Synergistic Effect of Preharvest Application with Some Elicitors on Quality and Shelf Life of Avocado Fruits

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ABSTRACT

Avocado (*Persea americana* Mill.) is a tropical and subtropical climacteric fruit of Central America. It is necessary to maintain high quality of the fruit after harvest for the distant imported market through sustainable solutions. Therefore, this experiment was aimed to increase the quality and shelf life of "Hass" avocado fruits through spray avocado trees with two elicitors, calcium chloride (control, 0.5%, 1%, 2%) and potassium silicate (control, 1%, 2%, 4%) which application after 30 and 75 days of fruit set. Fruits after harvest were placed in carton boxes and sorted into identical groups under temperature and humidity of normal room. it could be recommended by spraying Hass avocado trees with (0.5%) calcium chloride and (2%) potassium silicate as well as the interaction between them to maintaining the quality of fruits for as long as possible through storage and extend shelf life of fruits.

Keywords: Avocado Hass, calcium chloride, potassium silicate, Storage and Shelf Life.

INTRODUCTION

Avocado is a crop grown globally in tropical and subtropical regions **(Pachón *et al.*, 2022).** Among the countries where avocados are grown is Egypt, where the total area have reached to 372 acres with fruitful area about 291 acres, and the average production 894 tons with a productivity about 3 tons/acre according to **(Ministry of Agriculture and Land Reclamation, 2022)**.

Avocado fruits and its oil contain many bioactive compounds with biological activities beneficial to human health. The most distinctive in avocado fruits its content of unsaturated fatty acids in the oil mostly oleic and linolenic acids (**King-Loeza *et al.*, 2023).**

Due to numerous issues that arise during storage avocado fruits are particularly challenging to keep extended periods of time. One of these issues is fungi specially *Colletotrichum* spp. which can cause quality loss of the avocado fruits during storage, as well as decrease in the shelf life. This may account for about 20% of economic output losses **(Bañuelos-González *et al.*, 2023).**

By using various techniques, such as pre-harvest spraying elicitors safe and eco-friendly compounds on trees that minimize decay, preserve fruit quality, and extend shelf life it is possible to significantly reduce post-harvest losses.

Among these are materials calcium chloride, potassium silicates, chitosan, salicylic acid, ascorbic acid, gibberellin, naphthaleneacetic acid, gibberellic acid, 2-4 dichlorophenoxyacetic acid, putrescine, spermine, lyso-phosphatidyl ethanolamine, phenylalanine, ethrel, amino acids, micronutrients, potassium sulphate, oleic acid and phenylalanine.

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It has been proven that many inorganic salts (calcium chloride and potassium silicate) work to reduce the incidence of fruit rot during storage, and they act as antimicrobial substances and therefore effective against a group of fungal pathogens. They are considered an effective and safe alternative method for controlling post-harvest fruit rot **(Tarabih *et al.*, 2014).**

Calcium chloride works to maintain the integrity of the cell membrane by delaying changes in membrane lipids associated with aging as well as promoting membrane restructuring processes **(Picchioni *et al.*, 1996).**

The calcium present in calcium chloride penetrates through the pores of the skin and accumulates in the middle lamella of the cell wall, consequently, the cells were stabilized without decomposing, and ionic bonds were formed both inside and between the pectin layer, making the cell wall more resistant to the hydrolysis enzymes produced by fruit rot-causing organisms and making the cell wall rigid **(Tarabih *et al.*, 1993&2014)**.

Calcium also increases the synthesis of phenolic compounds within fruits, thus increasing the fruits' resistance to free radicals that accelerate fruit senescence **(Kohle *et al.*, 1985)**. Therefore, using it as a spray before harvest is expected to reduce the possibility of fruit decay during storage and extend the shelf life of avocado fruits. **(Youssef *et al*., 2012).**

Potassium silicate has many physiological roles that lead to improving the resistance of fruits to diseases during storage by stimulating defense mechanisms within the plant such as its ability to cause an increase in the production of defensive proteins (**Dan, 2002)**, reducing the rate of fruit respiration and thus reducing the rate of ethylene production **(Kaluwa *et al.*, 2010)**. Consequently, the polyphenol oxidase (PPO) enzyme activity decreases, causing fruits to degrade and develop brown tissues **(Lugo *et al.*, 2006).**

Potassium silicate has a role in influencing the activity of some antioxidant enzymes that participate in stress defense systems.

Silicon is deposited under the skin to form a double layer of silicon in the skin and thus it forms a mechanical barrier to prevent fungi from penetrating the fruit and therefore increasing the hardness of cell walls **(Epstein, 2009)**. As well as it has a role in binding calcium cations with the free carboxyl groups of the polygalactonate, polymer further catalyze the ligation polygalactonic acids with each other and also link pectin chains with calcium, which leads to increasing the rigidity of the membranes **(Grant *et al*., 1973)**.

Thus, applying potassium silicate as a pre-harvest spray to trees may help maintain fruit quality, decrease the chance of fungal growth and development during storage, and increase fruit shelf life **(Tarabih *et al.*, 2014).**

Therefore, this study aimed to investigate the effects of preharvest applications of calcium chloride and potassium silicate as well as their combination on improving yield and quality at harvest as well as shelf life under normal room conditions for avocado fruits.

MATERIALS AND METHODS

The research was carried out during two successive seasons (2021 and 2022) on 20-years old avocado trees (*Persea americana, Mill.*) cv. Hass grown on sandy soil at 6.5×6.5 meters apart (Approximately 100 trees/fed) with identical growth vigor grafted on Duke-7 rootstock under drip irrigation system in a private orchard located at New Nubaria, El-Beheira Governorate, Egypt.

This study was a factorial experiment field involved two spraying materials (calcium chloride and potassium silicate) each one was presented by four levels (control, 0.5%, 1%, 2%) and (control, 1%, 2%, 4%), respectively.

It should be pointed out that each material with different levels were foliar spray two times through each growing season i.e. 30 days after fruit set and 75 days after fruit set and TritonX-1000 at 0.05 % was used as a wetting agent for all trees. Control trees were sprayed with tap water plus TritonX-1000.

The experiment was arranged in a randomized complete block design thus the experiment was consisted of sixteen treatments with three replicate, one tree for each replicate.

Firstly, number of fruits of each tree were counted and calculate yield and then five fruits were harvested from each replicate for all treatments. According to **Ncama *et al*., (2018)** maturity indices which used to determine the harvest date were oil concentration (11.2%) and dry matter (21.7%). The fruits harvested were similar in color, size and free of any noticeable pathological or mechanical injuries and fruits were immediately packed and transported to the postharvest laboratory to estimate some chemical and physical measurements in zero time (after harvest) and then the experiment's shelf life began under conditions temperature and humidity of normal room that ended after (50% of fruits are decay).

The fruits were placed in carton boxes, and sorted into identical groups. Each treatment consisted of three replicates, each replicate consisting of 1 package containing 5 fruits (16 treatments X 3 replicates = 48 boxes). Samples were taken in zero time and in the end of the experiment (50% of fruits are decay) over 2021-2022 seasons.

Yield Measurements

Fruit weight (g): It was measured by balance.

Fruit numbers / tree: was counted the number of fruits/tree at harvest.

Yield (Kg/tree): It was measured by equation: average of fruit weigh X fruit number of tree.

Physical Properties Assessments:

Fruit firmness (Ib/inch2): It was measured with fruit texture analyzer (model GS-, serial NO. FTA2).

Fruit weight loss (%): It was measured according to (**Eman *et al*., 2023)** by equation:

Fruit weight loss%= [(Initial weight- weight at sampling date) / Initial weight] X 100

Chemical Properties Assessments:

Total soluble solids (T.S.S.): It was measured in pulp juice by using Zeiss hand Refractometer model HR-110.

Total acidity (%): It was measured according to **(A.O.A.C., 1990)** in pulp juice as a percentage of anhydrous citric acid by titration and phenolphthalein 1% as an indicator.

Respiration rate (Co_2 mcg.kg^{-1} hr^{-1}): It was measured according to (**Mareme, 2020)** using a Map-Pak gas analyser (VISCIANO-VIGAZ Analyser, France).

Polyphenol oxidase enzyme activity (EC 1.14.18.1): It was measured in pulp according to (**Oktay *et al* 1995)**.

Physiological disorder

Decay index (%): fruit was divided into five grades on the basis of empirical scales and calculated by the formula: Decay index (%) = (Σ (decay grade× number of fruits in this grade) / (highest decay grade× total number of fruits)) × 100 according to **(Li *et al*., 2019)**.

Statistical analysis

The analysis of variance (ANOVA) procedure of the COSTAT program was used to examine the data according to Duncan and the means were compared at 5% level of probability **(Duncan, 1955).**

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RESULTS

Effect of spraying with calcium chloride and potassium silicate on yield measurements of avocado cv. Hass trees:

Effect on fruit weight

Data in Table (1) showed that, showed that calcium chloride and potassium silicate levels did not have a significant effect on fruit weight compared with control in both seasons. In respect to the interaction, in most cases some treatments gave the highest significant values of fruit weight control, 0.5% $CaCl_2$ + 1% K_2SiO_3 and 2% $CaCl_2$ + 4% K_2SiO_3 compared with other treatments.

Studies of **Wahdan *et al.*, (2011)** and **Karemera *et al.*, (2014)** on mango trees concluded that spraying trees with calcium chloride as a pre-harvest application noticeably larger fruit weights compared with control.

Abidi *et al.*, (2023) showed that the applied potassium silicon at 3% and 4.5% enhanced the fruit weight of two peach cultivars "Early Bomba" and "Plagold 17" trees.

This outcome can be ascribed to that the increase in fruit weight is due to the nutritional status of the trees **(Samah and Ghada, 2024)**.

Table 1. Effect of spraying with calcium chloride and potassium silicate on fruit weight of avocado cv. Hass trees in 2021 and 2022 seasons

Fruit weight (g)					
Season 2021					
Potassium Silicate / Calcium Chloride	(K_2SiO_3) Control	(1%)	(2%)	(4%)	Mean
($CaCl_2$)$_1$: (Control)	221.8 a	149.4 d-f	199.8 ab	187.5 a-d	189.6 A
($CaCl_2$)$_2$: (0.5%)	165.8 b-e	183.8 a-e	202.2 ab	180.2 b-e	183.0 AB
($CaCl_2$)$_3$: (1%)	146.0 ef	156.2 c-f	170.3 b-e	171.4 b-e	161.0 C
($CaCl_2$)$_4$: (2%)	186.0 a-d	127.7 f	180.0 b-e	189.8 a-c	170.9 BC
Mean	179.9 A’	154.3 B’	188.1 A’	182.2 A’	-
	Season 2022				
($CaCl_2$)$_1$: (Control)	200.6 a	176.9 b-d	142.5 ef	163.3 c-e	170.8 A
($CaCl_2$)$_2$: (0.5%)	175.6 b-d	189.7 ab	159.2 de	160.4 de	171.2 A
($CaCl_2$)$_3$: (1%)	163.1 c-e	174.8 b-d	130.6 f	160.7 de	157.3 B
($CaCl_2$)$_4$: (2%)	182.0 a-d	167.0 cd	160.5 de	185.4 a-c	173.7 A
Mean	180.3 A’	177.1 AB’	148.2 C’	167.5 B`	-

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level according to Duncan´s test

Effect on fruit number/ tree

Data in Table (2) cleared that 1% calcium chloride gave the highest values of fruit number per tree with constate trend in the two seasons.

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Regarding potassium silicate levels, control gave the highest values of fruit number per tree in two seasons followed closely by 1% and 2% K_2SiO_3 in the first and second seasons, respectively.

In respect to the combining between calcium chloride and potassium silicate, the treatment 0.5% $CaCl_2$ + 2% K_2SiO_3 gave the highest significant values of fruit number per tree compared with other treatments in both seasons with notice that in 2021 season only there were no significant differences between this treatment and the second and third level of $CaCl_2$ under the first and third level of K_2SiO_3 and also the third and fourth level of $CaCl_2$ under the second level of K_2SiO_3.

Pisutpiboonwong and Khurnpoon (2017) noted that mulberry trees sprayed with 2% $CaCl_2$ resulted in significantly different in number of fruit and number of branches of tree.

Aiman *et al.*, (2023) showed that spraying with 4% calcium chloride had a great effect on pomegranate trees in increasing fruit number compared with control trees.

This outcome can be explained by **Mazumder *et al.*, (2021)** and **Al-Mohammadi and Ismail (2023)** who reported that calcium chloride and potassium silicate notable impact on enhancing the nutritional state of the trees which raises the trees' resistance to biotic and abiotic stresses and thus increases the number of fruits per tree.

Table 2. Effect of spraying with calcium chloride and potassium silicate on fruits number of avocado cv. Hass trees in 2021 and 2022 seasons

Fruits number/ tree					
Season 2021					
Potassium Silicate Calcium Chloride	**(K_2SiO_3)**				**Mean**
	Control	**(1%)**	**(2%)**	**(4%)**	
$(CaCl_2)_1$: (Control)	62.0 de	63.0 de	42.0 ef	90.0 b-d	64.0 B
$(CaCl_2)_2$: (0.5%)	118.0 ab	48.0 ef	104.0 a-c	38.0 ef	77.0 B
$(CaCl_2)_3$: (1%)	133.0 a	110.0 a-c	114.0 a-c	45.0 ef	101.0 A
$(CaCl_2)_4$: (2%)	51.0 ef	115.0 ab	28.0 f	85.0 cd	70.0 B
Mean	91.0 A’	84.0 AB	72.0 BC’	64.0 C’	-
	Season 2022				
$(CaCl_2)_1$: (Control)	80.0 de	57.0 e-g	66.0 ef	111.0 bc	79.0 C
$(CaCl_2)_2$: (0.5%)	124.0 b	53.0 fg	180.0 a	52.0 fg	102.0 B
$(CaCl_2)_3$: (1%)	124.0 b	111.0 bc	153.0 b	65.0 ef	113.0 A
$(CaCl_2)_4$: (2%)	51.0 fg	96 .0 cd	36.0 g	115.0 bc	75.0 C
Mean	95.0 AB’	79.0 C’	104.0 A’	86.0 BC’	-

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level according to Duncan´s test

Effect on yield

Data in Table (3) concluded that the second and third levels of $CaCl_2$ gave the highest values of yield in both seasons specially in the second season.

As for K_2SiO_3 treatments, control treatment had higher yield compared with all other treatments.

Regarding interaction, the treatment 0.5% $CaCl_2$ + 2% K_2SiO_3 gave the highest value of yield especially in the second season whereas in the first season some other treatments gave more or less similar values.

This results agreement with **Abd-Elall and Hussein (2018)** reported that spray Balady orange trees with calcium chloride at 2% improved yield of trees. And these results can be explained by **Mazumder *et al.*, (2021)** who said that calcium chloride enhancing the nutritional state of trees by raises the trees' resistance to biotic and abiotic stresses.

Contrary to what **Ibrahim and Ali (2021)** found that spraying Canino apricot trees with K_2SiO_3 at 0.05%, 0.1% and 0.2% significantly enhanced yield (kg/tree). Additionally, **Ennab and Khedr (2021)** said that spraying Balady mandarin trees with potassium silicate at 4g/l improve leaves nutritional status and thus enhance yield.

Table 3**.** Effect of spraying with calcium chloride and potassium silicate on yield of avocado cv. Hass trees in 2021 and 2022 seasons

	Yield (Kg)				
	Season 2021				
Potassium Silicate Calcium Chloride	**(K_2SiO_3)**				**Mean**
	Control	**(1%)**	**(2%)**	**(4%)**	
($CaCl_2$)$_1$: (Control)	13.5 b-d	9.6 c-e	8.2 de	16.9 ab	12.1 B
($CaCl_2$)$_2$: (0.5%)	19.6 ab	8.8 c-e	21.0 a	6.7 e	14.0 AB
($CaCl_2$)$_3$: (1%)	20.0 a	17.1 ab	19.6 ab	7.7 de	16.1 A
($CaCl_2$)$_4$: (2%)	9.4 c-e	14.7 a-c	5.1 e	16.0 ab	11.3 B
Mean	15.6 A’	12.6 B’	13.5 AB’	11.8 B’	-
	Season 2022				
($CaCl_2$)$_1$: (Control)	16.0 c	10.1 d	9.4 d	18.0 bc	13.4 B
($CaCl_2$)$_2$: (0.5%)	21.8 b	10.0 d	28.7 a	8.3 d	17.2 A
($CaCl_2$)$_3$: (1%)	20.2 bc	19.5 bc	20.0 b	10.3 d	17.5 A
($CaCl_2$)$_4$: (2%)	9.2 d	16.0 c	5.8 d	21.3 b	13.1 B
Mean	16.8 A’	13.9 B’	16.0 A’	14.5 B’	-

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level according to Duncan´s test

Effect of spraying with calcium chloride and potassium silicate on some physical properties of avocado cv. Hass trees

Effect on fruit firmness

Data in Table (4) cleared that there were no significant differences between all calcium chloride levels after harvest (0 day) in both seasons whereas after 21 days the second level of $CaCl_2$ gave the highest values in the two seasons with notice that there were no statical differences between this level and the second and third level in 2021 season only.

Regarding potassium silicate levels, after harvest (0 day) there were no clear differences in values of fruit firmness as a result of applying potassium silicate levels on trees but after 21 days of storage the third level of still maintains its firmness compared with other levels especially in the second season.

In respect to interaction, after harvest (0 day) the combinations 1% $CaCl_2$ + control and also control + 2% K_2SiO_3 gave the lowest values of fruit firmness in both seasons and the other combinations gave more or less similar values with the same statically but after 21 days of storage the trend of the results became clearer where the combination 0.5 $CaCl_2$ % + 2% K_2SiO_3 gave the highest values of firmness compared with other treatments in both seasons.

The previous studies found that for cells to maintain their middle lamella, calcium in calcium chloride is essential because calcium keeps the fruit's cell wall structure intact, it can successfully delay fruit ripening and softening **(Mohamed *et al.*, 2017)**.

Zhang and Ervin (2008) reported that applying silicon in potassium silicate inhibits the activities of key enzymes that break down fruit walls, including xylanase, polygalacturonase and cellulase. In the same trend, **Liang *et al.*, (2015)** said that silicon forming a sub-cuticle layer and caused the plant tissues to harden. And also, **Ferreira *et al.*, (2015)** added that silicone forming a complex with chemicals in cell walls and thus increasing the resistance of the cell wall to degradation.

Table 4. Effect of spraying calcium chloride and potassium silicate on fruit firmness after harvest and after twenty-one days at room temperature of avocado cv. Hass trees in 2021 and 2022 seasons

	Firmness (Ib/inch²)									
	Season 2021									
	After harvest (0 day)					21 days during shelf life at room temperature				
Potassium Silicate / Calcium Chloride	(K_2SiO_3)				Mean	(K_2SiO_3)				Mean
	Contro	(1%	(2%)	(4%)		Control	(1%)	(2%)	(4%)	
($CaCl_2$)1: (Control)	22.0 a	16.9 b-d	13.8 d	20.2 ab	18.3 AB	2.3 b	2.2 b	1.5 b	1.5 b	1.9 B
($CaCl_2$)2: (0.5%)	19.2 a-c	18.4 a-c	18.4 a-c	19.0 a-c	18.7 AB	2.4 b	2.2 b	6.1 a	3.2 ab	3.5 A
($CaCl_2$)3: (1%)	15.6 cd	17.2 b-d	18.6 a-c	18.4 a-c	17.5 AB	2.4 b	3.1 ab	2.5 b	2.6 b	2.7 AB
($CaCl_2$)4: (2%)	20.4 ab	22.1 a	16.6 b-d	19.9 ab	19.7	2.5 b	3.0 b	3.2 ab	2.1 b	2.7

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					A					AB
Mean	19.3 A’	18.7 A’	16.9 B’	19.4 A’	-	2.4 A’	2.6 A’	3.4 A’	2.4 A’	-
	Season 2022									
($CaCl_2$)$_1$: (Control)	23.8 a	23.7 a	16.1 bc	19.9 a-c	20.9 A	1.4 f	2.8 c-e	3.8 c	1.9 ef	2.5 C
($CaCl_2$)$_2$: (0.5%)	24.2 a	19.0 a-c	18.5 a-c	19.9 a-c	20.4 A	3.3 cd	3.3 cd	10.9 a	1.9 ef	4.9 A
($CaCl_2$)$_3$: (1%)	16.1 bc	23.7 a	17.5 a-c	22.8 ab	20.0 A	7.1 b	2.3 d-f	2.8 c-e	1.9 ef	3.5 B
($CaCl_2$)$_4$: (2%)	24.2 a	14.7 c	21.3 a-c	23.7 a	21.0 A	2.8 c-e	2.8 c-e	2.8 c-e	2.3 d-f	2.7 C
Mean	22.1 A’	20.3 AB’	18.4 B’	21.6 AB’	-	3.7 B’	2.8 C’	5.1 A’	2.0 D’	-

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level according to Duncan´s test

Effect on fruit weight loss

Data in Table (5) showed that there were no significant differences between all calcium chloride levels after 21 days during shelf life at room temperature in both seasons.

The trend results of potassium silicate levels in both seasons and also the interaction in first season only were in the same direction but in the second season the interaction results became clearer where the combinations 1% $CaCl_2$ + control, 1% $CaCl_2$ + 1% K_2SiO_3 and 0.5 $CaCl_2$ % + 2% K_2SiO_3 gave the lowest values of fruit weight loss with noted that some other combinations gave more or less similar values.

Our results agreement with **Abdel Gayed *et al.*, (2017)** found that spray peach trees with 2% calcium chloride led to decreasing in fruit weight loss as a result of maintaining on fruits firmness by decreasing in the enzyme activity responsible for disintegration of cellular structure which decreases the respiration rate.

Abidi *et al.*, (2023) reported that spraying peach and nectarine trees with 3.0% or 4.5% potassium silicate led to delaying in fruit weight loss by maintaining on fruit water content through storage.

Table 5. Effect of spraying calcium chloride and potassium silicate on fruit weight loss percentage after twenty-one days at room temperature of avocado cv. Hass trees in 2021 and 2022 seasons

	Fruit weight loss (%)				
	Season 2021				
	21 days during shelf life at room temperature				
Potassium Silicate Calcium Chloride	**(K_2SiO_3)**				
	Control	**(1%)**	**(2%)**	**(4%)**	**Mean**

($CaCl_2$)$_1$: (Control)	25.1 a	10.8 a	27.3 a	19.0 a	20.6 A
($CaCl_2$)$_2$: (0.5%)	16.5 a	22.4 a	12.2 a	23.4 a	18.6 A
($CaCl_2$)$_3$: (1%)	12.0 a	20.1 a	20.1 a	19.6 a	17.9 A
($CaCl_2$)$_4$: (2%)	12.1 a	19.4 a	18.0 a	21.9 a	17.9 A
Mean	16.4 A'	18.2 A'	19.4 A'	21.0 A'	-
	Season 2022				
($CaCl_2$)$_1$: (Control)	15.1 ab	13.8 ab	15.7 ab	14.7 ab	14.8 A
($CaCl_2$)$_2$: (0.5%)	13.8 ab	21.9 a	7.0 b	18.6 ab	15.4 A
($CaCl_2$)$_3$: (1%)	7.1 b	6.3 b	11.2 ab	14.8 ab	9.8 A
($CaCl_2$)$_4$: (2%)	16.5 ab	14.7 ab	10.5 ab	14.0 ab	13.9 A
Mean	13.1 A'	14.2 A'	11.1 A'	15.3 A'	-

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level according to Duncan´s test

Effect of spraying with calcium chloride and potassium silicate on some chemical properties of avocado cv. Hass trees:

Effect on T.S.S.

Data in Table (6) presented that, the second level of calcium chloride 0.5% after harvest (0 day) in both seasons gave the lowest value of T.S.S. with notice that there were no statical differences between this level and the fourth level in 2021 season and also the first level in 2022 season. After 21 days the third level of calcium chloride 1% gave the lowest values in both seasons with taking into consideration that in first season only there were no statical differences between this level and the second level 0.5% of calcium chloride.

Regarding potassium silicate levels, after harvest (0 day) there were no a clear effect of different levels on T.T.S. content in both seasons but after 21 days the results became more clearer where the third and fourth levels gave the lowest values in 2021 season whereas in 2022 season the trend was more specific that the third level only gave the lowest value compare with other levels.

As for the results of the interaction between the two materials under study, after harvest (0 day) the combinations gave the lowest values of T.S.S. in both seasons were control and 0.5% calcium chloride under control treatment of potassium silicate, 0% $CaCl_2$ + 1% K_2SiO_3 and 0.5 % $CaCl_2$ + 4%K_2SiO_3. As for the fruits were kept T.S.S. low compared with other treatments after 21days in both seasons were 1 % $CaCl_2$ + 0%K_2SiO_3 and 0.5 % $CaCl_2$ + 2%K_2SiO_3.

These results confirmed with **El-Dengawy *et al.*, (2019)** who reported that foliar application with 2% $CaCl_2$ on peach trees gave the lowest value of T.S.S. in fruit in all storage periods.

Our results can explain by **Karemera *et al*., (2014)** and **Samah and Ghada (2024)** who reported that the substances such as calcium chloride which reduce the formation of ethylene thus delay the ripening of the fruits and thus reduce the chance of a change in the soluble solids content of the fruits through an increase in enzymatic activity that converts the organic content in fruits into soluble solids and thus an increase in the fruits' content of soluble solids throughout storage periods.

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El Kholy *et al.*, (2018) explained that by the pre-harvest applications on loquat trees with potassium silicate due to the low respiration rate and thus delay of the senescence including increase in total soluble solids.

Abidi *et al.*, (2023) reported that foliar application with potassium silicate at 3% and 4.5% on peach trees enhanced T.S.S. through cold storage period.

Table 6. Effect of spraying with calcium chloride and potassium silicate on T.S.S. after harvest and after twenty-one days at room temperature of avocado cv. Hass trees in 2021 and 2022 seasons

T.S.S.										
Season 2021										
	After harvest (0 day)					21 days during shelf life at room temperature				
Potassium Silicate Calcium Chloride	(K_2SiO_3)				Mean	(K_2SiO_3)				Mean
	Control	(1%)	(2%)	(4%)		Control	(1%)	(2%)	(4%)	
($CaCl_2$)$_1$: (Control)	3.7a-d	3.7a-d	4.8a	4.2a-c	4.1AB	7.7a	7.1a-c	6.6a-d	5.5c-f	6.7A
($CaCl_2$)$_2$: (0.5%)	2.7d	3.5b-d	4.2a-c	3.2cd	3.4C	7.9a	7.0a-c	4.8ef	4.3f	6.0AB
($CaCl_2$)$_3$: (1%)	4.2a-c	4.5ab	4.0a-c	4.3a-c	4.3A	5.2d-f	7.5ab	6.0b-e	5.0ef	5.9B
($CaCl_2$)$_4$: (2%)	3.2cd	4.2a-c	3.5b-d	4.0a-c	3.7BC	6.3a-e	6.9 a-c	6.7a-d	7.0a-c	6.7A
Mean	3.4B’	4.0A’	4.1A’	3.9A’	-	6.8A’	7.1A’	6.0B’	5.5B’	-
	Season 2022									
($CaCl_2$)$_1$: (Control)	0.5e	0.8e	1.7cd	2.0bc	1.3B	7.5a	4.2cd	2.5g	4.5cd	4.7B
($CaCl_2$)$_2$: (0.5%)	0.7e	2.2b	1.3d	0.5e	1.2B	4.7c	3.2f	1.8h	4.7c	3.6C
($CaCl_2$)$_3$: (1%)	1.5d	2.2b	0.7e	2.2b	1.7A	2.0gh	4.5cd	3.0f	3.5ef	3.3D
($CaCl_2$)$_4$: (2%)	3.5a	0.7e	1.5cd	0.5e	1.6A	4.8c	5.5b	6.0b	4.0de	5.1A
Mean	1.6A’	1.5AB’	1.3B’	1.3B’	-	4.7A’	4.4B’	3.4C’	4.2B’	-

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level according to Duncan´s test

Effect on total acidity

Data in Table (7) concluded that, after harvest (0 day) the treatments which had a high acidity content were the first and second levels of calcium chloride in 2021 season only whereas after 21 days of storage in the same

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season there were no significant differences between all levels except between the second and the fourth levels of calcium chloride. As for the results in the second season, the levels gave the highest values of total acidity were the second level of calcium chloride after harvest and after 21 days of storage and also the fourth level after harvest only.

Regarding potassium silicate results, in the first season only there were no significant differences between all levels after harvest (0 day) but in the second season the direction became more slightly that the treatments gave the highest value of acidity were the fourth level and control. After 21 days of storage in 2021 season only the fourth level of potassium silicate gave the highest value of acidity but there were no significant differences between this level and control. As for the results in the second season the direction became more slightly that the third level gave the highest significant value compared with the other levels.

The combining cleared that after harvest (0 day) there were no significant differences among most interactions especially in the second season. As for combining treatments after 21 days of storage in both seasons, the combining 0.5% $CaCl_2$ + 2% K_2SiO_3 gave the highest value of total acidity with notice that there were no significant differences between it and control, 1% $CaCl_2$ + 4% K_2SiO_3 as well as 2% $CaCl_2$ + 4% K_2SiO_3 in first season only.

Our results are consistent with studies of **Khalil and Aly (2013)** and **Hegazi *et al.*, (2014)** who found that application of $CaCl_2$ on pomegranate trees significantly increased acidity.

Sigal-Escalada (2006) clarified that the increasing of acidity in fruits is linked to slower fruit ripening and decreased fruit respiration.

Karemera *et al.*, (2014) reported that there are many theories which can explain our results by the invertase enzyme's action during the storage period may have caused the acidity content to decrease by converting acid to sugars additionally, **Bijayanka *et al.*, (2023)** suggested that this might be because of less oxidation.

Hanumanthaiah *et al.*, (2015) found that the total soluble solids and total acidity of banana cv. "Neypoovan" fruits were significantly influenced by foliar applied potassium silicate at 2.0 and 4.0 ml/lit per plant, and they explained these results by the rise in total soluble solids could be the cause of the acidity decline.

Table 7. Effect of spraying with calcium chloride and potassium silicate on total acidity after harvest and after twenty-one days at room temperature of avocado cv. Hass trees in 2021 and 2022 seasons

	Total acidity (%)									
	Season 2021									
	After harvest (0 day)					**21 days during shelf life at room temperature**				
Potassium Silicate	**(K_2SiO_3)**				**Mean**	**(K_2SiO_3)**				**Mean**
Calcium Chloride	**Control**	**(1%)**	**(2%)**	**(4%)**		**Control**	**(1%)**	**(2%)**	**(4%)**	
($CaCl_2$)$_1$: (Control)	0.85a	0.46 cd	0.30 d	0.67a-c	0.57 A	0.18 a	0.10 cd	0.10 d	0.12 bc	0.11AB
($CaCl_2$)$_2$: (0.5%)	0.32 d	0.39 d	0.76 ab	0.43cd	0.47 AB	0.12 bc	0.10b-d	0.18 a	0.12 bc	0.13 A
($CaCl_2$)$_3$: (1%)	0.30 d	0.45 cd	0.74 cd	0.38 d	0.40 B	0.10 cd	0.10 cd	0.12 bc	0.18 a	0.11 AB

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$(CaCl_2)_4$: (2%)	0.36 d	0.38 d	0.45 cd	0.53b-d	0.43B	0.10 b-d	0.10 d	0.10 b-d	0.15 ab	0.10 B
Mean	0.46A'	0.42A'	0.50A '	0.50A'	-	0.12A B'	0.10 C'	0.11B'	0.14A'	-
	Season 2022									
$(CaCl_2)_1$: (Control)	1.2 a	0.77 bc	0.51 c	0.68 c	0.7 B	0.26 cd	0.26 cd	0.26 cd	0.51 bc	0.32 B
$(CaCl_2)_2$: (0.5%)	1.2 a	0.68 c	1.1 ab	1.5 a	1.1 A	0.21 d	0.26 cd	1.0 a	0.26 cd	0.44 A
$(CaCl_2)_3$: (1%)	0.51 c	0.77 bc	0.68 c	0.43 c	0.6 C	0.26 cd	0.26 cd	0.68 b	0.26 cd	0.37 B
$(CaCl_2)_4$: (2%)	1.3 a	1.2 a	0.68 c	1.2 a	1.1 A	0.26 cd	0.26 cd	0.26 cd	0.68 b	0.37 B
Mean	1.1 A'	0.85 BC'	0.75 C'	0.94 AB'	-	0.25 C'	0.26 C'	0.56 A'	0.43B'	-

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level according to Duncan´s test

Effect on respiration rate

Data in Table (8) concluded that, after harvest (0 day) the respiration rate increased by increasing calcium chloride levels up to the fourth level 2% and the third level 1% in both seasons, respectively. After 21 days of storage there were no statical differences between all calcium chloride levels in both seasons.

As for potassium silicate levels, after harvest (0 day) in 2021 season the fourth level gave the lowest value of respiration rate with notice that there were no significant differences between this level and the first and the third levels but after 21 days the third level gave the lowest value with notice that there were no significant differences between this level and control whereas in the second season after harvest (0 day) and 21 days the control treatment gave the lowest values of respiration rate and there were no statical differences with this level, the second level and the third level after 21 days only.

The trend of results in the interaction refer to that the combining gave the lowest significant value of respiration rate after harvest (0 day) and 21 days in both seasons was 0.5% $CaCl_2$ + 2%K_2SiO_3 in most cases.

Mohamed *et al.*, (2017) reported that the pre-harvest applications of potassium silicate and $CaCl_2$ coatings especially in combination between them may be due to the low respiration rate and thus delay of the senescence which could enhance resistance to infection and lesion development.

Table 8. Effect of spraying with calcium chloride and potassium silicate on respiration rate after harvest and after twenty-one days at room temperature of avocado cv. Hass trees in 2021 and 2022 seasons

Respiration rate (Co_2 mcg.kg^{-1} hr^{-1})		
Season 2021		
	After harvest (0 day)	**21 days during shelf life at room temperature**

Potassium Silicate / Calcium Chloride	(K_2SiO_3)				Mean	(K_2SiO_3)				Mean
	Control	(1%)	(2%)	(4%)		Control	(1%)	(2%)	(4%)	
($CaCl_2$)$_1$: (Control)	2.6a-c	2.3b-d	1.0d	1.7cd	1.9B	5.3 a	4.3 a-c	4.2 a-c	3.4b-d	4.4A
($CaCl_2$)$_2$: (0.5%)	2.7a-c	2.5a-c	2.2b-d	2.0b-d	2.3B	3.5b-d	4.7 ab	2.6 cd	4.6ab	3.8A
($CaCl_2$)$_3$: (1%)	1.6 cd	3.0a-c	2.5a-c	2.0b-d	2.3B	2.0 d	4.6 ab	2.7 cd	5.2ab	3.6A
($CaCl_2$)$_4$: (2%)	2.7a-c	3.2ab	3.7a	2.3a-d	3.0A	4.1 a-c	3.6 a-d	4.1 a-c	4.2a-c	4.0A
Mean	2.4AB’	2.8A’	2.4AB’	2.0B’	-	3.7AB’	4.3A’	3.5B’	4.4A’	-
	Season 2022									
($CaCl_2$)$_1$: (Control)	1.5g	4.2e	5.3d	6.5bc	4.2D	9.1ab	8.2ab	8.4ab	11.1ab	9.2A
($CaCl_2$)$_2$: (0.5%)	3.0f	6.4c	4.2e	6.1c	4.9C	11.1ab	10.6ab	6.2b	11.4ab	9.8A
($CaCl_2$)$_3$: (1%)	4.2e	4.2e	7.1b	8.8a	6.1A	6.3b	11.1ab	12.7a	13.7a	10.9A
($CaCl_2$)$_4$: (2%)	4.5e	5.2d	7.1b	5.9c	5.7B	9.1ab	9.7ab	11.0ab	10.4ab	10.0A
Mean	3.3D’	4.8C’	5.9B’	6.8A’	-	8.9B’	9.9AB’	9.6AB’	11.6A’	-

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level according to Duncan´s test

Effect on poly phenol oxidase enzyme activity

Data in Table (9) showed that, the third level of calcium chloride gave the lowest values of PPO activity after harvest (0 day) in both seasons but there were no significant differences between this level and the fourth level in 2021 season and also the second level in 2022 season. After 21 days, the lowest activity of PPO gave by the second level of calcium chloride with notice that there were no statical differences between it and the fourth level in first season only but in the second season there were no significant differences between all levels of calcium chloride.

As for the effect of potassium silicate on PPO activity in fruits, after harvest (0 day) the third level gave the lowest significant value of PPO activity in first season but in the second season and also after 21 days in the first season there were no statical differences between levels in most cases whereas in the second season after 21 days the trend of results became clearer while the third level gave the lowest significant value of PPO activity.

Regarding the interaction, in both seasons after harvest (0 day) and after 21days of storage there were no significant differences clear between all combinations in most cases.

These results agreement with **Pereira *et al.*, (2009)** who reported that a reduction in the severity of coffee leaf rust with foliar application of potassium silicate at 35 g/l with didn’t increase in the activities of polyphenol oxidases.

Wu *et al.*, (2023) reported that foliar application with calcium chloride at different concentrations (2.5, 5 and 10 g·L^{-1}) on Chinese cherries fruit reduced polyphenol oxidase activity.

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The explanation for our results lies in the function that potassium and calcium play a role in lowering the formation of ethylene which in turn prevents browning by decreasing the activity of polyphenol oxidase **(Hanumanthaiah *et al.*, 2015** and **Samah and Ghada 2024)**.

Table 9. Effect of spraying with calcium chloride and potassium silicate on poly phenol oxidase enzyme activity after harvest and after twenty-one days at room temperature of avocado cv. Hass trees in 2021 and 2022 seasons

Poly phenol oxidase activity (EU/g F.W.)										
Season 2021										
	After harvest (0 day)					**21 days during shelf life at room temperature**				
Potassium Silicate / **Calcium Chloride**	**(K_2SiO_3)**				**Mean**	**(K_2SiO_3)**				**Mean**
	Control	**(1%)**	**(2%)**	**(4%)**		**Control**	**(1%)**	**(2%)**	**(4%)**	
$(CaCl_2)_1$: (Control)	7.6 d	13.1 d	5.6 d	279.9 a	76.6 B	47.4 b	53.0 b	178.6 a	95.7 b	93.7 A
$(CaCl_2)_2$: (0.5%)	83.9 c	92.4 c	6.0 d	316.6 a	124.7 A	5.7 b	5.6 b	10.7 b	9.1 b	7.8 B
$(CaCl_2)_3$: (1%)	3.2 d	158.7b	25.2 d	4.0 d	47.8 C	28.3 b	232.0 a	6.5 b	20.9 b	71.9 A
$(CaCl_2)_4$: (2%)	14.3 d	164.2b	20.5 d	42.0 cd	60.3 BC	45.7 b	14.4 b	6.2 b	2.0 b	17.1 B
Mean	27.3C'	107.1B'	14.3D'	160.7A'	-	31.8 B'	76.2A'	50.5 AB'	31.9 B'	-
	Season 2022									
$(CaCl_2)_1$: (Control)	8.9 bc	0.0 c	23.5 a	11.0 a-c	10.8A	15.3 ab	7.0 c-e	0 .0 e	12.2 a-c	8.6A
$(CaCl_2)_2$: (0.5%)	5.3 bc	6.3 bc	0.0 c	5.6 bc	4.3B	15.6 a	2.6 de	0.0 e	10.4 a-d	7.2A
$(CaCl_2)_3$: (1%)	0.0 c	6.2 bc	15.2 ab	11.5 a-c	8.2AB	0.0 e	11.9 a-c	6.8 c-e	8.9 a-d	6.9A
$(CaCl_2)_4$: (2%)	15.5 ab	6.7 bc	16.5 ab	11.1 a-c	12.4A	7.5 b-e	6.7 c-e	2.8 de	15.3 ab	8.1A
Mean	7.4 B'	4.8 B'	13.8 A'	9.8 AB'	-	9.6 AB'	7.0 B'	2.4 C'	11.7 A'	-

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level according to Duncan´s test

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Effect of spraying with calcium chloride and potassium silicate on physiological disorders of avocado cv. Hass trees:

Effect on decay index

Data in Table (10) and Fig. (1) showed that, the second and third levels of calcium chloride gave the lowest values of decay index of fruits after 21 days during shelf life at room temperature in both seasons especially in the second season.

Regarding potassium silicate levels, there were no significant differences between all K_2SiO_3 levels in first season only but in the second season the trend of results cleared that the second level gave the lowest value of decay index of avocado fruits with noted that there were no statical differences between the first three levels of potassium silicate.

The results of the interaction cleared that these treatments didn't give decay till 21 days of storage in both seasons were 1% $CaCl_2$ + 0% K_2SiO_3, 2% $CaCl_2$ + 0% K_2SiO_3, 0.5% $CaCl_2$ + 1% K_2SiO_3, 2% $CaCl_2$ + 1% K_2SiO_3, 0 % $CaCl_2$ + 2% K_2SiO_3, 0.5% $CaCl_2$ + 2% K_2SiO_3, 1% $CaCl_2$ + 2% K_2SiO_3 and 0.5% $CaCl_2$ + 2% K_2SiO_3.

In this respect, **Kirkby and Pilbeam (1984)** reveled that during the growth and development stages of fruit, calcium is essential for preventing physiological decay.

Datnoff *et al.*, (1991) mentioned that silicon in calcium silicate is associated with components of cell walls which prevents fungi from breaking down cell walls by enzymatic means.

White and Broadley (2003) found that there were many advantageous effects of calcium pre-harvest application on trees such as maintaining on membranes of cells and also as mentioned **Zhang and Wang, (2019)** that calcium works on delay ripening hence preserving fruit quality.

Additionally, calcium is a crucial component of plant and plays a key role in maintaining and modulating a variety of cell functions by enhancing tissue's development of resistance to enzymes produced by fungi by stabilizing or strengthening the cell wall, increasing membrane stability and maintaining the cell's contact by reducing middle lamella degradation **(Dodd *et al.*, 2010)**.

Lal *et al.*, (2011) sprayed apricot cv. Harcot trees with 1.5% calcium chloride; **Irfan *et al.*, (2013)** sprayed fig (*Ficus carica* L. cv. Poona) trees with 4% calcium chloride and **Ribeiro *et al.*, (2020)** sprayed guava trees with 1% calcium chloride they reported that foliar application with calcium chloride reduced decay index of fruits during storage and extend self-life.

According to **Rab and Haq (2012)** the incidence of blossom end rot in tomato fruits was dramatically reduced by application $CaCl_2$ pre-harvest. In the same trend calcium has processing effects on both signal transmission and ethylene production **(Aghdam *et al.*, 2012)**.

Concerning potassium silicate roles **Fawe *et al.*, (2001)** found that numerous disease-suppressive processes have been linked to silicon for example a plant's resistance to infections may be linked to a particular silicon buildup and polymerization in its cell walls.

Similar results were noticed by **Kaluwa *et al.*, (2010)** and **Stamatakis *et al.*, (2003)** who reported that application of potassium silicate led to keep the fruit firmness.

These results can be explained by **Jamali and Rahemi (2011)** who concluded that silicon in potassium silicate works on increasing shelf life of carnation plants by decrease the ethylene production and also silicon forming complexes with organic compounds in the cell wall hence increasing their resistance in degrading enzymes.

Mditshwa *et al.*, (2013) reported that silicon in potassium silicate inhibited fungal infections therefore, reducing fruit decay. Additionally, **Al-mohammadi and Ismail (2023)** said that silicon serves to preserve the vitality of cell membranes by boosting the activity of antioxidant materials such as phenolic compounds and enzymes.

Furthermore, silicon in potassium silicate promotes cell wall strength to control a variety of plant diseases and this is linked to the physical barrier formed by the element's sedimentation under the cuticle and on the epidermal cell wall as well as the improvement of defense mechanisms like the production of phenolic compounds **(Lopes *et al.*, 2014)**.

As for foliar application of potassium silicate, **Hanumanthaiah *et al.*, (2015)** reported that foliar application of potassium silicate extended the shelf life of banana fruits.

Okba *et al.*, (2021) showed that foliar application with potassium silicate at 0.2% three times on 'Canino' apricot keeping fruit postharvest quality characteristics from sharp decline during cold storage.

Table 10. Effect of spraying with calcium chloride and potassium silicate on decay index after twenty-one days at room temperature of avocado cv. Hass trees in 2021 and 2022 seasons

Decay index (%)					
Season 2021					
21 days during shelf life at room temperature					
Potassium Silicate Calcium Chloride	**(K_2SiO_3)**				**Mean**
	Control	**(1%)**	**(2%)**	**(4%)**	
($CaCl_2$)$_1$: (Control)	75.0 a	75.0 a	0.0 e	50.0 b	68.8 A
($CaCl_2$)$_2$: (0.5%)	16.7 cd	0.0 e	0.0 e	0.0 e	4.2 C
($CaCl_2$)$_3$: (1%)	0.0 e	8.3 de	0.0 e	22.2 c	7.6 BC
($CaCl_2$)$_4$: (2%)	0.0 e	0.0 e	25.0 c	25.0 c	12.5 B
Mean	23.0 A'	20.8 A'	25.0 A'	24.3 A'	-
	Season 2022				
($CaCl_2$)$_1$: (Control)	75.0 a	66.7 a	0.0 e	44.4 b	63.2 A
($CaCl_2$)$_2$: (0.5%)	11.1 de	0.0 e	0.0 e	0.0 e	2.8 C
($CaCl_2$)$_3$: (1%)	0.0 e	5.5 e	0.0 e	19.5 d	6.3 C
($CaCl_2$)$_4$: (2%)	0.0 e	0.0 e	22.2 cd	33.3 bc	13.9 B
Mean	21.5 AB'	18.1 B'	22.2 AB'	24.3 A'	-

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level according to Duncan´s test

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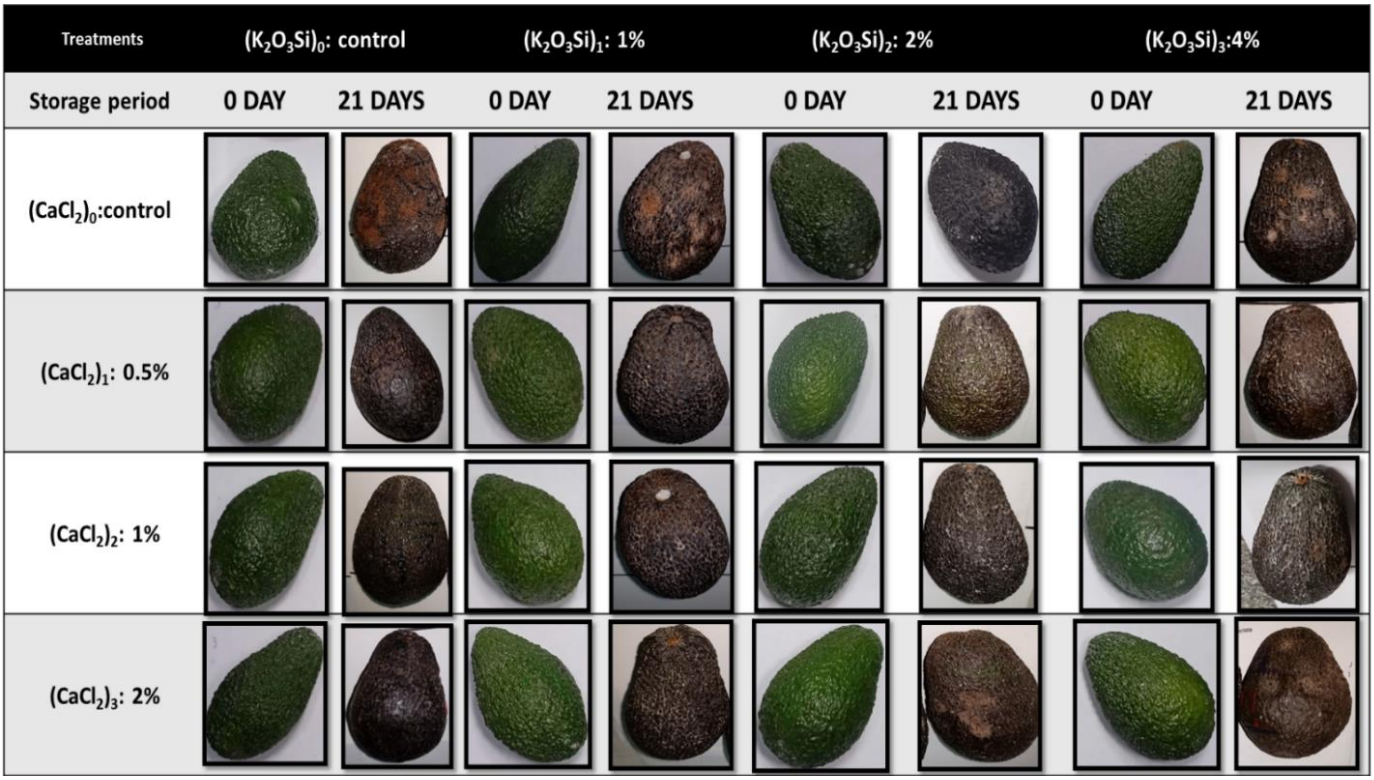

Fig. 1. Effect of spraying with calcium chloride and potassium silicate on decay index after harvest and after twenty-one days at room temperature of avocado cv. Hass trees in 2021 and 2022 seasons

CONCLUSION AND RECOMMENDATION

From the foregoing results, it could be recommended that spraying avocado trees cv. Hass with (0.5%) calcium chloride, (2%) potassium silicate and their combination between them especially and that after 30 and 75 days from fruit set led to enhancing yield, maintaining the quality of fruits for the longest possible period of shelf life (21 days).

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