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Silicon and Selenium Impact on Fruit Set, Yield and Fruit Quality of Selmy Date Palms Grown Under Sandy Soil Conditions

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ABSTRACT

This investigation was carried out during two consecutive seasons (2020 and 2021) on Selmy date palm cultivar grown on sandy soil at a confidential grove existing at point of 63 kilometer from Cairo-Alexandria desert road. The objective of this study was to monitor the alleviating effects of spraying silicon (Si) at 0.1 and 0.2%, selenium (Se) at 0.02 and 0.04% each alone or in combinations on fruit set%, fruit retention%, yield (kg) and some physical and chemical fruit traits. The results of the two seasons revealed that spraying Si and Se gave the best ameliorative mean values for the yield and fruit properties of Selmy date palm cultivar. However, Si was superior when comparing with Se in this concern. Combined applications were favorable than using each of Si or Se alone in this connection. Generally, treating Selmy date palm twice with a mixture of silicon at 0.2% + Selenium at 0.04% was the best, since it improved the yield with better fruit quality comparing with the other treatments.

Keywords: Date palm, Selmy cultivar, Silicon, Selenium, yield, fruit traits.

1. Introduction

Date palm is one of the oldest cultivated fruit trees in the world. It is known as tree of life because of its need for limited water inputs, its long-term productivity and its multiple purpose qualities. Egypt is considered one of the top ten date producers and total production of date fruits is about 1690959 tons (FAO 2020). In Egypt, many cultivars are grown in different regions according to the diversity of their climatic necessity. Selmy date is one of the most important wet dates.

In Egypt, it is necessary to face the ever-increasing demands of the high population by reclamations and improvements of new lands. Most of these lands are sandy and calcareous soils. So, the substantial problems of these type of soils are their low availability of water and nutrients, poor structure, higher salinity, low fertility, calcium carbonate, the ability of forming a surface crust and indurate layers at shallow depths. One of the best tools for date palm re-productivity is the fertilization (Khayat *et al*., 2007 and Mostafa, 2015). Spraying fertilizers has the important role to reduce application rates, uniform distribution of fertilizer materials and quick responses to the applied nutrients (Umar *et al*., 1999 and Mengel, 2002).

Silicon (Si) is deemed as a superb growth enhancing agent raises plant growth and motivates the productivity of various crop plants. Moreover, its application established the plant biomass height and productivity under multiple stress conditions (Ahmed *et al*., 2007). It also promotes plant cells length as well as extensibility it affords strength to the endoderm of the mature basal cells and progresses the extensibility of apical cells of the roots thus Si comes as a part in contribution of a vigorous expanded and deep root system. However, it is known as a vital element that enhances the potential against abiotic stresses i.e. salinity cold drought heavy metals and diseases (Mateos-Naranjo *et al*., 2013). Also, Si has well known by its contributes in efficient water utilization of plants by ameliorating leaf water prospect transpiration rate and photosynthesis under abiotic stress conditions (Shen *et al*., 2010). Moreover, Ahmad and Haddad (2011) reported that Si has a highly relation with osmotic adjustment by accelerate the aggregation of more than one from organic and inorganic substances such as proline P glycine betaine GB and antioxidant activities in plant that are subjected to stress environments.

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Selenium (Se) is a fundamental micro nutrient for both of humans and animals, but it leads to toxicity when taken in excrescent amounts. Plants are the first source of dietary Se but the core role of Se in plants is still debatable. However, Se at low doses give plants high protection from various abiotic stresses i.e. cold, drought, desiccation, and metal stress. Se is chemically identical to sulfur, hence occupied inside the plants via sulfur transporters present inside root plasma membrane, metabolized via sulfur assimilatory pathway, and volatilized into atmosphere. Se prompted oxidative stress; distorted protein structure and function are the main reasons of Se toxicity in plants at high dosages. Plants can play a vital role in conquering Se deficiency and toxicity in different aeras of the world, hence, detailed mechanism of Se metabolism inside the plants is essential for designing effective Se phytoremediation and bio fortification strategies (Meetu and Shikha, 2017 and Zhao *et al*., 2010).

Several investigators reported that Si and Se have a positive effect on the yield of different plants. Moreover, they also improve the physical and chemical properties of the fruits. Gad El-Kareem (2012), found that spraying Timor mango with potassium silicate at 0.1% was very effective in improving the yield and fruit quality (TSS and sugars) over the control treatment. Aly *et al.* (2019), found that spraying Keitte mango with potassium silicate (K-Silicate) at 15 cm^3/L plus amino acid at 7.5 cm^3/L significantly increased fruit weight, yield as kg/tree and total yield (ton/ feddan). Spraying inflorescences of "Khalas" date palms with K-Silicate at 0.1%+ active dry yeast at 500 ppm was more effective treatment in enhancing the yield and improving fruit quality as well as physical and chemical properties (Enas *et al.,* 2018). Using Si was very effective in enhancing growth and fruiting of different fruit crops (Gad El-Kareem, 2012 & Abd El-Wahab, 2015). In addition, Gad El- Kareem *et al.* (2014) found that four sprays of Se at 0.01 and 0.02% on Zaghloul date palms were very effective in enhancing the yield, bunch weight as well as physical and chemical characteristics of the fruits in compared to the check treatment.

The target of this study was detecting the beneficial effects of Si and Se sprays on fruit set, fruit retention, yield and fruit quality of "Selmy" date palms grown under sandy soil conditions.

2. Materials and Methods

This research was conducted on 15 years old Selmy date palms (*Phoenix dactylifera* L.) grown on sandy soil and planted at 6 meters apart under drip irrigation system in a private orchard located at 63 kilometers from Cairo-Alexandria desert road, Egypt, throughout the two seasons of 2020 and 2021. The chosen palms were healthy, had approximately uniform growth vigor and fruiting, and received regular horticultural practices which applied in the commercial orchard except for the tested treatments.

All palms were pollinated with the same male pollen source in both seasons. Palms were subjected to seven spraying treatments with three replicates per treatment (7 treatment × 3 replicate = 21 palms with one palm per each replicate). The treatments were arranged in a randomized complete block design and the experimental bunches were sprayed two times in each season as follow: the 1st spray was carried out one day before pollination and the second spray was done at the beginning of Kimri stage. The spraying treatments were as follows:

T_1 Control (Spraying with water only).
T_2 Potassium silicate at 0.1%.
T_3 Potassium silicate at 0.2%.
T_4 Sodium selenite at 0.02%.
T_5 Sodium selenite at 0.04%.
T_6 Potassium silicate at 0.1% + sodium Selenite at 0.02%.
T_7 Potassium silicate at 0.2% + sodium Selenite at 0.04%.

Si and Se were sprayed in the forms of potassium silicate (25% Si) and sodium selenite (20% Se). Triton B as a wetting agent was added to all materials at 0.05%, and the spraying was done using hand sprayer until runoff. Fruits were harvested at full mature stage at the beginning of October, according to skin color.

2.1. Measurements

2.1.1. Fruit set and fruit retention (%)

The initial fruit set was recorded one month after pollination and before the harvest time, the fruit retention percentage was measured. The following equations were used to get fruit set and fruit retention percentage:

$$\text{Fruit set \%} = \frac{\text{Number of fruit settled on the strand}}{\text{Total Number of flowers/strand}} \times 100$$

$$\text{Fruit retention \%} = \frac{\text{Number of retained fruits/strand}}{\text{Number of retained fruits + Number of flower scars}} \times 100$$

2.1.2. Fruit physical characteristics

Thirty fruits were picked from each bunch randomly to determine fruit weight (g), flesh weight (g), seed weight (g), fruit volume (cm^3), fruit dimensions (fruit length and diameter in cm). Then, fruit shape index (length/diameter) was calculated.

Bunches of each palm were harvested at full mature stage (beginning of September), according to skin color and weighed to determine the yield/palm (kg).

2.2. Fruit chemical characteristics

Total soluble solids (TSS %): A hand refractometer was used to determine TSS of date fruit juice.
Acidity (%) was determined as malic acid percentage as the method described in A.O.A.C. (1995).
TSS/acid ratio was calculated.
Total sugars (%) and reducing sugars (%): Flesh weight was used to determine total sugars and reducing sugars percentages according to Lane and Eynon method (A.O.A.C. 1995), then after, **non-reducing sugars (%)** were calculated by the difference between total and reducing sugars.

2.3. Statistical analysis:

Data were subjected to analysis and COSTAT program was used to statistically assess it for analysis of variance according to Snedecor and Cochran (1980). Then after, Duncan values at a probability of 0.05 were used to compare the significant differences between the whole treatments (Duncan, 1955).

3. Results

3.1. Fruit set and fruit retention:

Regarding the percentage of fruit set and fruit retention in response to Si, Se and the combination treatments, it is evident from the results presented in (Table 1) that all studied treatments resulted in a significant increment in fruit set and fruit retention percentages compared with the control in both experimental seasons.

Spraying inflorescences with K-Silicate at 0.2% + Na-Selenite at 0.04% recorded the highest fruit set (62.16 and 63.9%), followed by spraying K-Silicate 0.1% + Na-Selenite 0.02% which gave 60.2 and 61.4% in both experimental seasons.

Also, fruit retention took the same trend in both seasons of the study. Since the highest fruit retention (38.6 and 39.4%) was recorded when the palms were sprayed with K-Silicate at 0.2% + Na-Selenite at 0.04% followed by spraying K-Silicate at 0.1% + Na-Selenite at 0.02% which gave 37.2 and 38% in both seasons, respectively.

On the other hand, the control treatment exhibited the lowest fruit set (52.5 and 54.8%) and fruit retention (30.7 and 3.5 %) in both seasons of the study. The other tested treatments gained intermediate fruit set and retention.

Table 1: Effect of spraying silicon and selenium on fruit set and fruit retention of Selmy date palms grown under sandy soil conditions.

Treatments		Fruit set (%)		Fruit retention (%)	
		2020	2021	2020	2021
T_1	Control	52.53g	54.80g	30.73e	33.50f
T_2	K-Silicate at 0.1 %	56.76e	58.03e	35.13c	36.60d
T_3	K-Silicate at 0.2 %	58.63c	62.30b	36.90b	38.76b
T_4	Na-Selenite at 0.02 %	55.30f	55.20f	32.53d	34.50e
T_5	Na-Selenite at 0.04 %	57.83d	58.60d	33.20d	33.60f
T_6	K-Silicate at 0.1% + Na-Selenite at 0.02%	60.20b	61.40c	37.20b	38.03c
T_7	K-Silicate at 0.2% + Na-Selenite at 0.04%	62.16a	63.90a	38.60a	39.40a

Mean separation within each column by Duncan Multiple Range (0.05). Means with similar letters are insignificantly different.

3.2. Fruit physical properties:

Results illustrated in (Table 2) clear that, all investigated treatments either alone or in combinations, increased fruit weight, flesh weight, bunch weight and yield/palm as compared with the control in the two seasons of the study.

The highest fruit weight was recorded with T_7 (K-Silicate at 0.2% +Na-Selenite at 0.04%) which recorded 18.6 and 18.3 g, followed by T_3 (K-Silicate at 0.2%) which gave 17.5 and 17.8 g. On the other hand, T_1 (control treatment) exhibited the lowest fruit weight (14.00 and 14.30 g) in both seasons of the study. The other tested treatments gained intermediate fruit weight.

Table 2: Effect of spraying silicon and selenium on yield and some fruit physical quality of Selmy date palms grown under sandy soil conditions.

Treatments		Fruit weight (g)		Flesh weight (g)		Seed weight (g)		Bunch weight (kg)		Yield/palm (kg)	
		2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
T_1	Control	14.00e	14.3e	12.5e	12.8d	1.50a	1.50a	9.5e	9.7e	95.0e	97.0e
T_2	K- Silicate at 0.1%	16.2d	15.9d	14.9d	14.5c	1.26b	1.36b	10.3c	10.5c	103.6c	105.0c
T_3	K- Silicate at 0.2%	17.5b	17.8b	16.2b	16.5b	1.30b	1.30b	11.3b	11.5b	113.0b	115.0b
T_4	Na-Selenite at 0.02%	13.7e	14.5e	12.5e	13.2d	1.26b	1.33b	9.9d	10.0d	99.0d	100.0d
T_5	Na-Selenite at 0.04%	16.7c	17.2c	15.4c	16.2b	1.23b	1.30b	10.3c	10.5c	103.0c	105.0c
T_6	K- Silicate at 0.1% + Na-Selenite at 0.02%	16.5cd	16.1d	15.3cd	14.7c	1.20b	1.36b	11.2b	11.4b	112.0b	114.0b
T_7	K- Silicate at 0.2% + Na-Selenite at 0.04%	18.6a	18.3a	17.4a	17.0a	1.20b	1.30b	11.6a	11.9a	116.0a	119.0a

Mean separation within each column by Duncan Multiple Range (0.05). Means with similar letters are insignificantly different.

Also, the results in (Table 2) indicate that the highest flesh weight was found with T_7 (K-Silicate at 0.2% + Na-Selenite at 0.04%) which recorded 17.4 and 17.0 g, followed by T_3 (K-Silicate at 0.2%) which demonstrated 16.2 and 16.5 g while the lowest flesh weight (12.5 and 12.8 g) was obtained by control in the first and second seasons, respectively. The other tested treatments came in between.

In case of seed weight, results in (Table 2) show that all treatments had no effect in both seasons. T_1 (control) exhibited the highest seed weight (1.50g) in the first and second seasons, while the other treatments values were 1.20 - 1.30g in the first season and 1.30 - 1.36 g in the second one.

Regarding bunch weight (kg) results in (Table 2) clear that, bunch weight was significantly increased by T_7 (K-Silicate at 0.2% + Na-Selenite at 0.04%) which recorded the heaviest bunch weight (11.6 and 11.9 kg), followed by T_3 which gave 11.3 and 11.5 kg. However, the lowest bunch weight was obtained from T_1 (control) which registered 9.5 and 9.7 kg in the both experimental seasons, respectively.

The same trend of bunch weight was observed for yield/palm (kg) since spraying K-Silicate at 0.2% + Na-Selenite at 0.04% produced the highest yield/palm (116 and 119 kg) in the two seasons of

the study, followed by T_3 (K-Silicate at 0.2%) which gave 113 and 115 kg, while the lowest yield/palm (95 and 97 kg) was obtained from T_1 (control) in the first and second seasons, respectively.

It was noticed that there was a gradual promotion of bunch weight and yield/palm with increasing the concentration of K-Silicate from 0.1% or 0.2% either alone or with Na-Selenite at 0.02% - 0.04%, also the effects of spraying K-Silicate at 0.2% plus Na-Selenite at 0.04% on bunch weight and total yield/palm was accomplished better than K-Silicate during the two seasons.

Results in (Table 3) display that treating Selmy date palms two times with K-Silicate at 0.1 or 0.2% and Na-Selenite at 0.02-0.04% either in solitary or incorporation significantly promoted fruit physical characteristics as compared with the control in both seasons of the study.

Spraying bunches with K-Silicate at 0.2% + Na-Selenite at 0.04% registered the maximum values of fruit length (4.36 and 4.33 cm) and diameter (2.7cm) in the first and second seasons, respectively. While, the lowest values of fruit length (3.8 and 3.9 cm) and diameter (2.4 and 2.5 cm) were obtained from the control treatment in both seasons. The other tested treatments recorded intermediate values.

From the results observed in (Table 3) it is clear that all spraying treatments significantly raised fruit volume than the control in the two seasons of the study. Also spraying K-Silicate at 0.2% + Na-Selenite at 0.04% accorded the highest fruit volume (19 and 17.2 cm^3) in both seasons. While the lowest fruit volume (13.3 and 1.5 cm^3) was obtained with the control in the two seasons of the study.

Results in (Table 3) clear that there was insignificant effect between all treatments and the control concerning fruit shape index in both seasons of the study.

Table 3: Effect of spraying silicon and selenium on some fruit physical quality of Selmy date palms grown under sandy soil conditions.

Treatments		Fruit length (cm)		Fruit diameter (cm)		Fruit shape index		Fruit volume (cm^3)	
		2020	2021	2020	2021	2020	2021	2020	2021
T_1	**Control**	3.80c	3.90c	2.43c	2.56b	1.56b	1.52a	13.3f	13.5f
T_2	**K- Silicate at 0.1%**	4.20ab	4.06b	2.63a	2.63ab	1.59ab	1.54a	16.0d	15.0d
T_3	**K- Silicate at 0.2%**	4.33a	4.30a	2.60ab	2.70a	1.66a	1.59a	17.2c	17.26a
T_4	**Na-Selenite at 0.02%**	4.06b	3.96bc	2.50bc	2.56b	1.62ab	1.54a	13.6f	13.9e
T_5	**Na-Selenite at 0.04%**	4.26a	4.23a	2.63a	2.63ab	1.61ab	1.60a	17.5b	16.70b
T_6	**K- Silicate at 0.1% + Na-at Selenite 0.02%**	4.30a	4.26a	2.66a	2.66a	1.61ab	1.59a	15.5e	15.50c
T_7	**K- Silicate at 0.2% + Na-Selenite at 0.04%**	4.36a	4.33a	2.70a	2.70a	1.61ab	1.60a	19.0a	17.26a

Mean separation within each column by Duncan Multiple Range (0.05). Means with similar letters are insignificantly different.

3.3. Fruit chemical properties:

3.3.1. Total soluble solids%:

In this concern, results in (Table 4) indicate that all spraying treatments increased significantly TSS% compared to the control in the two seasons of the study. Spraying inflorescences with K-Silicate at 0.2% + Na-Selenite at 0.04% produced the highest TSS% (36.46 and 37.33%), followed by spraying inflorescences with K-Silicate at 0.1% + Na-Selenite at 0.02% which gave 35.30 and 35.33% in the first and second seasons, respectively, while, the control treatment exhibited the lowest TSS% (26.4 and 26.7%) in both seasons. The other tested treatments came in between.

3.3.2. Total acidity%:

Concerning the fruit juice acidity percentage, the results in (Table 4) show that all spraying treatments decreased significantly the total acidity as compared with the control in the first season. However insignificant differences between all spraying treatments and control were noticed in the second season.

3.3.3. TSS/acid ratio%:

Results in (Table 4) clear that all treatments increased significantly TSS/acid ratio as compared with the control treatment in both seasons of the study. The highest TSS/acid ratio (149.9 and 164.6 %) was recorded by spraying K-Silicate at 0.2% + Na-Selenite at 0.04% in both seasons, followed by

spraying K-Silicate at 0.1% + Na-Selenite at 0.02% which gave 149.2 and 151.4% in the two seasons of the study. Meanwhile, control treatment recorded the lowest TSS/acid ratio (62.5 and 65.8%) in the first and second seasons, respectively. The other tested treatments recorded intermediate values.

3.3.4. Total sugars%:

Results in (Table 4) indicate that all treatments had a significant effect on total sugars % compared to the control in the two seasons of the study. Meanwhile, the highest value was obtained by spraying inflorescences with K-Silicate at 0.2% + Na-Selenite at 0.04% which gave 52.0 and 53.0%, followed by spraying K-Silicate at 0.1% + Na-Selenite at 0.02% which produced 48.8 and 51.8% in both seasons of the study. The other tested treatments and control gained intermediate total sugars%. Also, reducing sugars took the same trend of total sugars in the two seasons.

3.3.5. Non-reducing sugars%:

As shown from (Table 4) all treatments increased significantly the non-reducing sugars% as compared to the control in both seasons of the study. Spraying inflorescences with K-Silicate at 0.2% + Na-Selenite at 0.04% recorded the highest non-reducing sugars (12.0 and 12.4%), followed by spraying K-Silicate at 0.1% + Na-Selenite at 0.02% which gave 11.7 and 12.2% in the two seasons of the study, while, the control exhibited the lowest non-reducing sugars (9.0 and 9.7%) in the first and second seasons, respectively.

Table 4: Effect of spraying silicon and selenium on fruit chemical properties of Selmy date palms grown under sandy soil conditions.

Treatments		TSS (%)		Acidity (%)		TSS/acidity ratio (%)	
		2020	2021	2020	2021	2020	2021
T_1	Control	26.46d	26.73d	0.42a	0.40a	62.53d	65.80e
T_2	K- Silicate at 0.1%	33.00b	33.00b	0.34b	0.31a	97.60c	104.90d
T_3	K- Silicate at 0.2%	34.50ab	35.40ab	0.29c	0.28a	119.06b	124.86c
T_4	Na-Selenite at 0.02%	28.00cd	30.00c	0.26cd	0.25a	107.73bc	118.53c
T_5	Na-Selenite at 0.04%	28.93c	30.06c	0.26cd	0.23a	111.56b	127.10c
T_6	K- Silicate at 0.1% + Na-Selenite at 0.02%	35.30a	35.33ab	0.23d	0.23a	149.20a	151.43b
T_7	K- Silicate at 0.2% + Na-Selenite at 0.04%	36.46a	37.33a	0.24d	0.22a	149.90a	164.66a

Table 4: Cont.

Treatments		Total sugars (%)		Reducing sugars (%)		Non-reducing sugars (%)	
		2020	2021	2020	2021	2020	2021
T_1	Control	35.30d	37.70c	26.30de	28.00c	9.00e	9.70d
T_2	K- Silicate at 0.1%	42.7bc	44.80b	32.50c	34.30b	10.20d	10.50c
T_3	K- Silicate at 0.2%	45.33bc	46.66b	34.33bc	35.06b	11.00c	11.60b
T_4	Na-Selenite at 0.02%	41.83c	43.33b	30.36cd	32.03b	11.46abc	11.30b
T_5	Na-Selenite at 0.04%	34.83d	36.83c	23.60e	25.43c	11.23bc	11.40b
T_6	K- Silicate at 0.1% + Na-Selenite at 0.02%	48.83ab	51.83a	38.80ab	39.63a	11.70ab	12.20a
T_7	K- Silicate at 0.2% + Na-Selenite at 0.04%	52.00a	53.00a	40.00a	40.60a	12.00a	12.40a

Mean separation within each column by Duncan Multiple Range (0.05). Means with similar letters are insignificantly different.

4. Discussion

Promoting growth and fruiting of Selmy date palms through using silicon and selenium could be attributed to the action of Se on increasing the activity of some enzymes such as, glutathione-peroxidase, antioxidant activities and protecting the plants from abiotic and biotic stresses, increasing biosynthesis

of carbohydrates as well as reducing the reactive oxygen species (Turakainen *et al.,* 2004 and Turakainen *et al.,* 2006). Also, the positive might be due to the effect of silicon on enhancing the plant tolerance to all stresses, improving water and nutrients uptake and transport, promoting root development and antioxidant defense systems (Hattori *et al.,* 2005, Ahmad and Haddad, 2011). The obtained results are in agreement with those obtained by Gad El-Kareem *et al.* (2014), El-Mahdy *et al.* (2017), Wassel and Ali (2018), Enas *et al.* (2018) and Waleed *et al.* (2020).

On the other hand, it was found from the previous studies that the uptake of nitrogen, potassium, phosphorus and zinc was substantially higher in the plants sprayed with silicon (Satisha *et al.,* 2017).

A significant promotion on fruit quality was observed with using both silicon and selenium together rather than application of each alone. Spraying K-silicate at 0.1 or 0.2% was preferable in improving fruit quality than using Na-Selenite at 0.02 or 0.04%. Meaningless, stimulating fruit quality was observed with increasing the concentration of each nutrient. The best results from economical point of view were obtained with spraying K-Silicate at 0.2% and Na-Selenite at 0.04% together. The untreated palms showed unfavorable observations on fruit quality. These results were true during the two seasons of the study.

5. Conclusion

Spraying Selmy date palms grown under sandy soil conditions twice with K-Silicate at 0.2% + Na-Selenite at 0.04% (one day before pollination and at the beginning of Kimri stage.) was the promising treatment for increasing fruit set, fruit retention, yield and improving fruit physical and chemical properties.

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