American-Eurasian J. Agric. & Environ. Sci., 22 (4): 227-237, 2022
ISSN 1818-6769
© IDOSI Publications, 2022
DOI: 10.5829/idosi.aejaes.2022.227.237

Effect of Sodium Selenate and Potassium Silicate on Growth, Productivity, Storability and Economical Evaluation of "Florida Prince" Peach and "Le-Conte" Pear: B. "Le-Conte" Pear

Naglaa H. Shakweer, Shaymmaa N. Sayed and Nevine M. Taha

Deciduous Fruits Department, Horticulture Research Institute,
Agricultural Research Centre, Giza, Egypt

Abstract: Sodium selenate (SS) at 2, 4 or 8 ppm and potassium silicate (PS) at 250, 500 or 1000 ppm were sprayed 4 times on "Le-Conte" pear trees during 2020 and 2021 seasons (at bud swelling, at fruit set, 1 month after fruit set and 1 month before harvest). The present results showed that, all concentrations of (SS) and (PS) markedly increased fruit set percentage, fruit yield, relatively increase of number of fruits / tree, fruit yield, yield efficiency, fruit shape index, fruit weight and size, TSS, total sugars, leaf content of N, P, K, S and Si and grower net income compared with control. On the other hand, the conducted treatments decreased fruit drop percentage, fruit firmness and juice acidity. The differences were mostly significant. Deal with storability, the conducted treatments supported pear fruits during cold storage at 0 ± 1 °C and 90 ± 5 RH for 2 months where they increased TSS and decreased fruit weight loss specially 8 ppm (SS) and 1000 ppm (PS), fruit firmness (from 22.0 at harvest to 10.0 lb/inch^2 after storage) and acidity (from 0.437 at harvest to 0.351 % after storage) to the suitable rate. It is noticeable that, increasing the dose of (SS) or (PS) clearly gave positive effect on pear fruits. So we can recommend pear growers to spray their trees with 8 ppm sodium selenate or 1000 ppm potassium silicate 4 times at bud swelling, at fruit set, 1 month after fruit set and 1 month before harvest to gain many profits of yield, fruit quality, storability, net income (for about 63560 or 58120 LE compared to 23320 LE / fed. For control).

Key words: Pear · Selenium · Silicon · Fruit quality · Economical evaluation · Storability

INTRODUCTION

"Le-Conte" pear is a hybrid between *Pyrus communis* and *P. serotina* and considered the main pear cultivar grown in Egypt. Improving yield and fruit quality without adversely affecting the environment is a major goal of horticulturists and could be achieved by using some stimulants in crop production . Stimulants may contain microorganisms, natural products or micronutrients [1].

Micronutrients are usually used singly or in various combinations. Spraying pear and peach trees by chelated microelements increased the elements content in leaves [2-5].

Selenium (Se) is an essential micronutrient due to its anticarcinogenic properties and positive influence on human immune system. Fortification of some fruits based on their rates of consumption and availability all year round appears to be an effective way to supplement Se in the human diet [6]. Currently, the effect of selenium on the physiology of the fruit have become a hotspot for the researchers [3, 4]. Se is rapidly converted into organic compounds in the roots whereas Se is delivered immediately to the xylem and translocated to leaves and metabolized in plastids via a sulfur assimilation pathway [7]. Kleine-Kalmer *et al.* [8] showed that, Se fertilization can promote the formation of valuable plant substances such as vitamin C and phenolic compounds in apple, enhance plant productivity and fruit quality (TSS, sugars, firmness and starch accumulation), hence improved their shelf life and fruit taste [9]. Also, Se treatments resulted in better pollen germination Lucas *et al*. [10], improved photosynthesis and protected photosystem in pear, grape and peach Feng *et al*. [11], inhibited ethylene production during the pear storage period Galic *et al*. [12],

Corresponding Author: Naglaa H. Shakweer, Deciduous Fruits Department, Horticulture Research Institute, Agricultural Research Centre, Giza, Egypt

subsequently delay fruit ripening, senescence and postharvest losses as well as played an effective role in glutathione peroxidase (as a cofactor), which is the only known seleno-enzyme in plants that contains this trace element [3].

Moreover, potassium silicate (K_2SiO_3) is a source of soluble potassium and silica, so it could be used as amendment in agricultural production, since it benefits enhancing tree yield, fruit volume, color, shelf life and fruit quality [13, 14]. In this line, Si application increased both phenolic and flavonoid antioxidants of fruit during cold storage so that, maintained cell membrane integrity [15]. In addition, Nasar *et al.* [16] showed that, "Pioneer" plum treated by 500 and 2500 ppm $K_2\ Si\ O_3$ and stored at 0°C for 28 days cleared less cell permeability due to the beneficial effect of Si during enhancing photosynthetic activity, improving K/Na ratio, stimulate the activity of some enzymes as xylanase, cellulase and polygalacturonase as well as nutrient and water uptake, plant pigments and all cell division [17].

The aim of this work is to evaluate the potential effects of foliar application of potassium silicate and sodium selenate on fruit set, drop, yield, fruit quality and storability of "Le-Conte" pear fruits during cold storage for two months at 0°C ± 1 and 90 ± 5 relative humidity (RH).

MATERIAL AND METHODS

The present investigation was carried out during two successive seasons (2020 and 2021) on 10 years old "Le-Conte" pear trees grafted on *Pyrus Communis* rootstock and grown on sandy soil at a private farm at km 86 of the Desert Road of Cairo Alex. The selected trees were nearly uniform in growth vigor and spaced at (4 x 5m) under drip irrigation system as well as subjected to the same cultural practices. Twenty one trees were arranged in a randomized complete block design the experiment included seven treatments with three replicate per treatments (one tree/replicate) . The trees were sprayed 4 times at: bud swelling (8 - 15 Feb.), at fruit set (8 - 17 March), one month after fruit set (23 Apr.) and one month before harvest time (17 of Jun.) by the following treatments:

- Sodium selenate ($Na_2\ Se\ O_4$) at 2 ppm (20 ml / 10 liters).
- Sodium selenate ($Na_2\ Se\ O_4$) at 4 ppm (40 ml / 10 liters).
- Sodium selenate ($Na_2\ Se\ O_4$) at 8 ppm (80 ml / 10 liters).
- Potassium silicate ($K_2\ Si\ O_3$) at 250 ppm (12.5 ml / 10 liters.
- Potassium silicate ($K_2\ Si\ O_3$) at 500 ppm (25 ml / 10 liters.
- Potassium silicate ($K_2\ Si\ O_3$) at 1000 ppm (50 ml / 10 liters.
- Control treatment sprayed with tap water.

The Following Data Were Recorded:

Fruit Set (%): Four flowering branches per trees in the four directions were labeled to calculate fruit set percentage, using the following equation: Number of fruit lets × 100/Number of opened flowers.

Fruit Drop (%): The remained fruits on marked branches were counted and recorded periodically till harvest to calculate fruit drop percentage, as the following equation:

Number of remained fruits × 100/ Number of fruit lets.

Number of Fruits / Tree: At harvest time (1 - 15 Aug.), number of fruits per tree were counted and recorded.

Fruit Yield (kg / tree): At harvest time the number of fruits per tree were counted and multiplied by fruit weight to estimate yield as kg / tree.

Relatively Increase of Fruit Yield (%): Was estimated from the equation: Relatively increase of fruit yield (%) = (fruit yield of treatment – fruit yield of control) x 100 / fruit yield of control.

Yield efficiency (kg / m^2): = (The yield of treatment –The yield of control) x100/ the yield of control.

Fruit Physical Characteristics: At harvest, sixty fruits / treatment (3 replicates) were randomly sampled to determine the following fruit physical characteristics:

Fruit Shape Index: Fruit length / fruit diameter width.

Fruit Weight (g): Determined by weighing a sample of fruits from each replicate and the mean fruit weight was calculated.

Fruit Size (cm^3): Using water displace meter method.

Firmness (Lb. / $Inch^2$): It was determined from the two sides of fruits by using a pressure tester (Advance Force Gorge RH13, UK).

Fruit Chemical Characteristics

Total Soluble Solids (TSS %): Was determined in fruit juice by Abbe hand refractometer.

Total Acidity (TA%): Was determined in fruit juice as malic acid according to A.O.A.C. [18].

Total Sugars (%): Was determined according to Tasun *et al.* [19].

Leaf Mineral Content: In mid Aug. of both seasons, fifty mature mid shoot leaves / tree were sampled, washed with tap water then with distilled water and oven dried at 50°C to constant weigh, ground, digested with sulphoric acid and hydrogen peroxide for the determination of N, P, K. Nitrogen percentage was estimated by micro-Kjeldahl Gunning method A.O.A.C. [18]. Phosphorus percentage was assessed colorimetically by hydroquinone method Faster and Cornelia [20]. Potassium percentage was estimated by flam photometer as Jackson [21]. Also, Silicon (mg/Kg), Selenium (mg/Kg) and Sulfate (%) elements were analyzed at Soil and Water Research Institute as described by Soltanpour and Schwab [22].

Economical Evaluation of the Tested Treatments: The effect of the studied treatments on economical evaluation were illustrated as 5600 liters/ fed. of 4 sprays / season. Chemicals, labors and constant costs were assessed for control and treatments. Constant cost includes (electricity for irrigation, fertilizers, pesticides, pruning and labors).

Yield price / ton: Was estimated by multiple yield of treatment (ton / fed.) x farm gate price (8000 LE / ton).

Total cost: = Chemicals +Labors cost + Constant cost.
Net income / fed. (LE): Was assessed as yield price per ton (LE) – total cost per fed. (LE).

Storability Study

Fruit Weight Loss (%): Was assessed as the equation = (Fruit weight at harvest - Fruit weight after one or two months x 100) / Fruit weight after one or two months.

Fruit Weight Loss (%): Was assessed as the equation = (Fruit weight at harvest - Fruit weight after one or two months x 100) / Fruit weight at harvest.

- Fruit firmness (Lb/inch^2).
- Juice TSS%.
- Juice acidity (%).

Statistical Analysis: All obtained data of both seasons were statistically analyzed (except economical evaluation) according to Snedecor and Cochran [23]. It is noticeable that, tables (1-5) have one factor (treatments effect) while tables (7-10) have two factors: Factor A (Storage periods) and Factor B (Treatments effect). The means and interaction effect between treatments were differentiated using LSD test at $p \leq 0.5$.

RESULTS

Effect of Sodium Selenate and Potassium Silicate on Fruiting

Fruit Set (%): Table (1) showed that, all studied treatments significantly increased the fruit set percentage compared to the control during the two studied seasons. Furthermore, increasing sodium selenite (SS) or potassium silicate (PS) dose was parallel to increase fruit set percentage. So, increasing SS from 2 to 4 and to 8 ppm significantly increased fruit set from (9.8 to 11.17 and 13.930 %) in the 1st season and from (10.3 to 12.43 and 13.7 %) in the 2nd season respectively. While, increasing PS from 250 to 500 and 1000 ppm significantly increased fruit set from (9.5 to 10.6 and 13.2 %) in 2020 season and from (10.4 to 12.3 and 14.2 %) during 2021 season respectively.

Fruit Drop (%): Control treatment recorded the highest fruit drop percentage (23.0 and 23.33 %) during the two tested seasons respectively (Table 1). On the other hand, all tested treatments decreased fruit drop percentages than the control. Also, it is noticeable that, higher SS or PS dose was accompanied by less fruit drop percentages in the two studied seasons and SS doses were more effective than PS ones.

Number of Fruits / Tree: Sodium selenate (SS) and potassium silicate (PS) have significant effect on increasing number of fruits per tree than control during two seasons of study. In addition, increasing SS or PS concentrations significantly induced higher number of fruits per tree than the other treatments. In this concern, SS treatments were more effective than PS ones (Table 1).

Fruit Yield (Kg / Tree): Table (1) and Fig. (2) revealed that, the present treatments significantly increased fruit yield more than control. The highest SS concentration (8 ppm) induced the highest fruit yield (54.2 and 44.9 kg / tree) as well as the highest PS concentration (1000 ppm) also caused higher fruit yield (39.2 and 47.0 kg / tree) than the control and other treatments during 2020 and 2021 seasons respectively.

Table 1: Effect of sodium selenate and potassium silicate on fruit set (%), fruit drop (%), number of fruits / tree and fruit yield (kg/tree) of "Le-Conte" pear during 2020 and 2021 seasons

	Fruit set (%)		Fruit drop (%)		Number of fruits / tree		Fruit yield (kg/tree)	
Treatments	2020	2021	2020	2021	2020	2021	2020	2021
Sodium selenate at 2 ppm	9.8 b	10.3 c	18.1 b	16.6 a	225.3 cd	197.0 c	20.8 d	22.b c
Sodium selenate at 4 ppm	11.2 b	12.4 ab	15.8 c	15.2 a	235.3 cd	270.3 b	24.1 d	33.6 b
Sodium selenate at 8 ppm	13.9 a	13.7 a	14.0 c	13.0 a	517.7 a	338.3 a	54.2 a	44.9 a
Potassium silicate at 250 ppm	9.5 b	10.4 c	22.3 a	21.0 a	250.3 c	217.7 c	31.0 c	24.9 c
Potassium silicate at 500 ppm	10.6 b	12.3 ab	20.0 ab	17.7 a	263.0 c	275.0 b	33.1 c	37.2 b
Potassium silicate at 1000 ppm	13.2 a	14.2 a	18.7 b	16.7 a	310.3 b	325.0 a	39.2 b	47.0 a
Control	7.2 c	5.4 d	23.0 a	23.3 a	185.3 e	200.0 c	15.4 e	16.1 d

*Mean followed by the same letter (s) within the same column was not significantly different ($P \leq 0.05$; LSD test)

Table 2: Effect of sodium selenate and potassium silicate on relatively increase of fruit yield and yield efficiency (kg/m^2) of "Le-Conte" pear during 2020 and 2021 seasons

	Relatively increase of fruit yield (%)		Yield efficiency (kg/m^2)	
Treatments	2020	2021	2020	2021
Sodium selenate at 2 ppm	38.6 cd	38.9 c	1.04 d	1.14 c
Sodium selenate at 4 ppm	62.1 c	112.1 b	1.21 d	1.68 b
Sodium selenate at 8 ppm	262.3 a	176.1 a	2.71 a	2.25 a
Potassium silicate at 250 ppm	103.9 bc	55.0 c	1.55 c	1.25 c
Potassium silicate at 500 ppm	133.6 b	137.7 b	1.66 c	1.86 b
Potassium silicate at 1000 ppm	169.3 b	195.5 a	1.97 b	2.35 a
Control	-	-	0.77 e	0.81 d

*Mean followed by the same letter (s) within the same column was not significantly different ($P \leq 0.05$; LSD test)

Table 3: Effect of sodium selenate and potassium silicate on fruit shape index (Length/Width), fruit weight (g), fruit size (cm^3) and fruit firmness (Lb/inch^2) of "Le-Conte" pear during 2020 and 2021 seasons

	Fruit shape index (Length/Width)		Fruit weight (g)		Fruit size (cm^3)		Fruit firmness (Lb/inch^2)	
Treatments	2020	2021	2020	2021	2020	2021	2020	2021
Sodium selenate at 2 ppm	1.19 d	1.15 c	97.8 b	114.8 c	127.5 b	164.6 d	22.6 b	23.0 a
Sodium selenate at 4 ppm	1.25 b	1.15 c	102.0 b	127.8 ab	194.2 a	205.4 a	22.3 b	21.8 abc
Sodium selenate at 8 ppm	1.30 a	1.29 a	104.9 b	133.9 ab	194.2 a	209.2 a	21.1 d	20.5 c
Potassium silicate at 250 ppm	1.19 d	1.13 c	124.0 a	120.0 abc	198.2 a	194.2 abc	22.8 b	22.8 a
Potassium silicate at 500 ppm	1.18 d	1.20 b	124.6 a	135.6 a	199.2 a	199.6 ab	22.3 b	22.5 ab
Potassium silicate at 1000 ppm	1.22 c	1.28 a	125.9 a	142.9 a	202.2 a	208.8 a	22.0 bc	22.4 ab
Control	1.29 a	1.15 c	82.9 c	80.4 d	116.3 c	157.1 d	24.9 a	23.3 a

*Mean followed by the same letter (s) within the same column was not significantly different ($P \leq 0.05$; LSD test)

Relatively Increase of Fruit Yield: Relatively increase of fruit yield than control was similar to the increase of SS from 2 to 4 and 8 ppm as well as the increase of PS dosage from 250 to 500 and 1000 ppm (Table 2).

Yield Efficiency (kg / m^2): Control treatment showed the least fruit yield efficiency (0.77 and 0.81) (Table 2). Increasing the dosage of SS or PS significantly increased fruit yield efficiency where 8 ppm SS resulted in (2.71 and 2.247 kg) fruits per m^2 of planting distance as well as 1000 ppm PS caused (1.97 and 2.35 kg) per m^2 of planting distance more than the other treatments in two studied seasons respectively.

Effect of Sodium Selenate and Potassium Silicate on Fruit Physical Characteristics

Fruit Shape Index (Length / Width): Increasing SS or PS dosage increased fruit shape index. That is mean pear fruit have longer length than width. Hence, fruit shape index can be concept as a marker to the present treatments effects (Table 3 and Fig. 1).

Fruit Weight (g) and Size (cm^3): The present treatments significantly caused heavier and larger pear fruits than control. Also, increasing SS or PS dosage get more fruit weight and size specially PS treatments (Table 3). On the other hand, control treatments induced less fruit weight and size in the two studied seasons respectively (Fig. 1).

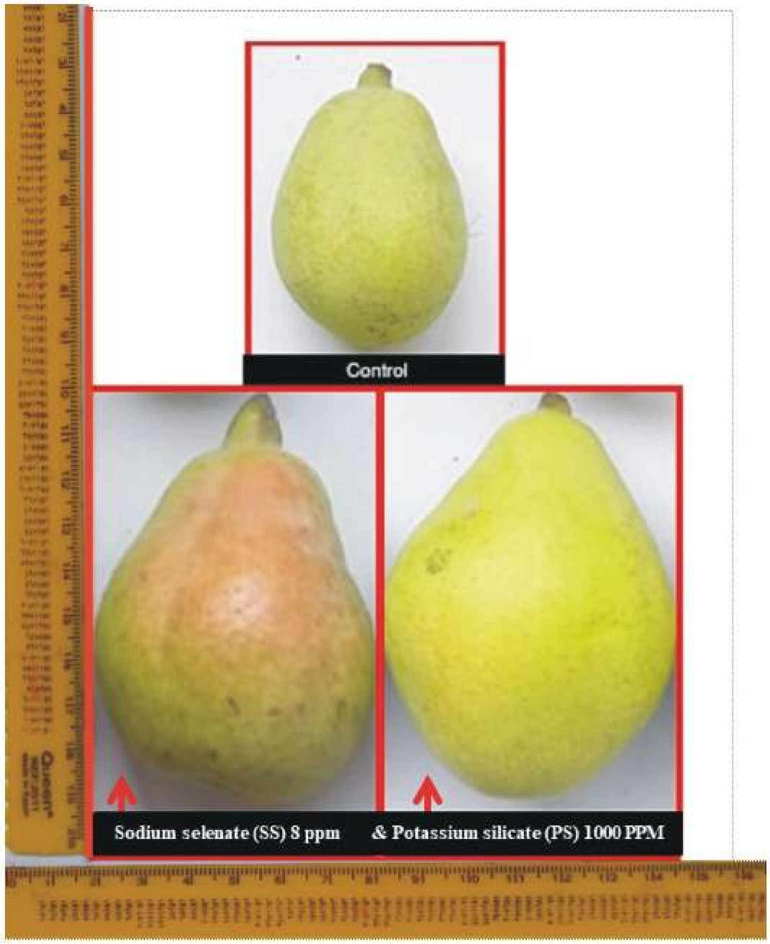


Fig. 1: Effect of Sodium Selenate and Potassium Silicate on fruit of "Le-Conte" pear

Fruit Firmness (Lb / inch^2): Table (3) showed that, control treatment get higher fruit firmness than both of SS or PS concentration. Meanwhile, higher SS or PS dosages get less fruit firmness at harvest time (21.1 and 20.5) and (22.0 and 22.4 lb/inch^2).

Effect of Sodium Selenate and Potassium Silicate on Fruit Chemical Characteristics

Fruit Juice TSS (%) and Acidity (%): It is noticeable that, control treatment clearly induced less TSS and higher acidity in pear fruit juice in the two studied seasons than the present treatments respectively (Table 4). Meanwhile, increasing SS or PS dosage markedly increased TSS while decreased acidity juice content than control and lower concentration. However, higher TSS and lower acidity means better fruit taste.

Total Sugars (%): Table (4) clearly showed that sodium selenate (SS) and potassium silicate (PS) treatments increased total sugars in the juice of pear fruits than control. It is also noticeable that total sugars markedly increased in the 2nd seasons than the 1st one may be as a result of the agreement effect of the present treatments, as well as sodium selenate was more effective than potassium silicate.

Effect of Sodium Selenate and Potassium Silicate on Leaf Mineral Content: Table (5) showed that, the present treatments effectively increased N, P and K concentrations than control respectively. Also, increasing the dosage of sodium selenate (SS) was reflected in higher N, P, K, leaf content than the other treatments as well as potassium silicate PS respectively. Meanwhile, increasing the dosage of SS markedly increased sulphur leaf content while increasing the dosage of PS clearly increased silicon leaf content. Adversity, the analysis sets could not assess the differences of selenium element in the present samples.

Table 4: Effect of sodium selenate and potassium silicate on TSS (%), acidity (%) and total sugars (%) of "Le-Conte" pear fruit during 2020 and 2021 seasons

	TSS (%)		Acidity (%)		Total sugars (%)	
Treatments	2020	2021	2020	2021	2020	2021
Sodium selenate at 2 ppm	12.8 b	12.7 abc	0.395 b	0.338 a	5.255 d	6.190 c
Sodium selenate at 4 ppm	13, 0 b	12.8 ab	0.376 bc	0.315 ab	5.640 c	6.225 c
Sodium selenate at 8 ppm	13.4 a	12.9 a	0.372 bc	0.272 d	6.743 a	6.891 a
Potassium silicate at 250 ppm	12, 3 c	13.0 a	0.403 b	0.314 ab	4.674 f	5.236 e
Potassium silicate at 500 ppm	13, 0 b	13.0 a	0.307 d	0.288 abcd	4.929 e	5.972 d
Potassium silicate at 1000 ppm	13.3 a	13.0 a	0.300 d	0.203 d	6.363 b	6.555 b
Control	11.0 d	12.0 d	0.432 a	0.360 a	3.390 g	4.803 f

*Mean followed by the same letter (s) within the same column was not significantly different ($P \leq 0.05$; LSD test)

Table 5: Effect of sodium selenate and potassium silicate on leaf mineral content of "Le-Conte" pear during 2021 season

Treatments	N (%)	P (%)	K (%)	S (%)	Se (mg/kg)	Si (mg/kg)
Sodium selenate at 2 ppm	2.15 b	0.17 b	1.96 c	0.10 b	< 0.2 a	20.0 c
Sodium selenate at 4 ppm	2.4 b	0.191 ab	2.03 bc	0.11 ab	< 0.2 a	20.0 c
Sodium selenate at 8 ppm	3.09 a	0.227 ab	2.29 ab	0.13 a	< 0.2 a	20.0 c
Potassium silicate at 250 ppm	2.2 b	0.174 b	2.09 bc	0.10 b	< 0.2 a	23.0 b
Potassium silicate at 500 ppm	2.47 ab	0.221 ab	2.29 ab	0.10 b	< 0.2 a	28.3 a
Potassium silicate at 1000 ppm	2.53 ab	0.273 a	2.41 a	0.10 b	< 0.2 a	28.9 a
Control	1.88 b	0.168 b	1.88 c	0.10 b	< 0.2 a	20.0 c

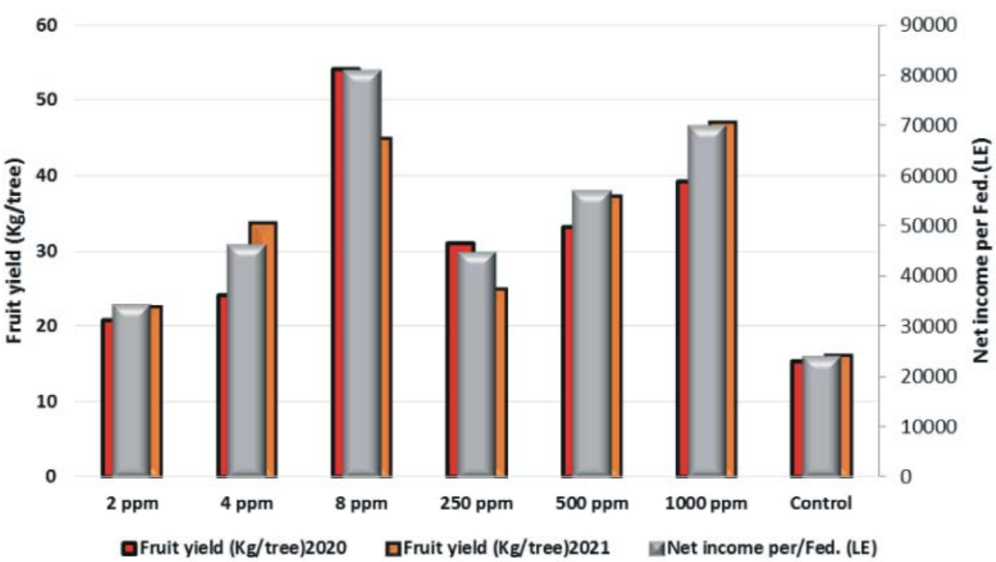
*Mean followed by the same letter (s) within the same column was not significantly different ($P \leq 0.05$; LSD test)

Table 6: Effect of sodium selenate and potassium silicate spray on economical evaluation of "Le-Conte" pear fruit during 2021 season

Treatments	Spraying rate /fed.(L)	No. of application/fed	Chemicals cost/fed. (LE)	Labors cost/fed (LE)	Chemicals + labors cost/fed (LE)	Constant cost (LE/fed)	Total cost / fed (LE)	Fruit yield (ton / fed.)	Farm gate price/ton (LE)	Yield price / ton (LE)	Net income (LE)
Sodium selenate at 2 ppm	5600	4	4200	500	4700	2500	7200	4.58	8000	36640	29440
Sodium selenate at 4 ppm	5600	4	8400	500	8900	2500	11400	6.08	8000	48640	37240
Sodium selenate at 8 ppm	5600	4	16800	500	17300	2500	19800	10.4	8000	83360	63560
Potassium silicate at 250 ppm	5600	4	2800	500	3300	2500	5800	5.87	8000	46960	41160
Potassium silicate at 500 ppm	5600	4	5800	500	6100	2500	8600	7.41	8000	59280	50680
Potassium silicate at 1000 ppm	5600	4	11200	500	11700	2500	14200	9.04	8000	72320	58120
Control	5600	4		500	500	2500	3000	3.29	8000	26320	23320

*Constant cost includes: Electricity for irrigation, fertilizers, pesticides, pruning and labors.

**Yield is the mean of the two studied seasons (ton / fed). There are 210 trees / fed.



*2, 4, 8 ppm Sodium selenite and 250, 500, 1000 ppm Potassium silicate

Fig. 2: Effect of 2, 4, 8 ppm SS and 250, 500, 1000 ppm PS on "Le-Conte" Pear fruit yield and net income per Fed

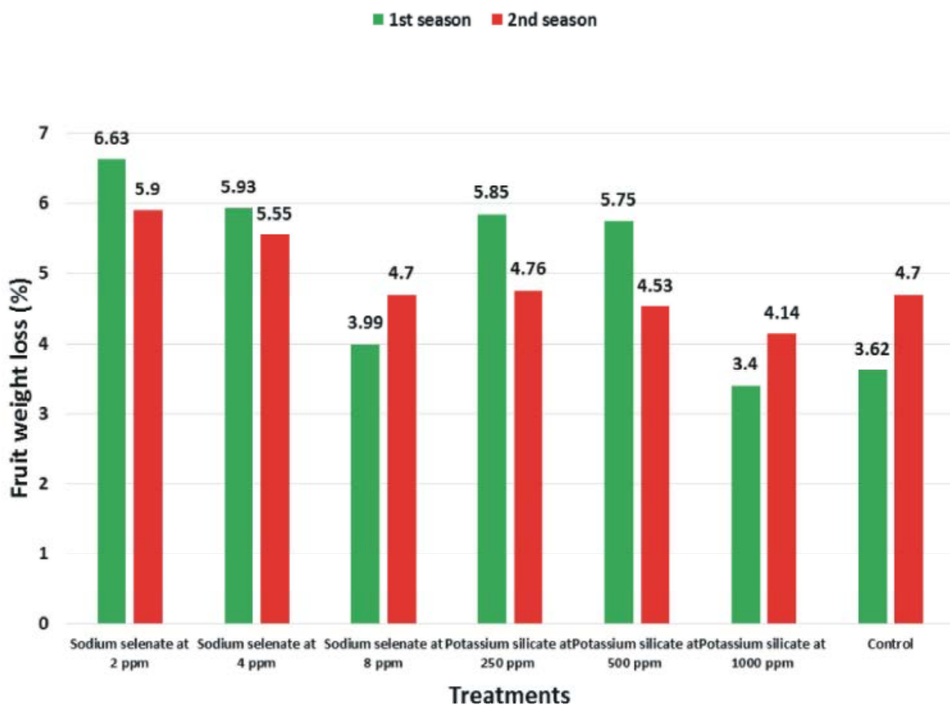


Fig. 3: Effect of 2, 4, 8 ppm SS and 250, 500, 1000 ppm PS on the average of fruit weight loss (%) of "Le-Conte" pear during cold storage for two months in 2020 and 2021 seasons

Effect of Sodium Selenate and Potassium Silicate Spray on Economical Evaluation: Table (6) showed that, spray rate was 5600 liter per fed. for 4 applications during each season. Labor cost per fed. was 500 LE while chemicals cost differed with treatments. Constant cost includes: electricity for irrigation, fertilizers, pesticides, pruning and labors which estimated by 2500 LE / fed. fruit yield differed with treatments. Assess farm gate price with 8000 LE per ton get yield price so get the net income which showed that, all studied treatments increased the net income than control. Also increasing the dosage of both sodium selenate (SS) and potassium silicate (PS) clearly increased the net income where 8 ppm SS get 63560 LE while 1000 ppm PS get 58120 LE than the other treatments and control . Hence, sodium selenate was more effective for net income than potassium silicate (Fig. 2).

Effect of Sodium Selenate and Potassium Silicate on "Le-Conte" Pear Fruit During Cold Storage

Fruit Weight Loss (%): The present storage of pear fruits at 0°C ± 1 and 90 ± 5 (RH) for two months are clearly affected by sodium selenite (SS) and potassium silicate (PS) treatments (Fig. 3). However, higher dose of SS or PS led to lower weight loss percentages in the two studied seasons respectively than less dose concentration. Meanwhile, higher fruit quality (fruit weight, size, TSS and total sugars) resulted from higher concentrations of SS and PS (Tables 3, 4) led to lower weight loss percentages in pear fruits comparable with lower dose of SS and PS. It is noticeable that, control treatment has less weight loss may be because of less fruit size with higher firmness.

Fruit Firmness (Lb / Inch^2): Sodium selenate at 2, 4 or 8 ppm and potassium silicate at 250, 500 or 1000 ppm clearly maintained pear fruit firmness than control throughout cold storage (Table 7). However, sodium selenite at 2 ppm in 2020 season as well as potassium silicate at 250 ppm in 2021 season were the most effective than the other concentration. Fruit firmness significantly decreased throughout cold storage from (22.6 to 19.1 and 7.8 Lb / inch^2) in the 1st season and from (22.4 to 18.8 and 8.2 Lb / inch^2) in the 2nd season respectively. As for the interaction effect, after 2 months of cold storage the present treatments supported pear fruit firmness than control.

Juice TSS (%): The present data (Table 8) showed that, TSS of pear juice significantly increased with increasing the period of cold storage from harvest (Zero time) to after one month as well as after two months

Table 7: Effect of sodium selenate and potassium silicate on fruit firmness (Lb/inch^2) of "Le-Conte" pear during cold storage in 2020 and 2021 seasons

	Storage period (Month)							
	0 Time (at harvest)		1 Month		2 Months		Mean (A)	
Treatments	2020	2021	2020	2021	2020	2021	2020	2021
Sodium selenate at 2 ppm	22.6 bc	20.7 b-d	21.8 bc	19.7 de	8.6 g	7.8 g	17.7 A	16.1 C
Sodium selenate at 4 ppm	22.3 bc	23.0 ab	19.1 d-f	18.5 ef	0.0 g	7.7 g	16.8 AB	16.4 B
Sodium selenate at 8 ppm	21.1 bd	21.8 a-c	19.3 d-f	18.1 ef	8.3 g	8.0 g	16.2 B	16.0 B
Potassium silicate at 250 ppm	22.8 b	22.5 ab	20.2 c-e	20.8 b-d	7.1 gh	8.2 g	16.7 AB	17.2 A
Potassium silicate at 500 ppm	22.3 bc	22.4 ab	17.9 ef	19.8 c-e	8.2 gh	8.8 g	16.1 B	17.0 AB
Potassium silicate at 1000 ppm	22.0 bc	22.8 ab	18.2 ef	18.0 f	7.5 gh	9.0 g	10.0 B	16.6 BC
Control	25.0 a	23.5 a	17.2 f	16.7 f	5.9 h	7.7 g	15.9 B	16.0 C
Mean (B)	22.6 A	22.4 A	19.1 B	18.8 B	7.8 C	8.2 C	-	-

*Mean followed by the same letter (s) within the same column was not significantly different ($P \leq 0.05$; LSD test).

** Factor A (Storage periods) and Factor B (Treatments effect).

Table 8: Effect of sodium selenate and potassium silicate on TSS (%) of "Le-Conte" pear juice during cold storage in 2020 and 2021 seasons

	Storage period (Month)							
	0 Time (at harvest)		1 Month		2 Months		Mean (A)	
Treatments	2020	2021	2020	2021	2020	2021	2020	2021
Sodium selenate at 2 ppm (A)	12.4 c	12.7 f	13.7 b	13.7 de	14.8 a	14.7 bc	13.6 B	13.7 C
Sodium selenate at 4 ppm	12.7 c	12.8 f	13.8 b	13.8 de	14.8 a	14.8 a-c	13.8 AB	13.8 A-C
Sodium selenate at 8 ppm	12.8 c	12.9 f	13.8 b	13.8 de	14.9 a	14.9 a-c	13.8 AB	13.9 AB
Potassium silicate at 250 ppm	12.8 c	13.0 f	13.8 b	13.5 e	14.8 a	14.5 c	13.8 AB	13.7 C
Potassium silicate at 500 ppm	12.9 c	13.0 f	13.9 b	14.0 d	15.0 a	15.0 ab	13.9 AB	14.0 AB
Potassium silicate at 1000 ppm	12.9 c	13.1 f	14.1 b	14.1 d	15.0 a	15.1 a	14.0 A	14.1 A
Control	11.1 e	11.0 b	11.9 d	12.2 g	12.8 a	13.1 f	11.9 c	12.1 D
Mean (B)	12.5 C	12.6 C	13.6 B	13.6 B	14.6 A	14.6 A	-	-

*Mean followed by the same letter (s) within the same column was not significantly different ($P \leq 0.05$; LSD test)

** Factor A (Storage periods) and Factor B (Treatments effect).

Table 9: Effect of sodium selenate and potassium silicate on fruit juice acidity (%) of "Le-Conte" pear during cold storage in 2020 and 2021 seasons

	Storage period (Month)							
	0 Time (at harvest)		1 Month		2 Months		Mean (A)	
Treatments	2020	2021	2020	2021	2020	2021	2020	2021
Sodium selenate at 2 ppm (A)	0.404 a-e	0.36 a	0.362 b-g	0.28 bc	0.22 i	0.27 bc	0.329 AB	0.303 A
Sodium selenate at 4 ppm	0.426 a-d	0.30 bc	0.343 c-g	0.27 bc	0.237 i	0.29 bc	0.335 AB	0.287 A
Sodium selenate at 8 ppm	0.449 a	0.33 ab	0.339 d-g	0.26 bc	0.29 f-i	0.247 c	0.359 A	0.279 AB
Potassium silicate at 250 ppm	0.421 a-c	0.36 a	0.341 c-g	0.257 c	0.22 i	0.277 bc	0.327 AB	0.299 A
Potassium silicate at 500 ppm	0.414 a-e	0.28 bc	0.336 d-g	0.29 bc	0.277 g-i	0.27 b-e	0.342 AB	0.281 AB
Potassium silicate at 1000 ppm	0.437 ab	0.36 a	0.366 a-f	0.294 bc	0.25 hi	0.28 bc	0.351 AB	0.311 A
Control	0.36 b-g	0.267 bc	0.329 e-h	0.257 c	0.233 i	0.237 bc	0.307 B	0.254 B
Mean (B)	0.416 A	0.322 A	0.345 B	0.273 B	0.247 C	0.267 B	-	-

*Mean followed by the same letter (s) within the same column was not significantly different ($P \leq 0.05$; LSD test)

** Factor A (Storage periods) and Factor B (Treatments effect)

during 2020 and 2021 seasons. It is also noticeable that, increasing the dose of sodium selenate to 8 ppm increased TSS percentages as well as increasing the dose of potassium silicate to 1000 ppm compared with control and the other treatments. However, potassium silicate at 1000 ppm after two months of cold storage recorded the highest TSS interaction during the two studied seasons.

Juice Acidity (%): The present results (Table 9) showed that, sodium selenate (SS) at 8 ppm induced higher acidity percentage in the 1st season and lower percentage in the 2nd season. Also, potassium silicate (PS) at 1000 ppm resulted in higher acidity percentages in the two studied seasons compared with control and the other concentration. On the other hand, acidity percentages significantly decreased with increasing storage period from harvest (Zero time) to one month and to two months of cold storage, this is clear the effectiveness of cold storage of pear fruits. As for the interaction effect, SS at 2 ppm and PS at 250 ppm caused the lowest acidity percentage after 2 months of cold storage. It is noticeable that, acidity percentage clearly were lower though the 2nd season than the 1st season may be as a result of the aggregate effect of the present treatments. Meanwhile, increasing SS or PS dosage markedly increased TSS while decreased acidity juice content. The balance of TSS and acidity in fruits improves the fruit taste [9].

DISCUSSION

The present study aimed to test the effect of sodium selenate (SS) at 2, 4 or 8 ppm as well as potassium silicate (PS) at 250, 500 or 1000 ppm spray for 4 times at: bud swelling, fruit set, one month after fruit set and one month before harvest time. We recorded the present data: fruit set percentage, fruit drop percentage, number of fruits per tree, fruit yield (kg / tree), relatively increase of fruit yield against control (%), fruit yield efficiency (kg / m^2), fruit physical characteristics (shape index, fruit weight, size and firmness), fruit chemical characteristics (TSS, acidity and total sugars), storability study for 1 or 2 months at 0°C ± 1 and 90 ± 5 (RH) to study fruit weight loss (%), firmness, TSS and acidity, leaf chemical analysis (N, P, K, S, Se and Si) as well as economical evaluation by estimate farm gate price and net income against total costs.

The present results illustrated that, fruit set percentage, fruit yield, fruit firmness, fruit shape index and TSS of fruit juice were about similar with both sodium selenate (SS) and potassium silicate (PS). However, SS treatments markedly increased number of fruits per tree and lowered fruit drop percentage. On the other hand, PS treatments clearly increased: relatively increase of fruit yield, fruit yield efficiency, fruit weight and size, net income per fed. while reduced fruit juice acidity. Meanwhile, increasing the dosage of SS or PS increased fruit set percentage, fruit yield, relatively increase in fruit yield, fruit yield efficiency, number of fruit per tree, fruit weight and size, fruit shape index, TSS and the net income per fed. while decreased fruit drop percentage, fruit firmness and fruit juice acidity. Moreover, 8 ppm of SS and 1000 ppm of PS positively increased pear fruit quality subsequently led to better storability feature (less fruit weight loss with higher TSS). However, Liu *et al.* [24] showed that, spraying sodium selenate (SS) at 5 mg^{-1} increased the content of K, S and Se and improved the storage properties of pear fruit where it promote the absorption of NPK in the leaves. Also, Kleine-Kalmer *et al.* [8] stated that, fertilization with Se can promote the formation of valuables plant substances such as some phenolic compounds in apple, enhance plant productivity and fruit quality (firmness, TSS, sugars and starch accumulation). In this respect, Das *et al*. [25] said that, exposure to Se increased both reducing and non-reducing sugars in the rice seedlings accompanied with an increase in the activities of sugar metabolizing enzymes like sucrose synthase and sucrose phosphate synthase. Also, Se treatments resulted in better pollen germination Lucas *et al*. [10], increased photosynthesis and protected photosystem in pear, grape and peach Feng *et al*. [11], delayed fruit ripening improved the shelf life and pear fruit taste Mosa *et al* [9], as well as postponed senescence and postharvest losses in weight, firmness, TSS and acidity [3, 26, 6, 12].

The beneficial effects of silicate (Si) were suggested through enhancing photosynthetic activity, improving K / Na ratio stimulate the activity of some enzymes as well as nutrient and water uptake, plant pignents and cell division [17]. Also, Kanai *et al*. [13] and Al-Wasfy [14], mentioned that, Si treatments enhanced fruit yield, volume, color, quality and shelf life. Mditshwa *et al.* [15] said that, Si applications increased both phenolic and flavonoid antioxidant during cold storage so that, maintained cell membrane integrity, where "Pioneer" plum treated by 500 – 2500 ppm of $K_2 SiO_3$ and stared at 0°C for 28 days cleared less cell permeability [16]. Meanwhile, Zayan *et al*. [27], Okba *et al.* [28] and Pavanello *et al*. [29] stated that, foliar application of potassium silicate improved leaf content of Si, increased fruit yield, quality, crop value with higher net income of "Desert red" peach as well as "Canino" apricot yield, fruit color, weight, size and firmness with high tolerance during storage.

So, we can recommend "Le-Conte" pear growers to spray their trees 4 times (at bud swelling, fruit set, one month after fruit set and one month before harvest time) by sodium selenate ($Na_2 Se O_4$) at 8 ppm or potassium silicate ($K_2 Si O_3$) at 1000 ppm to increase fruit yield, quality (at harvest and after cold storage) and net income.

ACKNOWLEDGEMENTS

Special thanks and deep gratitude to Dr. Mostafa Ahmed Fathi, Dr. Hossam Abd El-Maksoud Sayed and Mr. Nabil Abd El-Kreem.

REFERENCES

1. Russo, R.O. and G.P. Berlyn, 1990. The use of organic biostimulants to help low input sustainable agriculture. J. Sustainable Agric., 1(2): 19 -42.
2. Piaggesi, A., D. Pezzolato, G. Tommaso and G. Bassil, 2002. Measurements of microelments content in pear leaves. Acta Hort., 594: 259-266.
3. Pezzarossa, B., M. Gentile and R. Massai, 2012. Effect of foliar and fruit addition of sodium selenate on Se accumulation and fruit quality. J. Sci. Food Agric., 92: 781-786.
4. Pezzarossa, B., I. Rosellini, E. Borghesi and F. Molorgio, 2014. Effect of Se-enrichment on yield, fruit composition and ripening of tomato plants grown in hydroponics. Sci. Hortic, 165: 106-110.
5. Dierend, W., H. Schon and C. Budke, 2021. Iodine biofortification of apple and pear in an orchard using foliar sprays of different composition. Frontiers in Plant Science, pp: 12.
6. Babalar, M., S. Mohebbi, Z. Zamani and M.A. Askari, 2019. Effect of foliar application with sodium selenate on selenium biofortification and fruit quality maintenance of "Starking Delicious" apple during storage. J.l Sci. Food Agric., 99(11): 5149-5156.
7. De Bruno, A., A. Piscopo and R. Mafrica, 2020. Effect of agronomical and technological treatments to obtain selenium-fortified table olives. Agriculture, MDOIN, 10(7): 1-16.
8. Kleine-Kalmer, R., A. Profeta., D. Daum and U. Enneking, 2021. Willingness to purchase selenium and iodine biofortified apple adiscrte choice analysis with German consumers. Nutrients, 13(5): 1-18.
9. Mosa, W., S. Behiry, Ali and M. Salem, 2022. Pomegranate trees quality under drought condition using potassium silicate, nanosilver and selenium spray. Pub Med, 12(1).
10. Lucas, C. Costa, L.M. Luz, V.L. Nascimento, F.F. Araujo, M.N.S. Santos, C. De F.M. França, T.P. Silva, K.K. Fugate and F.L. Finger, 2020. Selenium-ethylene interplay in postharvest life of cut flowers. Front Plant Sci., 11: 584698.
11. Feng, T., S. Chen, D. Goo and G. Liu, 2015. Selenium improves photosynthesis and protects photosystem II in pear, grope and peach. Photosynthetica, 53: 609-612.
12. Galic, L., B. Ravnjak and Z. Loncaric, 2021. Agronomic biofortification of significant cereal crops with Se. Agronomyn, 11(5).
13. Kanai, S., K. Ohkura, J. Adu-gyamfi and K. Fujito, 2007. Depression of sink activity precedes the inhibition of biomass production in tomato plants subjected to potassium deficiency stress. J. Exp. Bot., 58: 2917-2928.
14. Al-Wasfy, M.M., 2014. The synergistic effects of using silicon with some vitamins on growth and fruiting of "Flame seedless" grapevines. Stem cell 5(1): 8-13.
15. Mditshwa, A., J. Bower, I. Bertling and S. Tesfoy, 2013. The potential of postharvest silicon dips to regulate phenolic in peel of citrus pas a method to mitigate chilling injury. African J. Biotech., 12: 1482-1489.
16. Nasar, S., H. Korkar and Abd El-hamid, 2013. Evaluation of silicon concentration and modified atmosphere packaging on behavior of Pioneer plum. World J. Agric. Sci., 9: 454-465.
17. Ma, J.F., 2004. Role of silicon in enhancing the resistance of plants of biotic and abiotic stresses. Soil Sci. Plant Nutr., 50: 11-18.
18. A.O.A.C, 1995. Official Methods of Analysis, pp: 832-849, USA.
19. Tasun, K., P. Chose and K. Ghen, 1970. Sugar determination according to DNS method. Biotechnology and Bioengineering, 12: 921.
20. Fostar, D.S. and T.S. Cornelia, 1967. Colorimetric methods of analysis. D. Van Nestrant Co. Inc., pp: 551-552.
21. Jackson, M.L., 1967. Soil chemical analysis. Prentice-Hall of India Pvt. Ltd., New Delhi, pp: 498.
22. Soltanpour, P.N and A.P. Schwab, 1991. Determination of nutrient availability element toxicity by AB-DTPA. Soil Test ICPS Adv. Soil. Sci., 16: 165-190.
23. Snedecor, G and W. Cochran, 1990. Statistical methods. 7th Ed. Iowa Univ., pp: 593 USA.
24. Liu, Q.L., Y.Y. Hao and G.L. Hao, 2015. Effects of spraying selenium on the mineral elements content and the storage properties of the pear fruits. Zhiwu Shengli Xuebao, 51(5): 655-660.
25. Das, D., P. Das and A.K. Biswas, 2018. Regulation of growth and carbohydrate metoboism in rice seedlings by selenium and sulphate. J. Plant Studies, 7(1): 61- 72.
26. Puccinelli, M., F. Malorgio and B. Pezzarosse, 2017. Selenium enrichment of Horticultural crops. Molecules, 22(6): 933.

27. Zayan, M.A., B.G. Mikhael and K.S. Okba, 2016. Treatments for improving tree growth, yield and fruit quality and for reducing double fruit and deep suture incidence in peach trees. Interna. J. hort. Sci., 22(3- 4): 7-19.
28. Okba, S.K., Y. Mazrou, H.M. Elmenofy, A. Ezzat and A. Salama, 2021. New insights of potassium sources impacts as foliar application on apricot. Plants, 10(6): 1163.
29. Pavanello, E.P., B. Auti, D.G. Simao and J.M. Olivelra, 2022. Effect of foliar applied silicon on brown. Crop Protection, 156: 105928.