RESPONSE OF STRAWBERRY GROWTH, YIELD AND MARKETABLE FRUIT QUALITY TO SPRAYING WITH MORINGA LEAF EXTRACT, CALCIUM AND POTASSIUM SILICATE

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ABSTRACT

Tow field and storage experiments were carried out to evaluate the effect of foliar application of moringa leaf extract, calcium, and potassium silicate on the growth, yield, and quality characteristics of strawberry fruits. The field experiment included 27 treatments: Foliar application of moringa leaf extract at the concentrations of 0, 5, and 10% which were symbolized as M_0, M_1, and M_2 respectively, calcium at the concentrations of 0, 1, and 2 g. L^{-1}, which were symbolized as Ca_0, Ca_1, and Ca_2 respectively, and potassium silicate at the concentrations of 0, 1.25, and 2.50 ml. L^{-1} which were symbolized as S_0, S_1, and S_2 respectively, with three replicates. The storage experiment was carried out according to the same design that was applied in the first experiment, at a temperature of 0-2 ºC. The results revealed that the M_2 treatment significantly increased Plant height, leaf number, crown diameter, flowering cluster number, plant yield, Fruit T.S.S, Vitamin C, as well as maintaining the T.S.S and Vitamin C after storage, and reduced the fruits distortion. The treatment of Ca_1 recorded a significant increment in the growth and yield parameters and reduced fruit distortion, Also the treatment of S_2 recorded significant values of the above-mentioned parameters, Moreover, the interactions of M_2Ca_1, M_2S_2, and Ca_1S_2 and the triple interaction of $M_2Ca_1S_2$ recorded the highest values of the studied parameters.

Keywords: ***Fragaria* X *ananassa* Duch., foliar application, post-harvest, storage, temperature.**

***Part of Ph.D. dissertation of the 1st author.**

مجلة العلوم الزراعية العراقية- 2024:55(1):440-452 **محمد ومجيد**

استجابة نمو وانتاجية الشليك وصفات جودة ثماره التسويقية للرش بمستخلص المورينغا الورقي والكالسيوم وسيليكات البوتاسيوم

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المستخلص

نُفذت تجربتين تجربة حقلية وتجربة حفظ للثمار لمعرفة استجابة نمو وانتاجية نبات الشليك وزيادة القابلية التسويقية للثمار وذلك بالرش بمستخلص المورينغا الورقي والكالسيوم وسيليكات البوتاسيوم، نفذت التجربة الحقلية وفق تصميم القطاعات العشوائية الكاملة وبثلاثة مكررات وتضمنت 27 معاملة تجريبية ناتجة من الرش الورقي بمستخلص المورينغا الورقي وبالتراكيز 0- 5- 10 % ورمز لها M_0 - M_1 - M_2 بالتتابع والكالسيوم وبالتراكيز 0 -1- 2غم. لتر$^{-1}$ ورمز لها Ca_0 Ca_1- Ca_2 بالتتابع وسيليكات البوتاسيوم وبالتراكيز 0- 1.25-2.50 مل. لتر$^{-1}$ ورمز لها S_0- S_1- S_2 بالتتابع، أما تجربة حفظ الثمار فنفذت بذات التصميم المستعمل في التجربة اعلاه وبدرجة حرارة 0-2 ºم، بينت النتائج تفوق المعاملة M_2 معنويا بزيادة ارتفاع النبات وعدد الاوراق وقطر التاج وعدد العناقيد الزهرية وحاصل النبات الواحد وقللت من نسبة الثمار المشوهة وادت الى زيادة النسبة المئوية للمواد الصلبة الذائبة الكلية T.S.S وفيتامين C في الثمار فضلا عن المحافظة علىT.S.S وفيتامينC بعد الحفظ، وأعطت المعاملةCa_1 زيادة في مؤشرات النمو والحاصل المذكورة اعلاه وقللت من نسبة الثمار المشوهة، كما تفوقت المعاملة S_2 في المؤشرات اعلاه، وبينت التداخلات تأثيراتها المعنوية في المؤشرات المدروسة أذ أعطى التداخل الثنائي M_2Ca_1 وM_2S_2 وCa_1S_2 والثلاثي عند $M_2Ca_1S_2$ أعلى المعدلات مقارنة مع معاملات المقارنة.

الكلمات المفتاحية: *Fragaria* X *ananassa* Duch.، الرش الورقي، بعد الحصاد ، حفظ الثمار، درجة الحرارة .

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INTRODUCTION

Fragaria X *ananassa* Duch. belongs to Rosaceae family and is considered of economic importance, widely cultivated around the world (35). Strawberry is among the plants that require high nutrient requirements, as it produces an abundant yield of fruits in proportion to the fruit size. Additionally, the plant is susceptible to diseases and insect infections, and its fruits are non-climacteric, but quickly perishable and have a short shelf life due to the high rate of respiration and high-water content (9, 21), Moringa leaf extract is Among the natural plant growth stimulators which is rich in essential nutrients, vitamins, amino acids, and plant growth hormones (14, 24), which contributes to providing the nutrients and natural growth regulators required for the plant, reflecting on the yield quantity and quality. Bakhsh et al. (8) noted that the foliar application of Moringa leaf extract in four concentrations (0, 2, 4, and 6%) on peach trees; the concentration of 2% had increased plant yield, T.S.S, and vitamin C in the fruits. Ismail and Ganzour (15) recorded that the foliar application of Moringa leaf extract (0, 2, 4, and 6%) on the strawberry plant has significantly increased plant height, leaf number, crown diameter, plant yield, vitamin C, and the fruit T.S.S. percentage Calcium and silicon are considered important nutrients for plants, due to their role in improving fruit quantity and quality, Calcium increases photosynthesis activity, and the transport and absorption of nitrates in the plant (34). It also reduces the rate of respiration and ethylene production during fruit storage and reduces the permeability of cell membranes (11). Mazahir et, al. (18) mentioned that the pre-harvesting application of calcium improves fruit quality and extends shelf life. Sidhu et al. (28) found that calcium nitrate foliar application at the concentrations of 0.2, 0.4, 0.6 and 0.8% on the growth of licorice plant; concentration of 0.4% recorded the highest leaf number and crown diameter. Sidhu et al. (29) also recorded an increment in plant yield, T.S.S percent, and vitamin C by the foliar application of 0.4% concentration of calcium nitrate. Silicon also plays an important role in regulating sugar metabolism (13) and contributes to the regulation and transportation of nutrients across cell membranes and improving the properties of cell walls (27), which reflects on plant's growth and yield. Nada (19) recorded an increase in plant height, leaf number, T.S.S, and vitamin C by the foliar application of four concentrations of potassium silicate (0.2, 0.4, 0.6 g. L^{-1}) on strawberry, as the concentration of 0.6 g. L^{-1} recorded the highest rates of the above-mentioned parameters. All given above; this study was aimed to improve the floral and vegetative growth of strawberry plant, which is reflected on the quantity, quality, and marketability of the fruits.

MATERIALS AND METHODS

Field experiment: The strawberry plants var. Festival were planted in a greenhouse according to the R.C.B.D design, with three replicates, three factors, and three concentrations for each factor were used, which were Moringa leaf extract M_0, M_1, M_2 for the concentrations 0, 5, and 10% respectively (26). The second factor was the granulated calcium (Disper Ca synergy) which symbolized as Ca_0, Ca_1, Ca_2 for the concentrations 0, 1, and 2 g. L^{-1} respectively, and potassium silicate in the concentrations of 0, 1.25, and 2.50 ml. L^{-1} which were symbolized as S_0, S_1, S_2 respectively. Foliar application was applied 6 times after two weeks post- planting.

Storage experiment: This experiment was carried out according to the R.C.B.D design; approximately 250 g of homogeneous fruits were taken from each treatment and the T.S.S percent and Vitamin C of the samples was recorded, Fruits were then placed in perforated plastic containers, then stored at a temperature of 0-2 ºC, and after 7 days of storage, The T.S.S and Vitamin C content were calculated.

Field experiment parameters

Plant height (cm): estimated at the end of the growth season by a measuring tape, from the surface of the soil to the top of the plant.

Leaf number (leaf. Plant^{-1})

The leaf number on the stem and side branches was calculated at the end of the growth season.

Crown diameter (mm) measured at the end of the growth season by aVernier.

The number of flower clusters (Clusters .Plant^{-1}).: Plant Yield (g) calculated by dividing the cumulative yield of plants by the plants number of each experimental unit.

distorted fruits percent (%) estimated according to the following equation:

distorted fruit ratio = (distorted fruits number) / (total fruits number) * 100

Storage experiment parameters

T.S.S Percent estimated using a Hand Refractometer

Vitamin C (mg. 100 g^{-1} fresh weight) estimated according to Abbas and Abbas (1).

RESULTS AND DISCUSSION

Field experiment results

Plant height (cm): Results in Table (1) reveal that the moringa leaf extract foliar application at the treatment of M_2 recorded a significant increment in plant height reaching 20.70 cm, in comparison with M_0 that recorded the lowest value reaching 18.20 cm. Also, The calcium foliar application at the treatment of Ca_1 was significantly increased, the studied parameter reaching 20.31 cm, compared to Ca_0, which recorded 18.91 cm. And the potassium silicate foliar application also recorded a significant increase in plant height at the treatment of S_2 which reaching 20.02 cm compared to S_0 that recorded 18.83 cm. The dual interaction between the study factors also affected the above-mentioned parameter; as the treatment of M_2Ca_1 recording the highest value reaching 20.83 cm compared with M_0Ca_0 that recorded 18.39 cm. The interaction treatment of M_2S_2 recorded the highest plant height reaching 22.00 cm compared to M_0S_0 which recorded 17.56 cm. The interaction treatment of Ca_1S_2 gave the highest plant height, which reached 20.94 cm, compared to Ca_0S_0, which recorded 18.33 cm. The effect of the triple interaction between the studied factors has recorded the most significant plant height value at the treatment of $M_2Ca_1S_2$ reaching 22.33 cm, compared to $M_0Ca_0S_0$, which recorded the lowest value reaching 15.67 cm.

Leaf number (leaf. $Plant^{-1}$)

Results in Table (2) reveal that the leaf number was significantly increased by the moringa leaf extract foliar application, as the M_2 treatment recorded the highest value reaching 29.43 leaf. $Plant^{-1}$ compared with M_0, which amounted to 25.24 leaf. $Plant^{-1}$. Also, the calcium foliar application at the treatment of Ca_1 has significantly increased the studied parameter, reaching 28.98 leaf. $Plant^{-1}$ compared with Ca_0 which was 25.37 leaf. $Plant^{-1}$. Also, the potassium silicate foliar application at the treatment of S_2 significantly increased the leaf number, which reaching 29.74 leaf. $Plant^{-1}$ compared with S_0 which was recorded 26.61 leaf. $Plant^{-1}$, while the lowest value recorded at the treatment S_1 reaching 26.37 leaf. $Plant^{-1}$. The dual interaction between moringa and calcium at the treatment of M_2Ca_1 has recorded the highest value peaked at 31.61 leaf. $Plant^{-1}$, which significantly differs from the treatment of M_0Ca_0, that recorded 24.56 leaf. $Plant^{-1}$. Also, the interaction treatment of M_2S_2 gave the highest value of the studied parameter reaching 32.50 leaf. $Plant^{-1}$ compared to M_0S_0 which recorded 24.44 leaf. $Plant^{-1}$. Also, the interaction treatment of Ca_1S_2 recorded the highest value reaching 31.00 leaf.$Plant^{-1}$ compared to the treatment of Ca_0S_0, which recorded 24.67 leaf. $Plant^{-1}$. The triple interaction between the studied factors has recorded the most significant increment of the studied parameter at the treatment of $M_2Ca_1S_2$ reaching 37.67 leaf. $Plant^{-1}$ compared with $M_0Ca_0S_0$ which recorded the lowest value reaching 18.67 leaf. $Plant^{-1}$.

Crown diameter (mm**)**

Results in Table (3) show a significant increment in the crown diameter of strawberry under the moringa leaf extract foliar application at the treatment of M_2 reaching 25.07 mm, in comparison with the control treatment, which recorded the lowest value reaching 23.59 mm. Also, the calcium foliar application at the treatment of Ca_1 has significantly increased the studied parameter, which recorded the highest value reaching 25.11mm compared to Ca_0, which recorded the lowest value reaching 23.35 mm. And the potassium silicate foliar application also has a significant increment at the treatment of S_2, reaching 25.56 mm compared to S_0, which recorded 23.94 mm, while the lowest value recorded at the treatment S_1 reaching 22.94 mm . Results also revealed that the dual interaction between the applied factors at the treatment of M_2Ca_1 recorded the highest rate of crown diameter, reaching 27.06 mm, compared to the treatment of M_0Ca_0, which recorded the lowest value reaching 22.50 mm.

Also, the treatment of M_2S_2 recorded the highest value reaching 26.06 mm compared to M_0S_0 which recorded 22.92 mm. Moreover, the treatment of Ca_1S_2 recorded the highest crown diameter, which reaching 26.22 mm, compared to Ca_0S_0, which recorded 21.94 mm. The results also revealed that the triple interaction of the treatment $M_2Ca_1S_2$ recorded the highest rate of crown diameter reaching 27.33 mm compared with $M_0Ca_0S_0$ which recorded 20.33 mm.

Table 1. Effect of foliar application Moringa leaf extract, calcium and potassium silicate and the interaction between them on Plant height (cm) of strawberry

M%	Ca g. L^{-1}	S ml. L^{-1} S_0-0	S_1-1.25	S_2-2.50	M*Ca
	Ca_0-0	15.67	17.33	22.16	18.39
M_0-0	Ca_1-1	20.00	20.00	18.50	19.50
	Ca_2-2	17.00	17.83	15.33	16.72
	Ca_0-0	17.33	17.33	18.50	17.72
M_1-5	Ca_1-1	19.33	20.50	22.00	20.61
	Ca_2-2	21.67	20.00	17.67	19.78
	Ca_0-0	22.00	17.83	22.00	20.61
M_2-10	Ca_1-1	18.00	22.17	22.33	20.83
	Ca_2-2	18.50	21.83	21.67	20.67
LSD 0.05			2.17		1.25
M*S		S_0	S_1	S_2	M
M_0		17.56	18.39	18.67	18.20
M_1		19.44	19.28	19.39	19.37
M_2		19.50	20.61	22.00	20.70
LSD 0.05			1.25		0.72
Ca*S		S_0	S_1	S_2	Ca
Ca_0		18.33	17.50	20.89	18.91
Ca_1		19.11	20.89	20.94	20.31
Ca_2		19.06	19.89	18.22	19.06
LSD 0.05			1.25		0.72
		S_0	S_1	S_2	
		18.83	19.43	20.02	
LSD 0.05			0.72		

Table 2. Effect of foliar application Moringa leaf extract, calcium and potassium silicate and the interaction between them on the Leaf number (leaf. $Plant^{-1}$)

M%	Ca g. L^{-1}	S ml. L^{-1} S_0-0	S_1-1.25	S_2-2.50	M*Ca
	Ca_0-0	18.67	21.33	33.67	24.56
M_0-0	Ca_1-1	30.00	23.50	20.67	24.72
	Ca_2-2	24.67	29.33	25.33	26.44
	Ca_0-0	26.17	18.17	27.67	24.00
M_1-5	Ca_1-1	23.00	34.17	34.67	30.61
	Ca_2-2	33.67	26.83	28.17	29.56
	Ca_0-0	29.17	23.67	29.83	27.56
M_2-10	Ca_1-1	28.00	29.17	37.67	31.61
	Ca_2-2	26.17	31.17	30.00	29.11
LSD 0.05			4.60		2.65
M*S		S_0	S_1	S_2	M
M_0		24.44	24.72	26.56	25.24
M_1		27.61	26.39	30.17	28.06
M_2		27.78	28.00	32.50	29.43
LSD 0.05			2.65		1.53
Ca*S		S_0	S_1	S_2	Ca
Ca_0		24.67	21.06	30.39	25.37
Ca_1		27.00	28.94	31.00	28.98
Ca_2		28.17	29.11	27.83	28.37
LSD 0.05			2.65		1.53
		S_0	S_1	S_2	
		26.61	26.37	29.74	
LSD 0.05			1.53		

Table 3. Effect of foliar application Moringa leaf extract, calcium and potassium silicate and the interaction between them on crown diameter (mm)

M%	Ca g. L^{-1}	S ml. L^{-1} S_0-0	S_1-1.25	S_2-2.50	M*Ca
M_0-0	Ca_0-0	20.33	21.50	25.67	22.50
	Ca_1-1	25.33	23.17	25.00	24.50
	Ca_2-2	23.17	24.33	23.83	23.78
M_1-5	Ca_0-0	24.50	21.83	26.17	24.17
	Ca_1-1	26.00	19.00	27.32	23.78
	Ca_2-2	23.00	22.33	24.83	23.39
M_2-10	Ca_0-0	21.00	23.50	25.67	23.39
	Ca_1-1	27.17	26.67	27.33	27.06
	Ca_2-2	25.00	24.17	25.17	24.78
LSD 0.05			3.58		2.07
M*S		S_0	S_1	S_2	M
M_0		22.94	23.00	24.83	23.59
M_1		24.50	21.06	25.78	23.78
M_2		24.39	24.78	26.06	25.07
LSD 0.05			2.07		1.19
Ca*S		S_0	S_1	S_2	Ca
Ca_0		21.94	22.28	25.83	23.35
Ca_1		26.17	22.94	26.22	25.11
Ca_2		23.72	23.61	24.61	23.98
LSD 0.05			2.07		1.19
		S_0	S_1	S_2	
		23.94	22.94	25.56	
LSD 0.05			1.19		

The increment in vegetative growth parameters represented by plant's height, leaves number, and crown diameter by the effect of Moringa extract can be due to moringa content of proteins, carbohydrates, vitamins, amino acids, and phenolic compounds (35), which contributed to the nutritional balance within the plant and growth stimulation; additionally, the extract contains plant hormones such as auxins, gibberellins and cytokinins (24), which increases the cell's division and elongation. All these factors combined can be contributed to increase the vegetative growth. These results are in agreement with (15) on strawberry and (5) on lettuce, when using natural extracts. The effect of calcium may be attributed the role of cell's expansion and division, as it contributes to the formation of spindle fibers during the cell division (31, 25). It also links between the components of the cell wall and pectic acid to form the calcium pectate that forms the cell wall structure, which stimulates the plant's growth (37). These roles of calcium stimulate the plant growth, and structural strength, which reflects on the vegetative growth parameters. This result is in agreement with (16) on gerbera, (28) on strawberry, (3, 4, 6) on carrots, (2) on broccoli and with (23) on potato plant. As for the role of potassium silicate, the increment occurred can be attributed to the role of silicon in regulation of nutrients absorption and transportation across the cell membranes (27). Additionally, the appropriate proportion of potassium that plays an important role in the various metabolic processes within the plant, as it is one of the macro-nutrients that the plant requires which is directly affected by photosynthesis in the plant (33) and metabolic processes control (10). It also works to transfer nutrients from the leaves to the roots and improves the nutrients absorption (30) which was reflected on the vegetative growth, these results were in agreement with (19). Also, the dual and triple interactions effect can be due to the individual role of these factors on the studied parameters, which played the same roles in the interaction.

Cluster number (clusters. $Plant^{-1}$)

The results in Table (4) show a significant increment in the studied parameters under the foliar application of moringa leaf extract at the treatment of M_2 which was recorded the highest values reaching 8.83 clusters. $Plant^{-1}$ compared to M_0 which was recorded the lowest value reaching 7.04 clusters. $Plant^{-1}$. Also, the calcium foliar application has significantly increased the studied parameter, as the treatment of Ca_1 recorded the highest value reaching 8.48 clusters. $Plant^{-1}$ compared with Ca_0 which recorded 7.13 clusters. $Plant^{-1}$. While the foliar application of potassium silicate did not significantly affect the studied parameter. The dual interaction at the treatment of M_2Ca_1 recorded the highest values reaching 9.61 clusters. $Plant^{-}$1, compared to the treatment of M_0Ca_0 which recorded 7.06 clusters. $Plant^{-1}$; also, the interaction treatment of M_2S_2 recorded the highest values reached 10.17 clusters. $Plant^{-1}$, compared to M_0S_0 which recorded 7.28 clusters. $Plant^{-1}$. Also, the interaction treatments of Ca_1S_2 and Ca_2S_1 recorded the highest values of the studied parameter reached 9.06 clusters. $Plant^{-1}$, compared to the interaction of Ca_0S_0 which recorded the lowest values reaching 6.83 clusters. $Plant^{-1}$. Results also revealed that the triple interaction at the treatment of $M_2Ca_1S_2$ recorded the most significant values of the studied parameter reaching 13.33 clusters. $Plant^{-1}$ compared with the interaction treatment of $M_0Ca_0S_0$ which recorded the lowest values reaching 5.33 clusters. $Plant^{-1}$.

Table 4. Effect of foliar application Moringa leaf extract, calcium and potassium silicate and the interaction between them on the Cluster number (clusters. $Plant^{-1}$)for strawberry

M%	Ca g. L^{-1}	S ml. L^{-1} S_0-0	S_1-1.25	S_2-2.50	M*Ca
M_0-0	Ca_0-0	5.33	5.67	10.17	7.06
	Ca_1-1	10.83	5.83	5.83	7.50
	Ca_2-2	5.67	8.00	6.00	6.56
M_1-5	Ca_0-0	7.00	4.50	8.33	6.61
	Ca_1-1	6.17	10.83	8.00	8.33
	Ca_2-2	10.67	10.33	7.00	9.33
M_2-10	Ca_0-0	8.17	7.67	7.33	7.72
	Ca_1-1	8.00	7.50	13.33	9.61
	Ca_2-2	8.83	8.83	9.83	9.17
LSD 0.05			2.43		1.40
M*S		S_0	S_1	S_2	M
M_0		7.28	6.50	7.33	7.04
M_1		7.94	8.56	7.78	8.09
M_2		8.33	8.00	10.17	8.83
LSD 0.05			1.40		0.81
Ca*S		S_0	S_1	S_2	Ca
Ca_0		6.83	5.94	8.61	7.13
Ca_1		8.33	8.06	9.06	8.48
Ca_2		8.39	9.06	7.61	8.35
LSD 0.05			1.40		0.81
		S_0	S_1	S_2	
		7.85	7.69	8.43	
LSD 0.05			N.S		

Plant yield (g)

The results in Table (5) show that the moringa leaf extract foliar application at the treatment of M_2 has recorded a significant increment in the plant yield reaching 341.10 g, compared to M_0, which recorded 305.80 g. Also, the calcium foliar application at the treatment of Ca_1 has significantly increased the studied parameter, which recorded 344.60 g, compared with the control treatment Ca_0, which gave the lowest value reaching 297.00 g. Also, the potassium silicate foliar application has significantly increased the plant yield at the treatment of S_2 reaching 335.20 g compared to S_0, which recorded 304.50 g. The results of the dual interaction at the treatment of M_2Ca_1 recorded the highest rate of plant yield, reaching 375.00 g, compared with the control treatment M_0Ca_0, which recorded 290.80 g. Also, The treatment of M_2S_2 recorded the highest rate of plant yield reaching 385.10 g, compared to M_0S_0, which recorded 291.30 g. It is also noted in the interaction between calcium and potassium silicate, that the treatment of Ca_1S_2 recorded the highest rate of 357.00 g compared to the control treatment of Ca_0S_0 reaching 291.80 g. The triple interaction of the studied factors also has a significant increment at the treatment of $M_2Ca_1S_2$ which recorded the most significant values reaching 436.30 gm, compared with the control treatment $M_0Ca_0S_0$, which recorded 243.40 g.

Table 5. Effect of foliar application moringa leaf extract, calcium and potassium silicate and the interaction between them on Plant yield (g)

M%	Ca g. L^{-1}	S ml. L^{-1}			M*Ca
		S_0-0	S_1-1.25	S_2-2.50	
M_0-0	Ca_0-0	243.40	272.70	356.40	290.80
	Ca_1-1	362.00	336.40	306.40	335.00
	Ca_2-2	268.60	326.90	279.10	291.50
M_1-5	Ca_0-0	289.10	237.00	297.10	274.40
	Ca_1-1	282.80	360.20	328.10	323.70
	Ca_2-2	310.80	372.70	294.20	325.90
M_2-10	Ca_0-0	342.80	249.90	384.70	325.80
	Ca_1-1	345.30	343.50	436.30	375.00
	Ca_2-2	295.40	338.10	334.20	322.60
LSD 0.05			34.98		20.19
M*S		S_0	S_1	S_2	M
M_0		291.30	312.00	314.00	305.80
M_1		294.20	323.30	306.40	308.00
M_2		327.80	310.50	385.10	341.10
LSD 0.05			20.19		11.66
Ca*S		S_0	S_1	S_2	Ca
Ca_0		291.80	253.20	346.00	297.00
Ca_1		330.10	346.70	357.00	344.60
Ca_2		291.60	345.90	302.50	313.30
LSD 0.05			20.19		11.66
		S_0	S_1	S_2	
		304.50	315.30	335.20	
LSD 0.05			11.66		

Fruits distortion percent (%)

The results in Table (6) reveal that the moringa leaf extract foliar application at the treatment of M_2 has significantly reduced the fruits distortion percent to 11.19% compared to M_0, which recorded 12.99%. The calcium foliar application also recorded a significant value at the treatment of Ca_1 which gave the lowest distortion percent, reaching 11.25%, in a significant difference compared with the control treatment Ca_0, which recorded 13.32%. while the potassium silicate foliar application did not affect this parameter. Results also revealed a significant increment by the dual interaction between moringa and calcium at the treatment of M_2Ca_1 which recorded the lowest distortion percent reaching 9.60% in a significant difference compared with the control treatment M_0Ca_0 which recorded 14.04%. The treatment of M_2S_2 recorded the lowest distortion percent reaching 10.22% compared to M_0S_0, which recorded 13.03%. Also, the interaction treatment of Ca_1S_2 recorded the lowest fruits distortion percent reaching 10.97%, compared to Ca_0S_0, recorded 13.85%. The results of the triple interaction among the studied factors revealed a significant decrement in the fruits distortion percent in most of the treatments with a significant difference from the comparison treatment, as the $M_2Ca_1S_2$ treatment recorded the lowest distortion percent reaching 8.74% compared with $M_0Ca_0S_0$, which recorded the lowest value reaching 15.99%.

Table 6. Effect of foliar application moringa leaf extract, calcium and potassium silicate and the interaction between them on the Fruits distortion percent (%)

M%	Ca g. L^{-1}	S ml. L^{-1} S_0-0	S_1-1.25	S_2-2.50	M*Ca
M_0-0	Ca_0-0	15.99	13.62	12.52	14.04
	Ca_1-1	10.06	12.86	12.68	11.87
	Ca_2-2	13.02	12.08	14.11	13.07
M_1-5	Ca_0-0	13.31	14.35	13.55	13.74
	Ca_1-1	13.51	11.86	11.49	12.29
	Ca_2-2	11.57	11.85	13.32	12.25
M_2-10	Ca_0-0	12.23	13.30	10.97	12.17
	Ca_1-1	10.34	9.72	8.74	9.60
	Ca_2-2	11.93	12.50	10.95	11.79
LSD 0.05			3.56		2.05
M*S		S_0	S_1	S_2	M
M_0		13.03	12.85	13.10	12.99
M_1		12.80	12.69	12.79	12.76
M_2		11.50	11.84	10.22	11.19
LSD 0.05			2.05		1.19
Ca*S		S_0	S_1	S_2	Ca
Ca_0		13.85	13.76	12.35	13.32
Ca_1		11.31	11.48	10.97	11.25
Ca_2		12.17	12.14	12.79	12.37
LSD 0.05			2.05		1.19
		S_0	S_1	S_2	
		12.44	12.46	12.04	
LSD 0.05			N.S		

The increment in the plant yield by the effect of moringa extract can be attributed to its role in the vegetative growth and reinforcement, which affected the increases the nutrients and carbohydrates accumulated within the plant, and then the increase in the clusters number and yield. These results are in agreement with (8, 15). The decrement in the fruits distortion percent can be attributed to the fact that the extract contains nutrients and plant hormones, which contribute to increase the percent of pollen formation, growth of the pollen tube and reduce the ovules abortion percent, and thus may lead to a decrease in fruit distortion percent. The effect of calcium can be due to the role of cell linkage during the last stages of fruit development (12), or to the role of improving the formation of cellular membranes and thus increasing the absorption of nutrients as well as regulating the transportation of nutrients across cellular membranes (32), which led to the accumulation of nutrients and its effect was reflected on the vegetative growth parameters and consequently the clusters number clusters and yield. These results were in agreement with (29). Calcium also reduced the fruits distortion percent, which can be due to its important role in stimulating the processes of pollination and fertilization in the plant (38), which led enhance the fruits formation and decrease the distortion. The application of potassium silicate had a significant role in increasing the clusters number of flower plant’s yield which can be due to its role in regulating and transporting nutrients across cell membranes and improving the cell’s wall characteristics (27), which led to reinforce the vegetative growth as revealed in tables 1, 2, and 3 and this effect was reflected on the yield parameters. As well as the foliar solution potassium has directly affected the photosynthesis (33) and metabolism control (10) and increases cell expansion (22), which, together with silicon, contributed to stimulate vegetative growth which was reflected on the clusters number and yield. These results are in agreement with (19). Also, the increment occurred by the dual and triple interactions is due to the individual role of these factors in increasing these parameters and the behavior of the interactions themselves when they interacted with each other.

Total Soluble Solids T.S.S (%)

The results in Tables (7) reveal the effect moringa leaf extract foliar application has a significant effect on increasing the T.S.S percent at the treatment of M_2 reaching 8.25%, compared to M_0, which recorded 7.93%. The calcium foliar application at the treatment of Ca_2 recorded the highest T.S.S percent reaching 8.46%, compared to Ca_0 which recorded 7.70%. The potassium silicate foliar application at the treatment of S_2 which recorded 8.50% compared to S_0, which recorded 7.76%. The dual interaction between has recorded a significant value of T.S.S, as the treatments of M_2Ca_1, M_2S_2 and Ca_1S_2 recorded the highest T.S.S percent with a significant difference in comparison with the control treatments. The triple interaction of the studied factors also revealed a significant increment on the studied parameter, as the interaction treatment of $M_2Ca_1S_1$ has recorded the highest values reaching 9.50%, compared to $M_0Ca_0S_0$, which recorded the lowest values reaching 6.40%.

Table 7. Effect of foliar application Moringa leaf extract, calcium and potassium silicate and the interaction between them on the Total Soluble Solids T.S.S (%) of the strawberry fruits

M%	Ca g. L^{-1}	S ml. L^{-1} S_0-0	S_1-1.25	S_2-2.50	M*Ca
M_0-0	Ca_0-0	6.40	7.93	8.67	7.67
	Ca_1-1	7.00	8.23	6.90	7.38
	Ca_2-2	8.90	8.97	8.67	8.73
M_1-5	Ca_0-0	7.10	7.50	8.90	7.83
	Ca_1-1	8.23	8.30	8.63	8.39
	Ca_2-2	8.27	7.77	8.90	8.42
M_2-10	Ca_0-0	7.67	7.33	7.83	7.61
	Ca_1-1	8.23	9.50	8.97	8.92
	Ca_2-2	8.00	8.00	8.63	8.21
LSD 0.05			0.94		0.54
M*S		S_0	S_1	S_2	M
M_0		7.43	8.27	8.08	7.93
M_1		7.87	7.86	8.92	8.22
M_2		7.97	8.28	8.50	8.25
LSD 0.05			0.54		0.31
Ca*S		S_0	S_1	S_2	Ca
Ca_0		7.06	7.59	8.47	7.70
Ca_1		7.82	8.68	8.19	8.23
Ca_2		8.39	8.13	8.84	8.46
LSD 0.05			0.54		0.31
		S_0	S_1	S_2	
		7.76	8.13	8.50	
LSD 0.05			0.31		

Vitamin C Content (mg. 100 g^{-1} fresh weight): The results in Table (8) reveal that the moringa leaf extract foliar application has significantly increased the fruits content of vitamin C, as the treatment of M_2 recorded the highest values reaching 56.67 mg. 100 g^{-1} fresh weight, compared with M_0 which recorded the lowest values reaching 53.59 mg. 100 g^{-1} fresh weight. Also, the calcium foliar application has significantly increased the studied parameter, as the treatment of Ca_2 recorded the highest vitamin C content reaching 56.07 mg. 100 g^{-1} fresh weight compared with Ca_0 which recorded the lowest values reaching 54.59 mg. 100 g^{-1} fresh weight. Also, the potassium silicate foliar application recorded a significant value at the treatment of S_2 reaching 56.67 mg. 100 g^{-1} fresh weight, compared with S_0, which recorded 54.56 mg.100 g^{-1} fresh weight. The dual interaction between at the treatments of M_2Ca_2, M_2S_2 and Ca_1S_2 recorded the highest values. The triple interaction of the studied factors also revealed a significant increment on the studied parameter, as the interaction treatment of $M_2Ca_2S_2$ has recorded the highest values reaching 59.67 mg. 100 g^{-1} fresh weight, compared to $M_0Ca_0S_0$, which recorded the lowest values reaching 46.00 mg. 100 g^{-1} fresh weight.

Table 8. Effect foliar application Moringa leaf extract, calcium and potassium silicate, and the interaction between them on the Vitamin C Content (mg. 100 g^{-1} fresh weight)

M%	Ca g. L^{-1}	S ml. L^{-1} S_0-0	S_1-1.25	S_2-2.50	M*Ca
	Ca_0-0	46.00	52.67	55.33	51.33
M_0-0	Ca_1-1	54.67	53.67	56.00	54.78
	Ca_2-2	55.67	54.67	53.67	54.67
	Ca_0-0	57.00	56.33	55.00	56.11
M_1-5	Ca_1-1	54.33	57.67	57.00	56.33
	Ca_2-2	56.67	56.33	55.67	56.22
	Ca_0-0	57.33	54.00	57.67	56.33
M_2-10	Ca_1-1	53.00	56.00	53.00	56.33
	Ca_2-2	56.00	56.00	59.67	57.33
LSD 0.05			3.85		2.22
M*S		S_0	S_1	S_2	M
M_0		52.11	53.67	55.00	53.59
M_1		56.00	56.78	55.89	56.22
M_2		55.56	55.33	59.11	56.67
LSD 0.05			2.22		1.28
Ca*S		S_0	S_1	S_2	Ca
Ca_0		53.44	54.33	56.00	54.59
Ca_1		54.00	55.78	57.67	55.81
Ca_2		56.22	55.67	56.33	56.07
LSD 0.05			2.22		1.28
		S_0	S_1	S_2	
		54.56	55.26	56.67	
LSD 0.05			1.28		

The results in Table (9 and 10) that the stored strawberry fruits has maintained the T.S.S percent and Vitamin C after 7 days of storage under the moringa leaf extract, calcium and potassium silicate foliar application and interaction between them, as the recorded moringa leaf extract at the M_2 treatment reaching 8.29% and 50.41 mg. 100 g^{-1} fresh weight respectively compared to M_0, which recorded 7.35% and 46.67mg. 100 g^{-1} fresh weight respectively. Also, the calcium foliar application at the treatment of Ca_1 recorded 8.47% and 49.89 mg. 100 g^{-1} fresh weight respectively compared to Ca_0 which recorded 7.36% and 47.89mg. 100 g^{-1} fresh weight respectively. Also, the potassium silicate foliar application which recorded a significant value of T.S.S% as the treatment of S_2 recorded 8.41% compared to S_0 reaching 7.09%. while the potassium silicate did not affect Content Vitamin C after 7 days of storage. Also, the storage temperature is one of the most important factors that determine the validity period and availability of the fruits after storage (20).

Table 9. Effect foliar application moringa leaf extract, calcium and potassium silicate and the interaction between them on the Total Soluble Solids T.S.S (%) of the strawberry fruits after 7 days of storage at a temperature of 0-2 ºC

M%	Ca g. L^{-1}	S ml. L^{-1} S_0-0	S_1-1.25	S_2-2.50	M*Ca
	Ca_0-0	6.00	7.50	7.33	6.94
M_0-0	Ca_1-1	8.00	6.67	7.83	7.50
	Ca_2-2	7.67	7.00	8.17	7.61
	Ca_0-0	5.90	8.33	7.67	7.30
M_1-5	Ca_1-1	8.00	9.33	9.33	8.89
	Ca_2-2	6.83	8.67	8.00	7.83
	Ca_0-0	6.53	8.50	8.50	7.84
M_2-10	Ca_1-1	7.57	9.00	10.50	9.02
	Ca_2-2	7.33	8.33	8.33	8.00
LSD 0.05			0.95		0.55
M*S		S_0	S_1	S_2	M
M_0		7.22	7.06	7.78	7.35
M_1		6.91	8.78	8.33	8.01
M_2		7.14	8.61	9.11	8.29
LSD 0.05			0.55		0.32
Ca*S		S_0	S_1	S_2	Ca
Ca_0		6.14	8.11	7.83	7.36
Ca_1		7.86	8.33	9.22	8.47
Ca_2		7.28	8.00	8.17	7.82
LSD 0.05			0.55		0.32
		S_0	S_1	S_2	
		7.09	8.15	8.41	
LSD 0.05			0.32		

Table 10. Effect of foliar application Moringa leaf extract, calcium and potassium silicate and the interaction between them on the Vitamin C Content (mg. 100 gm^{-1} wet weight) of the strawberry fruits after 7 days of storage at a temperature of 0-2 ºC

M%	Ca g. L^{-1}	S ml. L^{-1}			M*Ca
		S_0-0	S_1-1.25	S_2-2.50	
M_0-0	Ca_0-0	40.67	44.00	48.67	44.44
	Ca_1-1	50.67	50.00	45.67	48.78
	Ca_2-2	49.33	46.33	44.67	46.78
M_1-5	Ca_0-0	48.67	45.67	49.33	47.89
	Ca_1-1	48.33	52.00	49.67	50.00
	Ca_2-2	52.00	52.67	50.00	51.56
M_2-10	Ca_0-0	52.67	48.33	53.00	51.33
	Ca_1-1	47.00	52.00	53.67	50.89
	Ca_2-2	48.33	48.67	50.00	49.00
	LSD 0.05		5.38		3.11
	M*S	S_0	S_1	S_2	M
	M_0	46.89	46.78	46.33	46.67
	M_1	49.67	50.11	49.67	49.81
	M_2	49.33	49.67	52.22	50.41
	LSD 0.05		3.11		1.80
	Ca*S	S_0	S_1	S_2	Ca
	Ca_0	47.33	46.00	50.33	47.89
	Ca_1	48.67	51.33	49.67	49.89
	Ca_2	49.89	49.22	48.22	49.11
	LSD 0.05		3.11		1.80
		S_0	S_1	S_2	
		48.63	48.85	49.41	
	LSD 0.05		N.S		

The fruits applied with Moringa leaf extract had a high content T.S.S and vitamin C. This increment can be attributed to the role of the extract in the plant reinforcement that contributed to raise the plant efficiency, the photosynthesis products, and its transmission to the fruits, in addition to the fact that the extract contains cytokinin, which works to reduce the rate of respiration (7). Consequently, the less of soluble solids will be consumed in fruit juice, represented by sugars, organic, and amino acids, which led to an increase the T.S.S percent in fruits (table 7), as well as a decrease in the rate of respiration, which contributed to maintain the vitamin C from oxidation. These results are in agreement with (15). Also, the effect of calcium on the quality characteristics of strawberry fruits can be due to the important role in preventing the decomposition of cell walls (17). It also reduces the rate of respiration and ethylene production during the fruit storage and reduces the permeability of cell membranes (11) and thus will affect the percent of T.S.S. The low rate of fruit's respiration leads to the retention of sugars, acids, proteins, etc., and thus maintains the T.S.S percent, as well as the vitamin C by preventing its oxidation. These results are in agreement with (29). The effect of potassium silicate in increasing the mentioned parameters can be due to the role of potassium silicate on vegetative growth, which increased the photosynthesis and the accumulation of carbohydrate compounds. Silicon also regulates sugar metabolism and hormonal balance (13). Additionally, the foliar solution contains potassium, which contributes to the nutrients transferring from the leaves to the rest of the plant (30), which increased the transfer of produced materials to the fruits and increased T.S.S and vitamin C; these results are consistent with (19).

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