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Influence of Ethrel and Potassium Thiosulfate Spraying on Improving Fruit Coloration and Quality of Wonderful Pomegranate

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Abstract: This experiment was carried out during two successive seasons of 2019 and 2020 to study the effect of spraying ethrel at (1000, 500, 250 and 125 ppm) or potassium thiosulfate at (1 and 3 %) on Wonderful pomegranate trees grown in sandy soil at a private orchard at Alexandria desert road, Giza Governorate, Egypt. Potassium thiosulfate was sprayed twice (30 and 15 days before harvest), while, ethrel treatments were sprayed once (15 days before harvest) in each season. Results show that, potassium thiosulfate at 3 % significantly increased fruit length and fruit width (cm), fruit weight (g), yield (Kg/tree), total soluble solids, juice and peel anthocyanin content (%) as compared with other treatments. On the other hand, spraying ethrel at 125 ppm increased juice and fruit peel anthocyanin content (%) without causing leaf abscission and fruit drop percentage. While, percentages of fruit drop, leaf abscission, yellowish leaves and acidity were increased by the higher concentrations of ethrel. Generally, spraying potassium thiosulfate at 3% was more effective than the other treatments for enhancing pomegranate (Wonderful cv.) fruit coloration and quality under the same conditions of this experiment.

Key words: Pomegranate · Ethrel · Potassium thiosulfate · Fruit quality

INTRODUCTION

Pomegranate belongs to the genus Punica, which comprises two species, (*Punica granatum*) and (*Punica protopunica*). Pomegranate is one of the oldest known edible fruits and is capable of growing under different agro-climatic conditions ranging from the tropical to sub-tropical [1, 2]. The pomegranate is native to the subtropics and mild temperate regions. It grows best in areas having long hot, dry summer and cool winter. In Egypt, the total cultivated area of pomegranate is 85676 feddans with a total production of 381426 tons, according to the latest statistics of the Agriculture economics central administration [3]. In the last decades, Wonderful cv. started to spread specially in newly reclaimed lands. Adverse climatic conditions as heat stress leads to negative effects on pomegranates quality attributes as coloration and taste. These negative effects are more evident with Wonderful cv. in specific those grown in desert land. Thus it is crucial to find out effective treatments that would successfully enhance coloration and other affected attributes. Ethrel is of the most important and versatile ethylene –releasing agents market and registered for more than 20 crops. It is a synthetic plant growth regulator that undergoes chemical biodegradation at pH greater than 4.1 in cell cytoplasm to release ethylene [4, 5]. It was found to enhance color development and improve fruit quality characteristics of table grapes [6]. Also, being a senescence promoter, ethylene can also induce fruit drop and berry softening at maturity and during storage [7]. Thiosulfate potassium fertilizers are clear liquids that provide a source of sulfur (S) and potassium. Potassium is an essential macro-element required in large amounts for normal plant growth and development in addition to being involved in many physiological processes. Potassium cation plays a major role in enzyme activation, protein synthesis, stomatal function, stabilization of internal pH, photosynthesis, turgor-related processes and transport of metabolites [8]. Potassium being responsible for increasing sugar content might promote translocation of newly synthesized photosynthates causing a beneficial effect on the mobilization of stored metabolites [9]. It is also highly in plants at all levels, from individual cell to

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xylem and phloem transport. In addition, improves fruit quality by enhancing fruit size, juice contents, color and juice flavor [10, 11]. Sulphur plays a great role in plant metabolism and application of sulphur to the soil causes reduction in the soil pH, consequently enhancing the solubility and availability of many elements, also sulphur addition improved plants growth and yields [12]. It is an important component of amino acids such as, cysteine, cystine and methionine, which are essential for protein formations, It plays an important role in enzyme synthesis and activation, also it is required for chlorophyll formation. Sulphur is a component of sulfur-containing sulfolipids and it has a number of oxidizing functions in plant nutrition and a constituent of Fe-S proteins called Ferridoxin, responsible for transfer of electrons in photosynthesis [13, 14]. Some farmers resort to experiment with many materials to overcome the bad fruits coloring such as ethrel without knowing the concentration or side effect on trees and fruits.

For this reason, the scope of the present investigation was to study the effect of potassium or ethrel on improving fruit coloration and quality of Wonderful pomegranate trees grown in the newly reclaimed areas.

MATERIALS AND METHODS

The present study was carried out during 2019 and 2020 seasons on pomegranate (*Punica granatum* L.) Wonderful cv. trees in a private farm at Alexandria desert road, Giza Governorate, Egypt. The experimental trees were uniform vigour as possible, 8 -years old growing in sandy soil under drip irrigation system. Trees were planted at 3X5 meters apart and subjected to the same agriculture practices recommended by the Ministry of Agriculture Some physical and chemical characteristics of the studied soil are shown in Tables (1).

The experimental trees were subjected to the following treatments:

- Control (water sprayed)
- Spaying with Ethrel at 1000 ppm
- Spaying with ethrel at 500 ppm
- Spaying with ethrel at 250 ppm
- Spaying with ethrel at 125 ppm
- Spaying with Potassium thiosulfate at 1%
- Spaying with Potassium thiosulfate at 3%

Twenty-one trees were selected for each season, 3 trees per each treatment each tree acting as a replicate. Potassium thiosulfate (clear liquid solution, containing 25% potash and 17% sulfur) was sprayed twice at 30 and 15 days before harvest time (first week of October). Ethrel (48 %) was sprayed at 15 days before harvest.

Field observations and laboratory measurements were carried out as follows:

Fruit Drop (%):

Percentage of dropped fruits = No. of dropped fruits after spraying /No. of total fruits before spraying x 100

Leaf Abscission (%): Twelve shoots were tagged randomly before spraying from each tree to calculate the number of leaf abscission = Number of leaves before spray - Number of leaves after spray / Number of leaves before spray x 100

Yellowish Leaves (%):
Twelve shoots were tagged randomly before spraying from each tree to calculate the yellowish leaves % (when yellowing was 10% of the leaf).

Number of leaves before spray - Number of leaves after spray / Number of leaves before spray x 100

A representing sample of ten fruits was harvested / replicate tree for determining the following:

Fruit Physical Characters: Average fruit length (cm) and diameter (cm), weight (gm) and yield/tree (kg)

Fruit Juice Chemical Composition: Total soluble solids percentage (TSS %) was determined by using hand refractometer. Total acidity percentage was determined in grams as citric acid per 100 ml juice as described in A.O.A.C. [15], then, TSS/acid ratio was calculated. Total soluble sugars (%), were determined calorimetrically in a sample of 5 ml juice, according to the method described by Dubois *et al.* [16]. The amount of estimated sugars in each sample was calculated as glucose. Vitamin (C) content (mg. Ascorbic acid/ 100 ml juice) according to A. O. A. C. [15] was measured and total anthocyanin content (%) in fruit juice and rind was determined as described by Hsia *et al.* [17].

Statistical Analysis: The data were analyzed using variance analysis (ANOVA). Differences between means of treatments were compared by Duncan's Multiple Range Test (18), according to Snedecor and Cochran [19].

Table 1: Physical properties of the experimental soil

Parameters	Sand (%)	Silt (%)	Clay (%)	Texture class	Bulk density (gm^{-3})	Real density (gm^{-3})	Total porosity (%)	Field capacity (FC)	Wilting point (WP)	Available water (AW)	Water Holding capacity (WHC)
Soil depth (0-30cm)	84.5	8.50	7.00	Loamy Sand	1.49	2.51	40.6	20.90	9.55	11.4	29.4

RESULTS AND DISCUSSION

Fruit Dropping, Leaf Abscission and Yellowish Leaves (%): It can be noted in (Table 2) that, both potassium treatments and 125 ppm ethrel treatment did not differ significantly than control with respect both fruit drop and leaf abscission percentages. Whereas these percentages increased significantly and gradually by using ethrel at 250, 500 and 1000 ppm. In this respect, fruit drop (%) ranged from (0.5 and 0.5 %) for both potassium thiosulphate concentrations to reach (50 and 60 %) by ethrel at 1000 ppm treatment. Whilst, leaf abscission (%) scored (0.00 %) for control trees and those treated with both potassium thiosulphate treatments and 125 ppm ethrel treatment to be increased to reach (70.0 and 80.0 %) by ethrel at 1000 ppm treatment. This was true in both seasons respectively. As for yellowish leaves percentage, both potassium thiosulphate treatments had no effect on these parameters compared with control. Whereas ethrel treatments increased this percentage significantly in parallel with used concentrations. These results are in accordance with those of Bijan and Habib [20] on Rabbab pomegranate who noticed that, with increasing Ethrel concentrations leaf abscission and fruit drop percentage increased. Ethylene plays major roles in loosening and abscission of plant organs. It induces senescence regulator which cause leaves deterioration, triggers chlorophyll degradation and accelerates the senescence process [21]. It is possible that Ethrel might have stimulated the activation of enzymes leading to the development of abscission layer in the leaves [22]. The ethylene released from Ethrel enhances cellulase synthesis in the abscission zones of many plants and appears to be an important factor involved in abscission and subsequent fall of leaves [23].

Fruit Physical Characters

Fruit Length and Diameter (cm): The perusal of data (Table 3) indicates generally that as the concentration of ethrel increased (except for 125 ppm) gave the lowest values of fruit length and diameter. On the other hand, no significant differences occur between the control and the rest treatments (especially in 1st season for fruit length and 2nd season for fruit diameter) which showed the highest significant values. In this respect, applying potassium thiosulfate at 1% or 3% recorded the highest significant fruit length and diameter in both seasons and partnership with ethrel at 125 ppm.

Fruit Weight (g) and Fruit Yield/Tree (kg): The data presented in Table (4) indicate that the application of potassium thiosulfate induced significant positive effect on fruit weight and yield. Concerning fruit weight, the values ranged from 300 and 310 g with ethrel spraying at 1000 ppm to reach 400, 425 and 410 and 430 g with spraying potassium thiosulfate at 1% or 3% in both studied seasons. As for fruit yield /tree the records increased (20.50 and 25.50 and 20.5, 20.8 kg. /tree) with potassium thiosulfate at 1 and 3% to be decreased to (7.00 and 9.60 kg. /tree) with ethrel at 1000 ppm) this was true in both seasons. Low yield/tree by high concentrations of ethrel is may be due to increased fruit dropping.

These results are in accordance with those of Hamouda, *et al.* [24] who found that, potassium (K) at 10000 ppm gave the highest pomegranate fruit yield, means of fruit weight and fruit dimensions. Also, treating with potassium thiosulfate increased average fruit weight of Red Delicious and Gala apples [25]. The physiological effect of KNO_3 sprays was in its important role in balancing membrane potential and turgor, activating enzymes and regulating osmotic pressure according to Cherel [26] and Yanhai *et al.* [27]. Mohamed *et al.* [28] indicated that, pre-harvest application with KNO_3 (starting at two weeks after fruit set and repeated after one month from the first spraying date) improved apple fruit quality at harvest time. The fruit weight increased about (36%- 30%) due to potassium nitrate application, while spraying with ethrel was not significantly affected fruit weight. Foliar application of KNO_3 and potassium phosphate increased fruit size in pomegranate and orange fruits [29, 30]. In addition, Davarpanah *et al.* [31] found that, by increasing K concentration yield and number of pomegranate fruit increased.

Fruit Juice Chemical Composition:

Total Soluble Solids (TSS) and Acidity (%): Recorded data illustrated in Table (5) that, the differences did not reach the significance between the higher concentrations of ethrel (1000 and 500 ppm) on both fruit juice T.S.S.

Table 2: Effect of ethrel and potassium thiosulfate on fruit drop, leaf abscission and yellowish leaves (%) during 2016 and 2017 seasons

	Fruit drop (%)		Leaf abscission (%)		Yellowish leaves (%)	
Treatments	2016	2017	2016	2017	2016	2017
Control	1.0d	1d	0.00d	0.00d	0.00e	0.00e
Ethrel at 1000 ppm	50.0a	60.0a	70.0a	80.0a	80.0a	90.0a
Ethrel at 500 ppm	30.0b	35.0b	50.0b	65.0b	70.0b	85.0b
Ethrel at 250 ppm	15.0c	20.0c	35.0c	45.0c	50.0c	60.0c
Ethrel at 125 ppm	2.0d	2.0d	0.00d	0.00d	5.00d	6.00d
Potassium thiosulfate at 1%	0.5d	0.5d	0.00d	0.00d	0.00e	0.00e
Potassium thiosulfate at 3%	0.5d	0.5d	0.00d	0.00d	0.00e	0.00e

Values having the same letter are not significantly different at 5% level using Duncan's multiple Range Test.

Table 3: Effect of ethrel and potassium thiosulfate on fruit length (cm) and diameter (cm) during 2016 and 2017 seasons

	Fruit length (cm)		Fruit diameter (cm)	
Treatments	2016	2017	2016	2017
Control	9.00a	8.80c	9.50bc	9.35ab
Ethrel at 1000 ppm	8.60c	8.55d	9.30d	9.20d
Ethrel at 500 ppm	8.70bc	8.60d	9.35d	9.25cd
Ethrel at 250 ppm	8.80b	8.80c	9.40cd	9.30bc
Ethrel at 125 ppm	9.00a	8.90b	9.55b	9.35ab
Potassium thiosulfate at 1%	9.10a	8.95ab	9.60ab	9.40a
Potassium thiosulfate at 3%	9.10a	9.00a	9.70a	9.40a

Values have the same letter are not significantly different at 5% using Duncan's Test.

Table 4: Effect of ethrel and potassium thiosulfate on fruit weight (g) and fruit yield/tree (kg) during 2016 and 2017 seasons

	Fruit weight (g)		Fruit yield/tree (kg)	
Treatments	2016	2017	2016	2017
Control	355c	377b	17.75b	22.62b
Ethrel at 1000 ppm	300f	310e	7.00e	9.60e
Ethrel at 500 ppm	320e	325d	11.00d	13.00d
Ethrel at 250 ppm	330d	350c	14.50c	17.85c
Ethrel at 125 ppm	360c	380b	18.00b	22.80b
Potassium thiosulfate at 1%	400b	425a	20.00a	25.50a
Potassium thiosulfate at 3%	410a	430a	20.50a	25.80a

Values have the same letter are not significantly different at 5% level using Duncan's Test.

Table 5: Effect of ethrel and potassium thiosulfate on total soluble solids (TSS) and acidity (%) during 2016 and 2017 seasons

	TSS %		Acidity (%)	
Treatments	2016	2017	2016	2017
Control	17.0b	17.5bc	1.51de	1.43d
Ethrel at 1000 ppm	14.0c	13.0d	1.67a	1.72a
Ethrel at 500 ppm	14.0c	14.0d	1.63ab	1.66b
Ethrel at 250 ppm	15.0c	16.0c	1.58bc	1.57c
Ethrel at 125 ppm	17.0b	18.0b	1.54cd	1.44d
Potassium thiosulfate at 1%	18.0ab	19.0ab	1.45f	1.40d
Potassium thiosulfate at 3%	19.0a	20.0a	1.46ef	1.42d

Values have the same letter are not significantly different at 5% level using Duncan's Test

Table 6: Effect of ethrel and potassium thiosulfate on TSS/acid ratio and total sugars (%) during 2011 and 2012 seasons

	TSS/acid ratio		Total Sugars (%)	
Treatments	2016	2017	2016	2017
Control	11.26b	12.24b	11.0c	12.0d
Ethrel at 1000 ppm	8.38c	7.56d	10.0d	10.0f
Ethrel at 500 ppm	8.59c	8.43d	10.0d	10.0f
Ethrel at 250 ppm	9.49c	10.19c	11.0c	11.0e
Ethrel at 125 ppm	11.04b	12.50b	13.0b	13.0c
Potassium thiosulfate at 1%	12.41ab	13.57ab	13.0b	14.0b
Potassium thiosulfate at 3%	13.01a	14.08a	14.0a	15.0a

Values have the same letter are not significantly different at 5% level using Duncan's Test.

Table 7: Effect of ethrel and potassium thiosulfate on vitamin (C) mg ascorbic, total juice anthocyanin (%) and total rind anthocyanin (%) during 2016 and 2017 seasons

	Vitamin (C) mg ascorbic acid/100 ml juice		Total juice anthocyanin (%)		Total rind anthocyanin (%)	
Treatments	2016	2017	2016	2017	2016	2017
Control	20.0d	21.0d	0.30d	0.32c	0.25c	0.27b
Ethrel at 1000 ppm	18.0f	17.0g	0.31cd	0.32c	0.35a	0.34a
Ethrel at 500 ppm	18.0f	18.0f	0.31cd	0.33bc	0.34a	0.32a
Ethrel at 250 ppm	19.0e	19.0e	0.32b-d	0.34a-c	0.32ab	0.31a
Ethrel at 125 ppm	21.0c	22.0c	0.35ab	0.36ab	0.30b	0.32a
Potassium thiosulfate at 1%	22.0b	23.0b	0.34a-c	0.36ab	0.32ab	0.32a
Potassium thiosulfate at 3%	23.0a	24.4a	0.36a	0.37a	0.35a	0.35a

Values have the same letter are not significantly different at 5% level using Duncan's Test

and acidity (%) parameters (except for acidity % in 2nd season). The previously notice was also clear with both concentrations of potassium thiosulphate (1 and 3%). Generally, potassium thiosulphate at 1 and 3% produced the richest fruit juice in T.S.S. whereas it recorded the lowest values of acidity (%) in both 2016 and 2017 seasons. Spraying ethrel at 1000 ppm and 500 ppm enhanced T.S.S. but lowered acidity (%) in Wonderful fruit juice.

TSS/Acid Ratio and Total Sugars (%): It is apparent in Table (6) that, KTS at 3% positively enhanced significantly TSS/ acid ratio (13.01 and 14.08) and total sugars percentage (14.0 and 15.0) in both seasons. On the other hand, ethrel at higher concentration (1000 and 500 ppm) earned the lowest values of TSS/ acid (8.38, 7.56 and 8.59, 8.43) and total sugars (10%) in both seasons respectively.

Vitamin (C) mg Ascorbic, Total Juice Anthocyanin (%) and Total Rind Anthocyanin (%): Results in Table (7) indicate that, the highest significant fruit juice vitamin C and anthocyanin content were registered by KTS at 3% in both seasons. Furthermore, all treatments under study proved to enhance total juice and rind anthocyanin content comparing with the untreated ones. Spraying fruits by ethrel at (1000 and 500 ppm) gave the lowest values of vitamin C in both seasons. Regarding to juice and rind anthocyanin content, the lowest values were recorded by control in both seasons except in the second season of juice anthocyanin content both control and ethrel at 1000 ppm appeared the lowest values. These findings corroborate the results reported by Fawzi and Abd El-Monieum [32]; Kelany *et al.* [33] and Abdel-Aal [34] on grape and Goswami *et al.* [35] on pomegranate showed that, spraying ethrel improved fruit quality by increasing TSS, TSS/acid ratio and total sugars. According to Peppi *et al.* [36]; Lurie *et al.* [37] and El-Sayed [38] ethrel application have been shown to be more effective in promoting anthocyanin accumulation and thus enhancing color development. Also, Bound and Wilson [25] on apple, Ganeshamurthy *et al.* [39] on grape and Davarpanah *et al.* [31] on pomegranate reported that, a positive correlation between the concentrations of K application and TSS; the higher concentrations of K, the higher TSS contents. This may be due to involvement of K in translocation and accumulation of sugars and other soluble solids in fruit can be stated as possible reasons for increase in TSS as a result of K fertilization [40]. Foliar sprays of K increased anthocyanin index and total

anthocyanin contents in fruit juice [31]. The increase in total anthocyanin contents as a result of K spray are in line with the findings of Tehranifar and Tabar [41] and Moor *et al.* [42] who reported that the contents of anthocyanin in pomegranate and strawberry increased by K fertilizers. Potassium plays crucial roles in anthocyanins synthesis through increasing the translocation of sugars into fruits (grape and apple), as well as acting as a cofactor and stimulator of some enzymes like UDP galactose: flavanoide-3-o-glicosil transferase [43, 44].

CONCLUSION

According to the obtained results of our study we can recommend to spray pomegranate trees (Wonderful cv.) with potassium thiosulfate at 3% (30 and 15 days before harvest time) for enhancing fruit coloration and quality under the same conditions of the present study.

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