Impact of some Reducing Abiotic Stress Substances on Valencia Orange Tree Growth and Productivity

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ABSTRACT

During 2021 and 2022 seasons, we tested the effect of applying Potassium silicate (0.1%), Selenium (50 ppm), and Nile power compound (0.2%), either as single treatments or their combination, on antagonizing water stress-induced deterioration in Valencia orange trees. We observed the growth, nutritional status, yield, and fruit quality of the trees grown in clay soil under a flooding irrigation system. Experimental water stress was induced in the orchard by irregular irrigation periods during blooming and fruit set, that caused a negative effect on tree yield and fruit quality. The irrigation was delayed by three days from the time the trees needed to be watered in all trees during the two seasons. Various treatments were sprayed four times, instituted in the 1st week of March, May, July, and September. The tested treatments proved to be effecting against abiotic stress by significantly enhancing all tree growth characters under study i.e., leaf pigments, nutrient content, yield, and fruit quality over the control treatment. Moreover, Nile power compound and Selenium treatments were better than Potassium silicate in this respect. Generally, using the Nile power compound, selenium, and potassium silicate as a mixture were preferable than using each one alone during the two experimental seasons.

To help mitigate the negative impact of water stress on the fruiting of Valencia orange trees, a recommended approach is to spray potassium silicate (0.1%), selenium (50 ppm), and Nile power compound (0.2%). This application should be done four times a year, during the first week of March, May, July, and September.

Keywords: Valencia orange - Abiotic stress - Potassium silicate- Selenium- Nile power compound.

INTRODUCTION

Citrus is one of the most important fruit crops worldwide. According to the latest Statistics of the Ministry of Agriculture (2021), Egypt citrus ranked the 1st in terms of cultivated area and productivity. The total cultivated area of citrus in Egypt reached about 440.210 feddans producing about 4.503.226 tons. Orange occupies about 85% of citrus area.

According to Rayman (2002), selenium is vital to the cellular defense against oxidative stress in plants, humans, and animals. Previous research established the beneficial effects of Selenium on plant protection against abiotic stress, as noted by Hartikainen and Xue (1999). Moreover, Seppanenet al. (2003)observed that selenium activates protectives mechanisms that reduce oxidative stress in chloroplasts by protecting against reactive oxygen intermediates. Besides, selenium has been shown to improve carbohydrate accumulation and yield, as reported by Turakainenet al. (2004 and 2006). Accumulating evidence attributed the anti-oxidative effects of selenium on plants to increasing antioxidant enzymes, specifically glutathione-peroxidase, which has been observed in selenium-treated plants (Dayeret al., 2008). Furthermore, the research of Hanson et al. (2003 and 2004) established the selenium-mediated protective effects against phloem-feeding aphids and herbivorous caterpillars. Nonetheless, selenium mitigated both paraquat- and photooxidative-induced oxidative stress and deterioration of photosynthesis (Seppanen, et al., 2003), which was associated with enhancing the activity of superoxide dismutase (SOD) and tocopherols.

Selenium-mediated improvements of fruit as well as other horticultural crops have been established by earlier research studies. These results has demonstrated that foliar application of selenium can be highly beneficial in improving the growth, yield, and fruit quality of various crops (Whanger, 2002; Nowak-Barbara, 2008; Gad El-Kareem et al., 2014; Ibrahim and Al-Wasfy, 2014; Uwakiem 2015; Masoud, 2017; and Aklet al., 2018).

Earlier research has demonstrated that the application of silicon (Si) in the form of potassium silicate mitigates the negative impact of water stress on plant growth, nutritional status, yield, and fruit quality. Si increases the plants' resistance to drought by maintaining water balance, leaf erectness, photosynthesis, and the vascular structure of xylem under high transpiration conditions. Additionally, Si acts by promoting water transport, supporting root development despite disadvantageous conditions, and mitigating oxidative stress (Epstein, 1999; Alvarez and Datnoff, 2001; Aziz et al., 2002; Meloet al., 2003; and Hattori et al., 2005). Many studies have reported the drought-fighting potential of potassium silicate or silicon in fruit orchards. Silicon compounds alleviated nutritional deficiencies, improved yield, and enhanced fruit quality (Meumenn and Zur-Nieden, 2011; Gad El-Kareem, 2012; Al-Wasfy, 2013; Ibrahim and Al-Wasfy, 2014; El-Gioushy, 2016; Habasy-Randa 2016; El-Sayedet al., 2016; and Radwan, 2017).

The use of balanced nutritional supplements, particularly Nile Power, is crucial. This organic substance is fully digestible and contains a wide range of macro and micronutrients, amino acids, and plant enzymes. It is also rich in vegetable proteins and was designed to stimulate plant growth cycles, even in the face of climate changes such as heat stress, water stress, frost, and the impact of climatic distances. Moreover, Nile Power can help safeguard plant cells against senescence. Its content of Macro and micronutrients play a significant role in enhancing plant pigments, proteins, carbohydrates, fats, enzymes, vitamins, natural hormones, antioxidants, cell division, and water uptake (Adriano, 1985 and Yagodin, 1990).

The aim of the present study was of prime importance as investigate the effect of potassium silicate, selenium and Nile power compound on Valencia tree growth, nutritional status, productivity, and fruit quality.

MATERIALS AND METHODS

During the 2021 and 2022 growing seasons, a study was conducted on fifteen 33-year-old Valencia orange (*Citrus sinensis L.*) trees that were uniform and similar in growth vigor. These trees were budded onto *Citrusaurantium* rootstocks (aka sour orange) and were selected from the Sids Horticulture Research Station Garden (Beni-Suef Governorate, Egypt). Trees are planted according to the square arrangement method at spacing of 6 x 6 meters (116 tree/Fed.). The orchard soil was composed of well-drained silt clay, and the water table was at least two meters deep. The river Nile water was used for surface irrigation.

The experimental trees were subjected to standard horticultural practices that were already being applied in the orchard, including fertilization, pruning, hoeing, irrigation, and pest and fungal control. Soil analysis was conducted using well-established procedures (**Wilde *et al.*, 1985),** and the results are presented in Table (1).

Table (1): Results of the soil analysis.

Constituents	Values	Constituents	Values(ppm)
Sand(%)	4.1	N%	0.09
Silt (%)	22.5	P^+	5.20
Clay (%)	73.4	K^+	611.0
Texture	Clay	Mg^{++}	6.00
pH (1:2.5 extract)	7.58	Zn^{++}	3.80
E.C. (1:2.5extract) (mmhous)	0.81	Fe^{++}	4.90
$CaCO_3$ (%)	1.72	Mn^{++}	6.50
O.M. (%)	2.11		

This experiment included the following treatments:

T_1- Control group: Trees were sprayed with water.

T_2- Potassium silicate group: Trees were sprayed with Potassium silicate (0.1%).

T_3- Selenium (Se) group: Trees were sprayed with Se at 50 ppm.

T_4- Nile power compound group: Trees were sprayed with Nile power (0.2%).

T_5- Combination group: Trees were sprayed with Potassium silicate (0.1%) + Selenium (50 ppm) + Nile power (0.2%).

Each treatment group comprised three trees. All spray treatments (Control, Potassium silicate, Selenium, Nile power, or the combination) were repeated four times per season in the first week of the months of March, May, July and September. Nile power was purchased from The Turkish Egyptian Company for Chemical Industries and Agricultural Fertilizers (A.R.E.). Foliar applications were facilitated by adding Triton B (0.5 ml/L) to increase the wettability of the spray material under study. Spraying continued till runoff (~10 L/tree), while the control (untreated) trees received the vehicle (water containing only 0.05% of Triton B)

Experimental parameters:

Throughout both seasons, the following measurements were taken:

1. Shoot length (cm), shoot thickness (cm), and leaf area (cm^2) for the spring cycle's vegetative growth characters, following the methodology outlined by Ahmed and Morsy (1999).
2. Leaf pigments, including chlorophyll a & b, total chlorophylls, and total carotenoids (mg/g F.W.), as per the procedures described by Fadle and Seri El-Deen (1978).
3. Total carbohydrates in the leaves, using the approach outlined by Smith et al. (1956).
4. Leaf content of N, P, K (%) and proline, during the spring growth cycle, in non-fruiting shoots, as per the methodology described by Wilde et al. (1985) and Bates et al. (1973).
5. The initial fruit setting and retention (%).
6. Yield, expressed as the number (per tree) and the weight (kg/tree).
7. Some physical fruit characteristics, such as the fruit weight (g), shape index, peel weight percentage (w/w), pulp percentage (w/w), and peel thickness (cm).
8. Some chemical characteristics, including the percentages of TSS, total and reducing sugars, and ascorbic acid (as mg/100 mL/juice), following the procedures outlined by A.OA.C. (2000) and Lane and Eynon (1965).

The experimental design utilized a Randomized Complete Block Design (RCBD), and statistical analysis of the experimental results was conducted using the new least significant difference (New L.S.D.) test at 5% significance level, as described by Snedecor and Cochran (1980) and Mead et al. (1993).

RESULTS AND DISCUSSIONS

1-Growth characteristics:

Based on the data presented in Table (2), it is evident that the application of potassium silicate at 0.1%, selenium at 50 ppm, and Nile power at 0.2%, either individually or in combination, resulted in a significant increase in shoot length, shoot thickness, and leaf area when compared to the control treatment. Nile power was significantly superior to potassium silicate or selenium. The potassium silicate group showed the lowest values in this regard. Application of three materials (potassium silicate, Se, and Nile power) had significant beneficial effects on enhancing all growth characteristics than using each of them separately. When the trees received 0.1% potassium silicate combined with both selenium (50 ppm) and 0.2% Nile power they demonstrated the maximum values of shoot length (9.00, 6.83 cm), shoot thickness (0.18, 0.19 cm), and leaf area (29.40, 27.50 cm^2) during both seasons, respectively. The shortest (5.17, 4.50 cm) and the thinnest shoots (0.12, 0.13 cm) as well as the smallest leaf areas (27.034, 24.80 cm^2) during both seasons, respectively, were obtained from the control untreated group.

Table (2): Effect of some inducing abiotic stress substances on some vegetative growth characteristic, chlorophylls a, b and total chlorophylls in the leaves of Valencia orange trees during 2021 and 2022 seasons.

Characteristics / Treatments	Shoot length (cm)		Shoot thickness (cm)		Leaf area (cm^2)		Chlorophyll a (mg/g f.w.)		Chlorophyll b (mg/g f.w.)		Total chlorophylls (mg/g f.w.)	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
T_1-Control	5.17	4.50	0.12	0.13	27.34	24.80	1.08	0.95	0.52	0.52	1.60	1.47
T_2–Potassium silicate at 0.1%	6.33	5.67	0.15	0.16	27.62	26.24	1.08	1.07	0.56	0.58	1.64	1.65
T_3–selenium at 50 ppm	8.50	5.83	0.16	0.17	28.16	26.80	1.09	1.11	0.60	0.64	1.69	1.75
T_4–Nile power at 0.2%	8.67	6.33	0.17	0.18	28.90	27.00	1.33	1.27	0.66	0.68	1.99	1.95
T_5–Potassium silicate at 0.1% + selenium at 50 ppm + Nile power at 0.2%	9.00	6.83	0.18	0.19	29.40	27.50	1.41	1.38	0.71	0.75	2.12	2.13
New L.S.D. at 5%	0.12	0.14	0.02	0.03	0.11	0.13	0.09	0.11	0.06	0.08	0.11	0.13

2-Leaf chemicalcomposition:

The data in Tables (2 and 3) show that the application of potassium silicate at 0.1%, selenium at 50 ppm, and Nile power at 0.2%, either individually or in combination, had a significant impact on increasing total carotenoids, chlorophylls a and b, which was also reflected on the content of total chlorophylls. Moreover, these treatments enhanced the leaf percentages of N, P, K, and proline, compared with the check treatment. The highest increase in leaf chemical composition was observed with the combined application of Nile power compound, selenium, and potassium silicate, which was superior to using either substance alone.

In both seasons, the combined application of potassium silicate at 0.1%, selenium at 50 ppm, and Nile power at 0.2% resulted in the maximum values of chlorophyll a, chlorophyll b, total chlorophylls, and total carotenoids, with values of 1.41 and 1.38, 0.71 and 0.75, 2.12 and 2.13, and 0.94 and 0.99 mg/g F.W, respectively. Similarly, the leaves of these trees showed the highest levels of total carbohydrates, leaf N, leaf P, leaf K, and proline, with values of 32.1 and 36.2%, 1.98 and 1.93%, 0.22 and 0.23%, 1.26 and 1.49%, and 51.2 and 52.2 mg/g F.W., in both seasons, respectively. In contrast, untreated trees produced the minimum values. This trend was consistent in both seasons.

Table (3): Effect of some inducing abiotic stress substances on total carotenoids, total carbohydrates (%) and percentages of N, P, K and proline in the leaves of Valencia orange trees during 2021 and 2022 seasons.

Characteristics / Treatments	Total carotenoids (mg/g. f.w.)		Total carbohydrates (%)		Leaf N (%)		Leaf P (%)		Leaf K (%)		Proline (mg/g. f.w.)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
T_1-Control	0.51	0.45	26.0	32.4	1.61	1.58	0.15	0.14	0.99	1.28	43.0	43.5
T_2-Potassium silicate at 0.1%	0.70	0.52	27.5	33.0	1.81	1.71	0.17	0.18	1.08	1.29	47.2	47.9
T_3-selenium at 50 ppm	0.76	0.89	29.0	33.1	1.86	1.78	0.19	0.19	1.12	1.34	49.0	49.8
T_4-Nile power at 0.2%	0.91	0.97	31.9	35.8	1.91	1.91	0.21	0.22	1.25	1.38	49.9	50.4
T_5-Potassium silicate at 0.1 (%) + selenium at 50 ppm + Nile power at 0.2%	0.94	0.99	32.1	36.2	1.98	1.93	0.22	0.23	1.26	1.49	51.2	52.2
New L.S.D. at 5%	0.08	0.09	0.40	0.50	0.04	0.05	0.02	0.02	0.05	0.06	0.8	0.9

3- Percentages of fruit setting and yield:

Table (4) shows that the individual and combined application of substances that can reduce abiotic stress, such as potassium silicate at 0.1%, selenium at 50 ppm, and Nile power compound at 0.2% significantly increased initial fruit setting and retention percentages. Besides, these treatments significantly had positive effects on the yield per tree, i.e., they increased the total weight and number of produced fruits, compared with the control untreated counterparts. The most effective substances in promoting these parameters were Nile power compound, selenium, and potassium silicate, in descending order. Furthermore, it was found that the combined application of these three substances was significantly more effective than using any one substance alone. The maximum initial fruit set (18.99, 16.80 %), fruit retention (2.33, 3.85%), and yield (61.55, 60.20 kg per tree) resulted when the trees received a combination of potassium silicate, selenium, and Nile power compound at the specified concentrations. In both seasons, the untreated trees exhibited the lowest values for fruit setting and yield. This trend was consistent in the second season as well.

Table (4): Effect of some inducing abiotic stress substances on the percentages of Initial fruit setting and fruit retention % as well as yield and fruit weight of Valencia orange trees during 2021 and 2022 seasons.

Characteristics / Treatments	Initial fruit setting %		Fruit retention %		No. of fruits/tree		Fruit weight (g.)		Yield / tree (kg.)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
T_1-Control	12.01	12.17	1.85	1.84	378.0	322.0	145.5	155.0	55.10	50.00
T_2-Potassium silicate at 0.1%	12.41	12.55	1.88	2.40	374.0	343.0	155.5	158.5	58.20	54.20
T_3-selenium at 50 ppm	14.80	14.15	2.06	2.96	365.0	348.0	160.3	161.0	58.42	56.10
T_4-Nile power at 0.2%	16.53	15.85	2.16	3.80	370.0	356.0	165.5	167.0	61.05	59.50
T_5-Potassium silicate at 0.1% + selenium at 50 ppm + Nile power at 0.2%	18.99	16.80	2.33	3.85	338.0	342.0	182.7	176.0	61.55	60.20
New L.S.D. at 5%	0.26	0.28	0.04	0.05	7.3	7.7	8.1	9.0	2.2	2.5

4- Physical and chemical characteristics of the fruits:

Data in Tables (5 and 6) indicate that the application of potassium silicate, selenium, or Nile power compound, at the indicated concentrations, either individually or in combination, significantly improved fruit quality by increasing fruit weight, juice %, TSS %, percentage of reducing as well as total sugars, and ascorbic acid content, while decreasing the percentages of fruit peel weight, peel thickness, and total acidity when compared with the untreated trees.

Using potassium silicate, selenium, and Nile power compound, in ascending order, promoted the fruit quality. Fruit quality was significantly improved in response to application of three materials comparing to using each alone in this respect. The fruit quality of control-untreated trees was not as good as the treated trees.

Table (5): Effect of some inducing abiotic stress substances on some physical characteristics of the fruit of Valencia orange trees during 2021 and 2022 seasons.

Treatments \ Characteristics	Fruit shapeindex		Fruit peel weight (%)		Fruit peel thickness (cm.)		Juice (%)	
	2021	2022	2021	2022	2021	2022	2021	2022
T_1-Control	1.04	1.02	28.0	27.5	0.32	0.31	40.7	44.0
T_2-Potassium silicate at 0.1%	1.02	1.02	27.0	26.5	0.30	0.30	42.7	46.5
T_3-selenium at 50 ppm	1.02	1.04	25.6	25.0	0.29	0.28	43.7	48.0
T_4-Nile power at 0.2%	1.01	1.03	24.0	23.6	0.28	0.27	47.2	49.0
T_5-Potassium silicate at 0.1% + selenium at 50 ppm + Nile power at 0.2%	1.01	1.03	22.8	22.0	0.28	0.27	48.6	49.6
New L.S.D. at 5%	NS	NS	1.1	1.2	0.02	0.02	0.8	0.9

Table (6): Effect of some inducing abiotic stress substances on some chemical characteristics of fruits of Valencia orange trees during 2021 and 2022 seasons.

Treatments \ Characteristics	TSS (%)		Total acidity (%)		TSS/acid ratio		Total sugars (%)		Reducing sugars (%)		Vitamin C (mg/100 ml Juice)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
T_1-Control	11.2	11.5	1.40	1.36	8.0	8.4	7.2	7.3	3.6	3.7	48.92	44.6
T_2-Potassium silicate at 0.1%	11.7	12.0	1.28	1.22	9.1	9.8	7.7	7.8	4.0	4.2	52.40	47.60
T_3-selenium at 50 ppm	12.1	12.1	1.19	1.11	10.1	10.9	8.0	8.2	4.2	4.4	52.65	48.04
T_4-Nile power at 0.2%	12.6	12.6	1.05	1.00	12.0	12.6	8.5	8.6	4.4	4.5	55.80	51.27
T_5-Potassium silicate at 0.1% + selenium at 50 ppm + Nile power at 0.2%	13.2	13.1	1.00	0.95	13.2	13.7	9.0	9.2	5.0	5.1	55.90	54.8
New L.S.D. at 5%	0.6	0.7	0.08	0.09	0.4	0.5	0.4	0.5	0.3	0.4	0.16	0.17

DISCUSSION

The positive effects of potassium silicate on the growth and fruiting of Valencia orange trees can be attributed to its ability to reduce the impact of reactive oxygen species (ROS) and enhance resistance to abiotic and biotic stresses, as well as its role in promoting the biosynthesis of organic foods. In addition, potassium silicate facilitates water transport and growth under adverse conditions and stimulates antioxidant defense. These factors collectively help to alleviate the adverse effects of abiotic stress on the trees (Aziz et al., 2002; Meloet al., 2003 and Hattori, et al., 2005).

The results of the current work are supported by previous studies, which showed similar effects of potassium silicate against different biotic and abiotic stresses (Al-Wasfy, 2013; Ibrahiem and Al-Wasfy 2014; El-Gioushy, 2016; Habasy-Randa 2016; Sayedet al., 2016 and Radwam, 2017).

Selenium has been reported by several studies to activate important antioxidant enzymes (e.g., glutathione peroxidase), promote tolerance of trees to abiotic and biotic stress, and facilitate the biosynthesis essential macromolecules such as proteins and carbohydrates. Selenium also has an antioxidant effect by abrogating ROS production and its deleterious effects. Together, these selenium-mediated actions protect plant cells against senescence and apoptosis, as reported by Nowak-Barbara (2008) andJakovljevicet al. (2011). The results of this study are consistent with previous research that has shown a positive effect of selenium on the growth, yield, and fruit quality of Valencia orange trees, as reported by Ibrahiem and Al- Wasfy(2014), Gad El- Kareem et al. (2014), Masoud (2017) andAklet al. (2018).

Nile power compound contains many nutrients such as 8% nitrogen and 7.2 % K_2O, and some amino acids. These nutrients serve important regulatory functions in plant metabolism and development. They promote the manufacture of proteins, lipids, carbohydrates, and natural hormones as well as a number of enzymes important in plant growth. These nutrients are also essential for encouraging cell proliferation and expansion, transfer of water and nutrients across plant tissues, and the synthesis of amino acids (Devlin and Withdam, 1983 and Nijjar, 1985). Our results provide further evidence to those obtained by others (Ebeid–Sanaa, 2007; El-Sayed, Esraa, 2010; Mohamed and El-Sehrawy, 2013 and Abdel-Aziz et al., 2015) on the positive impact of Nile power compound on fruit crops.

CONCLUSION

It is advised to spray a combination containing 0.1% potassium silicate, 50 ppm of selenium, and 0.2% Nile power compound four times per season in March, May, July, and September, each at the 1st week of the month, to reduce the undesirable effect of water stress on the fruiting of Valencia orange trees.

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تأثير بعض مضادات الاجهاد على نمو ومحصول وبعض صفات الجودة لثمار البرتقال الفالنشيا

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الملخص العربي

خلال موسمى 2021 و 2022 تم اختبار التأثير الفردى والمشترك لرش ثلاثة مواد مضادة للإجهاد وهى سليكات البوتاسيوم بتركيز 0.1% والسلينيوم بتركيز 50 جزء فى المليون ومركب نايل باور بتركيز 0.2% لتقليل الآثار الضارة الناتجة عن الإجهاد المائى على النمو والحالة الغذائية وكمية المحصول وجودة الثمار فى أشجار البرتقال الفالنشيا النامية فى تربة طينية ونظام الرى هو الرى بالغمر حيث تم تأخير ميعاد الرى ثلاثةأيام عن موعد احتياجات الأشجار إلى الرى فى جميع الريات خلال الموسمين.

ولقد تم رش الأشجار المنتخبة لتنفيذ هذه التجربة أربعة مرات خلال موسمى الدراسة فى الاسبوع الأول من شهر مارس ومايو ويوليو وسبتمبر.

إن الإستخدام الفردى والمشترك للمواد الثلاثة سليكات البوتاسيوم والسلينيوم والنايل باور فعالا فى تحسين جميع صفات النمو الخضرى ومحتوى الورقة من الصبغات والعناصر وكمية المحصول وخصائص الجودة للثمار وذلك بالمقارنة بمعاملة الكنترول ولقد تفوق استخدام مركب النايل باور والسلينيوم عن سليكات البوتاسيوم فى هذا الصدد وكان استخدام الثلاثة مواد جنبا إلى جنب أفضل من استخدم أى من هذه المواد بمفردها.

التوصية: لتقليل الآثار الضارة للإجهاد على أشجار البرتقال الفالنشيا يوصى برش سليكات البوتاسيوم بتركيز 0.1% مع السلينيوم بتركيز 50 جزء فى المليون مع مركب النايل باور بتركيز 0.2% أربعة مرات فى الاسبوع الأول من شهر مارس ومايو ويوليو وسبتمبر.