EFFECT OF MORINGA LEAVES EXTRACT, CALCIUM, AND POTASSIUM SILICATE ON THE GROWTH, YIELD, AND QUALITY OF STRAWBERRY FRUITS

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ABSTRACT

A field and storage experiments were carried out in order to evaluate the effect of the foliar application of Moringa leaves extract, calcium, and potassium silicate on the growth, yield, and quality characteristics of strawberry fruits. The field experiment with three replicates was included 27 treatments consisted of the 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} that symbolized as S_0, S_1, and S_2 respectively. The storage experiment was carried out according to the same design that applied in the first experiment, at a temperature of 0-2ºC. The results revealed that the M_2 treatment was significantly increased the leaves content of chlorophyll, Leaves area, shoots dry weight, flowers number, the fruit set percent and number, leaves and fruits content of calcium, fruits firmness, and it also reduced the damage percent and the weight loss. While the treatment of Ca_1 recorded the most significant values of growth and yield indicators, and the lowest damage percent and weight loss. Also, the Ca_2 treatment recorded the highest leaves and fruits content of calcium, and firmness. S_2 also recorded the highest values in the above indicators. The interaction treatments revealed significant values in the above-mentioned indicators, as the interactions of M_2Ca_1, M_2S_2, and Ca_1S_2 and the triple interaction of $M_2Ca_1S_2$ were recorded the highest values compared to the control treatments.

Keywords: ***Fragaria* X *ananassa* Duch., foliar application, nutrition , storage, marketability.**
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تأثير مستخلص اوراق المورينغا والكالسيوم وسيليكات البوتاسيوم في نمو وحاصل وصفات جودة ثمار الشليك

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المستخلص

نُفذت تجريتين حقلية ومخزنيه لدراسة تأثير الرش بمستخلص اوراق المورينغا والكالسيوم وسيليكات البوتاسيوم في نمو وحاصل وصفات جودة ثمار الشليك، نفذت التجربة الحقلية في أحد البيوت البلاستيكية 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 0–1.25–2.5 مل. لتر$^{-1}$ ورمز لها S_0– S_1– S_2 بالتتابع، أما التجربة المخزنيه نفذت بذات التصميم المستعمل في التجربة اعلاه وبدرجة حرارة 0–2 مْ، بينت النتائج تفوق المعاملة M_2 معنويا بزيادة الكلوروفيل في الاوراق والمساحة الورقية والوزن الجاف للمجموع الخضري وعدد الازهار ونسبة العقد وعدد الثمار ونسبة الكالسيوم في الاوراق والثمار وصلابة الثمار وقللت من نسبة التلف والفقد بالوزن، وأعطت المعاملةCa_1 زيادة في مؤشرات النمو والحاصل المذكورة اعلاه وقللت من نسبة التلف والفقد بالوزن، أما المعاملة Ca_2 أعطت أعلى نسبة في الكالسيوم بالأوراق والثمار والصلابة، كما تفوقت S_2 في المؤشرات اعلاه، وبينت التداخلات تأثيراتها المعنوية في المؤشرات أعلاه أذ أعطى التداخل الثنائي M_2Ca_1 و M_2S_2 وCa_1S_2 و الثلاثي عند$M_2Ca_1S_2$ أعلى المعدلات مقارنة مع معاملات المقارنة.

الكلمات المفتاحية: *Fragaria* X *ananassa* Duch.، الرش الورقي، التغذية، حفظ، القابلية التسويقية.

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INTRODUCTION

Strawberry *Fragaria* X *ananassa* Duch. belongs to Rosaceae family and considered as one of economic importance, widely cultivated and consumed worldwide (28). The fruits high content of nutrients such as minerals, vitamins, anthocyanins, and phenolic acids which have important biological characteristics for human health (19). Recently, natural stimulants have received wide attention (4, 6); Moringa leaves extract is one of the most important plant extracts which is safe, easy to prepare, cheap, and an alternative source of inorganic fertilizers with a high content of protein, essential amino acids, and minerals (16, 27). It also contains the antioxidants such as phenols and vitamin C, which makes it a natural growth stimulator for plants (29, 30, 35). It is also a rich source of growth regulators, especially zeatin derived from cytokinin. Ismail and Ganzour (17) revealed that the foliar application of Moringa leaf extract at the concentrations 0, 2, 4, and 6% on the strawberry plant recorded a significant increment in the leaves content of N, P, K, and Ca under the concentration of 6%, plant's height, leaves number, leaves area, fruit's weight, plant's yield, total yield, the firmness, and vitamin C. The fruits quality of the strawberry fruits are quickly deteriorated, which makes it important to study the fruits storage, including the fruits firmness, the mechanical damages, and fungal infections, which leads to great economic losses for the outcome. The calcium in the plant plays an important role in regulating the growth and development, as it is contributed to the basic components of cell walls and membranes. Zhang and Wang (40) indicated that calcium binds to pectic acid in the cell wall to form calcium pectate, which forms the cell wall structure, and gives strength and firmness to the walls structure; calcium also stimulates the photosynthesis process and regulating nitrogen metabolism (10) which is reflected on the plant growth. Mazahir et al., (21) noted that the application of calcium before harvest is the safest and most effective way to improve fruit quality and extend the shelf life, it also reduces the permeability of cell membranes during storage and prevents fruits deterioration and reduces the fruits respiration rate and ethylene production during storage (9). Hamail et al,.(13) recorded that the application of different sources of calcium on the strawberry plant has increased the plant's height, leaves number, leaves area, leaves content of chlorophyll, flowers number, and plant yield. Additionally; calcium increased the productivity and quality in plants (1, 2, 3). Silicon has a fundamental role in plants besides calcium as it enhances the firmness of the cell wall structure in plants (12), as well as its effect in improving growth and productivity by increasing photosynthesis process in plants (22), it also has a role in regulating nutrient absorption and transport of nutrients across cell membranes when they are deposited in cell walls (34). Potassium silicate is the main source of soluble potassium and silicon as it is used widely in the agricultural production as it provides the necessary quantity of potassium which is important in plant growth and development (31). Saleem and Joody (25) noted that the application of Silicon at 4 and 6 mL L^{-1} on apple trees has increased the leaves content of N, P, K, and Ca. Nada (24) recorded an increment the plant's height, leaves number, leaves area, leaves content of chlorophyll, total yield, and fruits weight, under the foliar application of four concentrations of potassium silicate 0, 0.2, 0.4, 0.6 g. L^{-1} As the concentration of 0.6 g. L^{-1} recorded the highest values for the mentioned indicators of strawberry plant, therefore, this study was aimed to improve the vegetative and floral characteristics of strawberry plant, which improves the fruits quality and marketability.

MATERIALS AND METHODS

Field experiment: The factorial experiment was carried out according to the RCBD design, with three replicates, three factors, and three concentrations for each factor, which were Moringa leaf extract M_0, M_1, M_2 for concentrations 0, 5, and10% respectively (33). The second factor was the granulated Calcium (DISPER Ca sinergy), which symbolized as Ca_0, Ca_1, Ca_2, respectively, for the concentrations 0, 1, and 2 g. L^{-1}, and potassium silicate in the concentrations of 0, 1.25, and 2.5 ml. L^{-1} which were symbolized as S_0, S_1, S_2 respectively. The seedlings were planted on 30/10/2020, the total of experimental units were 81. The foliar application was applied 6 times after two weeks from seeding, in 10 days between each one.

Storage experiment: This experiment was carried out according to the RCBD design; approximately 250 g of homogeneous fruits were taken from each treatment on 15/3/2021 and the fruits were placed in perforated plastic containers, then stored at a temperature of 0-2 ºC, and after 7 days of preservation, the damage and weight loss percent were calculated.

Field experiment traits

Leaves content of Chlorophyll (mg. $100g^{-1}$ f.w.) was estimated according to Goodwin (11) method.

Leaves area (dm^2. $plant^{-1}$): was estimated according to Sadik et al,. (26) method.

Vegetative dry weight (g) : was estimated after drying in an electric oven at a temperature of 70 °C until the weight was stable and then the average was calculated.

Flowers number (flowers. $Plant^{-1}$): was calculated starting from the middle of December until the end of the flowering season in June.

fruit set Percent (%): was calculated according to the following equation: Florescence Percent = (fruits number ÷ total flowers number) * 100

Fruits number (fruits. $Plant^{-1}$): was calculated for each experimental unit and divided by the plant's number of the experimental unit.

Leaves and fruits content plants of calcium (%) were estimated according to Al-Sahaf (5) method.

Fruits firmness (kg. cm^{-2}) was estimated by a pressure meter.

Storage experiment traits

Damage percent (%): was calculated according to the following equation:

Damage Percent (%) = (damaged fruits number of the sample) / (total fruits number of the sample) * 100

Weight loss percent (%): was calculated according to the following equation:

Weight loss % = (final weight - initial weight) / (initial weight) * 100

RESULTS AND DISCUSSION

Indicators of vegetative growth: Results in Table 1, 2, and 3 reveal that the foliar application of Moringa leaf extract has increased the leaves content of chlorophyll, leaves area, and shoot's dry weight. As the treatment M_2 recorded the highest values, reached 346.20 mg.$100g^{-1}$, 21.90 dm^2 and 31.59 g, compared with M_0, which recorded the lowest values reached 314.50 mg. 100 g^{-1}, 16.19 dm^2 and 27.67g, respectively. This increment can be attributed to providing the nutrients required for the plant, as well as the high amounts of proteins, carbohydrates, oils, vitamins, and amino acids, which positively reflected on plant growth (39), or it could be due to the extract content of growth hormones, especially cytokinin, which plays an important role in the formation of chloroplasts and increasing the efficiency of photosynthesis. These results agreed with the results of others (17). Also, the foliar application of calcium had a significant effect under the concentration of Ca_1 which recorded a significant increment among the mentioned indicators reached 334.90 mg. 100 g^{-1}, 20.91 dm^2, 31.15 g, compared to Ca_0 treatment which recorded the lowest values reached 322.40 mg. $100gm^{-1}$, 17.72 dm^2, 28.61 gm respectively.The positive effect of calcium can be due to stimulating photosynthesis and regulating nitrogen metabolism (10), therefore, it contributes to increase the accumulation of photosynthetic production and plant growth. It also works as a link between the components of the cell wall with pectic acid, as the calcium pectate forms the structure of the cell wall, which ensures the continued growth of the plant and the structure strength (40, 41). It also increases the cells division and elongation and thus increases the leaves area and the vegetative dry weight. The results agreed with what was stated by Hamail et al,. (13) on the strawberry plant and with (32) on the potato plant, (18) on gerbera. Also, the application of S_2 was recorded significant values of the above-mentioned indicators, reached 334.50 mg.100 g^{-1}, 21.63 dm^2 and 31.00 g, compared with S_0, which recorded 325.50 mg.100 g^{-1}, 17.85 dm^2 and 26.98 g, respectively. The improvement of plant growth by the potassium silicate can be attributed to the fact that silicon increases the size of the chloroplasts and the number of grana, which increases the leaves content of chlorophyll and thus increases the photosynthesis production and increases the dry matter accumulation in the plant (9 , 20, 38). In addition to the fact that the nutrient used in the study contains an appropriate amount of potassium, which directly affects photosynthesis in plants, (7, 37). It also works to transfer nutrients from the leaves to the roots and improves the nutrients absorption (36) which is reflected on the plant's growth and development.

Table 1. Effect of Moringa leaf extract, calcium and potassium silicate on the chlorophyll leaves content (mg. 100gm^{-1} wet weight) of strawberry plant

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	274.10	312.10	318.80	301.70
	Ca_1-1	312.80	288.90	295.60	229.10
	Ca_2-2	342.60	334.30	350.90	342.10
M_1-5	Ca_0-0	333.50	313.30	329.60	325.50
	Ca_1-1	330.80	346.20	345.80	340.90
	Ca_2-2	325.80	305.30	307.60	312.90
M_2-10	Ca_0-0	330.40	324.80	364.50	339.90
	Ca_1-1	343.90	377.80	372.50	364.70
	Ca_2-2	335.50	341.00	325.40	334.00
LSD 0.05			30.21		17.44
M*S		S_0	S_1	S_2	M
M_0		309.80	311.80	321.80	314.50
M_1		330.10	321.60	327.70	326.40
M_2		336.60	347.80	354.20	346.20
LSD 0.05			17.44		10.07
Ca*S		S_0	S_1	S_2	Ca
Ca_0		312.70	316.70	337.60	322.40
Ca_1		329.20	337.60	338.00	334.90
Ca_2		334.70	326.80	328.00	329.80
LSD 0.05		17.44			10.07
		S_0	S_1	S_2	
		325.50	327.10	334.50	
LSD 0.05			10.07		

Table 2. Effect of Moringa leaf extract, calcium and potassium silicate on the Leaves area (dm^2. plant^{-1}) of strawberry plant

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	12.33	14.05	22.00	16.13
	Ca_1-1	22.36	12.07	14.96	16.46
	Ca_2-2	13.74	19.06	15.18	15.99
M_1-5	Ca_0-0	16.18	13.64	21.60	17.14
	Ca_1-1	15.60	27.22	25.06	22.63
	Ca_2-2	22.44	19.96	19.53	20.64
M_2-10	Ca_0-0	20.50	15.18	24.00	19.89
	Ca_1-1	18.21	25.00	27.69	23.63
	Ca_2-2	19.28	22.61	24.67	22.18
0.05 LSD			4.23		2.44
M*S					M
M_0		16.14	15.06	17.38	16.19
M_1		18.08	20.27	22.06	20.14
M_2		19.33	20.93	25.45	21.90
LSD 0.05			2.44		1.41
S*Ca		S_0	S_1	S_2	Ca
Ca_0		16.34	14.29	22.53	17.72
Ca_1		18.73	21.43	22.57	20.91
Ca_2		18.49	20.54	19.79	19.61
LSD 0.05			2.44		1.41
			S		
		17.85	18.75	21.63	
LSD 0.05			1.41		

Also, the dual interaction between the study factors recorded significant values under the treatment of M_2Ca_1 significantly in increasing these indicators, as it reached 364.70 mg. 100 g^{-1}, 23.63 dm^2, 34.67 g respectively, Compared to M_0Ca_0, which recorded 301.70 mg.100 g^{-1}, 16.13 dm^2 and 27.72 g. The M_2S_2 treatment also recorded significant values reached 354.20 mg.100 g^{-1}, 25.45 dm^2 and 32.72 g. While the M2S1 treatment recorded the highest dry weight and did not differ significantly from the M_2S_2 treatment compared with M_0S_0, which recorded 309.80 mg. 100 g^{-1}, 16.14 dm^2, and 26.72g respectively. The Ca_1S_2 treatment also recorded the highest value of the leaves content of chlorophyll 338.00 mg.100 g^{-1} and the leaves area was 22.57 dm^2. While the Ca_2S_1 treatment recorded the highest dry weight and did not differ significantly from the Ca_1S_2 treatment, which recorded 33.89 g and 33.78 g compared with Ca_0S_0, which amounted to 312.70 mg. 100g^{-1}, 16.34 dm^2, and 25.56 g respectively. The triple interaction has a positive and significant effect in increasing the vegetative growth indicators; as the $M_2Ca_1S_2$ treatment recorded the highest values in leaves area and dry weight, reached 27.69 dm^2 and 38.33 g, respectively. Whereas the treatments $M_2Ca_1S_1$ and $M_2Ca_1S_2$ recorded the highest values of chlorophyll and did not differ significantly, reached 377.80 mg.100 g^{-1} and 372.50 mg.100g^{-1}, respectively, compared with $M_0Ca_0S_0$ which recorded the lowest values reached 274.10 mg.100 g^{-1}, 12.33 dm^2, and 22.00 g, respectively. The significant effect of the dual and triple interaction can be due to the individual and accumulative effect of the applied treatments on the studied indicators.

Table 3. Effect Moringa leaf extract, calcium and potassium silicate on the Vegetative dry weight (gm) of strawberry plant

%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	22.00	26.17	35.00	27.72
	Ca_1-1	30.50	26.17	27.33	28.00
	Ca_2-2	27.67	30.50	23.67	27.28
M_1-5	Ca_0-0	25.83	26.33	30.67	27.61
	Ca_1-1	25.83	26.33	30.67	30.78
	Ca_2-2	26.50	30.17	35.67	30.72
M_2-10	Ca_0-0	28.83	31.00	31.67	30.50
	Ca_1-1	28.33	37.33	38.33	34.67
	Ca_2-2	24.83	35.83	28.17	29.61
LSD 0.05			5.27		3.04
M*S		S_0	S_1	S_2	M
M_0		26.72	27.61	28.67	27.67
M_1		26.89	30.61	31.61	29.70
M_2		27.33	34.72	32.72	31.59
LSD 0.05			3.04		1.75
S*Ca		S_0	S_1	S_2	Ca
Ca_0		25.56	27.83	32.44	28.61
Ca_1		28.44	31.22	33.78	31.15
Ca_2		26.94	33.89	26.78	29.20
LSD 0.05			3.04		1.75
S		S_0 26.98	S_1 30.98	S_2 31.00	
LSD 0.05			1.75		

Indicators of flower growth

The results of Tables 4, 5, and 6 reveal that the treatment M_2 recorded the highest values of flowers number 33.36 flower. $Plant^{-1}$, The fruit set 63.51%, and the fruits number 21.19 fruit. $plant^{-1}$, compared with M_0 which recorded the lowest values reached 29.33 flower. $Plant^{-1}$ 57.10 %, and 17.04 fruits. $plant^{-1}$ respectively. This increment can be attributed to the role of moringa leaf extract in increasing the leaves content of chlorophyll Table 1 and thus increasing the photosynthesis process which is reflected on the leaves area Table 2 and the flowers number, fruit set%, and the fruits number. The effect of potassium silicate can be attributed the role of increasing the leaves content of chlorophyll and leave area Table 1 and 2, which is reflected on the photosynthesis process efficiency, and this is reflected on the yield indicators, as we note an increment in the fruit set percent Table 5 and this leads to an increase in the fruits number Table 6 In addition, silicon increases the vitality of pollen, (8). The dual interaction between the study treatments also had a significant effect on the mentioned indicators, as the M_2Ca_1 treatment recorded the highest values reached 34.11 flowers. Plant^{-1} 70.29% and 24.12 fruits. Plant^{-1} compared with M_0Ca_0, which recorded the lowest values reached 27.67 flowers. Plant^{-1}, 56.36%, and 15.61 fruits. Plant^{-1} respectively. Also, the M_2S_2 treatment recorded a significant effect reached 35.81 flowers. Plant^{-1} 66.94% and 24.18 fruits. plant^{-1} compared with M_0S_0 which gave 30.17 flowers. plant^{-1}, 54.27%, and 16.39 fruits. plant^{-1} respectively. The Ca_1S_2 treatment also recorded a significant increment among the studied indicators,

Table 4. Effect of Moringa leaf extract, calcium and potassium silicate on the Flowers number (flowers. Plant^{-1}) of strawberry plant

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	25.33	26.67	31.00	27.67
	Ca_1-1	34.33	32.33	32.17	32.94
	Ca_2-2	30.83	30.00	26.67	29.17
M_1-5	Ca_0-0	29.17	26.00	33.00	29.39
	Ca_1-1	24.83	36.33	31.67	30.94
	Ca_2-2	36.17	33.00	24.83	31.33
M_2-10	Ca_0-0	30.83	29.17	36.00	32.00
	Ca_1-1	34.50	30.00	37.83	34.11
	Ca_2-2	30.83	37.50	33.60	33.98
LSD 0.05			5.74		3.31
M*S		S_0	S_1	S_2	M
M_0		30.17	29.67	29.94	29.93
M_1		30.06	31.78	29.83	30.56
M_2		32.06	32.22	35.81	33.36
LSD 0.05			3.31		1.91
S*Ca		S_0	S_1	S_2	Ca
Ca_0		28.44	27.28	33.33	29.69
Ca_1		31.22	32.89	33.89	32.67
Ca_2		32.61	33.50	28.37	31.49
LSD 0.05			3.31		1.91
S		S_0 30.76	S_1 31.22	S_2 31.86	
LSD 0.05			1.91		

Table 5. Effect of Moringa leaf extract, calcium and potassium silicate on the fruit set (%) of strawberry plant

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	54.77	59.79	54.51	56.36
	Ca_1-1	53.19	55.67	55.08	54.65
	Ca_2-2	54.84	64.22	61.84	60.30
M_1-5	Ca_0-0	55.29	59.64	53.31	56.08
	Ca_1-1	61.41	58.29	60.25	59.98
	Ca_2-2	55.76	62.44	70.64	62.95
M_2-10	Ca_0-0	63.87	58.81	60.35	61.01
	Ca_1-1	61.78	72.09	77.01	70.29
	Ca_2-2	56.74	57.48	63.47	59.23
LSD 0.05			11.02		6.36
M*S		S_0	S_1	S_2	M
M_0		54.27	59.89	57.15	57.10
M_1		57.49	60.12	61.40	59.67
M_2		60.79	62.79	66.94	63.51
LSD 0.05			6.36		3.67
S*Ca		S_0	S_1	S_2	Ca
Ca_0		57.98	59.41	56.05	57.82
Ca_1		58.79	62.02	64.12	61.64
Ca_2		55.78	61.38	65.32	60.83
LSD 0.05			6.36		3.67
S		S_0 57.52	S_1 60.94	S_2 61.83	
LSD 0.05			3.67		

reached 33.89 flowers. $plant^{-1}$, 64.12%, and 20.35 fruits. $plant^{-1}$ compared with Ca_0S_0 which recorded the lowest values reached 28.44 flowers. $Plant^{-1}$, 57.98%, and 16.43 fruits. $Plant^{-1}$ respectively. The triple interaction also recorded the most significant values under the treatment $M_2Ca_1S_2$ reached 37.83 flowers. $Plant^{-1}$, 77.01%, and 29.70 fruits. $Plant^{-1}$ compared with $M_0Ca_0S_0$ which recorded the lowest value reached 25.33 flowers. $Plant^{-1}$, 54.77% and 13.87 fruits. $Plant^{-1}$ respectively. The effect of the interaction among the studied treatments can be attributed to individual and accumulative effect on the studied indicators.

Table 6. Effect of Moringa leaf extract, calcium and potassium silicate on the fruits number (fruits. $Plant^{--1}$) of strawberry plant

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	13.87	15.86	17.08	15.61
	Ca_1-1	18.31	17.92	17.57	17.93
	Ca_2-2	16.98	19.27	16.47	17.57
M_1-5	Ca_0-0	15.78	15.51	17.64	16.31
	Ca_1-1	15.33	21.06	18.79	18.40
	Ca_2-2	20.00	20.27	17.39	19.22
M_2-10	Ca_0-0	19.62	16.96	21.65	19.41
	Ca_1-1	21.18	21.48	29.70	24.12
	Ca_2-2	17.47	21.50	21.18	20.05
LSD 0.05			4.15		2.39
M*S		S_0	S_1	S_2	M
M_0		16.39	17.68	17.04	17.04
M_1		17.04	18.95	17.94	17.98
M_2		19.42	19.98	24.18	21.19
LSD 0.05			2.39		1.38
S*Ca		S_0	S_1	S_2	Ca
Ca_0		16.43	16.11	18.79	17.11
Ca_1		18.28	20.16	22.02	20.15
Ca_2		18.15	20.35	18.35	18.95
LSD 0.05			2.39		1.38
S		S_0	S_1	S_2	
		17.62	18.87	19.72	
LSD 0.05			1.38		

Indicators of Fruit quality

The results in Tables 7, 8, and 9 indicat that the foliar application of Moringa leaf extract has significantly increased the leaves and fruits content of calcium and fruits firmness under the treatment of M_2 reached 1.55%, 1.30% and 3.28 kg. cm^{-2}, compared with M_0 which recorded the lowest values reached 1.49%, 1.28% and 3.04 kg. cm^{-2} respectively. The significant effect of Moringa extract can be attributed to its high content of mineral nutrients, including calcium, and that the direct foliar application on the leaves has created a direct contact with the leaf and thus absorbed by the plant, and this led to an increase in its percentage in the leaves and that calcium is one of the stable nutrients inside the plant, which led to its accumulation in aerial parts of the plant. The foliar application of calcium also led to a significant increment in the studied indicators, as the Ca_2 treatment recorded the highest rate reached 1.56%, 1.30% and 3.35 kg. cm^{-2}, compared with Ca_0 which recorded the lowest values reached 1.47%, 1.28% and 2.72 kg. cm^{-2} respectively.

Table 7. Effect of Moringa leaf extract, calcium and potassium silicate on the Leaves content of Calcium (%)of strawberry plant

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	1.35	1.44	1.47	1.42
	Ca_1-1	1.45	1.53	1.55	1.51
	Ca_2-2	1.57	1.57	1.52	1.55
M_1-5	Ca_0-0	1.46	1.50	1.50	1.49
	Ca_1-1	1.47	1.60	1.52	1.53
	Ca_2-2	1.46	1.54	1.57	1.52
M_2-10	Ca_0-0	1.48	1.49	1.56	1.51
	Ca_1-1	1.53	1.56	1.56	1.55
	Ca_2-2	1.62	1.58	1.60	1.60
LSD 0.05			0.10		0.06
M*S		S_0	S_1	S_2	M
M_0		1.46	1.51	1.51	1.49
M_1		1.46	1.55	1.53	1.51
M_2		1.54	1.54	1.57	1.55
LSD 0.05			0.06		0.03
Ca*S		S_0	S_1	S_2	Ca
Ca_0		1.43	1.48	1.51	1.47
Ca_1		1.48	1.56	1.54	1.53
Ca_2		1.55	1.57	1.57	1.56
LSD 0.05			0.06		0.03
S		S_0	S_1	S_2	
		1.49	1.53	1.54	
LSD 0.05			0.03		

This increment could be due to the foliar application of calcium is an effective and quick method and directly supplies the plant with calcium, as a stable nutrient inside the plant (23), this led to an increases in the leaves and fruits content of calcium, and fruits firmness is due to the increase in the leaves and fruits content calcium (Table 8 and 9). Also, calcium maintains the structure of the cell walls in the tissues of the fruit and thus maintains the firmness, delays the ripening, and maintains the quality. Calcium is also involved with pectic acid present in the cell wall to form calcium pectate, which forms the structure of the cell wall, giving strength and firmness to the structure of the cell wall (41) which is reflected on increasing the fruits firmness. While the foliar application of potassium silicate did not affect calcium content fruits and firmness; the treatment S_2 has increase the leaves content of calcium reached 1.54% compared to S_0, which recorded the lowest values reached 1.49%. This increment can be attributed to the role of silicon in regulating nutrient absorption and transportation across cell membranes when deposited in cell walls (34), these results were in agreement with (25), or it could be attributed to the application of potassium, which works to transfer nutrients from the leaves to the roots and improves the nutrients absorption (36). It is also show that the dual interaction between the treatments, had a significant increment under the application of M_2Ca_2 which recorded the highest values reached 1.60%, 1.32% and 3.56 kg. cm^{-2} compared to M_0Ca_0 which recorded the lowest values reached 1.42%, 1.25% and 2.74 kg. cm^{-2} respectively. Also, the M_2S_2 treatment recorded the highest leaves content of calcium reached 1.57% and fruits, 1.31%, compared to M_0S_0 which recorded 1.46% and 1.27%, respectively. As for the M_2S_0 treatment, it is recorded the highest rate of fruit firmness, reached to 3.31 kg. cm^{-2}, followed by the M_2S_2 treatment, which recorded 3.28 kg. cm^{-2} compared to M_0S_0 which recorded the lowest values reached 2.98 kg. cm^{-2}. While the Ca_2S_2 treatment recorded a significant increment in the leaves and fruits content of calcium reached 1.57%, and 1.31% respectively, while the Ca_2S_0 treatment recorded the highest rate of fruit firmness, reached 3.41 kg. cm^{-2} compared to Ca_0S_0 which recorded the lowest values reached 2.64 kg. cm^{-2}. The results of the triple interaction revealed that the application of $M_2Ca_2S_2$ treatment was recorded the highest values reached 1.60%, 1.31% and 3.93 kg. cm^{-2} respectively, compared to $M_0Ca_0S_0$ which recorded the lowest values reached 1.45%, 1.23% and 2.17 kg. cm^{-2} respectively. The effect of dual and triple interactions is attributed to the individual and accumulative effect of these treatments on the studied indicators.

Table 8. Effect of Moringa leaf extract, calcium and potassium silicate on the fruit content of Calcium (%)of 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	1.23	1.26	1.25	1.25
	Ca_1-1	1.26	1.28	1.29	1.28
	Ca_2-2	1.31	1.33	1.29	1.31
M_1-5	Ca_0-0	1.30	1.29	1.28	1.29
	Ca_1-1	1.32	1.31	1.31	1.31
	Ca_2-2	1.30	1.27	1.27	1.28
M_2-10	Ca_0-0	1.30	1.28	1.32	1.30
	Ca_1-1	1.28	1.29	1.29	1.29
	Ca_2-2	1.30	1.32	1.32	1.32
	LSD 0.05		0.06		0.03
	M*Si	S_0	S_1	S_2	M
	M_0	1.27	1.29	1.27	1.28
	M_1	1.30	1.29	1.29	1.29
	M_2	1.29	1.29	1.31	1.30
	LSD 0.05		0.03		0.02
	Ca*Si	S_0	S_1	S_2	Ca
	Ca_0	1.27	1.27	1.29	1.28
	Ca_1	1.29	1.29	1.29	1.29
	Ca_2	1.30	1.31	1.29	1.30
	LSD 0.05		0.03		0.02
	S	S_0 1.29	S_1 1.29	S_2 1.29	
	LSD 0.05		NS		

Table 9. Effect of Moringa leaf extract, calcium and potassium silicate on the fruits firmness (kg. cm^{-2}) of 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	2.17	3.00	3.07	2.74
	Ca_1-1	3.20	3.23	2.63	3.02
	Ca_2-2	3.67	3.37	3.10	3.34
M_1-5	Ca_0-0	2.27	2.20	2.87	2.44
	Ca_1-1	3.27	3.30	3.33	3.30
	Ca_2-2	3.37	3.00	3.07	3.14
M_2-10	Ca_0-0	3.50	2.93	2.50	2.98
	Ca_1-1	3.13	3.40	3.40	3.31
	Ca_2-2	3.30	3.43	3.93	3.56
	LSD 0.05		0.41		0.24
	M*Si	S_0	S_1	S_2	M
	M_0	2.98	3.20	2.93	3.04
	M_1	2.97	2.83	3.09	2.96
	M_2	3.31	3.26	3.28	3.28
	LSD 0.05		0.24		0.14
	Ca*Si	S_0	S_1	S_2	Ca
	Ca_0	2.64	2.71	2.81	2.72
	Ca_1	3.20	3.31	3.12	3.21
	Ca_2	3.41	3.27	3.37	3.35
	LSD 0.05		0.24		0.14
	S	S_0 3.09	S_1 3.10	S_2 3.10	
	LSD 0.05		NS		

Storage experiment: The results of Table 10 and 11 indicat that the damage percent and weight loss were decreased by the applied treatments; as the M_2 treatment recorded the lowest damage percent and weight loss, reached 4.46% and 6.20%, compared to M_0, which recorded the lowest values reached 7.89% and 7.83%. The role of Moringa leaf extract lies in its richness of mineral nutrients, especially calcium, (29, 30, 35) which is noted from Table 8 which reveal the increment in fruits content of calcium and thus maintains the firmness of cell membranes and prevents them from being infected with pathogens and reducing damage and weight loss. The Ca_1 treatment recorded the lowest damage percent and weight loss, reached 4.99% and 6.89%, respectively. The role of calcium can be attributed to the important structural role in cell membranes, which has contributed to reduce the amount of fruit weight loss, as well as its role in increasing the fruits firmness Table 9, which contributed to reduce pathogens and thus reducing the rate of fruit damage (14, 15). The calcium reduces the chance of plant tissues infection by fungal and pathogenic causes. S_1 recorded the lowest damage percent reached 5.02%, compared to S_0 which recorded the lowest values reached 7.77%, while S_2 recorded the lowest percentage weight loss 5.79% compared to S_0 which recorded the highest weight loss reached 7.77% The decrement in the damage percent and weight loss in fruits due to the effect of potassium silicate that could be attributed to the deposition of silicon as a layer under the epidermis, which reduces transpiration and maintains cell elongation and thus maintains tissue firmness and decreases moisture loss and thus decreases weight loss. Also, the dual interaction under the treatment of M_2Ca_1 has significantly reduced damage percent and weight loss reached 3.46% and 8.69% respectively, compared to M_0Ca_0 which recorded the highest damage percent reached 11.00%. The M_2S_2 treatment recorded least damage rate reached 3.58% compared to M_0S_0 which recorded the highest damage percent reached 11.00%, while the Ca_1S_2 treatment recorded the least damage rate of 4.57% and the least weight loss of 5.04%. The positive effect is observed with the triple interaction in most of the treatments; the $M_2Ca_1S_2$ treatment recorded the lowest damage percent and weight loss, reached 3.32% and 2.67%, compared to $M_0Ca_0S_0$, which recorded the highest damage percent reached 18.17% and 11.77%, respectively. The decrement in the damage percent and weight loss under the dual and triple interaction among the applied treatments can be attributed to the individual and accumulative effect of each factor as there is no contradiction or competition among the applied factors.

Table 10. Effect of Moringa leaf extract, calcium and potassium silicate on the Damage percent (%) of strawberry fruits

M%	Ca g. L^{-1}	S ml. L^{-1}			M*Ca
		S_0-0	S_1-1.25	S_2-2.50	
	Ca_0-0	18.17	8.17	6.67	11.00
M_0-0	Ca_1-1	6.67	6.67	3.70	5.68
	Ca_2-2	8.17	4.17	8.67	7.00
	Ca_0-0	8.33	4.17	5.55	6.02
M_1-5	Ca_1-1	6.67	4.17	6.67	5.83
	Ca_2-2	6.67	3.70	3.33	4.57
	Ca_0-0	7.41	4.17	3.70	5.09
M_2-10	Ca_1-1	3.70	3.33	3.32	3.46
	Ca_2-2	4.17	6.67	3.70	5.85
	LSD 0.05		7.46		4.31
	M*S	S_0	S_1	S_2	M
	M_0	11.00	6.33	6.35	7.89
	M_1	7.22	4.01	5.18	5.47
	M_2	5.09	4.72	3.58	4.46
	LSD 0.05		4.31		2.49
	S*Ca	S_0	S_1	S_2	Ca
	Ca_0	11.30	5.50	5.31	7.37
	Ca_1	5.68	4.72	4.57	4.99
	Ca_2	6.33	4.85	5.23	5.47
	LSD 0.05		4.31		2.49
	S	S_0	S_1	S_2	
		7.77	5.02	5.03	
	LSD 0.05		2.49		

Table 11. Effect of Moringa leaf extract, calcium and potassium silicate on the Weight loss percent (%) of strawberry fruit

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	11.77	7.98	7.05	8.93
	Ca_1-1	7.41	6.90	8.57	7.63
	Ca_2-2	1.07	7.44	3.28	6.93
M_1-5	Ca_0-0	7.56	7.14	6.28	6.99
	Ca_1-1	8.91	7.85	3.89	6.88
	Ca_2-2	5.41	9.20	6.04	6.88
M_2-10	Ca_0-0	7.39	3.13	5.89	5.47
	Ca_1-1	7.41	8.43	2.67	6.17
	Ca_2-2	4.04	8.40	8.42	6.95
LSD 0.05			4.08		2.36
M*S		S_0	S_1	S_2	M
M_0		9.75	7.44	6.30	7.83
M_1		7.29	8.06	5.40	6.92
M_2		628	6.65	5.66	6.20
LSD 0.05			2.36		1.36
S*Ca		S_0	S_1	S_2	Ca
Ca_0		8.90	6.08	6.41	7.13
Ca_1		7.91	7.73	5.04	6.89
Ca_2		6.51	8.35	5.91	6.92
LSD 0.05			2.36		1.36
S		S_0 7.77	S_1 7.38	S_2 5.79	
LSD 0.05			1.36		

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