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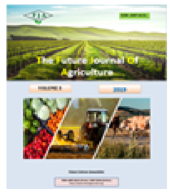

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RESPONSE OF WONDERFUL POMEGRANATE TO PRE-HARVEST SPRAY BY POTASSIUM, IRON AND BORON AS ALTERNATIVE TO FERTIGATION

Hamdy, I.M. Ibrahim[1,*], Nour A. Abdou[2] and Moustafa O.A. Omar[1]

[1]Hort. Dept., Fac. Agric., Minia Univ., **Egypt**

[2]Decidous fruit Res. Dept., Horticultural Res. Inst., ARC, **Egypt.**

*Corresponding author: hamdy_france@yahoo.com **Received:** 20 August 2019 **; Accepted:** 19 Sept. 2019

ABSTRACT: During 2017 and 2018 seasons, Wonderful pomegranate treated with potassium sulphate (K_2SO_4) and/or ferrous sulphate ($FeSO_4$) and boric acid (H_3BO_3). The main object was examining the effect of these three compounds and their interaction on trees flowering, yield and leaf mineral content. Treating the trees three times with K_2SO_4, $FeSO_4$and H_3BO_3 caused a remarkable stimulation on number of total and perfect flowers, compared with untreated control. Furthermore, treating the trees with K_2SO_4 and/or $FeSO_4$& H_3BO_3 caused increasing yield (Kg/tree) and very effective in enhancing leaf N, P & K%. The combined application of the three compounds was superior than the single application of each compound on enhancing all flowering aspects and yield and improved leaves NPK. For enhancing flowering, crop of yields and leaf mineral contents (NPK) of Wonderful pomegranate, it is suggested to spray the trees with a mixture of K_2SO_4 and/or $FeSO_4$ and H_3BO_3 three times yearly during the fruit growth cycle.

Key words: Wonderful pomegranate, yield, flowering, potassium, iron, boron.

INTRODUCTION

Pomegranate trees (*Punica granatum* L.) belongs to *Myrtales* order and *Punicaceae* family, which is mainly grown in subtropical and tropical regions (**Al-Yahai *et al.*, 2009; Saeedi *et al.*, 2012; Davarpanah *et al.*, 2017 and Omar, 2014)**.The fruits are consumed fresh (grains) or they are used in different industrial purposes such as juice, jams, jelly, cocktail syrup, and wines. They are considered as a healthy food because of the high content of antioxidant compounds (**Legua *et al.*, 2012**). 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 (**Holland *et al.*, 2001 & 2009; Drogoudi*et al.*, 2012** and **Abou El-Wafa, 2015**). The pomegranate is native to the subtropics and mild temperate regions.

The total acreage of pomegranate in Egypt reached 34450 fad. out of them 11752 fad., is fruitful producing about 106260 tons with an average of 9.42 tons/fad. **(Statistics of the Ministry of Agriculture, 2015)**.

Foliar sprays with fertilizers including macro and micro nutrients such as potassium (K),iron (Fe) and boron(B) have been shown to be convenient for field use, have a good effectiveness and very rapid plant response **(Fernández *et al.*, 2013 and Laegreid *et al.*, (1999**). The foliar application of mineral nutrients using sprays, offers a method of supplying nutrients to higher plants more efficiently than methods involving root application when soil conditions are not suitable for Fe availability **(Fernandez *et al.*, 2006; Erdal *et al.*, 2004**),also, foliar fertilizers help to avoid toxicity symptoms that may occur after soil application of the same microelements.Potassium has a definite role in the fruit crops nutrition. It activates the enzymes, root growth, proteins, diseases resistance, shelf-life of fruits, water turgor, photosynthesis, water and nutrient uptake, salinity and drought resistances. It reduces respiration, energy, and water loss and incidence of pests and regulates the opening and closing of stomata. It has a higher roles in the biosynthesis and translocation of sugars (**Yagodin, 1990; Marschner 1997; Cakamak, 2005 and Mengel 1985 & 2007**). Iron (Fe) has an important role as a micronutrient element. It conceder as a limiting factor for fruit agricultural production in many areas of the world (**Fernandez *et al.*, 2006 and Abadia *et al.*, 2011**).

The main target of this study was elucidating the effect of single and complained foliar application of $K2SO_4$, $FeSO_4$ and H_3BO_3 on flowering, yield and leaf mineral content of pomegranate Wonderful cultivar grown in sandy soil under Minia Governorate conditions.

Materials and Methods:

The present investigation was conducted during two seasons 2016/2017 and 2017/2018 on one hundred-eight uniform in vigor Wonderful pomegranate trees, grown in private orchard located at the Cairo-Assiut Eastern Desert Road, facing Minia Distract, El- Minia Governorate (250 km southern Cairo city), where the soil texture is sandy, since water table depth is not less than two meters. The chosen pomegranate trees are ten-years old and planted at 4 X 4 meters apart. The formation of the chosen trees is multi trunk (3 trunk/tree) an open vase system with 4 to 6 principal branches and at least two principal layers of production. Winter pruning was followed at the first week of January. Drip irrigation system was adopted. However, irrigation carried by used water supply from underground well with pressure and volume controllers. The chosen trees are subjected to regular horticulture practices that were commonly applied in the orchard including fertilization, (namely: 80 g/tree nitrogen applied in the form of ammonium nitrate "33% N", 245 kg/feddan, calcium superphosphate "15.5% P_2O_5" 200 kg/feddan and 150 kg/feddan potassium sulphate, as well as irrigation, hoeing and pest management.

Soil and irrigation water analysis: The soil where the present experiment carried out was sandy texture (Table 1). A composite sample of soil and irrigation water were collected and subjected to Physical and chemical analysis according to the procedures outlined by **Walsh & Beaton (1986)** and **Buurman *et al.*, (1996)**. The data of soil and water sample analyses are shown in Table (1).

Table 1. Physical and chemical analysis of experiment soil and the well water used in irrigation

Soil analysis		Water analysis	
Constituents	**Values**	**Constituents**	**Values**
Sand %	79.4	E.C (mmhos/cm)	1. 3
Silt %	12.5	Hardness	19.7
Clay %	8.1	pH	7.35
Texture	Sandy	Ca (mg/L)	38.4
EC(1:2.5 extract) mmhos/cm	5.2	Mg (mg/L)	24.3
Organic matter %	0.45	K (mg/L)	5.07
pH (1 : 2.5 extract)	8.29	Na (mg/L)	95.8
Active lime %	9.0% ($CaCO_3$)	Sum of Cations (mg/L)	8.16
N (mg/kg)	185	Alkalinity (mg/L)	182
Phosphorus (ppm)	8.80 ppm	Chlorides (mg/L)	121
Available Ca (meq/100g)	19.9	Nitrate (mg/L)	11.0
Available Mg (meq/100g)	2.33	Sulphates (mg/L)	53.1
Available K (meq/100g)	0.56	Sum of anions (mg/L)	7.69
C/N Ratio	17.2	SAR	2.97

Experimental work: In order to study the effect and the suitable concentration of spraying K_2SO_4, $FeSO_4$ and H_3BO_3 compounds were tested on Wonderful pomegranate. K_2SO_4 was sprayed at four concentrations namely 0.0, 0.5%, 1.0% and 1.5% single or companied with $FeSO_4$ (at 100 & 200 ppm) or/and H_3BO_3 at (50 & 100 ppm) were tested on Wonderful pomegranate cultivar of the present experiment. The trees were sprayed with K_2SO_4 on the first of April, May and June, while $FeSO_4$ and H_3BO_3 on mid of April, May and June each season. Then, this study included the following thirty six treatments from two factors (A & B) and its interactions. The first factor (A) comprised from four potassium sulphate concentrations. The second factor (B) comprised from nine concentrations of $FeSO_4$ and H_3BO_3. Each treatment was replicated three times, one tree per each. Then the present study included one hundred eight trees. Triton B (at 0.05 g/liter) as a wetting agent was added to all spraying solutions, even control trees.

Experimental design: Treatments were arranged in a complete randomized block in a split plot design. However, the potassium sulphate ranked in main plot and ferrous sulphate & Boric acid ranked the split plot, each treatment was replicated three times, and one tree per each was used.

The responses of the tested trees to foliar spray treatments were evaluated through the following parameters:

Flowering behavior: During the flowering period, the total number of flowers/tree, perfect flower numbers/tree and mal flower numbers/tree were counted.

Measurement of total yield: The fruits were harvested when fruits become fully colored at maturation date (last week of September) in the two experimental seasons. The yield per tree was recorded in terms of weight (kg) and number of fruits per tree, and then fruit yield (kg) per tree was calculated.

Vegetative growth

- Shoot length (cm)

- Number of new shoot / tree

- Leaf area (cm^2): leaf samples were taken from the middle part of the shoot of the spring flush and the leaf area (cm^2) was determined by using Plan meter.

Determination of Nitrogen, Phosphorus and Potassium contents in leaves:

16 leaves picked from the medal part of 8 main shoots for each tree were taken at the middle of June during the three seasons. The blades were separated and discarded and the petioles only were saved for determining different nutrients. The petioles washed with distillated water and dried at air and oven dried and grounded, then 0.5 g weight was digested using H_2SO_4 and H_2O_2 until clear solution was obtained **(Martin-Préval*et al.*, 1984)**. The digested solution was quantitatively transferred to 100 ml volumetric flask and completed to 100 ml by distilled water. Thereafter, contents of Nitrogen (N), Phosphorus (P), Potassium (K) for each sample were determined according to the method described by **Walsh and Beaton (1986)**.

Statistical analysis of data: All the obtained data were tabulated and subjected for the proper statistical analysis; by analysis of variance (ANOVA) using the statistical package MSTATC Program. Comparisons between means were made by the F-test and least significant differences (New L.S.D) at p = 0.05 (**Snedecor and Cochran, 1990**).

RESULTS AND DISCUSSION

Flowering behavior

Data in Table (2) show the compound sprayed or the concentration used, during the first season, spraying the three examined compounds K_2SO_4, $FeSO_4$, and H_3BO_3 failed to vary the flowering behaviors of pomegranate trees significantly. While, during the second season spraying the three examined compounds at different concentrations were significant improving the flowering behaviors. However, total flower numbers/tree, perfect flower numbers/tree were promoted with increasing the concentrations of K_2SO_4 from 0.0% to 1.5%.

Regarding the single or combined sprays of $FeSO_4$ and H_3BO_3 show the number of total flowers/tree and bisexual flowers number/tree varied significantly during the second season. However, increasing the concentration used of $FeSO_4$ from 100 to 200 ppm and H_3BO_3 from 50 to 100 ppm remarkable enhanced the total number of flowers and perfect flowers number. Furthermore, regardless the concentration, the combination K_2SO_4plus H_3BO_3 remains more favorable effect in total number of flowers and bisexual flower numbers than those of K_2SO_4 plus $FeSO_4$. Data concerning the second season showed that, regarding the interaction between the three examined compounds recorded significant promotion. However, the trees treated with K_2SO_4, $FeSO_4$ and H_3BO_3 at high concentrations exhibited the highest numbers of total flowers and perfect flowers (518 total flowers/tree and 219 bisexual flowers/tree) during the second season respectively. While, the untreated trees produced unfavorable effect and least total flower numbers and perfect flower

It's well known that, potassium is vital to several areas of plant growth, including drought tolerance, disease resistance, stem strength, improved texture, and photosynthesis processes. These important roles of potassium can promote flowering behavior of Wonderful pomegranate trees. However, boron is especially immobile in most plant tissues and will not readily move from other parts of the fruit tree to the flower buds when it is needed for pollen tube growth, pollen production and other reproductive functions. So, Foliar sprays of boron during the flower bud formation and differentiation will ensure an adequate supply of boron during the critical stages of flowering and fruit development, may be lead to increasing total number of flowers and bisexual flower numbers/tree (**Mengle 1985; Bambal *et al.*, 1991; Marschner, 1997;Cakamak 2005; Mengle 2007; Davarpanah *et al.*, 2013 and Dalal *et al.*, 2017**).

Total yield (kg) and its components

It is noticed from the obtained data in Table (3) that, treating Wonderful pomegranate trees with K_2SO_4 (at 0.05% to 1.5%), $FeSO_4$ (at 100 & 200 ppm), and H_3BO_3 (at 50 & 100 ppm) had significantly improved the fruit weight in the two seasons compared with untreated trees. The trees were sprayed with high concentration of K_2SO_4 (1.5%) recorded highest fruit weight (g) compared to untreated trees with any compound which gave the least values in the two seasons.

The interactions between K_2SO_4, $FeSO_4$, and H_3BO3 treatments were significant on fruit weight (g) in the two seasons. The highest fruit weight (449 and 431 g) were produced from spraying trees with K_2SO_4 at higher level (1.5%) in combination with $FeSO_4$ at 200 ppm plus H_3BO3 at 100 ppm. While, the least values were recorded from trees sprayed with K_2SO_4 at 0.0% x H_3BO_3 and $FeSO_4$ at 0.0 ppm (329 g) in the first season and those sprayed with K_2SO_4 at 0.0% x H_3BO_3 at 50 ppm and 0.0 ppm $FeSO_4$ (335 g) in the second one.

The obtained results concerning the effect of K, Fe and B on yield, fruit number/trees as well as fruit weight are in accordance with those obtained by **Mengle, 2007; Omar (2015); Ibrahim and Al-Wasfy (2014); Mohamed (2014) and Abo-Ali (2019)**.

Table 2. Effect of spraying potassium sulphate, ferrous sulphate, and boric acid on number of total flowers, number of bisexual flowers and number of mal flowers, of pomegranate cv. Wonderful, during 2017 and 2018 seasons

Treatments	Total flowers number					Bisexual flowers number					Mal flowers number				
	First Season (2017)					First Season (2017)					First Season (2017)				
	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B
Fe 0.0 + B 0.0 ppm	401.0	405.0	406.0	411.0	**406.0**	135.0	136.0	149.0	142.0	**140.5**	266.0	269.0	257.0	269.0	**265.3**
Fe 100 ppm + B 0.0 ppm	402.0	404.0	405.0	405.0	**404.0**	136.0.	127.0	139.0	134.0	**134.5**	266.0	277.0	266.0	271.0	**270.0**
Fe 200 ppm + B 0.0 ppm	409.0	407.0	409.0	404.0	**407.0**	137.0	139.0	140.0	144.0	**139.8**	272.0	268.0	269.0	260.0	**267.3**
B 50 ppm + Fe 0.0 ppm	402.0	411.0	403.0	407.0	**406.0**	138.0	138.0	150.0	151.0	**141.7**	264.0	279.0	253.0	256.0	**263.0**
B 100 ppm + Fe 0.0 ppm	409.0	408.0	412.0	409.0	**410.0**	141.0	146.0	141.0	142.0	**142.5**	268.0	262.0	271.0	267.0	**267.0**
Fe 100 + B 50 ppm	404.0	405.0	409.0	406.0	**406.0**	133.0	144.0	142.0	151.0	**144.5**	271.0	261.0	267.0	255.0	**263.5**
Fe 100 ppm + B 100 ppm	409.0	409.0	407.0	406.0	**408.0**	142.0	145.0	150.0	147.0	**146.0**	267.0	264.0	257.0	259.0	**261.8**
Fe 200 ppm + B 50 ppm	410.0	400.0	409.0	409.0	**407.0**	144.0	150.0	143.0	150.0	**146.3**	266.0	250.0	266.0	259.0	**260.3**
Fe 200 ppm + B 100 ppm	409.0	408.0	411.0	406.0	**409.0**	143.0	143.0	152.0	151.0	**148.0**	266.0	261.0	259.0	255.0	**260.3**
Mean A	**406.0**	**406.0**	**408.0**	**407.0**		**138.7**	**140.9**	**145.1**	**145.0**		**267.3**	**265.7**	**268.0**	**261.2**	
New LSD 5%	**A= NS ; B= NS ; AB= NS**					**A= NS ; B= NS ; AB= NS**					**A= NS ; B= NS ; AB= NS**				
Treatments	**Second Season (2018)**					**Second Season (2018)**					**Second Season (2018)**				
	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B
Fe 0.0 + B 0.0 ppm	400.0	459.0	459.0	461.0	**445.0**	121.0	126.0	131.0	133.0	**127.8**	279.0	333.0	328.0	328.0	**317.0**
Fe 100 ppm + B 0.0 ppm	414.0	464.0	468.0	473.0	**455.0**	131.0	127.0	133.0	143.0	**133.5**	283.0	337.0	335.0	330.0	**321.3**
Fe 200 ppm + B 0.0 ppm	416.0	467.0	469.0	477.0	**457.0**	131.0	138.0	144.0	145.0	**139.5**	285.0	329.0	325.0	332.0	**317.8**
B 50 ppm + Fe 0.0 ppm	418.0	469.0	477.0	482.0	**465.0**	147.0	159.0	162.0	169.0	**159.3**	271.0	310.0	315.0	313.0	**302.3**
B 100 ppm + Fe 0.0 ppm	422.0	479.0	485.0	493.0	**470.0**	171.0	177.0	187.0	197.0	**183.0**	251.0	302.0	298.0	296.0	**286.8**
Fe 100 + B 50 ppm	451.0	482.0	479.0	499.0	**478.0**	164.0	169.0	178.0	189.0	**175.0**	287.0	313.0	301.0	310.0	**302.7**
Fe 100 ppm + B 100 ppm	457.0	488.0	495.0	505.0	**486.0**	173.0	189.0	195.0	209.0	**191.5**	284.0	299.0	300.0	296.0	**294.8**
Fe 200 ppm + B 50 ppm	459.0	495.0	499.0	512.0	**491.0**	171.0	187.0	189.0	212.0	**189.3**	288.0	308.0	310.0	300.0	**301.5**
Fe 200 ppm + B 100 ppm	469.0	498.0	505.0	518.0	**498.0**	191.0	199.0	212.0	219.0	**205.3**	278.	299.0	293.0	299.0	**292.3**
Mean A	**433.0**	**478.0**	**481.0**	**491.0**		**141.0**	**164.3**	**170.1**	**179.5**		**278.4**	**314.4**	**311.7**	**311.6**	
New LSD 5%	**A= 10.2 ; B= 13.5 ; AB= 19.7**					**A= 7.6 ; B= 11.2 ; AB= 16. 53**					**A= NS ; B= N ; AB= 21.93**				

Table 3. Effect of spraying potassium sulphate, ferrous sulphate, and boric acid on fruit numbers/tree, fruit weight (g) and yield (kg)/tree of pomegranate cv. Wonderful, during 2017 and 2018 seasons

Treatments	Number of fruits/tree					Fruit weight (g)					Yield (kg)/tree				
	First Season (2017)					First Season (2017)					First Season (2017)				
	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B
Fe 0.0 + B 0.0 ppm	43.00	43.00	40.00	45.00	**42.75**	329.00	339.00	365.00	374.00	**351.80**	14.30	14.70	14.02	16.08	**14.81**
Fe 100 ppm + B 0.0 ppm	42.00	41.00	40.00	44.00	**41.75**	359.00	365.00	371.00	389.00	**371.00**	15.10	14.90	14.84	17.12	**15.50**
Fe 200 ppm + B 0.0 ppm	39.00	48.00	46.00	48.00	**45.25**	369.00	388.00	403.00	412.00	**393.00**	14.40	18.60	18.54	19.78	**17.83**
B 50 ppm + Fe 0.0 ppm	41.00	46.00	45.00	43.00	**43.75**	345.00	361.00	387.00	389.00	**370.50**	14.20	16.60	17.42	16.73	**16.23**
B 100 ppm + Fe 0.0 ppm	40.00	44.00	40.00	46.00	**42.50**	349.00	379.00	399.00	403.00	**382.50**	13.80	16.70	15.96	18.54	**16.29**
Fe 100 + B 50 ppm	44.00	40.00	43.00	42.00	**42.25**	369.00	387.00	392.00	415.00	**390.80**	16.20	15.50	16.86	17.43	**16.50**
Fe 100 ppm + B 100 ppm	43.00	46.00	45.00	44.00	**44.50**	377.00	411.00	409.00	414.00	**402.80**	16.20	18.90	18.41	18.22	**17.94**
Fe 200 ppm + B 50 ppm	42.00	41.00	44.00	43.00	**42.50**	389.00	420.00	431.00	439.00	**419.80**	16.40	17.40	18.96	18.53	**17.76**
Fe 200 ppm + B 100 ppm	43.00	45.00	45.00	44.00	**44.25**	406.00	423.00	443.00	449.00	**430.30**	17.60	19.40	19.05	19.76	**18.95**
Mean A	**41.89**	**43.78**	**43.14**	**44.33**		**365.30**	**384.90**	**400.00**	**409.30**		**15.27**	**16.98**	**17.12**	**18.02**	
New LSD 5%	**A= NS ; B= NS ; AB= NS**					**A= 13.20 ; B= 15.30 ; AB= 22.30**					**A= 1.67 ; B= 2.31 ; AB= 3.35**				
Treatments	**Second Season (2018)**					**Second Season (2018)**					**Second Season (2018)**				
	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B
Fe 0.0 + B 0.0 ppm	44.00	48.00	53.00	55.00	**50.00**	339.00	349.00	355.00	364.00	**351.80**	14.90	17. 50	18.80	20.00	**17.80**
Fe 100 ppm + B 0.0 ppm	44.00	48.00	55.00	59.00	**51.50**	348.00	355.00	371.00	389.00	**365.80**	15.20	16.30	20.40	22.90	**18.67**
Fe 200 ppm + B 0.0 ppm	47.00	50.00	60.00	61.00	**54.50**	359.00	378.00	403.00	412.00	**388.00**	16.80	18.90	24.20	25.20	**21.27**
B 50 ppm + Fe 0.0 ppm	49.00	51.00	62.00	67.00	**57.30**	335.00	355.00	387.00	389.00	**366.50**	16.40	18.20	23.90	26.10	**21.17**
B 100 ppm + Fe 0.0 ppm	51.00	55.00	61.00	63.00	**57.50**	340.00	369.00	389.00	398.00	**374.00**	17.30	20.30	23.70	25.10	**21.61**
Fe 100 + B 50 ppm	53.00	60.00	67.00	70.00	**62.50**	352.00	377.00	390.00	406.00	**380.80**	18.70	22.60	26.10	28.40	**21.46**
Fe 100 ppm + B 100 ppm	57.00	60.00	68.00	73.00	**64.50**	362.00	399.00	411.00	418.00	**397.50**	20.60	23.90	27.90	30.50	**25.76**
Fe 200 ppm + B 50 ppm	61.00	63.00	70.00	73.00	**66.80**	377.00	401.00	421.00	429.00	**407.00**	22.90	25.30	29.50	31.30	**27.26**
Fe 200 ppm + B 100 ppm	62.00	66.00	71.00	74.00	**68.30**	381.00	412.00	429.00	431.00	**413.30**	23.60	27.20	30.50	31. 90	**28.29**
Mean A	**52.00**	**55.70**	**63.00**	**66.10**		**354.80**	**377.20**	**395.10**	**404.00**		**18.50**	**21.13**	**25.02**	**26.82**	
New LSD 5%	**A= 2.55 ; B= 2.99 ; AB= 4.85**					**A= 14.40 ; B= 13.90 ; AB= 20.30**					**A= 2.25 ; B= 3.34 ; AB= 4.88**				

Vegetative growth

Shoot lengths (cm)

Obtained data in Table (4) show that the main shoot lengths of Wonderful pomegranate were remarkable increased due to sprayed the potassium sulphate, Fe-sulphate and boric acid in the two experimental seasons, in comparison with those of untreated trees. Moreover, such increase was gradually enhanced parallel with the increase in the concentration used. Therefore, the average shoot lengths remarkably enhanced from the first to the second year.

Regardless the concentration used, among the three examined compounds, sprayed the trees with potassium sulphate was superior to the other two compounds used (Fe-sulphate and boric acid), the data tack similar trend during the two experimental seasons.

On the other hand, the least values of shoot length (65.3 and 66.5 cm) were recorded on the untreated trees followed by those treated with boric acid alone at 50 ppm (73.6 and 80.5 cm) in the two experimental seasons respectively.

Regarding the interaction between spraying potassium sulphate and iron sulphate and/or boric acid for shoot lengths, it was significantly in the two experimental seasons as illustrated in Table (4). It is clear that spraying Wonderful pomegranate with potassium sulphate accompanied with Fe-sulphate or/and boric acid as well as Fe-sulphate and boric acid together at 100 ppm give higher shoot lengths rather than control treatment.

It is clear from the same Table that the positive effect $FeSO_4$ or/and H_3BO_3 has increased whine the trees received it accompanied with potassium sulphate at 0.5% to 1.5%. However, the highest shoot lengths were obtained from the trees treated by potassium sulphate at 1.5% combined with Ferrous sulphate at 200 ppm and boric acid at 100 ppm (96.6 and 104.7 cm) in the two experimental seasons respectively. While the untreated trees present the lowest shoot lengths (65.3 and 66.5 cm respectively) followed by those treated with K_2SO_4 alone at 1.5% (68.0 and 69.1 cm in the two experimental seasons respectively).

The interaction between potassium concentration and ferrous sulphate, as well as, boric acid treatments was significant for shoot lengths in both experimental seasons (Table 4). The shoot lengths were produced due to supplying Wonderful pomegranate with potassium at high level (1.5%) in combination with $FeSO_4$ at 100 & 200 ppm and H_3BO_3 at 50 and 100 ppm during both seasons or spraying plant plants with medium level of K_2SO_4 (1.0%) in combination with $FeSO_4$ at 200 ppm and H_3BO_3 in all cases. However, the trees received a mixture of the three elements at highest concentration produced the highest shoot lengths in both seasons (90.8 and 94.5 cm) respectively.

The stupendous effect of the three examined elements as essential nutrients may be explained by its effect on some important physiological processes in plant. Potassium is required for various biochemical and physiological processes that are responsible for plant growth and development. Potassium also plays critical roles in controlling protein metabolism, enzyme activity, membrane polarization, and various metabolic processes (**Arona and singh 1970; Hastings and Gutknecht, 1978; Walker *et al.*, 1996; Schachtman and Shin, 2007; Amtmann *et al.*, 2006; Mengel 1985 & 2007; Sumam *et al.*, 2017** and **Hasanuzzman *et al.*, 2018**). Additionally, fundamental physiological processes in plants including photosynthesis, photorespiration, and growth are dramatically affected by K+ availability (**Gattward *et al.*, 2012; Pettogrew, 2008**).Fe and B can stimulate some important enzymes responsible for cell devotion and cell elongation such as Oxidoreductase, peroxidases enzymes Moreover, **Yang *et al*., (2014)** confirmed that potassium absorption and accumulation in plant was positive correlated with the level of some growth regulators. However, K, Fe and B treatments stimulate the absorption other important elements by plant roots and consequently nutrients in the soil which became more available to plant (**Prajapati and Modi, 2012** and **Wassel *et al.*, 2015**).

Number of new shoot / tree

Data obtained during the two experimental seasons as illustrated in Table (4) show the number of leaves per shoot, displayed that, regardless the compound or the concentration used. Non-significant differences were observed in the number leaves/shoot in the first experimental season. While, in the second season, all treatments concerning the three examined compounds caused significant increase the leaves number per shoot than those recorded for the control treatment.

Regarding the concentration used, trees treated with potassium sulphate at 1.5% give higher and significant number of leaves/shoot than those treated with other potassium sulphate concentrations. This stimulation was related to increasing in concentration of potassium sulphate from 0.0% to 1.5% (66.6, 69.3, 73.0 and 74.3 leaf/shoot), in the second experimental season, respectively.

The obtained data showed also that all treatment concerning added ferrous sulphate and boric acid each alone or in companied caused a significant increase in the number of leaves per shoot especially in the second season. It is clear also that the combined treatments of $FeSO_4$ and H_3BO_3 lead to enhance of the number of new shoot per tree than those treated the trees with each one alone.

The interaction between K_2SO_4, $FeSO_4$ and H_3BO_3 was significant in the second season (Table 4). It was clear that Fe-sulphate at 100 & 200 ppm and boric acid at 50 & 100 ppm accompanied with potassium sulphate at 0.5% to 1.5% present higher and significant number of leaves/shoot, in the second season. However, the highest number of leaves per shoot (80 leaves/shoot) was observed whine the trees received the mixture of K_2SO_4 at 1.5% + $FeSO_4$ at 200 ppm + H_3BO_3 at 100 ppm.

Leaf area (cm^2)

Data obtained during the two experimental seasons as illustrated in Table (4) show the Wonderful pomegranate leaf area, displayed that, regardless the compound or the concentration used the three examined compounds caused significant increase the leaf area (cm^2) rather than the check treatment, in the two experimental seasons.

It is clear from the obtained data that treating Wonderful pomegranate with potassium sulphate at 0.5% to 1.5%, ferrous sulphate at 100 to 200 ppm and boric acid at 50 and 100 ppm significantly was followed by stimulating the leaf area relative to the control treatment. The stimulation on leaf area (cm^2) was related to the increase in concentrations of K_2SO_4 from 0.5 to 1%, $FeSO_4$ from 100 to 100 ppm and boric acid from 50 to 100 ppm. It is worth to mention that the effect of spraying $FeSO_4$ at 100 or 100 ppm was more effective than spraying boric acid at 50 to 100 ppm in the two experimental seasons (Table 4).

Numerically, increasing the concentrations of K_2SO_4 from 0.5% to 1.5% caused 5.0, 8.5 & 13.0 cm^2 in the first season however; this positive effect was clearer in the second season 5.8, 12.2 and 21.5 cm^2 respectively. Furthermore, the spraying the trees with $FeSO_4$ at 100 ppm + H_3BO_3 50 ppm and $FeSO_4$ at 200 ppm + H_3BO_3 100 ppm caused remarkable increases in leaf area (20.0 & 40.0 cm2 and 57.4 & 60.7 cm^2) in the two experimental seasons respectively.

Regarding the interaction between potassium sulphate and ferrous sulphate, as well as, boric acid treatments was significant for leaf area (cm^2) in the both seasons (Tables, 4). The leaf area was produced due to spraying Wonderful pomegranate trees with potassium sulphate at high level (1.5%) in combination with any of $FeSO_4$ concentrations during both seasons or at 1.0% with $FeSO_4$ at 200 ppm in combination with boric acid at 100 ppm in all cases. The highest leaf area level was obtained when the threes received potassium sulphate at 1.5%, ferrous sulphate at 200 ppm and boric acid at 100 ppm (8.95 and 10.68 cm^2) in the two seasons respectively, while the control treatment present the least leaf area level (6.0 and 6.1 cm^2) respectively.

In the present study all the treatments (potassium, ferrous sulphate or/and boric acid) caused a remarkable enhancement of shoot lengths, number of leaves per shoot and leaf surface area, these results are true for the two experimental seasons for the shoot lengths but for the second season only for the number of leaves per shoot. Similar results were observed by **Wassel *et al.*, 2015, Omar (2016), Davarpah *et al.*, (2013 and 2016), Hamouda *et al.*, (2015), Abd El-Rhman *et al.*, (22017)** and **Ampem (2017), Bambal *et al* ., (1991)** on different pomegranate cultivars, and similar results were observed on other fruit trees by **Ibrahim *et al.*, 2009** on grapevines**, Dalal *et al.*, (2017), Abo El-Enin (2012) and Ozturk *et al.*, (2019), Gurel and Basar (2016) and Gill *et al.*, (2012)** on pear trees**, Arona and Singh (1970)** on guava trees , **Alila *et al.*, (2004)** on papaya trees, and **Ben-Mimoun and Marchand (2013)** on some other deciduous and evergreen fruit trees.

Leaf mineral contents

Data listed in Table (5) indicated that spraying trees with the highest potassium level (1.5%) produced highest N, P and K content in leaves (1.75 & 1.75% for N, 0.296 & 0.298% for P and 1.62 & 1.61% for K) in the two seasons respectively. Treatment of with $FeSO_4$ at 200 ppm plus $H_3BO_3$100 ppm recorded higher N, P and K% than untreated control and other treatments in both seasons. The trees treated with $FeSO_4$ at 100 & 200 ppm and H_3BO_3 at 50 and 100 ppm was paralleled with increasing leaves potassium contents rather than non-application. Furthermore, the investigated interaction had a significant effect on the leaves potassium contents. The interactions with spraying K_2SO_4 at 1.5% plus $FeSO_4$ at 200 ppm and H_3BO_3 at 100 ppm was responsible for producing the maximum values of N, P and K% (1.86 & 1.85 % for N, 0.39 & 0.38 % for P and 1.79 & 1.78 % for K). While, untreated trees produced the least values of N, P and K content in the two seasons respectively.

The positive effect of potassium, iron and boron in improving mineral absorption by fruit trees and promoting their content in leaves also has been monitored by many researchers such as: **Mohamed (2014); Hamouda *et al.*, (2015) and Abd El-Rhman (2017)** on Manfalouty pomegranate, **Omar (2015) and Abo Ali (2019)** on Wonderful pomegranate, **Abadia *et al*. (2011) and Mosa *et al*. (2015**) on apple trees, **Al Wasfy (2014)** on grapevines, **Gurel and Basar (2016)** on pear trees and **Ibrahim and Al Wasfy (2014) and Dalal *et al*. (2017)** on orange trees.

Table 4. Effect of spraying potassium sulphate, ferrous sulphate, and boric acid on shoot lengths (cm), number of new shoot / tree and leaf area of pomegranate cv. Wonderful, during 2017 and 2018 seasons

Treatments	Shoot lengths (cm)					Number of new shoot/ tree					Leaf area (cm^2)				
	First Season (2017)					First Season (2017)					First Season (2017)				
	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B
Fe 0.0 + B 0.0 ppm	65.3	68.0	71.5	73.3	**69.8**	64	63	65	64	**64.0**	6.0	6.2	6.6	6.9	**6.50**
Fe 100 ppm + B 0.0 ppm	68.2	72.3	76.6	78.5	**73.9**	64	61	66	63	**63.5**	7.1	7.4	7.7	7.9	**7.53**
Fe 200 ppm + B 0.0 ppm	69.4	73.4	80.2	82.5	**76.6**	65	66	65	62	**64.5**	7.7	7.8	8.1	8.4	**8.06**
B 50 ppm + Fe 0.0 ppm	67.4	75.2	74.4	77.3	**73.6**	64	61	66	63	**63.5**	6.6	6.8	7.0	7.3	**6.93**
B 100 ppm + Fe 0.0 ppm	74.4	76.6	77.6	79.4	**77.0**	63	64	63	66	**64.0**	7.0	7.0	7.5	7.7	**7.24**
Fe 100 + B 50 ppm	76.1	77.2	78.8	83.1	**78.8**	65	65	63	64	**64.3**	7.2	7.7	7.9	8.1	**7.77**
Fe 100 ppm + B 100 ppm	77.2	85.5	88.3	88.3	**84.8**	66	66	61	65	**64.8**	7.5	7.9	8.2	8.7	**8.15**
Fe 200 ppm + B 50 ppm	82.6	87.8	90.4	91.6	**88.1**	62	63	63	66	**63.5**	8.2	8.3	9.1	9.3	**8.76**
Fe 200 ppm + B 100 ppm	84.4	89.6	92.1	96.9	**90.8**	64	62	66	66	**64.5**	8.4	8.4	9.3	9.5	**8.95**
Mean A	**73.8**	**78.5**	**81.1**	**83.5**		**64.2**	**63.6**	**64.2**	**64.3**		**7.30**	**7.66**	**7.92**	**8.25**	
New LSD 5%	**A= 3.52 ; B= 5.32 ; AB= 7.76**					**A= NS B= NS AB= NS**					**A= 0.37 ; B=0.41 ; AB=0.594**				
Treatments	**Second Season (2018)**					**Second Season (2018)**					**Second Season (2018)**				
	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B
Fe 0.0 + B 0.0 ppm	66.5	69.1	78.5	79.4	**73.4**	62	65	67	68	**65.5**	6.1	7.4	8.1	8.6	**7.55**
Fe 100 ppm + B 0.0 ppm	69.6	70.2	81.4	83.3	**76.1**	66	69	69	74	**69.7**	8.1	9.5	9.9	10.3	**9.45**
Fe 200 ppm + B 0.0 ppm	73.4	74.5	86.6	88.7	**80.8**	66	69	70	77	**70.5**	9.4	9.0	10.2	10.4	**9.75**
B 50 ppm + Fe 0.0 ppm	70.3	73.2	86.9	89.8	**80.5**	64	66	71	71	**68.0**	8.2	9.0	9.6	11.2	**9.50**
B 100 ppm + Fe 0.0 ppm	72.5	76.2	89.2	90.7	**82.2**	66	68	73	72	**69.8**	8.9	9.6	9.8	11.1	**8.85**
Fe 100 + B 50 ppm	77.4	79.6	90.8	93.6	**85.4**	67	69	75	72	**70.8**	9.6	9.8	10.3	10.8	**10.13**
Fe 100 ppm + B 100 ppm	79.5	84.5	92.7	95.1	**87.9**	68	71	75	76	**72.5**	9.7	9.9	10.4	11.0	**10.25**
Fe 200 ppm + B 50 ppm	84.7	87.7	97.8	103.0	**93.3**	69	73	78	79	**74.8**	9.6	9.6	9.9	11.3	**10.10**
Fe 200 ppm + B 100 ppm	85.4	89.4	98.5	104.7	**94.5**	71	74	79	80	**76.0**	9.8	10.2	10.8	11.9	**10.68**
Mean A	**75.5**	**78.3**	**89.2**	**92.0**		**66.6**	**69.3**	**73.0**	**74.3**		**8.81**	**9.33**	**9.88**	**10.73**	
New LSD 5%	**A= 4.2 ; B= 5.1 ; AB= 7.45**					**A= 2.22 ; B= 3.71 ; AB= 5.40**					**A= 0.35 ; B= 0.59 ; AB= 0.855**				

Table 5. Effect of spraying potassium sulphate, ferrous sulphate, and boric acid on leaves Nitrogen, phosphorus and potassium percentages of pomegranate cv. Wonderful, during 2017 and 2018 seasons

Treatments	Nitrogen %					Phosphorus %					Potassium %				
	First Season (2017)					First Season (2017)					First Season (2017)				
	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B
Fe 0.0 + B 0.0 ppm	1.41	1.47	1.49	1.51	**1.47**	0.18	0.20	0.23	0.24	**0.213**	1. 32	1.39	1.41	1.44	**1.39**
Fe 100 ppm + B 0.0 ppm	1.50	1.56	1.61	1.67	**1.59**	0.20	0.22	0.23	0.25	**0.225**	1.37	1.44	1.47	1.48	**1.44**
Fe 200 ppm + B 0.0 ppm	1.59	1.62	1.70	1.72	**1.66**	0.23	0.25	0.27	0.29	**0.260**	1.42	1.49	1.54	1.55	**1.50**
B 50 ppm + Fe 0.0 ppm	1.62	1.69	1.72	1.73	**1.69**	0.20	0.22	0.23	0.25	**0.225**	1.35	1.42	1.47	1.49	**1.43**
B 100 ppm + Fe 0.0 ppm	1.64	1.66	1.69	1.76	**1.69**	0.21	0.25	0.25	0.27	**0.245**	1.39	1.51	1.57	1.66	**1.53**
Fe 100 + B 50 ppm	1.68	1.71	1.76	1.78	**1.73**	0.24	0.27	0.30	0.31	**0.280**	1.44	1.65	1.67	1.69	**1.61**
Fe 100 ppm + B 100 ppm	1.64	1.74	1.79	1.79	**1.74**	0.28	0.30	0.30	0.33	**0.304**	1.50	1.64	1.66	1.72	**1.63**
Fe 200 ppm + B 50 ppm	1.69	1.76	1.82	1.84	**1.78**	0.30	0.32	0.34	0.36	**0.328**	1.58	1.69	1. 71	1.77	**1.69**
Fe 200 ppm + B 100 ppm	1.70	1.78	1.84	1.86	**1.80**	0.32	0.33	0.35	0.39	**0.343**	1.61	1.72	1.75	1.79	**1.72**
Mean A	**1.58**	**1.63**	**1.74**	**1.75**		**0.243**	**0.262**	**0.277**	**0.296**		**1.44**	**1.55**	**1.58**	**1.62**	
New LSD 5%	**A= 0.10 ; B= 0.12 ; AB= 0.17**					**A= NS ; B=0.112 ; AB= 0.164**					**A= 0.09 ; B= 0.09 ; AB= 0.13**				
Treatments	**Second Season (2018)**					**Second Season (2018)**					**Second Season (2018)**				
	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B	K_2SO_4 0.0%	K_2SO_4 0.5%	K_2SO_4 1.0%	K_2SO_4 1.5%	Mean B
Fe 0.0 + B 0.0 ppm	1.42	1.47	1.49	1.51	**1.47**	0.18	0.20	0.23	0.24	**0.213**	1. 30	1.37	1.42	1.44	**1.38**
Fe 100 ppm + B 0.0 ppm	1.60	1.66	1.70	1.73	**1.67**	0.21	0.21	0.25	0.25	**0.230**	1.35	1.42	1.45	1.46	**1.42**
Fe 200 ppm + B 0.0 ppm	1.62	1.68	1.73	1.74	**1.69**	0.23	0.25	0.28	0.29	**0.263**	1.40	1.47	1.53	1.55	**1.49**
B 50 ppm + Fe 0.0 ppm	1.63	1.70	1.73	1.75	**1.70**	0.22	0.23	0.24	0.25	**0.235**	1.36	1.44	1.48	1.49	**1.44**
B 100 ppm + Fe 0.0 ppm	1.66	1.66	1.69	1.76	**1.69**	0.23	0.24	0.26	0.26	**0.248**	1.37	1.52	1.57	1.59	**1.51**
Fe 100 + B 50 ppm	1.68	1.71	1.76	1.78	**1.73**	0.24	0.27	0.30	0.32	**0.280**	1.40	1.62	1.69	1.69	**1.60**
Fe 100 ppm + B 100 ppm	1.69	1.74	1.79	1.79	**1.75**	0.26	0.28	0.29	0.34	**0.293**	1.49	1.60	1.68	1.72	**1.62**
Fe 200 ppm + B 50 ppm	1.71	1.77	1.82	1.83	**1.78**	0.28	0.32	0.34	0.36	**0.325**	1.54	1.63	1.68	1.74	**1.65**
Fe 200 ppm + B 100 ppm	1.74	1.78	1.82	1.85	**1.80**	0.32	0.32	0.37	0.38	**0.348**	1.60	1.70	1.74	1.78	**1.71**
Mean A	**1.64**	**1.69**	**1.73**	**1.75**		**0.241**	**0.265**	**0.292**	**0.298**		**1.42**	**1.53**	**1.58**	**1.61**	
New LSD 5%	**A= 0.10 ; B= 0.13 ; AB= 0.20**					**A= 0.021 ; B= 0.067 ; AB= 0.095**					**A= 0.08 ; B=0.10 ; AB= 0.14**				

CONCLUSION

In conclusion, for improve flowering behavior, yield and its components and leaves mineral content of Wonderful pomegranate, it is necessary spraying the trees with potassium sulphate at 1.5%, ferrous sulphate at 200 ppm and boric acid at 100 ppm three times on during growth cycle.

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