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EFFECT OF FOLIAR BY SELENIUM AND POTASSIUM HUMATE AS A SOIL APPLICATION ON GROWTH AND PRODUCTIVITY OF SUGAR APPLE TREES UNDER SALINITY CONDITIONS

Shaimaa M.M. Ataya
Department of Plant Production, Desert Research Center, Cairo, Egypt
E-mail: drshaimaajhi1512@gmail.com

This investigation was conducted at Sedyghazy private orchard, which is situated on Abu Ghaleb Road, Giza Governorate, Egypt, at El-kilo 164 km from Cairo to the Alex Desert Road. For two seasons (2019 and 2020), the experiment was conducted on 10-year-old Abdel-Razek *Annona* trees budded on Baladi *Annona* rootstock and planted at 3.5 x 3.5 meters apart. The trees were grown in sandy soil under a drip irrigation system (EC= 3.41 dS m^{-1}). The experiment was arranged in a spilt-plot design and the main plots were represented four levels of foliar application of selenium (Se) (0, 5, 10 and 15 ppm), while the subplots included four rates of potassium humate (KH) as a soil application (0, 15, 30 and 60 g/tree) as possible alleviators of salinity. Data revealed that, for enhancing chlorophyll content and dry matter (%) with the exception of KH 0 g/tree × Se 0 ppm, all other possible combinations of KH × Se showed similar favorable effects. It is worthy to mention that KH 60 g/tree × Se 15 ppm, KH 30 g/tree × Se 15 ppm and KH 60 g/tree × Se 10 ppm were the most appropriate treatments for enhancing most of the significant yield attributes, fruit quality and leaf nutrient contents of Abdel-Razek *Annona* trees under salty soil. On the contrary, the same practices led to a reduction in leaf Na^+ content in Abdel-Razek *Annona* trees. It could be recommended that a soil application of KH 60 g/tree followed by foliar spray with Se 15 ppm is suitable in mitigating the effects of salt stress and provided the best results in terms of fruit quality, production and nutritional status.

Keywords: *Annona*, soil amendments, total antioxidant, macronutrients, micronutrients

INTRODUCTION

Annona sp. is an evergreen deciduous tropical fruit tree belonging to the family Annonaceae, which is concentrated in the tropics and is endemic to the West Indies, South and Central America, Ecuador, Peru, Brazil, India, Mexico, the Bahamas and Bermuda. The species most commonly cultivated in this family are *Annona cherimola* (cherimoya), *Annona squamosa* (sugar apple) and *Annona muricata* (soursop). It has been widely used globally in traditional medicine for various diseases. In Egypt, a new hybrid, Abdel Razek Annona is known as a hybrid between *Annona cherimola* × *Annona squamosal* (Lora et al., 2018 and Kumar et al., 2021). The leaves and seeds of the *Annona* species exhibit pharmacological activity, including antibacterial, anticancer, antidiabetic and anti-inflammatory properties (Al Kazman et al., 2022). *Annona squamosa* Linn. leaf isolates have demonstrated anticancer properties against cervical cancer (Swantara et al., 2022). Furthermore, leaf extract of *Annona muricata* L. shows potent antioxidant, anti-inflammatory and cytoprotective effects against DOX-induced testicular dysfunctions (Abou-El-magd et al., 2024). Crude extracts of *Annona squamosa* at different concentrations were incubated with leukemia cells HL60 cells for 24 h to evaluate the useful characteristics of its extract against oxidative damage. At all extract concentrations, catalase and superoxide dismutase (SOD) activities significantly increased in exposed cells. It also increased glutathione levels. So *Annona squamosa* might effectively protect against oxidative damage (Dilworth et al., 2023).

Saline conditions considerably inhibited the growth of *Annona muricata* seedlings, and the rate of reduction increased by increasing salinity level (Chima et al., 2019). A notable decrease in *Annona cherimola* development was caused by NaCl, with both ions accumulating in all tissues, especially in the leaves and shoots (Ebert, 1998). Sugar apple trees suffer from saline conditions, whether in the soil or irrigation water. These conditions cause the appearance of symptoms of salt stress, including tip and marginal necrosis, leaf browning and drop (leaf death), stem dieback and death of the tree (Crane et al., 2005).

Selenium (Se) plays a substantial role in plants tolerance to various abiotic stresses, such as those caused by drought, salinity, heavy metals, cold, high light and water (Feng et al., 2013). In adequate concentrations, Se can improve plant growth with higher fruit quality, extend fruit shelf life and increase plant resistance against a variety of stresses due to its significant impact on the antioxidant ability of plants. It does so by increasing the activity of antioxidant enzymes, thereby reducing the accumulation of excess reactive oxygen species and mitigating oxidative damage to cell membranes (Ryant et al., 2020 and Liu et al., 2022). Many studies have demonstrated that spraying Se on pomegranate trees (Zahedi et al., 2019), peach trees under drought stress (Al-Yazal et al., 2023) and blueberry trees (Wang et al., 2018) resulted in significant improvements in vegetative growth and plant productivity, as well as stimulation of chlorophyll biosynthesis and an increase in net photosynthetic rate.

The application of various chemicals and organic materials is commonly practiced in soil reclamation and the enhancement of physicochemical soil properties (Gonçalo Filho et al., 2020). Adding potassium humate (KH) could improve organic matter, soil structure, cation exchange capacity and water properties, all of which affect plant growth (Abo-Gabien et al., 2020).

Furthermore, KH has a positive effect in alleviating stresses such as drought and salinity (Kumari et al., 2021). In ‘Red Roumi’ grapevines, supplementing with KH at a rate of 6.0 g/vine gained the highest values of yield per vine and per feddan, berry and cluster weight, SSC, total anthocyanin and total proteins and carbohydrates in canes (Sefan, 2020). KH also enhances growth, yield and fruit quality of Manfalouty pomegranate trees, Fagri Kalan mango trees under salinity conditions and date palm trees under South Sinai conditions (Abd El-Rhman, 2017; Abdalla et al., 2022 and Ataya et al., 2022).

Application and integration between KH and Se at appropriate rates to alleviate the deleterious impact of salinity were evaluated to sustain and enhance the yield and quality of Abdel Razek *Annona* under saline conditions.

MATERIALS AND METHODS

1. Field Experiment

A field experiment was conducted during two seasons (2019 and 2020) in a private orchard (“Sedyghazi” farm) located on Abu Ghaleb Road at El-kilo 164 from Cairo-Alex Desert Road, Giza Governorate, Egypt. The study was carried out on 10-year-old Abdel-Razek Annona trees, known as a hybrid between *Annona cherimola* × *Annona squamosa*, budded on Baladi *Annona* planted at 3.5 x 3.5 meters apart (320 trees/ feddan). The trees were grown in sandy soil under a drip irrigation system (EC= 3.41 dS m^{-1}). Table (1) displays the chemical analysis of the irrigation water and the soil attributes of the experiment are displayed in Table (2).

Each experimental season started in January and ended at the end of August. Sixty-four fruitful Abdel-Razek *Annona* trees were selected based on similarity in their shape, size and for being disease-free. They were given the same horticultural practices adopted in *Annona* orchards of the region.

Table (1). Chemical analysis of water.

pH	EC (ds/m)	Soluble cations (meq/L)				Soluble anions (meq/L)			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{-}
8.2	3.41	10	1.3	20.2	0.12	-----	0.8	10.1	20.1

Table (2). Physical and chemical attributes of the experiment soil.

Sand %	Silt %	Clay %	Soil Texture	pH	EC (ds/m)	Soluble cations (meq/L)				Soluble anions (meq/L)			
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO^{-}_4	Cl^{-}
93.1	0.2	6.4	Sandy	7.0	2.71	9.1	7.2	13.1	0.3	-----	1.3	5.8	18.7

2. Experiment Design

The experiment was arranged in a split-plot design. The main plots were assigned to the foliar application of Se, and the subplots were designated for KH. Consequently, the experiment was consisted of sixteen treatments with four replicates; each replicate was represented by one tree.

3. Rates and Application Methods of Experimental Materials

Four levels of Se were applied as a foliar application (main plots)

1. Control (without Se)
2. Se at 5 ppm
3. Se at 10 ppm
4. Se at 15 ppm

Se as sodium selenite (Na_2SeO_3) was sprayed to the point of runoff three times during each growing season: the first in the last week of February at the beginning of new leaves emergence, the second at the last week of March, and the third at last week of April. Control trees were sprayed with irrigation water only. As a wetting agent, 0.1% Triton B was applied to every treatment, including the control.

Four rates of potassium humate as a soil application (subplots):

1. Control (without KH)
2. KH 15 g/tree/year
3. KH 30 g/tree/year
4. KH 60 g/tree/year

The different KH levels were applied once in winter (mid-January) as a ditch application beneath the drippers for each selected tree.

4. Data Recorded and Determinations

4.1. Total leaf chlorophyll content (SPAD reading)

At the end of the growing season (last August), six leaves were collected and chlorophyll content was determined using a SPAD – 502 MINOLTA chlorophyll meter.

4.2. Leaf dry matter percentage

The same leaf samples were weighed and then oven-dried at 70°C until their weight remained constant. Leaf dry matter (%) was calculated using the equation: Leaves dry weight/ Leaves fresh weight) * 100

4.3. Yield and its components

At harvest time (late August), Abdel-Razek *Annona* fruits were harvested in both seasons (2019 and 2020). The yield, expressed as the number and weight of fruits per tree, was determined. Three fruits from each tree were used to calculate the average fruit weight, which was then multiplied by the number of fruits per tree to obtain the yield per tree (kg).

4.4. Fruit quality

Three fruits from each tree were used to measure the following fruit physical and chemical characteristics.

4.4.1. Fruit physical attributes

Fruit volume (cm^3), seed weight (g), peel weight (g), pulp weight (g) and pulp percentage (pulp weight/fruit weight × 100) were calculated. Fruit length (cm) was measured from the top to the base of the fruit and fruit width (cm) was measured at the broadest point.

4.4.2. Fruit chemical attributes

Total soluble solids percentage (TSS%) were determined using a hand refractometer. Total titratable acidity percentage in fruit juice was expressed as anhydrous citric acid according to AOAC (2012). TSS/acid ratio was then computed. Total antioxidants in the fruit were determined according to Prieto et al. (1999).

4.5. Leaf mineral content

Twenty-five spring flush leaves from each tree were collected at the end of August in each season, washed with distilled water and dried in an electric oven (60-70ºC) until their weight remained consistent. The samples were then milled into fine powder for mineral analysis. For nitrogen (N) and potassium (K), samples were digested using sulfuric acid and hydrogen peroxide according to Parkinson and Allen (1975). Total N was determined by modified micro-Kjeldahl according to Pregl (1945), and K and sodium (Na) were measured by a flame photometer (Irri, 1976).

For calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), and Se, leaf samples were digested with nitric acid and hydrogen peroxide using a microwave digestion labstation closed system (Ethos Pro, Milestone, Italy) and analyzed by inductively coupled argon plasma (ICAP 6500 Duo, Thermo Scientific, England). A 1000 mg/L multi-element certified standard solution (Merck, Germany) was used as a stock solution for instrument standardization.

4.6. Proline

Proline amino acid was determined according to Bates et al. (1973).

5. Statistical Analysis

Data were subjected to computerized statistical analysis using Statistix 9 for analysis of variance (ANOVA) according to Snedecor and Cochran (1972). The treatment means were compared using LSD at 0.05 level.

RESULTS

1. Leaf Relative Chlorophyll Content (SPAD) and Leaf Dry Matter Percentage

Results in Table (3) show that the relative chlorophyll content (SPAD reading) and dry matter percentage were statistically affected by KH in both

Table (3). Main and interaction impact of potassium humate and selenium foliar spray on SPAD reading (leaf relative chlorophyll content) and leaf dry matter % of Abdel Razek *Annona* trees during 2019 and 2020 seasons.

Selenium (ppm)	Potassium humate (g/tree)									
	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H 15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean
	SPAD reading					Dry matter %				
	1st season									
Se 0 ppm	31.63 e	32.86 de	34.53 a-d	35.20 abc	**33.55 B**	39.69 f	40.53 ef	41.45 c-f	42.67 a-d	**41.08 B**
Se 5 ppm	34.23 a-d	34.23 a-d	33.20 cde	34.06 bcd	**33.93 B**	41.71 c-f	42.15 a-e	41.49 c-f	43.36 abc	**42.18 AB**
Se 10 ppm	33.86 bcd	35.33 ab	35.70 ab	35.66 ab	**35.14 A**	41.82 b-f	42.05 b-e	44.27 a	41.02 def	**42.29 AB**
Se 15 ppm	35.06 abc	35.23 abc	34.56 a-d	36.20 a	**35.26 A**	42.51 a-e	44.07 ab	43.37 abc	43.55 abc	**43.38 A**
Mean	**33.70** B	**34.41 AB**	**34.50 A**B	**35.28 A**		**41.43 B**	**42.20 A**B	**42.64 A**	**42.65 A**	
	2nd season									
Se 0 ppm	33.33 f	37.53 cde	36.86 e	39.26 a-d	**36.75 B**	40.19 g	48.10 c-f	52.66 ab	47.43 def	**47.10 C**
Se 5 ppm	37.26 de	39.26 a-d	39.03 a-d	38.60 a-e	**38.54 A**	51.79 abc	49.94 a-f	46.07 f	46.69 ef	**48.62 BC**
Se 10 ppm	37.56 cde	37.80 b-e	39.43 abc	40.23 a	**38.75 A**	48.22 c-f	48.82 b-f	51.23 a-d	52.70 ab	**50.24 AB**
Se 15 ppm	39.70 ab	39.96 a	39.23 a-d	39.00 a-d	**39.47 A**	48.41 c-f	50.51 a-e	49.14 a-f	53.51 a	**50.39 A**
Mean	**36.96 B**	**38.64 A**	**38.64 A**	**39.27 A**		**47.15 B**	**49.34 A**B	**49.77 A**	**50.08 A**	

Means followed by the same letter(s) in each row, column or interaction are not significantly different at 5% level.

seasons. All KH rates outperformed the untreated trees in enhancing SPAD readings and dry matter percentage. Regarding Se spraying, in the first season, Se at 15 ppm or 10 ppm produced the highest SPAD readings, while in the second season all Se rates surpassed the untreated trees in increasing SPAD readings, regardless of the concentration. Meanwhile, the highest leaf dry matter percentage was achieved by Se at 15 ppm in both seasons. Concerning the interaction, it is clear that untreated trees recorded the lowest significant values for both traits. Other combinations produced more boosting impact on both traits, with KH at 60 g/tree x Se at 15 or 10 ppm and KH at 30 g/tree x Se at 10 ppm being the most effective treatments for SPAD readings and leaf dry matter percentage in the first and second seasons, respectively.

2. Yield and Its Components

Table (4) presents yield and its constituents. Fruit weight, fruit number and tree yield were significantly affected by both KH application and Se foliar spraying. For KH, applying 30 g/tree or 60 g/tree gained the highest significant values of yield and its components in both seasons, except for fruit weight in the second season, where only the higher rate (60 g/tree) achieved the highest significant values. Regarding Se, all yield traits generally increased progressively with increasing Se levels up to 15 ppm, which exhibited the highest significant values of all yield traits. The only exceptions were fruit number/tree and fruit weight in the first season, where Se at 10 ppm and 15 ppm showed the highest significant values with insignificant differences between the two rates. The interaction between KH and Se was significant in both seasons, with various combinations. The combinations of KH at 30 g/tree or 60 g/tree x Se at 15 ppm were the most effective which resulted in the greatest fruit number/tree, heaviest fruit weight and highest yield/tree in both seasons. Additionally, the combination of KH at 30 g/tree x Se at 10 ppm gave a similar increment in yield and its components in the first season. Other combinations had more boosting effect on the yield and its components as compared with untreated trees, which recorded the least significant values.

3. Fruit Quality

3.1. Fruit physical attributes

Data in Tables (5 and 6) show the impact of KH and Se foliar spray on some physical attributes of "Abdel Razek" *Annona* fruits during 2019 and 2020 seasons. Data in Table (5) illustrate that KH and Se treatments significantly affected fruit volume, length and width in both seasons. Regarding KH, in most cases, treatment of KH at 30 g/tree and 60 g/tree achieved the highest significant values in both seasons, except for fruit volume in the second season, where only the highest level of KH (60 g/tree) gave the highest fruit volume.

Table (4). Main and interaction impact of potassium humate and selenium foliar spray on fruit number/tree, fruit weight (g) and fruit yield/tree (kg) of Abdel Razek *Annona* trees in 2019 and 2020 seasons.

Selenium (ppm)	Potassium Humate (g/tree)														
	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean
	Fruit number/tree					Fruit weight (g)					Fruit yield/tree (kg)				
	1st season														
Se 0 ppm	20.66 f	22.33 ef	26.33 bcd	25.00 de	**23.58 C**	453.3 f	554.6 ef	596.0 de	682.0 a-e	**571.5 C**	9.35 f	12.36 ef	15.94 de	17.06 cd	**13.68 D**
Se 5 ppm	26.00 bcd	26.33 bcd	25.33 cde	26.33 bcd	**26.00 B**	621.0 b-e	624.6 b-e	650.0 a-e	705.6 a-d	**650.3 B**	16.10 d	16.46 d	16.46 d	18.46 bcd	**16.87 C**
Se 10 ppm	28.00 bcd	28.66 bc	28.00 bcd	29.00 ab	**28.41 A**	573.6 ef	662.6 a-e	733.3 ab	750.0 a	**679.9 AB**	16.10 d	18.89 bcd	20.50 bc	21.75 ab	**19.31 B**
Se 15 ppm	26.66 bcd	28.66 bc	32.33 a	32.33 a	**30.00 A**	601.3 cde	732.3 abc	751.6 a	765.6 a	**712.7 A**	15.90 de	20.95 ab	24.32 a	24.58 a	**21.44 A**
Mean	**25.33 C**	**26.50 BC**	**28.00 AB**	**28.16 A**		**562.3 C**	**643.5 B**	**682.7 AB**	**725.8 A**		**14.36 C**	**17.16 B**	**19.30 A**	**20.46 A**	
	2nd season														
Se 0 ppm	19.00 h	19.66 h	26.00 def	24.66 fg	**22.33 D**	464.7 h	560.3 g	567.7 g	603.0 de	**548.9 D**	8.83 g	11.02 f	14.74 e	14.87 e	**12.36 D**
Se 5 ppm	27.33 c-f	26.66 c-f	25.00 efg	23.00g	**25.50 C**	571.3 fg	597.2 e	616.5 cd	634.2 bc	**604.8 C**	15.62 de	15.92 de	15.42 de	14.57 e	**15.38 C**
Se 10 ppm	26.33 c-f	28.00 cd	28.00 cd	29.00 bc	**27.83 B**	592.2 ef	605.7 de	652.3 b	653.2 b	**625.8 B**	15.59 de	16.96 cd	18.26 bc	18.94 b	**17.43 B**
Se 15 ppm	26.33 c-f	27.66 cde	31.33 ab	33.33 a	**29.66 A**	550.0 g	639.9 b	716.4 a	725.6 a	**657.9 A**	14.49 e	17.70 bc	22.42 a	24.18 a	**19.70 A**
Mean	**24.75 B**	**25.00 B**	**27.58 A**	**27.50 A**		**544.5 D**	**600.7 C**	**638.2 B**	**654.0 A**		**13.63 C**	**15.40 B**	**17.71 A**	**18.14 A**	

Means followed by the same letter(s) in each row, column or interaction are not significantly different at 5% level.

Table (5). Main and interaction impact of potassium humate and selenium foliar spray on fruit volume (cm^3), fruit length (cm) and fruit width (cm) of Abdel Razek *Annona* trees in 2019 and 2020 seasons.

Selenium (ppm)	Potassium Humate (g/tree)														
	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H 15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean
	Fruit volume (cm^3)					Fruit length (cm)					Fruit width (cm)				
	1st season														
Se 0 ppm	476.6 e	571.6 de	600.0 cd	690.0 a-d	**584.5 C**	9.10 e	10.90 d	11.50 bcd	12.06 abc	**10.89 C**	9.10 f	10.46 e	10.60 de	11.46 a-d	**10.40 C**
Se 5 ppm	626.6 bcd	626.6 bcd	658.3 a-d	706.6 abc	**654.5 B**	11.33 bcd	11.13 bcd	11.53 bcd	12.06 abc	**11.51 B**	10.83 b-e	10.93 b-e	10.80 cde	11.46 a-d	**11.00 B**
Se 10 ppm	590.0 d	673.3 a-d	736.6 ab	756.6 a	**689.1 A**	11.33 bcd	11.63 bcd	12.16 ab	12.23 ab	**11.48 AB**	11.00 b-e	11.10 b-e	11.43 a-d	11.33 a-d	**11.21 AB**
Se 15 ppm	623.3 cd	750.0 a	766.6 a	770.0 a	**727.5 A**	11.00 cd	12.00 a-d	12.23 ab	12.96 a	**12.05 A**	10.70 de	11.70 abc	11.73 ab	12.03 a	**11.54 A**
Mean	**579.1 C**	**655.4 B**	**690.4 AB**	**730.8 A**		**10.69 C**	**11.41 B**	**11.85 AB**	**12.33 A**		**10.40 C**	**11.05 B**	**11.14 AB**	**11.57 A**	
	2nd season														
Se 0 ppm	467.7 k	563.3 j	596.7 hi	613.3 g	**560.2 D**	10.90 h	11.367 fg	11.36 fg	11.86 cd	**11.37 C**	10.13 h	11.10 fg	10.83 g	11.46 bcd	**10.88 C**
Se 5 ppm	550.0 j	633.3 ef	650.0 cd	666.7 b	**625.0 C**	11.23 gh	11.63 c-f	11.83 cd	11.53 d-g	**11.55 B**	10.90 g	11.20 ef	11.60 abc	11.03 fg	**11.18 B**
Se 10 ppm	606.7 gh	620.0 fg	646.7 de	663.3 bc	**634.1 B**	11.40 efg	11.76 cde	11.76 cde	12.00 bc	**11.73 B**	10.93 g	11.23 def	11.46 bcd	11.40 cde	**11.25 B**
Se 15 ppm	583.3 i	653.3 bcd	703.3 a	716.7 a	**664.1 A**	11.63 c-f	11.83 cd	12.36 ab	12.50 a	**12.08 A**	10.90 g	11.46 bcd	11.70 ab	11.80 a	**11.46 A**
Mean	**551.92 D**	**617.4 C**	**649.1 B**	**665.0 A**		**11.29 C**	**11.65 B**	**11.83 AB**	**11.97 A**		**10.71 C**	**11.25 B**	**11.40 A**	**11.42 A**	

Means followed by the same letter(s) in each row, column or interaction are not significantly different at 5% level.

Concerning Se effect, foliar spraying with 10 ppm or 15 ppm in the first season achieved the highest values, with no significant difference between them. In the second season, Se at 15 ppm alone gave the highest significant values.

On the other hand, treatment of Se at 15 ppm alone proved to give the highest significant values in the second season. With respect to the interaction, untreated trees KH0 x Se 0 recorded the least significant values in the two growing seasons. The result also revealed that, although there were many promising combinations that resulted in increasing fruit volume, length and width, the most notable and remarkable treatments in the 2nd season were KH 60 x Se 10 ppm and KH 60 g/tree x Se 15 ppm. While in the first season all combinations between KH and Se gave higher values as compared with untreated trees.

Data in Table (6) reveal that pulp weight was significantly affected by KH and Se levels in both seasons. Trees treated with KH at 30 g/tree and 60 g/tree gave the heaviest pulp in the first season, while in the second season, the highest pulp weight was recorded only with KH at 60 g/tree. Regarding Se, the highest level of 15 ppm produced the highest pulp weight in both seasons. For the interaction between two factors, treatments of KH at 60 g/tree x Se at 15 ppm, KH at 60 g/tree x Se at 10 ppm and KH at 30 g/tree x Se at 15 ppm were the most notable combinations in both seasons. Result also demonstrated that, KH, Se foliar spraying and their interaction had no significant effect on peel weight and seed weight in the first season. Whereas in the second season, fruits obtained from trees treated with KH at 60 g/tree x Se at 10 ppm exhibited the lowest peel weight, while the lowest seed weight was obtained with KH at 60 g/tree x Se at 5 ppm, through no consistent trend was observed among the other treatments. Pulp percentage was significantly affected by KH in both seasons. The greatest significant pulp percentage was recorded by KH at 30 g/tree or 60 g/tree in both seasons. For Se, spraying at 10 or 15 ppm resulted in the highest pulp percentage in the second season. Concerning the interaction, the most remarkable combination was KH at 60 g/tree x Se at 10 ppm, which produced the greatest pulp percentage.

3.2. Fruit chemical attributes

As shown in Table (7), all fruit chemical attributes except total acidity were significantly impacted by KH soil amendment and Se foliar spraying in the 2019 and 2020 seasons.

Data regarding TSS% revealed that, fruits of *Annona* trees that received KH 60 g/tree outperformed the untreated trees in both the first and second seasons. As for Se, spraying Se with 10 ppm or 15 ppm was an effective application for increasing TSS in *Annona* fruits in the two seasons. Concerning interaction, except for untreated trees the remaining possible interactions between KH x Se exhibited similar improvement in TSS% in the first season. While treatment of KH 60 g/tree x Se 15 ppm had a higher value

Table (6). Main and interaction impact of potassium humate and selenium foliar spraying on peel weight (g), seed weight (g), pulp weight (g) and pulp % of Abdel Razek *Annona* fruits in 2019 and 2020 seasons.

Selenium (ppm)	Potassium Humate (g/tree)																			
	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean
	Peel weight (g)					Seeds weight (g)					Pulp weight (g)					Pulp %				
1st season																				
Se 0 ppm	108.67 b	113.0 ab	133.3 ab	140.3 ab	**123.8 A**	9.33 b	16.66 a	10.46 ab	16.00 ab	**11.28 B**	335.3 f	432.3 ef	452.0 e	525.6 a-e	**436.3 C**	73.98 a	78.55 a	75.92 a	77.18 a	**76.41 A**
Se 5 ppm	136.0 ab	132.0 ab	129.6 ab	133.3 ab	**132.7 A**	11.66 ab	11.00 ab	15.00 ab	11.83 ab	**12.37 AB**	473.3 cde	481.6 b-e	505.3 a-e	560.5 a-d	**505.2 B**	76.01 a	77.19 a	77.84 a	79.21 a	**77.56 A**
Se 10 ppm	134.6 ab	141.0 ab	143.0 a	146.6 a	**141.3 A**	10.66 ab	14.00 ab	12.33 ab	13.66 ab	**12.66 AB**	428.3 ef	507.6 a-e	578.0 abc	589.6 a	**525.9 AB**	74.48 a	76.25 a	78.77 a	78.70 a	**77.05 A**
Se 15 ppm	129.6 ab	138.3 ab	151.3 a	152.0 a	**142.8 A**	9.33 b	12.66 ab	16.00 ab	13.66 ab	**14.75 A**	455.0 de	581.3 ab	584.3 ab	600.0 a	**555.1 A**	75.18 a	79.41 a	77.67 a	78.29 a	**77.63 A**
Mean	**127.2 A**	**131.0 A**	**139.3 A**	**143.0 A**		**12.08 A**	**11.75 A**	**13.45 A**	**13.79 A**		**423.0 C**	**500.7 B**	**529.9 A\B**	**568.9 A**		**74.91 B**	**77.85 A**	**77.55 A\B**	**78.34 A**	
2nd season																				
Se 0 ppm	113.3 f	137.0 cd	130.3 de	137.0 cd	**129.4 B**	15.00 abc	11.33 efg	13.33 b-e	15.33 ab	**13.74 A**	336.3 j	412.0 i	424.0 i	450.7 fgh	**405.7 D**	72.37 h	73.54 fgh	74.66 efg	74.74 efg	**73.83 B**
Se 5 ppm	136.7 cd	152.0 ab	144.0 bc	135.7 cd	**142.1 A**	9.50 gh	9.50 gh	10.00 gh	8.00 h	**9.25 C**	425.2 hi	435.7 ghi	462.5 ef	490.5 cd	**453.4 C**	74.43 fgh	72.96 gh	75.04 efg	77.33 bcd	**74.94 B**
Se 10 ppm	143.0 bc	138.3 cd	119.0 ef	113.0 f	**128.3 B**	14.00 bcd	10.67 fg	17.00 a	12.67 c-f	**13.58 A**	435.2 ghi	456.7 efg	516.3 bc	527.5 b	**483.9 B**	73.49 fgh	75.39 def	79.13ab	80.74 a	**77.18 A**
Se 15 ppm	115.7 f	146.3 abc	142.7 bc	156.0 a	**140.1 A**	12.00 d-g	11.21 efg	12.71 b-f	11.88 d-g	**11.95 B**	422.3 i	482.3 de	561.0 a	557.7 a	**505.8 A**	76.79 cde	75.36 def	78.31 bc	76.86 b-e	**76.83 A**
Mean	**127.1 C**	**143..4 A**	**134.0 B**	**135.4 B**		**12.62 A\B**	**10.67 C**	**13.26 A**	**11.97 B**		**404.7 D**	**446.6 C**	**490.9 B**	**506.6 A**		**74.27 B**	**74.31 B**	**76.78 A**	**77.42 A**	

Means followed by the same letter(s) in each row, column or interaction are not significantly different at 5% level.

Table (7). Main and interaction impact of potassium humate and selenium foliar spray on TSS, acidity% and TSS/acid ratio of Abdel Razek *Annona* fruits in 2019 and 2020 seasons.

Selenium (ppm)	Potassium humate (g/tree)														
	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean
	TSS					Acidity %					TSS/acid ratio				
	1st sesason														
Se 0 ppm	16.83 c	19.60 ab	20.26 ab	20.80 a	**19.37 B**	0.227 a	0.220 abc	0.223 ab	0.213 abc	**0.221 A**	74.34 e	89.09 cd	90.77 bcd	97.56 ab	**87.94 C**
Se 5 ppm	20.56 ab	18.80 b	20.33 ab	19.66 ab	**19.84 AB**	0.213 abc	0.220 abc	0.210 bc	0.213 abc	**0.214 AB**	96.43 ab	85.42 d	96.75 ab	92.19 a-d	**92.70 B**
Se 10 ppm	19.50 ab	20.66 ab	20.36 ab	20.93 a	**20.36 A**	0.207 c	0.210 bc	0.213 abc	0.217 abc	**0.212 B**	94.34 abc	98.41 a	95.55 abc	96.65 ab	**96.24 A**
Se 15 ppm	20.76 a	19.90 ab	21.20 a	21.36 a	**20.80 A**	0.217abc	0.207 c	0.217 abc	0.220 abc	**0.215 AB**	95.85 ab	96.23 ab	97.83 a	97.10 ab	**96.75 A**
Mean	**19.41 C**	**19.74 B\C**	**20.54 A\B**	**20.69 A**		**0.216 A**	**0.214 A**	**0.216 A**	**0.216 A**		**90.24 B**	**92.28 A\B**	**95.22 A**	**95.87 A**	
	2nd season														
Se 0 ppm	18.03 h	19.90 efg	19.53 fgh	20.33 def	**19.45 C**	0.230 a	0.217 abc	0.227 ab	0.213 bc	**0.222 A**	78.47 d	91.79 b	86.11 c	95.28 ab	**87.91 C**
Se 5 ppm	18.66 gh	21.03a-f	20.73 a-f	21.53 a-d	**20.49 B**	0.227 ab	0.220 abc	0.213 bc	0.220 abc	**0.220 A**	82.36 cd	95.60 ab	97.21 a	97.91 a	**93.27 B**
Se 10 ppm	20.50 c-f	20.96 a-f	21.96 abc	22.16 ab	**21.40 A**	0.216 abc	0.217 abc	0.227 ab	0.227 ab	**0.222 A**	94.79 ab	96.76 ab	96.93 ab	97.81 a	**96.57 A**
Se 15 ppm	21.13 a-e	20.60 b-f	21.13 a-e	22.20 a	**21.26 AB**	0.220abc	0.207c	0.216 abc	0.223 ab	**0.217 A**	96.04 ab	99.81 a	97.55 a	99.40 a	**98.20 A**
Mean	**19.58 C**	**20.62 B**	**20.84 A\B**	**21.55 A**		**0.223 A**	**0.215 B**	**0.221 A\B**	**0.221 A\B**		**87.91 C**	**\95.99 A\B**	**94.45 B**	**\97.60 A**	

Means followed by the same letter(s) in each row, column or interaction are not significantly different at 5% level.

compared with other treatments and untreated trees which gave the lowest value.

Data concerning fruit acidity showed that the application of KH and Se spraying had a non-significant effect on fruit acidity in both seasons. With respect to interaction, one can notice that untreated trees KH 0 x Se 0 had higher values as compared with other combinations. g/tree

Concerning TSS/acid ratio, data showed clearly that applying KH irrespective the level had a noticeable significant improvement in values of TSS/acid ratio compared with untreated trees in the two seasons. As for Se spraying, spraying Se at 10 ppm and 15 ppm gave the highest TSS/acid ratio in both seasons. With respect to the interaction, the combination of KH 30 g/tree x Se 15 ppm in both seasons and KH 60 g/tree x Se 15 ppm in the second season was the most beneficial treatment.

Regarding total antioxidant, as shown in Fig. (1) all KH levels had significantly higher values of total antioxidant as compared with control which had the lowest values in both seasons. Foliar spraying of Se at 15 in the first season and 10 or 15 ppm in the second one enhanced the total antioxidant by 38.44, 45.31 and 37.45% greater than control in both seasons respectively. Concerning the interaction combination of KH 30 g/tree x Se 15 ppm was the most promising treatment in both seasons.

4. Leaf Mineral Content

4.1. Macronutrient content

Both leaf nitrogen and potassium content as shown in Table (8) of "Abdel Razek" *Annona* trees were assessed under application of KH and spraying of Se in 2019 and 2020 seasons.

Results concerning leaf potassium content illustrated that, leaf potassium content was improved gradually by increasing KH up to 60 g/tree in both seasons. Regarding Se spray, Se at 15 ppm resulted in higher leaf potassium content as compared with other treatments in both seasons. As for interaction, despite there being many remarkable combinations that enhanced leaf potassium content however KH 60 g/tree x Se 15 ppm, KH 60/tree x Se 10 ppm and KH 30 g/tree x Se 15 ppm were the noteworthy combinations in the two seasons.

Data in Table (9) clarify that leaf Ca and Mg content were significantly affected with KH, foliar application of Se and their interaction in both seasons. Regarding KH it is worth mentioning that the highest level of KH 60 g/tree resulted in the highest Ca content in both seasons while KH at 30 g/tree and 60 g/tree had the highest Mg content in both seasons without significant differences between them. As for Se foliar spray, it was noticed that untreated trees gained the lowest values of Ca and Mg, in contrast to all Se levels which recorded the highest values of Ca and Mg in the first season. While in the second season Se at 15 or 10 ppm gave the highest Ca content. Moreover, Se at the highest level (10 ppm) had higher Mg content as compared with other levels. With respect to interaction, it is apparent that the interaction between KH x Se was significant with varied affirmative combinations KH 60 g/tree x Se 15 ppm, KH60 g/tree x Se 10 ppm and KH 30 g/tree x Se 10ppm were the most effective interaction for enhancing leaf Ca and Mg content.

As shown in Tables (10 and 11) micronutrients in “Abdel Razek” *Annona* leaves were significantly enhanced by KH and Se spraying in the 2019 and 2020 seasons.

Data concerning leaf Fe content demonstrated that KH at 30 g/tree or 60 g/tree had the highest values in the first season, whereas in the second season, the high level of KH 60 g/tree had the highest leaf Fe content. The result also revealed that all Se rates surpassed Se 0 ppm for enhancing leaf Fe content in the first season while in the second season trees receiving Se at 10 pm or 15 ppm resulted in the highest Fe content. Regarding the interaction, untreated trees gained the least significant values in both seasons. Other combinations between the KH x Se improved leaf Fe content while treatment of KH 60 g/tree x Se 15 ppm or 60 g/tree x Se 10 ppm were the most beneficial treatments in the two seasons.

Data regarding leaf Zn content showed clearly that Zn content was enhanced gradually by increasing the KH level up to 60 g/tree, especially in the first season. As for Se foliar spray, it was noticed that leaf Zn content significantly increased by increasing Se level up to 10 ppm. Meanwhile the difference between Se at 10 ppm and Se at 15 ppm was insignificant in both seasons. With respect to the interaction, despite several promising combinations that improved leaf Zn content however KH 60 g/tree x Se 10 ppm in both seasons and KH 60 g/tree x Se 15 ppm in the second season were the prominent combinations.

Results concerning leaf Mn content clarified that, applying KH at 30 g/tree and 60 g/tree achieved the highest values of Mn content with a non-significant difference between them in the two seasons. Results also showed that, all Se levels improved leaf Mn content especially in the second season. With respect to the interaction between KH and Se, many combinations caused similar improvement in leaf Mn content especially in the first season; meanwhile, the combination of KH 60 g/tree x Se 15 ppm had higher values as compared with other treatments in the two seasons.

Data in Table (11) revealed that, both Se and sodium content of “Abdel Razek” *Annona* leaves were significantly affected by applying KH and Se in both seasons.

Trees receiving the highest level of KH at 60 g/tree resulted in the highest leaf Se content in the two seasons. As for Se spraying, the highest leaf Se values were recorded with Se at 10 ppm and Se 15 ppm in the two seasons. With respect to the interaction, it is worth noting that, the highest values were obtained by the combination of KH at 60 g/tree x Se 15 in both seasons. On the contrary untreated trees exhibited the lowest values in the two seasons.

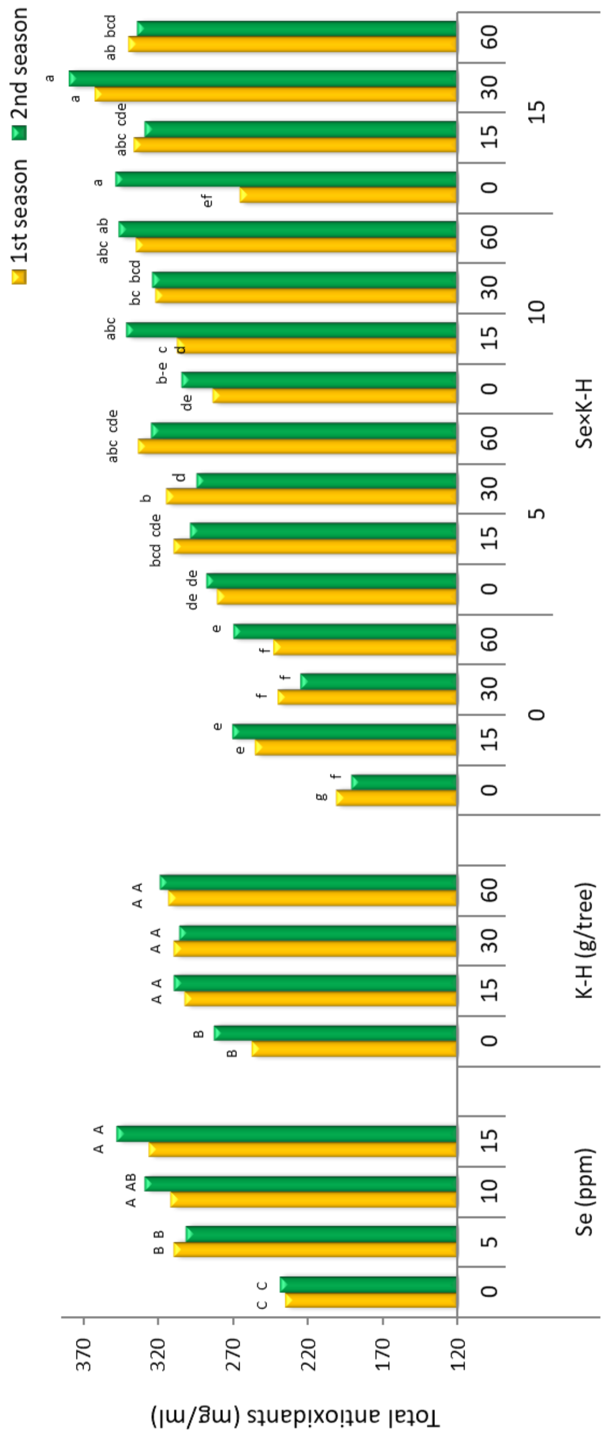

Fig. (1). Main and interaction impact of potassium humate and selenium foliar spray on total antioxidant of Abdel Razek *Annona* fruits in 2019 and 2020 seasons.

Table (8) Main and interaction impact of potassium humate and selenium foliar spray on leaf nitrogen % and leaf potassium % of Abdel Razek *Annona* trees in 2019 and 2020 seasons.

Selenium (ppm)	Potassium humate (g/tree)									
	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean
	Nitrogen %					Potassium %				
	1[st] season									
Se 0 ppm	2.27 f	2.56 a-e	2.66 a-d	2.68 a-d	**2.44 B**	1.66 e	1.86 bcd	1.98 ab	1.98 ab	**1.87 C**
Se 5 ppm	2.37 ef	2.43 c-f	2.57 a-e	2.40 def	**2.54 AB**	1.81 cd	1.82 cd	1.95 ab	1.97 ab	**1.88 BC**
Se 10 ppm	2.53 a-f	2.70 abc	2.53 a-f	2.74 ab	**2.62 A**	1.78 de	1.93 abc	1.97 ab	2.00 a	**1.93 B**
Se 15 ppm	2.50 b-f	2.62 a-e	2.53 a-f	2.79 a	**2.61 AB**	1.89 a-d	1.99 a	2.00 a	2.00 a	**1.97 A**
mean	**2.42 B'**	**2.58 A'**	**2.57 A'**	**2.65 A'**		**1.78 C'**	**1.90 B'**	**1.97 A'B'**	**1.99 A'**	
	2[nd] season									
Se 0 ppm	2.27 f	2.33 ef	2.53 de	2.70 a-d	**2.46 C**	1.68 f	1.91 b-e	1.95 a-d	1.98 abc	**1.88 B**
Se 5 ppm	2.34 ef	2.58 d	2.67 bcd	2.79 abc	**2.61 B**	1.83 e	1.88 cde	1.96 abc	2.00 ab	**1.92 AB**
Se 10 ppm	2.62 cd	2.74 a-d	2.72 a-d	2.91 a	**2.73 A**	1.83 e	1.98 abc	1.99 abc	2.03 a	**1.96 AB**
Se 15 ppm	2.70 a-d	2.83 abc	2.88 ab	2.87 ab	**2.82 A**	1.85 de	1.99 abc	1.99 abc	2.03 a	**1.96 A**
Mean	**2.48 C'**	**2.62 B'**	**2.70 B'**	**2.81 A'**		**1.80 C'**	**1.94 B'**	**1.97 A'B'**	**2.01 A'**	

Means followed by the same letter(s) in each row, column or interaction are not significantly different at 5% level.

Table (9). Main and interaction impact of potassium humate and selenium foliar spray on leaf calcium% and leaf magnesium% of Abdel Razek *Annona* trees in 2019 and 2020 seasons.

Selenium (ppm)	Potassium humate (g/tree)									
	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean
	Calcium %					Magnesium %				
	1st season									
Se 0 ppm	1.21 ef	1.31 de	1.36 cde	1.58 ab	**1.37 B**	0.510 h	0.633 fg	0.690 c-f	0.746 bcd	**0.645 B**
Se 5 ppm	1.29 de	1.42 cd	1.62 ab	1.69 a	**1.51 A**	0656 efg	0.723 b-e	0.713 b-e	0.780 ab	**0.718 A**
Se 10 ppm	1.11 f	1.47 bc	1.63 ab	1.72 a	**1.48 A**	0.673 d-g	0.720 b-e	0.833 a	0.736 bcd	**0.740 A**
Se 15 ppm	1.25 ef	1.50 bc	1.58 ab	1.67 a	**1.50 A**	0.610 g	0.740 bcd	0.753 bc	0.850 a	**0.738 A**
Mean	**1.22 C**	**1.43 C**	**1.55 B**	**1.67 A**		**0.612 C**	**0.704 B**	**0.747 A**	**0.778 A**	
	2nd season									
Se 0 ppm	1.07 i	1.45 fg	1.63 cde	1.71 abc	**1.47 B**	0.353 f	0.430 def	0.560 b-e	0.750 ab	**0.523 B**
Se 5 ppm	1.33 h	1.41 gh	1.61 cde	1.64 bcd	**1.50 B**	0.373 ef	0.546 c-f	0.690 abc	0.653 abc	**0.565 AB**
Se 10 ppm	1.51 efg	1.57 def	1.63 cde	1.76 ab	**1.62 A**	0.420 def	0.570 bcd	0.633 abc	0.730 abc	**0.590 AB**
Se 15 ppm	1.41 gh	1.57 def	1.66 bcd	1.80 a	**1.61 A**	0.426 def	0.643 abc	0.753 ab	0.806 a	**0.655 A**
Mean	**1.33 D**	**1.50 C**	**1.63 B**	**1.73 A**		**0.393 C**	**0.547 B**	**0.659 A**	**0.735 A**	

Means followed by the same letter(s) in each row, column or interaction are not significantly different at 5% level.

Table (10). Main and interaction impact of potassium humate and selenium foliar spray on leaf iron mg/l, leaf zinc mg/L and leaf manganese mg/l of Abdel Razek *Annona* trees in 2019 and 2020 seasons.

Selenium (ppm)	Potassium Humate (g/tree)														
	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean
	Iron mg/L					Zinc mg/L					Manganese mg/L				
	1[st] season														
Se 0 ppm	224.3 g	380.0 def	463.0 abc	462.4 abc	**377.6 B**	44.60 e	53.00 de	66.65 abc	67.66 abc	**57.97 B**	51.93 f	65.46 de	72.06 bcd	82.30 abc	**67.94 B**
Se 5 ppm	378.0 ef	415.9 b-f	403.2 c-f	466.0 abc	**415.8 A**	55.13 cde	60.45 bcd	71.60 ab	69.86 ab	**64.26 AB**	55.93 ef	71.00 cd	83.16 ab	81.83 abc	**72.98 AB**
Se 10 ppm	398.4 c-f	433..6 a-e	434.27 a-e	474.5 ab	**435.2 A**	50.37 de	67.20 abc	70.12 ab	77.65 a	**66.33 A**	55.10 ef	84.90 a	88.12 a	86.99 a	**78.77 A**
Se 15 ppm	360.8 f	389.8 def	455.3 a-d	500.2 a	**431.3 A**	62.53 bcd	69.70 ab	67.56 abc	72.16 ab	**67.99 A**	56.95 ef	81.11 abc	80.80 abc	91.34 a	**77.55 A**
Mean	**345.2C**	**400.0 B**	**438.9 A**	**475.8 A**		**53.16 C**	**62.58 B**	**68.98 AB**	**71.83 A**		**54.98 C**	**75.61 B**	**81.03 AB**	**85.61 A**	
	2[nd] season														
Se 0 ppm		390.6 fgh	431.1 b-f	445.5 b-e	**394.9 B**	48.10 f	60.13 cd	67.00 abc	68.53 abc	**60.94 B**	56.33 f	68.66 def	72.44 cde	76.86 bcd	**68.57 B**
Se 5 ppm	360.4 h	371.9 gh	442.0 b-e	456.3 bc	**407.6 B**	58.10 de	63.83 bcd	68.75 abc	68.37 abc	**64.76 AB**	60.86 ef	73.73 b-e	80.66 a-d	81.26 a-d	**74.13 A**
Se 10 ppm	400.7 e-h	453.0 bcd	422.9 c-f	477.2 ab	**438.4 A**	50.33 ef	61.26 cd	70.53 ab	72.69 a	**64.20 AB**	61.83 ef	77.89 bcd	84.61 abc	85.33 ab	**77.41 A**
Se 15 ppm	392.6 fgh	407.3 d-g	433.1 b-f	510.0 a	**435.7 A**	56.66 def	68.09 abc	72.51 ab	74.08 a	**67.34 A**	62.59 ef	78.50 bcd	83.99 abc	92.32 a	**79.35 A**
Mean	**366.5 D**	**405.7 C**	**432.2 B**	**472.2 A**		**53.29 C**	**63.33 B**	**69.70 A**	**70.92 A**		**60.40 C**	**74.69 B**	**80.42 AB**	**83.94 A**	

Means followed by the same letter(s) in each row, column or interaction are not significantly different at 5% level.

Table (11). Main and interaction impact of potassium humate and selenium foliar spray on leaf Selenium mg/L and leaf sodium mg/L of Abdel Razek *Annona* trees in 2019 and 2020 seasons.

Selenium (ppm)	Potassium Humate (g/tree)									
	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean	K-H (0 g/tree)	K-H (15 g/tree)	K-H (30 g/tree)	K-H (60 g/tree)	Mean
	Selenium mg/L					Sodium mg/L				
	1st season									
Se 0 ppm	1.22 f	1.92 de	2.00 cde	2.40 bcd	**1.88 B**	0.308 a	0.278 ab	0.272 abc	0.212 def	**0.267 A**
Se 5 ppm	1.60 ef	2.00 cde	2.00 cde	2.45 bcd	**2.10 B**	0.245 bcd	0.213 def	0.214 def	0.182 ef	**0.213 B**
Se 10 ppm	2.06 cde	1.99 cde	2.54 bc	2.83 ab	**2.37 A**	0.212 def	0.239 bcd	0.198 def	0.164 fg	**0.203 B**
Se 15 ppm	2.15 cde	2.00 cde	2.86 ab	3.25 a	**2.56 A**	0.221 cde	0.159 fg	0.118 g	0.123 g	**0.155 C**
Mean	**1.76 C**	**1.99 C**	**2.35 B**	**2.73 A**		**0.246 A**	**0.222 A\\B**	**0.200 B**	**0.170 C**	
	2nd season									
Se 0 ppm	1.57 h	1.60 h	2.32 efg	2.56 c-g	**2.01 B**	0.260 a	0.237 abc	0.227 abc	0.176 efg	**0.225 A**
Se 5 ppm	2.02 gh	2.30 efg	2.22 efg	2.62 b-f	**2.29 B**	0.249 ab	0.221 bcd	0.212 cde	0.170 fg	**0.213 A**
Se 10 ppm	2.04 fgh	2.96 a-d	2.77 b-e	3.16 ab	**2.73 A**	0.208 cde	0.203 c-f	0.186 def	0.142 gh	**0.189 B**
Se 15 ppm	2.41 d-g	3.00 abc	3.20 ab	3.50 a	**3.02 A**	0.232 abc	0.221 bcd	0.177 efg	0.120 h	**0.183 B**
Mean	**2.01 C**	**2.46 B**	**2.62 B**	**2.96 A**		**0.2370A**	**0.220 A**	**0.200 B**	**0.152 C**	

Means followed by the same letter(s) in each row, column or interaction are not significantly different at 5% level.

4.2. Micronutrients content

As shown in Table (11), trees receiving the highest level of KH at 60 g/tree resulted in the lowest leaf sodium content in the two seasons. As for Se spraying, the lowest sodium content values were recorded with Se at 15 ppm in the first season. Meanwhile in the second season, treatments of Se at 10 ppm and Se 15 ppm had the least values with no significant difference between them. With respect to the interaction, it is worth noting that, least values were obtained by the combination of KH at 60 g/tree x Se 15 ppm in the both seasons. On the contrary untreated trees exhibited the highest values in the two seasons.

5. Proline Content

Data in Fig. (2) revealed that, proline content of "Abdel Razek" *Annona* leaves was significantly affected by applying KH and Se in both seasons. Trees receiving the highest level of KH at 60 g/tree resulted in the highest leaf proline content in the two seasons. As for Se spraying, the highest leaf proline content values were recorded with Se 15 ppm the first season. While in the second one, Se at 10 ppm or 15 ppm showed the highest significant values. With respect to the interaction, it is worthy to note that, the highest values were obtained by the combination of KH at 60 g/tree x Se 15 in both seasons. On the contrary, untreated trees exhibited the lowest values in the two seasons.

DISCUSSION

The noticeable effect of KH could be due to stimulating root growth through enhancing the root fresh mass and delaying the senescence of roots (Liang et al., 2007). Moreover, KH contains many nutrients in addition to natural humic acid, which enhances the uptake of minerals such as P, N and K. So it improves the nutritional status of the plant, which is reflected in increasing yield and its components (Ibrahim and Ali, 2018). Many studies have demonstrated that, KH considerably increases Red Roumi' grapevines yield (Sefan, 2020). Manfalouty pomegranate (Abd El-Rhman, 2017) and Fagri Kalan mango (Abdalla et al., 2022). Our findings regarding yield and its constituents in Table (4) are consistent with these observations, where application of KH 30 g/tree or 60 g/tree achieved increases of 42.47 and 34.40 % higher than the control treatment in the 1st season and 33.08 and 29.93% in the 2nd season.

Additionally, KH had a prominent effect on promoting hormone production, stimulating root growth, and improving the absorption of minerals. Thus, it improved chlorophyll and enhancing photosynthesis (Shen et al., 2024). This remarkable influence could explain the increase in SPAD reading and dry matter (Table 3).

KH had a noticeable impact on enhancing microbial activity in the rhizosphere, boosting nutrient availability through chelation processes, and improves soil structure by encouraging aggregate formation. Moreover, KH improved soil respiration and soil organic carbon and the available nutrient content in the soil. Consequently, the effects of salt are reduced (Liu et al., 2024 and Rupngam et al., 2025). This remarkable influence could explain the increased macro- and micronutrients. On the other hand, Sun et al. (2022) reported that the soil's available B, Ca, N and K, had the biggest impact on the weight of a single fruit, whereas the soil's available Fe, K, B and Ca had the biggest impact on the amount of soluble solids in the fruit. Hence, the increased availability of elements, which was enhanced due to KH, led to an increase in fruit physical and chemical attributes (Tables 5, 6 and 7).

Under salinity stress, high amounts of Na have a negative effect on the uptake of nutrients, especially potassium; where elevated Na^+ causes a decrease in K^+ availability by inhibiting K^+ activity in the soil solution and also Na^+ competes with K^+ for uptake sites at the plasma membrane (Abdeldym et al., 2020). Therefore, maintaining cellular K^+ level above a certain threshold and preserving a high cytosolic K^+/Na^+ ratio (either by retaining K^+ or preventing Na^+ from accumulating in leaves) is crucial for plant growth and salt tolerance (Farag et al., 2022). Under saline conditions, our findings indicate that KH enhanced the K^+ level of leaves and the Na^+ concentration decreased. This outcome is consistent with earlier research by El-Beltagi et al. (2023).

The remarkable effect of Se could be identified as its effectiveness in increasing cell division (Aghaie and Forghani, 2023). Furthermore, Se improved photosynthetic pigments such as carotenoids, pheophytins and chlorophylls. It also increases the enzymatic metabolism of antioxidants (Cunha et al., 2022), which enhances plant growth under stress conditions. This positive impact could explain the increased relative chlorophyll content and dry matter (Table 3). Where Se spray at 15 ppm increases the SPAD reading by 5.09% and 7.40% also improves dry matter by 5.59 and 6.98% greater than Se 0 in both seasons.

Se regulates physiological functions, such as osmoregulation, which preserves water retention in plant cells (Liu et al., 2022). So, Se can be applied to alleviate the adverse effects of salinity stress (Feng et al., 2013). This positive effect could explain the increased yield (Table 4) and fruit chemical traits (Table 7). Where Se at 15 ppm improves yield/tree by 56.72 and 59.38% greater than control in the two seasons. Similar findings were documented by Zhu et al. (2017) revealed that Se fertilizer increases soluble solids, soluble protein, vitamin C and soluble sugar. In addition, Karimi et al. (2020) showed that Se had an additive effect on the accumulation of total phenol, total flavonoid and soluble sugars in leaves of vines under salinity stress (75 mM NaCl).

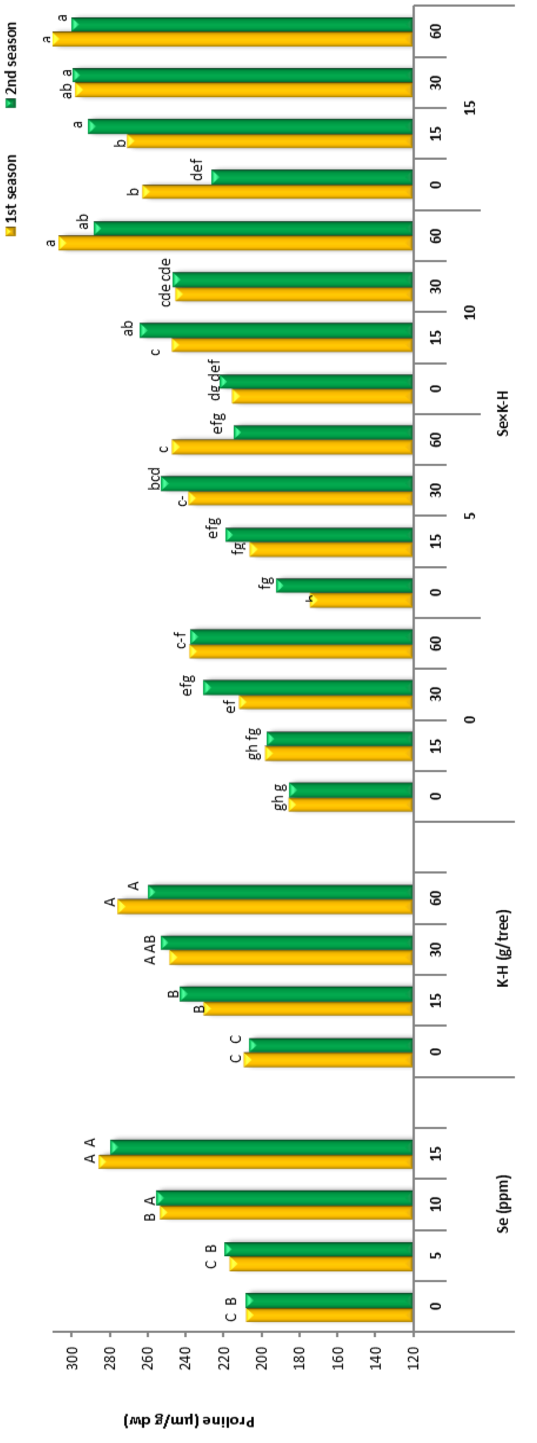

Fig. (2). Main and interaction impact of potassium humate and selenium foliar spray on leaf proline µm/g dw of Abdel Razek *Annona* trees in 2019 and 2020 seasons.

In addition, Se boosts both enzymatic and non-enzymatic antioxidant capacities in grapevine leaves. On the other hand, numerous studies showed that Se enhances yield and its components in peach trees (Al-Yazal et al., 2023), *Manfalouty pomegranate* (Abdelghany et al., 2024) and Mango (Almutairi et al., 2023). Additionally, Shahverdi et al. (2020) observed that under salinity conditions (30, 60 and 90 mM NaCl), spraying Se individually or in combination with Fe and boron gained alleviated salt stress and enhanced the root morphological traits (root length, root volume, root area, root dry weight and root fresh weight) of *Stevia rebaudiana*. This beneficial effect could account for the rise in macro- and micronutrients (Tables 8, 9 and 10). Moreover, many studies reported that the external application of Se led to an increase in salt stress tolerance by promoting osmolyte accumulation, such as proline and soluble sugar (Karimi et al., 2020 and Mushtaq et al., 2023). These observations align with our findings regarding proline (Fig. 2). Additionally, Farag et al. (2022) demonstrated that Se achieves significant improvement in K, Ca and the K/Na ratio, which aligns with our findings.

CONCLUSION

The current investigation demonstrated that salt stress effects could be mitigated by enhancing soil attributes as an indirect effect of KH, as well as the direct impact of Se foliar spray to modify the physiological state and productivity of Abdel-Razek *Annona* trees. In general, under salinity stress, adding KH as a soil application of 60 g/tree, followed by spraying Se (15 or 10 ppm), achieved noticeable improvement in relative chlorophyll content, dry matter, fruit productivity traits, and fruit quality.

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تأثير الرش الورقي بالسيلينيوم وهيومات البوتاسيوم كإضافة أرضية على نمو وإنتاجية أشجار القشطة تحت ظروف الملوحة

شيماء محمد محمد عطايا
قسم الإنتاج النباتي، مركز بحوث الصحراء، المطرية، القاهرة، مصر

أجريت هذه الدراسة في مزرعة "سيدي غازي" الخاصة، الواقعة على طريق أبو غالب، محافظة الجيزة، مصر، الكيلو١٦٤ طريق القاهرة الإسكندرية الصحراوي. لمدة موسمين (٢٠١٩ و٢٠٢٠). أجريت التجربة على أشجار القشطة عبد الرازق، عمرها ١٠ سنوات، مطعومة على أصل القشطة البلدي، مزروعة على بُعد ٣,٥ × ٣,٥ متر في تربة رملية تحت نظام الري بالتنقيط وملوحة ($EC = 3.41$ ds m^{-1}). تم توزيع التجربة في تصميم القطع المنشقة، حيث إحتوت القطع الرئيسية على أربعة مستويات من الرش الورقي بالسيلينيوم (Se) (٠، ٥، ١٠، ١٥ جزء في المليون)، واحتوت القطع الفرعية على أربعة مستويات من هيومات البوتاسيوم (KH) (٠، ١٥، ٣٠، ٦٠ جرام/شجرة) كعوامل مُحتملة لتخفيف الملوحة. أظهرت النتائج أنه لتحسين محتوى الكلوروفيل ونسبة المادة الجافة باستثناء المعاملة (KH0 جم/شجرة x Se0 جزء في المليون) أظهرت جميع التوليفات الأخرى بين KH × Se تأثيرات محفزة مماثلة. تجدر الإشارة إلى أن KH60 جم/شجرة x Se15 جزء في المليون وKH30 جم / شجرة x Se15 جزء في المليون وKH60 جم/ شجرة x Se10 جزء في المليون كانت المعاملات الأكثر ملاءمة لتعزيز المحصول ومكوناته وجودة الثمار والمحتوى الغذائي لأوراق أشجار القشطة عبد الرازق تحت ظروف الملوحة. على العكس من ذلك، أدت نفس المعاملات إلى تقليل محتوى الصوديوم في أوراق أشجار القشطة عبد الرازق. يمكن التوصية بتطبيق (KH60 جم / شجرة) كإضافة أرضية للأشجار متبوعًا بالرش الورقي بـ Se ١٥جزء في المليون، حيث كان مناسبًا للتخفيف من آثار الإجهاد الملحي وأعطى أفضل النتائج من حيث جودة الثمار والإنتاجية والحالة الغذائية للأشجار.