. It is clear from the two tables that the bi-interaction treatment between the mulching type and the biofertilizer, represented by the treatment of the mulching with white polyethylene and biofertilization (Azotobacter at a concentration of 10 ml. Plant-1 + Mycorrhizae at a concentration of 10 ml. Plant-1) had a significant effect on increasing the number of flowers, which amounted to (33.07 and 34.38) flower. Plant - 1 for both seasons, respectively, compared to the treatment of mulching with straw and not adding fertilizer, which recorded (25.41 and 26.72) flowers. Plant-1 for both season.Likewise, with regard to the bi- interaction between the mulching type and calcium concentrations, the treatment of mulching with white polyethylene and spraying calcium at a concentration of 5 (mg L-1) had a positive effect in increasing the number of flowers of strawberry plant for both growing seasons, as it reached (33.18 and 34.49) flowers. Plant-1 for both seasons, respectively, as measured by straw and the control treatment for calcium, which recorded (25.53 and 26.84) flowers. Plant-1 for both season. As for the interaction treatment between biofertilization and calcium spraying, the biofertilization treatment (Azotobacter at a concentration of 10 ml. Plant-1 + Mycorrhizae at a concentration of 10 ml. Plant-1) and calcium at a concentration of 5 (mg L-1) positively affected the increase in The average number of flowers for strawberry plant reached (35.32 and 36.63) flowers. Plant-1 compared to the treatment of no addition and spraying, which recorded (22.96 and 24.27) flowers. Plant-1 for both season.Tables 3 and 4 show the individual effect of the three experimental factors, as the mulching treatment with black polyethylene, the biofertilization treatment (for the mixture of mycorrhizae and azotobacter), and the spraying treatment for calcium at a concentration of (5) g. L-1 individually had a positive effect on increasing the average number of flowers for strawberry plant for both season, respectively, as it reached (30.53 and 31.84), (32.75 and 34.06), and (32.90 and 34.21) flowers. Plant-1, respectively, compared to the treatment of mulching with straw, the treatment without addition of biofertilization, and the control treatment of calcium, individually, which recorded the highest average number of flowers, reaching ((29.52 and 30.83), (26.44 and 27.75), (26.54 and 27.85)) flowers. Plant-1 and for both season.

Table (2) Effect of mulching type, Bio-fertilizer, and calcium sprays and their interactions on the number of flowers (flower, plant-1) for first season 2023-2024.

mulching type × Bio-fertilizer	Calcium concentrations (g L-1)			Bio-fertilizer	mulching type
	5	2.5	0		
27.23	29.74	27.75	24.20	Control	Black polyethylene
30.53	32.60	32.19	26.81	*Azotobacter*	
31.62	34.69	31.76	28.42	*Mycorrhizae*	
32.74	34.35	33.97	29.89	*Azot. + Myco.*	
26.68	29.61	26.94	23.50	Control	White polyethylene
30.22	32.52	31.85	26.30	*Azotobacter*	
31.21	34.15	31.42	28.06	*Mycorrhizae*	
33.07	36.46	33.60	29.16	*Azot. + Myco.*	
25.41	29.52	25.52	21.19	Control	Straw
29.94	33.76	31.67	24.40	*Azotobacter*	
30.29	32.31	30.69	27.86	*Mycorrhizae*	
32.45	35.15	33.50	28.69	*Azot. + Myco.*	
2.784	3.938			L.S.D $_{0.05}$	
mulching effect	mulching type × Calcium concentrations				
30.53	32.84	31.42	27.33	Black polyethylene	
30.30	33.18	30.95	26.75	White polyethylene	
29.52	32.68	30.34	25.53	Straw	
1.473	1.844			L.S.D $_{0.05}$	
Bio-fertilizer effect	Bio-fertilizer × Calcium concentrations				
26.44	29.62	26.74	22.96	Control	
30.23	32.96	31.90	25.84	*Azotobacter*	
31.04	33.72	31.29	28.11	*Mycorrhizae*	
32.75	35.32	33.69	29.25	*Azot. + Myco.*	
1.726		2.347		L.S.D $_{0.05}$	
32.90		30.90	26.54	تأثير Calcium concentrations	
1.026				L.S.D $_{0.05}$	

Table (3) Effect of mulching type, Bio-fertilizer, and calcium sprays and their interactions on the number of flowers (flower, plant-1) for the second season 2023-2024.

mulching type × Bio-fertilizer	Calcium concentrations (g L-1)			Bio-fertilizer	mulching type
	5.00	2.50	0.00		
28.54	31.05	29.06	25.51	Control	Black polyethylene
31.84	33.91	33.50	28.12	*Azotobacter*	
32.93	36.00	33.07	29.73	*Mycorrhizae*	
34.05	35.66	35.28	31.20	*Azot. + Myco.*	
27.99	30.92	28.25	24.81	Control	White polyethylene
31.53	33.83	33.16	27.61	*Azotobacter*	
32.52	35.46	32.73	29.37	*Mycorrhizae*	
34.38	37.77	34.91	30.47	*Azot. + Myco.*	
26.72	30.83	26.83	22.50	Control	Straw
31.25	35.07	32.98	25.71	*Azotobacter*	
31.60	33.62	32.00	29.17	*Mycorrhizae*	
33.76	36.46	34.81	30.00	*Azot. + Myco.*	

2.784	3.938			L.S.D $_{0.05}$
mulching effect	mulching type × Calcium concentrations			
31.84	34.15	32.73	28.64	Black polyethylene
31.61	34.49	32.26	28.06	White polyethylene
30.83	33.99	31.65	26.84	Straw
1.473	1.844			L.S.D $_{0.05}$
Bio-fertilizer effect	Bio-fertilizer × Calcium concentrations			
27.75	30.93	28.05	24.27	Control
31.54	34.27	33.21	27.15	*Azotobacter*
32.35	35.03	32.60	29.42	*Mycorrhizae*
34.06	36.63	35.00	30.56	*Azot.* + *Myco.*
1.726		2.347		L.S.D $_{0.05}$
34.21		32.21	27.85	تأثير Calcium concentrations
1.026				L.S.D $_{0.05}$

4-3-2 Number of opened flowers (flower.plant-1):

It is clear from Tables 4 and 5 that treatment with mulching with black polycarbonate and biofertilization (Azotobacter at a concentration of 10 ml. Plant-1 + Mycorrhizae at a concentration of 10 ml. Plant^{-1}) and spraying with calcium at a concentration of 5 (mg L^{-1}) had a significant effect in increasing the rate of the number of opened flowers. For the two growing seasons (2022 - 2023 and 2023 - 2024), it excelled morally and gave the highest average number of opened flowers, reaching (35.96 and 37.33) flowers. -1 plant for both seasons according to the order when compared to the straw mulching treatment and the control, which had (19.63 and 21.00) flowers. Plant -1 for both seasons according to the ranking for both seasons.

The two tables showed that mulching with black poly had a significant effect on the studied trait, as it increased the average number of opened flowers, reaching (29.80 and 31.17) flowers. Plant - 1 for both seasons according to the order when compared to the straw mulching treatment, which amounted to (28.50 and 29.87) flowers. Plant -1 for both seasons according to arrangement. It was also shown that the bio fertilization treatment (Azotobacter at a concentration of 10 ml + Mycorrhizae at a concentration of 10 ml) had a positive effect on the studied trait and the average number of opened flowers reached (32.13 and 33.50) flowers. Plant-1 for both seasons according to the order, and thus it was significantly superior to the rest of the addition and control treatments for the aforementioned trait, reaching (25.20 and 26.57) flowers. Plant^{-1} for both seasons, according to the order. As for calcium spraying, it showed a positive effect on the studied trait and achieved moral superiority at the concentration of 5 (mg l-1), as the average number of opened flowers reached (32.35 and 33.71) flowers. Plant $^{-1}$ for both seasons according to the order compared to the other spraying treatment and the control, which gave the least number of opened flowers.

It is clear from the two tables that the treatment of bi-interaction between bio fertilization and calcium spraying. bio fertilization treatment (Azotobacter at a concentration of 10 ml. Plant-1 + Mycorrhizae at a concentration of 10 ml. Plant^{-1}) and calcium at a concentration of 5 (mg L^{-1}) affected positively in increasing the rate of the number of flowers of strawberry plant reached (35.18 and 36.55) flowers. Plant^{-1} compared to the treatment of no addition and spraying, which recorded (21.40 and 22.77) flowers. Plant^{-1} for both season.

Likewise, with regard to the bi- interaction between the mulching type and calcium concentrations, the treatment of mulching with black polyethylene and spraying calcium at a concentration of 5 (mg L^{-1}) had a positive effect in increasing the number of opened flowers of strawberry plant for both growing seasons, as it reached (32.95 and 34.32) flowers. Plant^{-1} for both seasons, respectively, as measured by straw mulching and the control treatment for calcium, which recorded (24.58 and 25.95) flowers. Plant-1 for both season. As for the treatment of the bi-interaction between the mulching type and the biofertiliser, represented by the treatment of the mulching with black polyethylene and biofertilization (Azotobacter at a concentration of 10 ml + Mycorrhizae at a concentration of 10 ml) had a significant effect on increasing the number of opened flowers, which amounted to (32.71 and 34.08).) flower. Plant $^{-1}$ for both seasons, respectively, compared to the treatment of mulching with straw and not adding fertilizer, which recorded (23.99 and 25.36) flowers. Plant-1 for both season.

Table (4) The effect of mulching type, Bio-fertilizer, and calcium sprays and their interactions on the number of blooming flowers (flower.plant-1) for first season 2023-2024.

mulching type × Bio-fertilizer	Calcium concentrations (g L-1)			Bio-fertilizer	mulching type
	5	2.5	0		
25.99	29.09	26.25	22.64	Control	Black polyethylene
29.49	31.99	30.84	25.63	*Azotobacter*	
31.02	34.75	30.63	27.69	*Mycorrhizae*	
32.71	35.96	33.73	28.43	*Azot. + Myco.*	
25.62	28.74	26.19	21.94	Control	White polyethylene
29.14	31.63	30.64	25.16	*Azotobacter*	
30.38	33.86	30.05	27.24	*Mycorrhizae*	
32.18	35.29	33.29	27.96	*Azot. + Myco.*	
23.99	28.00	24.34	19.63	Control	Straw
29.17	33.29	30.29	23.94	*Azotobacter*	
29.34	31.26	29.90	26.86	*Mycorrhizae*	
31.51	34.28	32.36	27.90	*Azot. + Myco.*	

2.546	5.328			L.S.D 0.05
mulching effect	mulching type × Calcium concentrations			
29.80	32.95	30.36	26.10	Black polyethylene
29.33	32.38	30.04	25.58	White polyethylene
28.50	31.71	29.22	24.58	Straw
1.989	2.818			L.S.D 0.05
Bio-fertilizer effect	Bio-fertilizer × Calcium concentrations			
25.20	28.61	25.59	21.40	Control
29.27	32.30	30.59	24.91	*Azotobacter*
30.25	33.29	30.19	27.26	*Mycorrhizae*
32.13	35.18	33.13	28.10	*Azot. + Myco.*
1.373		3.035		L.S.D 0.05
32.35		29.88	25.42	تأثير Calcium concentrations
1.689				L.S.D 0.05

Table (5) The effect of mulching type, Bio-fertilizer, and calcium sprays and their interactions on the number of blooming flowers (flower.plant-1) for the second season 2023-2024.

mulching type × Bio-fertilizer	Calcium concentrations (g L-1)			Bio-fertilizer	mulching type
	5.00	2.50	0.00		
27.36	30.46	27.62	24.01	Control	Black polyethylene
30.86	33.36	32.21	27.00	*Azotobacter*	
32.39	36.12	32.00	29.06	*Mycorrhizae*	
34.08	37.33	35.10	29.80	*Azot. + Myco.*	
26.99	30.11	27.56	23.31	Control	White polyethylene
30.51	33.00	32.01	26.53	*Azotobacter*	
31.75	35.23	31.42	28.61	*Mycorrhizae*	
33.55	36.66	34.66	29.33	*Azot. + Myco.*	
25.36	29.37	25.71	21.00	Control	Straw
30.54	34.66	31.66	25.31	*Azotobacter*	
30.71	32.63	31.27	28.23	*Mycorrhizae*	
32.88	35.65	33.73	29.27	*Azot. + Myco.*	
2.546	5.328			L.S.D 0.05	
mulching effect	mulching type × Calcium concentrations				
31.17	34.32	31.73	27.47	Black polyethylene	
30.70	33.75	31.41	26.94	White polyethylene	
29.87	33.08	30.59	25.95	Straw	
1.989	2.818			L.S.D 0.05	
Bio-fertilizer effect	Bio-fertilizer × Calcium concentrations				
26.57	29.98	26.96	22.77	Control	
30.64	33.67	31.96	26.28	*Azotobacter*	
31.62	34.66	31.56	28.63	*Mycorrhizae*	
33.50	36.55	34.50	29.47	*Azot. + Myco.*	
1.373		3.035		L.S.D 0.05	
33.71		31.25	26.79	تأثير Calcium concentrations	
1.689				L.S.D 0.05	

4-3-3 Number of set flowers (flower.plant-1):

Tables 6 and 7 show the individual positive effect of the three experimental factors, where the mulching treatment with black polyethylene, the biofertilization treatment (for the mixture of mycorrhiza and azotobacter), and the calcium spraying treatment at a concentration of (5) g. L-1 individually had a positive impact on increasing the rate of the number of holding flowers for strawberry plant for both season (2022-2023, 2023-2024), which achieved the highest rate of the number of holding flowers reaching ((28.70 and 29.99), (31.17 and 32.46). (31.54 and 32.83)) Flower. Plant-1, respectively, compared to the straw mulching treatment, the treatment without addition of biofertilization, and the comparison treatment for calcium, individually, which recorded ((27.51 and 28.80), (24.27 and 25.56), (24.25 and 25.54)) flower. Plant-1 and for both season.

It is also clear from the two tables that the bi-interaction treatment between the type of mulching and the biofertilizer, represented by the mulching treatment with black polyethylene and biofertilization (Azotobacter at a concentration of 10 ml + Mycorrhizae at a concentration of 10 ml) had a positive effect on increasing the number of set flowers, which amounted to (32.13 and 33.42) flowers. Plant-1 for both seasons, respectively, compared to the treatment of mulching with straw and not adding fertilizer, which recorded the lowest rate of set flowers, amounting to (23.50 and 24.79) flowers. Plant-1 for both season, and also with regard to the bi- interaction between the mulching type and calcium concentrations, the treatment of mulching with black polyethylene and spraying calcium at a concentration of 5 (mg L-1) had a positive effect in increasing the number of set flowers of strawberry plant for both growing seasons, as it reached (32.02 and 33). .31) Flower. Plant-1 for both seasons, respectively, as measured by straw mulching and the control treatment for calcium, which recorded (23.46 and 24.75) flowers. Plant-1 for both season. As for the interaction treatment between biofertilization and calcium spraying, the biofertilization treatment (Azotobacter at a concentration of 10 ml. Plant-1 + Mycorrhizae at a concentration of 10 ml. Plant-1) and calcium at a concentration of 5 (mg L-1) positively affected the increase in The average number of set flowers of strawberry plant reached (34.70 and 35.99) flowers. Plant-1 compared to the treatment of no addition and spraying, which recorded (20.71 and 22.00) flowers. Plant-1 for both season.

The triple interaction treatment, represented by mulching with black polycarbonate, biofertilization (Azotobacter at a concentration of 10 ml. plant-1 + Mycorrhizae at a concentration of 10 ml. plant-1), and calcium spraying at a concentration of 5 (mg l-1) significantly increased the number of set flowers in both seasons of the study and gave the highest The average number of knotted flowers reached (35.64 and 36.93) flowers. Plant-1 for both seasons according to the order when compared to the treatment of mulching with straw and the control treatment of biofertilization and calcium, which recorded (19.38 and 20.67) flowers. Plant-1 for both seasons according to the order.

Table (6) The effect of mulching type, Bio-fertilizer, and calcium sprays and their interactions on the number of clustered flowers (flower.plant-1) for first season 2023-2024.

mulching type × Bio-fertilizer	Calcium concentrations (g L-1)			Bio-fertilizer	mulching type
	5	2.5	0		
24.82	28.04	24.71	21.71	Control	Black polyethylene
28.37	31.04	27.71	24.37	*Azotobacter*	
29.49	33.37	29.37	25.72	*Mycorrhizae*	
32.13	35.64	33.04	27.71	*Azot.* + *Myco.*	
24.49	27.73	24.71	21.04	Control	White polyethylene
28.92	33.34	29.71	23.72	*Azotobacter*	
28.06	30.37	28.11	25.71	*Mycorrhizae*	
31.11	34.74	31.38	27.21	*Azot.* + *Myco.*	
23.50	27.41	23.71	19.38	Control	Straw
28.48	33.02	29.04	23.37	*Azotobacter*	
27.82	30.04	28.04	25.37	*Mycorrhizae*	
30.27	33.72	31.37	25.71	*Azot.* + *Myco.*	
2.685	4.236			L.S.D $_{0.05}$	
mulching effect	mulching type × Calcium concentrations				
28.70	32.02	29.21	24.88	Black polyethylene	

28.15	31.54	28.48	24.42	White polyethylene
27.51	31.05	28.04	23.46	Straw
2.075	2.367			L.S.D 0.05
Bio-fertilizer effect	Bio-fertilizer × Calcium concentrations			
24.27	27.73	24.38	20.71	Control
28.59	32.47	29.49	23.82	*Azotobacter*
28.46	31.26	28.51	25.60	*Mycorrhizae*
31.17	34.70	31.93	26.88	*Azot*. + *Myco*.
1.459		2.391		L.S.D 0.05
31.54		28.58	24.25	تأثير Calcium concentrations
1.201				L.S.D 0.05

Table (7) The effect of mulching type, Bio-fertilizer, and calcium sprays and their interactions on the number of clustered flowers (flower.plant-1) for the second season 2023-2024.

mulching type × Bio-fertilizer	Calcium concentrations (g L-1)			Bio-fertilizer	mulching type
	5.00	2.50	0.00		
26.11	29.33	26.00	23.00	Control	Black polyethylene
29.66	32.33	31.00	25.66	*Azotobacter*	
30.78	34.66	30.66	27.01	*Mycorrhizae*	
33.42	36.93	34.33	29.00	*Azot*. + *Myco*.	
25.78	29.02	26.00	22.33	Control	White polyethylene
30.21	34.63	31.00	25.01	*Azotobacter*	
29.35	31.66	29.40	27.00	*Mycorrhizae*	
32.40	36.03	32.67	28.50	*Azot*. + *Myco*.	
24.79	28.70	25.00	20.67	Control	Straw
29.77	34.31	30.33	24.66	*Azotobacter*	
29.11	31.33	29.33	26.66	*Mycorrhizae*	
31.56	35.01	32.66	27.00	*Azot*. + *Myco*.	
2.685	4.236			L.S.D 0.05	
mulching effect	mulching type × Calcium concentrations				
29.99	33.31	30.50	26.17	Black polyethylene	
29.44	32.83	29.77	25.71	White polyethylene	
28.80	32.34	29.33	24.75	Straw	
2.075	2.367			L.S.D 0.05	
Bio-fertilizer effect	Bio-fertilizer × Calcium concentrations				
25.56	29.02	25.67	22.00	Control	
29.88	33.76	30.78	25.11	*Azotobacter*	
29.75	32.55	29.80	26.89	*Mycorrhizae*	
32.46	35.99	33.22	28.17	*Azot*. + *Myco*.	
1.459		2.391		L.S.D 0.05	
32.83		29.87	25.54	تأثير Calcium concentrations	
1.201				L.S.D 0.05	

4-3-4 Number of fruits (fruit.plant -1):

It is clear from Tables 8 and 9 that the triple interaction treatment, represented by mulching with white polyurethane, biofertilization (Azotobacter at a concentration of 10 ml + Mycorrhizae at a concentration of 10 ml), and spraying calcium at a concentration of 5 (mg L-1) led to an increase in the average number of fruits for the two growing seasons (2022 - 2023 and 2023 - 2024).), as it excelled morally and gave the highest average number of fruits, reaching (34.82 and 36.00) fruits. Plant - 1 for both seasons according to the order when compared to the straw mulching treatment and the control, which were (18.82 and 20.00) fruits. Plant-1 for both seasons according to the order for both seasons.

It is also clear from the two tables that the bi-interaction treatment between the mulching type and the biofertilizer, represented by the treatment of mulching with black polyethylene and biofertilization (Azotobacter at a concentration of 10 ml + Mycorrhizae at a concentration of 10 ml) had a positive impact on increasing the average number of fruits, which amounted to (30.60 and 31.78) fruits. Plant-1 for both seasons, respectively, compared to the treatment of mulching with straw and not adding fertilizer, which recorded the lowest average number of fruits (22.67 and 23.85). Plant-1 for both season.

Likewise, with regard to the bi- interaction between the mulching type and calcium concentrations, the treatment of mulching with white polyethylene and spraying calcium at a concentration of 5 (mg L-1) had a positive effect in increasing the number of fruits of strawberry plant for both growing seasons, as it reached (31.02 and 32.19) fruits. Plant-1 for both seasons, respectively, as measured by straw mulching and the control treatment for calcium, which recorded (22.55 and 23.73) fruits. Plant-1 for both season,

As for the biofertilization treatment and calcium spraying, the biofertilization treatment (Azotobacter at a concentration of 10 ml + Mycorrhizae at a concentration of 10 ml) and calcium at a concentration of 5 (mg L-1) had a positive effect on increasing the average number of fruits and it reached (33.84 and 35.02) fruits. Plant-1 compared to the treatment of no addition and spraying, which recorded the lowest number of fruits for both season.

Tables 44 and 45 show the individual effect of the three experimental factors, as the mulching treatment with black polyethylene, the biofertilization treatment (for the mixture of mycorrhiza and azotobacter), and the spraying treatment for calcium at a concentration of (5) g. L-1 individually had a positive effect on increasing the average number of fruits for strawberry plant for both season, respectively, as it reached (27.65 and 28.83), (30.07 and 31.25), (30.58 and 31.75)) fruits. Plant-1, respectively, compared to the straw mulching treatment, the treatment without addition of biofertilization, and the comparison treatment for calcium, individually, which recorded the lowest average number of fruits, which reached ((26.47 and 27.65), (23.35 and 24.53), (23.31 and 24.49)) fruits. Plant-1 and for both season.

Table (8) The effect of mulching type, Bio-fertilizer, and calcium sprays and their interactions on the number of fruits (fruit.plant-1) for first season 2023-2024.

mulching type × Bio-fertilizer	Calcium concentrations (g L-1)			Bio-fertilizer	mulching type
	5	2.5	0		
23.88	26.82	23.99	20.82	Control	Black polyethylene
27.67	30.5	29.13	23.82	*Azotobacter*	
28.45	32.49	28.03	24.82	*Mycorrhizae*	
30.60	33.87	31.48	26.45	*Azot. + Myco.*	
23.52	26.82	23.90	19.83	Control	White polyethylene
28.02	32.42	28.60	23.05	*Azotobacter*	
27.55	30.00	27.82	24.82	*Mycorrhizae*	
30.32	34.82	30.27	25.88	*Azot. + Myco.*	
22.67	26.15	23.04	18.82	Control	Straw
26.85	30.82	24.92	21.82	*Azotobacter*	
27.09	29.82	26.82	24.62	*Mycorrhizae*	
29.27	32.82	30.07	24.93	*Azot. + Myco.*	
3.497	4.770			L.S.D 0.05	
mulching effect	mulching type × Calcium concentrations				
27.65	30.81	28.16	23.98	Black polyethylene	
27.35	31.02	27.65	23.40	White polyethylene	
26.47	29.90	26.96	22.55	Straw	

3.367	3.381			L.S.D 0.05
Bio-fertilizer effect	Bio-fertilizer × Calcium concentrations			
23.35	26.60	23.64	19.82	Control
27.51	31.10	28.55	22.90	*Azotobacter*
27.69	30.77	27.56	24.75	*Mycorrhizae*
30.07	33.84	30.61	25.75	*Azot.* + *Myco.*
1.409		2.426		L.S.D 0.05
30.58		27.59	23.31	تأثير Calcium concentrations
1.247				L.S.D 0.05

Table (9) The effect of mulching type, Bio-fertilizer, and calcium sprays and their interactions on the number of fruits (fruit.plant-1) for the second season 2023-2024.

mulching type × Bio-fertilizer	Calcium concentrations (g L-1)			Bio-fertilizer	mulching type
	5.00	2.50	0.00		
25.06	28.00	25.17	22.00	Control	Black polyethylene
28.85	31.23	30.31	25.00	*Azotobacter*	
29.63	33.67	29.21	26.00	*Mycorrhizae*	
31.78	35.05	32.66	27.63	*Azot.* + *Myco.*	
24.70	28.00	25.08	21.01	Control	White polyethylene
29.20	33.60	29.78	24.23	*Azotobacter*	
28.73	31.18	29.00	26.00	*Mycorrhizae*	
31.50	36.00	31.45	27.06	*Azot.* + *Myco.*	
23.85	27.33	24.22	20.00	Control	Straw
28.03	32.00	29.10	23.00	*Azotobacter*	
28.27	31.00	28.00	25.80	*Mycorrhizae*	
30.45	34.25	31.25	26.11	*Azot.* + *Myco.*	
3.497	4.770			L.S.D 0.05	
mulching effect	mulching type × Calcium concentrations				
28.83	31.99	29.34	25.16	Black polyethylene	
28.53	32.19	28.83	24.57	White polyethylene	
27.65	31.08	28.14	23.73	Straw	
3.367	3.381			L.S.D 0.05	
Bio-fertilizer effect	Bio-fertilizer × Calcium concentrations				
24.53	27.78	24.82	21.00	Control	
28.69	32.28	29.73	24.08	*Azotobacter*	
28.87	31.95	28.74	25.93	*Mycorrhizae*	
31.25	35.02	31.79	26.93	*Azot.* + *Myco.*	
1.409		2.426		L.S.D 0.05	
31.75		28.77	24.49	تأثير Calcium concentrations	
1.247				L.S.D 0.05	

The results of the tables mentioned above, which included floral and quantitative measurements of the yield of strawberry plant, showed that the fertilizer combination (mulching with black and white plastic with biofertilizer and spraying with calcium) at high levels compared to the levels of other fertilizer combinations showed superiority in the above traits.

The reason may be due to the fact that mulching with plastic and used fertilizers increased the number of leaves, crowns, and leaf area, as well as an increase in the leaves' content of chlorophyll and nutrients, which led to an increase in plant activity, especially the photosynthesis process, and then an increase in the formation of flowers and an increase in their number, followed later by an increase in fruit set. Increasing the injection of synthetic materials from the leaves to the set fruits, which increases the size of the fruits and increases their weight, thus increasing the yield of one plant and thus increasing the productivity of one house. This is consistent with (Macit et al., 2007), meaning that improving vegetative growth reflects positively on the number of flowers and fruits. Due to the readiness and availability of necessary elements within the surroundings of the roots (Ebrahimi et al. 2012).

Regarding the increase in the number of flowers in the plant, showed when covered with polyethylene, as the transparent polyethylene gave the largest number of flowers. The reason for this increase is attributed to the physiological role of mulching with transparent polyethylene, as it led to an improvement in the nutritional conditions of the plant through the penetration of sunlight into the soil, an increase in its temperature, carbon dioxide gas, an increase in the activity of microorganisms, and the provision of water and nutrients, which leads to an increase in the effectiveness of the photosynthesis process in The plant, which results in strong vegetative growth, reflects positively on early flowering, increasing the number of flowers, raising the rate of their setting, and flower growth and opening (Al-Masoum, 1991 and Wien et al., 1993) Polycarbonate covers also work In general, it is recommended to reduce the contact of flowers and fruits with the soil and irrigation water, which reduces the possibility of them falling (Hankin et al., 1982), and this is consistent with what (Abdul, 2014) reached in her study on strawberry plant. Also, the treatment of mulching with black and white polyethylene and organic waste (straw) gave a significant increase in the traits of fruit growth (the number of fruits, their weight and size) and the yield of a single and total plant, as the reason for this increase is due to the mulching The soil increased the absorption of elements and their assimilation by the plant, thus increasing the efficiency of the shoot and root system. It contributed to good fruit growth and helped increase the nutrients manufactured as a result of the photosynthesis process, thus producing large fruits. The increase in the weight of the fruits is due to the fact that this treatment created a number of Few fruits, which increased their share of nutrients manufactured in the plant, which led to the formation of large fruits at the expense of the formation of a large number of fruits, and the increase in the weight and number of fruits was reflected in an increase in the yield per plant and total, is in line with the result obtained (Kirnak et al. , 2001),

On the other hand, the reason may be attributed to the increase in production components (weight, number, size) to the increased growth of the leaves of strawberry plant and the nutritional content shown in which increased the number of buds in Their axils, and a large portion of these buds may turn into flower buds, which leads to an increase in the number of fruits (Darrow, 1966). The more the plant has strong vegetative growth, the more flowers it produces, and the more fruits it produces compared to plants with small vegetative growth. The reason for the increase in the size of the fruits may be due to the increase in materials manufactured in the process of photosynthesis, which contributed to the formation of a larger number of fruits and an increase in the average weight of the fruit, and then an increase in the yield per plant and total as a result of the transfer of photosynthesis products from the source area, the leaves, to the reservoir, which is the fruits (sink to source (Mengel and Kirkby, 2001) Also, increasing vegetative growth leads to an increase in vital processes within the plant and an increase in metabolic materials, including an increase in plant hormones, encouraging the synthesis of sugars, and an increase in the rate of transpiration with an increase in the temperature rate in the fourth and fifth months of harvest, which accelerates the movement of materials from the source (leaves) to the fruit reservoir (Watson et al., 2002) in strawberry plant. This is consistent with Hasanein and others (2011) in their evaluation study on strawberry plant and with what they have achieved (Khalil, 2016) and (Tuffah, 2019) in their study on strawberry plant.

The superiority of the combination of the mixed vaccine (mycorrhizal fungi and azotobacter bacteria), spraying with calcium fertilizer at a concentration of (5g.l-1), and mulching with black plastic in terms of flowering and productivity indicators of the yield can also be attributed to the positive interaction between the mycorrhizal fungus and azotobacter bacteria and the effect of calcium fertilizer on metabolic activities. These activities may have increased due to the effect of the mycorrhizal fungus on plant growth, resulting from its secretion of many compounds that work to increase root and vegetative growth, which in turn is reflected in the plant's yield and quality. These compounds include siderophores, IAA, cytokinin, and GA3, as well as the ACC-deaminase enzyme. Which is produced by bacteria and mycorrhizae. These compounds are transferred to plant tissues through the symbiotic relationship between the mycorrhizae and the plant (Al-Samarrai and Al-Tamimi, 2018), in addition to what the azotobacter bacteria do to fix nitrogen and the phosphorus and micronutrients that these mycorrhizas prepare for the mycorrhizae. It reaches the plant as well as its absorption by the roots, which increases the plant's biomass, which is also reflected in good root growth. It increases the process of absorption of water and nutrients, which increases the rate of the carbon synthesis process and increases the products of this process that are transferred in the presence of potassium from the manufacturing areas (leaves) to The rest of the plant (Havlin et al., 2005). Good vegetative growth, as shown by the results of the above-mentioned vegetative growth tables, results in obtaining the best traits of floral growth, represented by the number of flowers and the percentage of flowers that are set and open which increases the number of fruits in the plant The increase in carbon building products and their transfer from manufacturing places (source) to storage places (downstream), which are fruits, led to an increase in the weight of the fruit which was subsequently reflected in an increase in the yield per plant and the total yield as in These results are consistent with the findings of (Janmohammadi et al., (2016), (Wahab et al., (2016), (Ibrahim et al., (2015) and Doifode) and Nandkar, (2014).

As for the effect of calcium on the significant increase in the floral and quantitative traits of the yield, the results obtained from this study can be explained by the direct or indirect effect of the calcium element on growth in general and on production in particular, as the calcium element participates in the process of transporting carbohydrates from their places of production in It also works to increase the efficiency of the plant in assimilation of CO_2 gas, and thus leads to an improvement in vegetative traits and yield (Abu Dahi and Al-Younis, 1988). Also, the concentration of calcium at its optimum limits has a direct effect on plant growth and raising the set rate, which increases From the number of fruits, their size and weight, and this in turn reflects positively on the yield of a single plant and the total yield (Dechem et al., 1973), because an increase in calcium beyond the optimum level causes the activation of oxalates, which reduces the synthesis and transport of carbohydrates, and may affect the absorption of other elements, especially magnesium (Hall, 1977) It is also clear from the above-mentioned results that treatment with calcium has led to an increase in the amount of yield. This increase may be attributed to the activity of some enzymes as a result of treatment with calcium, which led to an increase in cell division, an increase in the number of flowers and the percentage of knots, and then an increase in the plant's yield and the total yield (CIRULLI). and Cicarese, 1981) and (Liang et al. 2008) These results were consistent with the findings of (Rozbiany and Tah, 2020) in their study on two varieties of strawberry plant (Festival and Albion) and (Salama and Abou- Zaid, 2023) in their experiment on olive trees of the "Kalamata" variety. This is consistent with and explains the superiority of the flowering, fruiting, and quantitative indicators of the fruits when strawberry plants were treated with the fertilizer combination (mulching with black plastic with biofertilizer and calcium) at their highest levels.

Conclusion

The study highlights that the combination of mulching with black polyethylene, biofertilization using Mycorrhiza and Azotobacter, and calcium spraying at 5 g/L significantly enhances the growth and fruit yield of the Rubygem strawberry cultivar. The findings reveal that this integrated treatment yields the highest values across multiple growth parameters, including the number of flowers, fruit set, and fruit weight, suggesting a synergistic effect of these treatments. The implications of this research are substantial for agricultural practices, indicating that using these combined treatments can improve strawberry production efficiency. Future research should focus on exploring the long-term effects of these treatments on soil health and their applicability to other strawberry cultivars and different agricultural environments to confirm the generalizability of these results.

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