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(Original Article)

Effect of Foliar Spraying of Calcium and Boron Nano-fertilizers on Growth and Fruiting of Certain Pomegranate Cultivars

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Abstract

Little is known about the effect of foliar nano-nutrients application on pomegranate trees. The experiment was split-plot arranged in a randomized complete block design on some pomegranate cultivars grown at the Experimental Orchard, Faculty of Agriculture, Assiut University, Egypt during three successive season of 2018, 2019 and 2020. The research was to study response of some pomegranate cultivars to foliar spraying with nano-boron and nano-calcium. All the tested applications significantly increased the growth of trees as well as significantly improved the yield and fruit quality and reduced the fruit cracking percentage. Spraying nano-boron plus nano-calcium gave the highest values of growth traits, yield and fruit quality. No significantly differences on all studied traits due to spray nano-boron or nano-calcium singly or in combination. The highest growth traits and yield were recorded on Wonderful followed by Higazy cvs. On other hand, the best fruit quality was detected on Manfalouty pomegranate compared to other studied cultivars.

It is recommended to spray Manfalouty, Higazy and Wonderful pomegranate trees with nano-boron or nano-calcium individually or in combination three times to get high yield with good fruit quality.

Keywords: *Pomegranate, Nano- fertilizers, Calcium, Boron, Yield, Fruit quality*

Introduction

Pomegranate (*Punica granatum* L., Punicaceae), a lovable fruit and ornamental of Mediterranean cultivation, it is considered as substantial minerals and is one of the most suitable fruits of tropical and sub-tropical regions.

Pomegranates are local to central Asia, but have been strewn about of many geographical regions, overall the Mediterranean basin, East Asia, North and South America, Africa and Australia, among others (Holland *et al*., 2009). Pomegranate fruit and juice are well known for their medicinal and therapeutic properties and for their contribution to human health, through their prevention of various chronic diseases such as cardiovascular diseases, cancer and diabetes (Faria and Calhau, 2011 and Vlachoyannis *et al.*, 2015).

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In Egypt, the total area of pomegranate trees was reached 80515 fed. and produced about 672064 tons. Assiut Governorate is considered the main cultivated area 10819 fed. and produce about 189811 ton according to (M.A.L.R. 2020).

Reducing pomegranate production due to crack the fruit is very high. This problem due to improper water management and deficiency of micronutrients. So, it may be used among different horticulture practices, growth regulators have been proper in the recent time to increase the fruit production and to improve the quality of different fruit crops.

Plant nutrients foliar spraying have many beneficial effects on pomegranate, therefore, foliar sprays of nutrients in adequate quantity should be applied at appropriate time for optimum growth, yield, fruit quality and control of fruit cracking. Foliar application has the advantage of regular divide of fertilizer materials and quick response.

Nano-particles are atomic or molecular aggregates with a size ranging from 1 to 100 nm than can affect the physiochemical properties of a substance relative to its bulk form. Nano-particle are soluble and high stable (Pérez-de-Luque, 2017). They attracted widespread attention because of their low toxicity and high bioavailability (Abdulsalam *et al*., 2018). The size of nano-particles plays an important role in their biological activity, especially in the range of 5-200 nm. So, nano-nutrients can scavenge free radicals in a size-dependent manner (Peng *et al*., 2007).

The Nano-technology as a new powerful technology possesses the ability to exist massive variation in food and agricultural process. Fertilizer derived from the Nano-technology draw attention in agriculture. Nano-technology can have positive impact on energy, the economy and environment by improving fertilizer products. It can be encapsulated inside nano-materials, coated with a thin productive polymer film, or delivered as particles or emulsions of nano-scale dimensions (De Rosa *et al*., 2010). Using of nano-fertilizers induce an increase nutrient efficiency, reduce leaching pollutants into soil and groundwater, minimizes the potential negative effects associated with over dosage and reduce the frequency of the application. Hence, nano-fertilizer has a high potential for achieving sustainable agriculture, especially in developing countries (Naderi and Danesh-Shohraki, 2013).

Calcium is an effective element of a fruit's physiological resistance, stabilizes the cell membrane and increases cell turgor pressure (Faust, 1989; Picchioni *et al*., 1995 and Mastrangelo *et al*., 2000). Calcium disorders prevent physiological maturity before harvesting, such as delay and decrease in the quality of the fruit within many fruit species (Pooviah, 1979 and Hernandez-Munoz *et al*., 2006).

Boron has a substantial role in plant metabolism physiological like as nucleic acid metabolism, protein, natural hormone biosynthesis, building and transition of carbohydrates, photosynthesis, cell division, cell wall synthesis membrane action and water uptake (Kaneko *et al,* 1997; Mengel *et al.,* 2001 and El-Sheikh *et al*.,

2007). Boron is accountable to activate of dehydrogenase enzymes, sugar translocation, nucleic acids and plant hormones (Brady and Weil, 1996). Boron deficiency can cause serious problems such as defective fruit development, less yield and poor fruit quality (Maurer and Taylor, 1999). Boron foliar spraying have effective within a limited number of studies to decrease the avalanche of fruit, fruit cracking, controlling boron levels and plant bio regulators (PBR) applications (Singh *et al*., 2003). Application of boron increases fruit set and yields by its role in pollen tube germination and elongation (Abd-Allah, 2006).

Several investigators studied the effect of boron and calcium on fruit set, productivity and fruit quality of pomegranate cultivar. Foliar sprays of boron and calcium improved the yield and fruit quality and reduced the fruit cracking and thus resulted in significantly increased the economic returns (Sheikh and Manjula, 2012; Goargiuas, 2016; Korkmez *et al*., 2016 , Masoud *et al*., 2019 and Morwal & Das, 2021). One of the advantages of using nano-fertilizers is that application can be done in smaller amounts than when using common fertilizers, hence could be more efficient, decreased soil pollution and other environmental risks that may occur when using chemical fertilizers (Selivanov and Zorin, 2001; Naderi *et al*., 2011 and El-Salhy *et al*., 2021). Foliar spray with nano-boron fertilizer significantly increased the nutritional status, increased the yield and significantly fruit quality and decreased the fruit cracking of pomegranate (Khalil & Aly, 2013 and Davarpanaha *et al*., 2016).

Therefore, this study was carried out to study the effect of foliar spraying of nano-boron and nano-calcium on improving yield, fruit quality and leaf mineral content of certain pomegranate cultivars trees.

Materials and Methods

This experiment was executed through three successive seasons of 2018, 2019 and 2020 on certain pomegranate cultivars i.e., Manfalouty, Higazy and Wonderful. Trees were gown at the Experimental Orchard, Faculty of Agriculture, Assiut University. The soil of the experimental orchard is a clay loam and the trees planted at 5x5 m apart. They were 35 years old at the beginning of the investigation. Eighteen uniform and healthy trees were selected for each cultivar and devoted for carrying out this study. The experiment consisted of 6 treatments, each treatment comprised of 3 trees. Regular agricultural practices were applied to all experimental trees as recommended.

The spraying treatments were as following:

1. Foliar spraying water (control).
2. Foliar spray Nano-B_2O_3 at 10 ppm.
3. Foliar spray Nano- B_2O_3 at 20 ppm
4. Foliar spray Nano CaO at 1%
5. Foliar spray Nano CaO at 2%
6. Foliar spray Nano- B_2O_3 at 10 ppm + Nano CaO at 1%.

The previous spraying compounds were exercised three times. The 1st spraying time was done on the 2nd week of May and repeated on the 2nd week of June and August every season.

The nutrients were added via a compound contains all the nano-nutrient in a balanced forms. The source of nano-boron fertilizers used containing (17% B_2) and nano- calcium fertilizer (26.5% Ca) was produced by Nano Lab, Faculty of Science, Assiut University, Egypt. A surfactant, super film at 0.1% was added to the spraying solution.

The following parameters were measured during the three studied seasons:

Vegetative growth

Four main branches almost nearly in growth and distribution in four sides of tree were selected and labeled in April for the following vegetative measurements:

Shoot length (cm).

Leaf area (cm^2), where thirty full mature leaves/tree (from the 3rd to 4th basal nodes of shoot base) were randomly taken and weighing 60 sections of 1 cm^2 (2 sections of 1 cm^2/leaf) and then the average leaf area was estimated according to the following equation:

$$The\ average\ leaf\ area\ (cm^3) = \frac{Leaves\ weight\ (g)}{Sections\ weight\ (g)}\ x\ 2$$

Leaf total chlorophyll was estimated by using chlorophyll meter (Minolta SPAD 502 plus). Using ten leaves from the fourth terminal expended leaf of the shoot.

Yield

At harvest, all the fruits were picked on the 1st and 2nd weeks of October every season. Fruits per tree were counted and weighed to estimate the total yield weight/tree (kg). As well as cracked fruits were sorted. The percentage of cracked fruit relative to the total number of fruits was calculated.

After fruit picking, five fruits from each tree were randomly selected and directly transported to the laboratory of fruit section for determining the following physical and chemical properties:

Average fruit weight (g)

Average fruit peel weight (g) and then calculated the percentage of arils weight relative to the average fruit weight.

Juice weight of 100 g arils.

Total soluble solids % was estimated by using the hand refractometer.

Total acidity as citric acid, reducing sugar and vitamin C were determined according to A.O.A.C. (1995).

Total juice anthocyanin content was calculated according to Rabino and Mancinelli (1986**)**.

The experiment was split-plot arranged in a randomized complete block design with three replication, one tree each. The three cultivars were imposed in the main plots, while the nutrient treatments were put in the sub-plots. Data were tabulated and statistically analyzed according to Snedecor and Cochran (1972) and Mead *et al*. (1993). Means were compared using the least significant differences (LSD) values at 5% level of the probability

Results

Effect of nano-nutrient spraying on vegetative growth

Data presented in Tables (1, 2 & 3) showed the effect of some nano-nutrients spraying on shoot length and leaf parameters of some pomegranate cultivars during 2018, 2019 and 2020 seasons. It is obvious from the data that the results took similar trend during the three studied seasons.

Table 1. Effect of nano-boron and nano-calcium foliar spraying on shoot length of some pomegranate cultivars during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	81.4	83.9	96.7	87.3	91.4	94.3	95.8	93.8	97.3	99.5	102.1	99.6
Nano-boron at 0.1% spraying	87.8	90.4	110.5	96.2	99.6	102.1	109.3	103.7	104.2	106.6	109.8	106.9
Nano-boron at 0.2% spraying	86.9	91.0	110.9	92.9	100.2	103.8	110.6	104.9	105.1	108.1	110.6	107.9
Nano-calcium spraying 1%	86.1	88.9	108.8	94.6	96.9	100.9	108.5	102.1	102.6	104.7	107.1	104.8
Nano-calcium spraying 2%	86.5	89.2	110.1	95.3	97.6	101.5	108.8	102.6	103.3	105.4	108.4	105.7
B 0.1 + Ca 1% spraying	88.7	91.7	111.9	97.4	101.5	104.6	111.9	106.0	106.6	108.5	112.7	109.3
Mean	86.2	87.5	108.2		97.9	101.2	107.5		103.2	105.5	108.5	
LSD	A: 3.76	B: 5.24	AB:9.08		A: 3.41	B: 4.81	AB:8.32		A: 3.46	B: 4.85	AB: 8.39	

Table 2. Effect of nano-boron and nano-calcium foliar spraying on leaves number/shoot of some pomegranate cultivars during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	45.3	43.6	48.7	45.9	46.3	44.1	50.3	46.9	47.2	50.3	53.8	50.4
Nano-boron at 0.1% spraying	49.9	48.5	53.2	50.5	51.6	47.3	54.9	51.3	52.6	53.9	57.7	54.7
Nano-boron at 0.2% spraying	50.6	49.4	54.3	53.4	52.0	48.1	55.8	52.0	53.3	54.8	58.3	55.5
Nano-calcium spraying 1%	48.3	46.7	51.4	48.9	49.8	46.2	53.2	49.7	50.9	51.2	54.6	52.2
Nano-calcium spraying 2%	49.7	48.2	53.1	50.3	50.3	47.1	54.8	50.7	51.6	52.9	56.4	53.6
B 0.1 + Ca 1% spraying	51.2	49.6	54.7	51.5	52.8	48.8	56.3	52.6	54.1	56.1	59.9	56.7
Mean	50.1	47.7	52.6		50.5	46.9	54.2		51.6	53.2	56.8	
LSD	A: 2.18	B: 3.90	AB:5.29		A: 1.98	B: 2.79	AB:4.83		A: 2.21	B: 3.12	AB: 5.39	

Table 3. Effect of nano-boron and nano-calcium foliar spraying on leaf area of some pomegranate cultivars during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	6.41	8.22	7.93	7.52	6.92	7.90	7.65	7.56	6.81	8.12	7.66	7.53
Nano-boron at 0.1% spraying	7.13	9.19	8.85	8.39	7.37	8.87	8.88	8.37	7.67	9.02	8.76	8.48
Nano-boron at 0.2% spraying	7.11	9.22	9.10	8.48	7.28	8.99	8.93	8.33	7.78	9.11	8.85	8.58
Nano-calcium spraying 1%	6.84	8.86	8.58	8.09	7.12	8.58	8.62	8.11	7.56	8.85	8.58	8.33
Nano-calcium spraying 2%	6.76	9.05	8.81	8.23	7.21	8.69	8.68	8.19	7.63	8.91	8.65	8.40
B 0.1 + Ca 1% spraying	7.25	9.65	9.46	8.79	7.63	9.22	9.31	8.72	8.11	9.38	9.33	8.94
Mean	6.91	9.03	8.79		7.26	8.71	8.68		7.59	8.90	8.64	
LSD	A: 0.31	B: 0.44	AB:0.76		A: 0.29	B: 0.41	AB:0.71		A: 0.32	B: 0.45	AB: 0.79	

Data showed that the shoot length and leaf traits were significantly affected by various sources of nano-nutrients used and studied cultivars fertilization compared to checked treatments.

Spraying with nano-born or nano-calcium singly or in combination increased the shoot length and number and area of leaves compared to spray water (check treatment, T_1). The highest shoot length and leaf area were recorded due to spray nano-boron and nano-calcium in combination (T_6). No significant differences on shoot length due to spray nano-boron or nano-calcium singly or in combination. The obtained leaf area was (7.52, 8.19, 8.21, 8.09, 8.48 & 8.79 cm^2), (7.56, 8.37, 8.33, 8.11, 8.19 & 8.72 cm^2) and (7.53, 8.48, 8.58, 8.33, 8.40 & 8.94 cm^2) due to spray water (T_1), 0.1% boron (T_2), 0.2% nano-boron (T_3), 1% nano-calcium (T_4), 2% nano-calcium (T_5) and 0.1% nano-boron plus 1% nano-calcium (T_6) during the three studied seasons, respectively. No significant differences leaf area could be observed due to spray nano-boron singly or combined with nano-calcium.

Hence, the increment percentage of leaf area was attained 11.56, 12.76, 7.58, 9.18 & 16.88, 10.71, 10.19, 7.28, 8.33 & 15.34 and 12.61, 13.94, 10.62, 11.55 & 18.70% average of the three studied seasons) due to T_2, T_3, T_4, T_5 to T_6 over the check treatment (T_1), respectively. Also, the presented data showed that the studied cultivars significantly varied for their vegetative traits. The maximum values of shoot length and number of leaves were detected on wonderful pomegranate cultivar followed by Manfalouty pomegranate cultivars. On other hand, the maximum leaf area was recorded on Higazy pomegranate cultivar followed wonderful pomegranate trees. No significant differences on shoot length and leaf number of Manfalouty and Higazy trees, as well as on leaf area between wonderful and Higazy pomegranate trees. Manfalouty trees had the shortest shoot length and least leaf area. Higazy trees had least leaf number compared to other studied cultivars.

Moreover, interaction between the two studied factors, Tables (1, 2 & 3) indicated that all nano-nutrients spraying induce a significantly increased the

vegetative growth traits compared to spray water (check treatment). All combination of wonderful cultivar gave the highest effects on these studied vegetative traits compared to other combination either Manfalouty or Higazy cultivars. The maximum values of shoot length and leaf numbers were recorded on wonderful pomegranate trees that sprayed with nano-boron plus nano-calcium. Whereas the maximum leaf area was detected on Higazy trees that sprayed with mixture of nano-boron and nano-calcium compared to other studied pomegranate cultivars.

Effect of nutrients spraying on yield:

Data in Tables (4 & 5) showed that sprayed the trees with nano-boron, nano-calcium or combination of them significantly increased the yield/tree compared to spray water (check treatment, T_1). On the other hand, these spraying treatments significantly decreased the fruit cracking percentage compared to spray water.

Table 4. Effect of nano-boron and nano-calcium foliar spraying on yield/tree of some pomegranate cultivars during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	73.82	82.54	101.85	86.07	76.13	86.00	103.75	88.63	77.35	88.41	102.81	89.52
Nano-boron at 0.1% spraying	78.10	88.91	109.50	92.17	81.50	92.41	111.18	95.03	83.56	95.45	110.78	96.60
Nano-boron at 0.2% spraying	79.16	89.25	110.16	92.86	83.21	93.45	112.36	96.34	84.61	96.11	111.70	97.47
Nano-calcium spraying 1%	80.11	91.48	112.91	94.83	84.43	95.21	115.11	98.25	85.92	97.91	114.63	99.49
Nano-calcium spraying 2%	80.92	92.15	114.10	95.72	83.85	96.11	116.33	98.76	85.59	98.70	115.75	100.01
B 0.1 + Ca 1% spraying	81.80	93.35	115.33	96.83	84.76	97.85	118.00	100.20	86.29	100.53	118.63	101.82
Mean	78.99	89.61	110.64		82.31	93.51	112.79		83.89	96.19	112.38	
LSD	A: 3.36	B: 4.75	AB:8.22		A: 3.77	B: 5.35	AB:9.21		A: 3.86	B: 5.47	AB: 9.46	

Table 5. Effect of nano-boron and nano-calcium foliar spraying on fruit cracking % of some pomegranate cultivars during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	11.10	12.22	13.65	12.32	10.43	11.96	13.49	11.94	10.38	12.61	13.65	12.21
Nano-boron at 0.1% spraying	5.66	6.25	6.04	5.98	5.34	4.70	6.00	5.35	5.84	5.68	5.93	5.82
Nano-boron at 0.2% spraying	5.16	5.11	6.32	5.33	4.68	4.60	5.84	5.08	5.30	5.18	5.42	5.30
Nano-calcium spraying 1%	5.36	5.34	5.91	5.54	4.11	4.53	5.72	4.79	5.41	5.39	5.65	5.48
Nano-calcium spraying 2%	4.65	5.84	4.59	5.03	3.98	4.72	4.85	4.52	4.38	4.82	5.11	4.77
B 0.1 + Ca 1% spraying	4.93	4.61	4.11	4.55	4.22	3.84	4.61	4.22	4.65	4.54	4.88	4.69
Mean	6.13	6.56	6.69		5.46	5.73	6.74		5.99	6.37	6.77	
LSD	A: 0.18	B: 0.25	AB:0.44		A: 0.31	B: 0.44	AB:0.75		A: 0.32	B: 0.45	AB: 0.77	

The maximum yield/tree and least fruit cracking percentage were recorded on the trees that sprayed by nano-boron plus nano-calcium (T_6). Therefore, it is clear that using mixture of nano-boron and nano-calcium have beneficial effects on the pomegranate production.

The recorded yield/tree was 86.07, 92.17, 92.86, 94.83, 95.72 & 96.83, 88.63, 95.03, 96.34, 98.25, 98.71 & 101.82 kg/tree (as an av. of the three studied seasons) due to T_1 to T_6, respectively.

Hence, the increment percentage of yield/tree was 7.09, 7.89, 10.18, 11.21 & 12.50, 7.22, 8.69, 10.85, 11.43 & 13.05 and 7.91, 8.89, 11.14, 11.71 & 13.74% due to T_2 to T_6 over T_1, respectively.

Also, the fruit cracking percentages attained 12.32, 5.98, 5.33, 5.54, 5.03 & 4.55, 11.94, 5.08, 5.35, 4.79, 4.52 & 4.22 and 12.21, 5.82, 5.30, 5.48, 4.77 & 4.69% (as an av. of the three studied seasons) due to T_1 to T_6, respectively. The decrement percentage of fruit cracking due to nano-boron or nano-calcium spraying under water spraying attained 51.46, 56.74, 55.03, 59.17 & 63.07, 57.45, 55.19, 59.89, 62.14 & 64.66 and 52.33, 56.59, 55.12, 60.92 & 61.59% (as an av. of the three studied seasons) due to T_2 to T_6, respectively.

The maximum yield/tree and fruit cracking were recorded on wonderful cultivar followed Higazy and Manfalouty pomegranate trees. No significant differences on fruit cracking of Higazy and wonderful cultivars during the first and third season. Manfalouty cultivar had the lightest yield/tree and least fruit cracking. Higazy cultivar in the middle position among Manfalouty and Wonderful cultivar.

Moreover, interaction between the two studied factors, Tables (4 & 5) indicated that all nano-nutrients spraying induce a significantly increased the yield/tree and decreased the fruit cracking percentage compared to spray water (check treatment). All combination of wonderful cultivar gave the highest effects on these studied yield traits compared to other combination either Manfalouty or Higazy cultivar. The maximum values of yield/tree were recorded on wonderful pomegranate trees that sprayed with nano-boron plus nano-calcium. Whereas least fruit cracking percentage was detected on Manfalouty cultivar that sprayed with nano-boron plus nano-calcium compared to other studied pomegranate cultivars.

Effect of nutrients spraying on fruit quality

It is noticed from the obtained data presented in Tables (6 to 14) that the nano-nutrients spraying significantly improved the fruit quality in terms of increasing the fruit weight, arils percentage and total soluble solids as well as sugar, and anthocyanin and vitamin C contents and decreasing the total acidity compared to spray water. No significant differences in these traits due to spraying via either nano-boron or nano-calcium singly or mixture of them. Using mixture of nano-boron and nano-calcium gave the highest values of these studied traits. The recorded fruit weight was (430.70, 456.71, 458.36, 463.76, 467,17 & 474.58), (445.48, 471.14, 474.50, 478,26, 481.98 & 490.10) and (451.12, 477.75, 481.48, 488.86, 489.12 & 496.81g as av. of the three studied seasons) due to T_1 to T_6, respectively.

The corresponding TSS and vitamin C contents were (14.43, 15.08, 15.21, 15.13, 15.40 & 15.48), (14.14, 14.82, 14.92, 14.80, 15.10 & 15.14) and (14.37, 15.03, 15.15, 15.10, 15.38 & 15.42%) and (19.87, 21.43, 21.69, 21.62, 21.77 & 21.88), (19.37, 20.97, 21.21, 20.21, 21.25 & 21.40) and (20.08, 21.63, 21.89, 21.82, 21.95 & 21.99 mg/100g as an av. of three studied seasons, respectively. The increment percentage in fruit weight was (6.04, 6.42, 7.68, 8.47 & 10.19), (5.76, 6.51, 7.36, 8.19 & 10.02) and (5.90, 6.73, 8.37, 8.42 & 10.13% as an av. of the three studied seasons due to T_2 to T_6 over the control, respectively. In addition, the corresponding increment percentages of TSS% was (4.50, 5.41, 4.85, 6.72 & 7.28%), (4.81, 5.52, 4.466, 6.79 & 7.07%) and (4.59, 5.43, 5.08, 7.03 & 7.31as an av. of the two studied seasons, respectively.

The heaviest fruit weight area was recorded on wonderful cultivar followed Higazy pomegranate cultivar. No significant differences on fruit weight and arils % of Wonderful and Higazy cultivars. Manfalouty fruits had the highest values of arils % and juice volume, whereas Higazy fruits gave the least one compared to other studied cultivars.

Table 6. Effect of nano-boron and nano-calcium foliar spraying on fruit weight of some pomegranate cultivars during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	394.45	432.81	464.85	430.70	417.53	457.10	461.80	445.48	411.53	466.31	475.33	451.12
Nano-boron at 0.1% spraying	417.25	459.24	493.63	456.71	441.27	483.58	488.57	471.14	436.81	493.75	502.81	477.75
Nano-boron at 0.2% spraying	418.41	460.57	496.11	458.36	443.81	487.17	492.53	474.50	439.55	498.25	506.63	481.48
Nano-calcium spraying 1%	424.11	465.68	501.48	463.76	449.18	490.11	495.50	478.26	445.11	501.13	510.30	488.86
Nano-calcium spraying 2%	427.53	469.37	504.61	467.17	451.32	494.76	500.21	481.98	446.68	505.18	515.50	489.12
B 0.1 + Ca 1% spraying	434.36	476.84	512.55	474.58	457.83	503.41	508.95	490.10	453.18	513.80	523.48	496.81
Mean	**419.35**	**460.75**	**495.54**		**438.99**	**486.02**	**491.26**		**438.81**	**496.4**	**505.64**	
LSD	**A: 13.51**	**B: 18.99**	**AB:32.85**		**A: 16.91**	**B: 23.77**	**AB:41.13**		**A: 17.25**	**B: 24.31**	**AB:42.10**	

Table 7. Effect of nano-boron and nano-calcium foliar spraying on arils percentage of some pomegranate cultivars during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	53.48	50.63	48.25	50.79	50.86	47.95	47.31	48.71	52.47	48.36	48.73	49.85
Nano-boron at 0.1% spraying	55.86	53.10	51.34	53.43	53.12	50.33	51.22	51.56	54.28	50.86	52.29	52.48
Nano-boron at 0.2% spraying	56.22	52.84	51.46	53.51	53.53	50.46	50.96	51.65	54.49	51.14	52.85	52.83
Nano-calcium spraying 1%	56.46	53.28	52.18	53.97	53.46	50.55	52.45	52.15	54.73	51.00	53.91	53.21
Nano-calcium spraying 2%	56.75	53.22	52.36	54.11	53.65	50.36	53.11	52.37	54.80	50.85	54.17	53.27
B 0.1 + Ca 1% spraying	57.15	53.71	52.48	54.45	54.23	51.11	52.68	52.34	55.23	51.79	54.28	53.77
Mean	55.99	52.80	51.35		52.98	50.13	51.29		54.38	50.66	52.71	
LSD	A: 1.96	B: 2.78	AB:4.82		A: 1.35	B: 1.98	AB:3.30		A: 1.41	B: 1.98	AB: 3.42	

Also, Manfalouty fruits had the highest total soluble solids and reducing sugar as well as anthocyanins and vitamin C contents compared to other studied cultivars. No significant differences reducing sugar and vitamin C contents of Higazy and Wonderful cultivars.

Moreover, interaction between the two studied factors, Tables (6 to 14) indicated that all nano-nutrients spraying induce a significantly improved the fruit traits compared to spray water (check treatment). All combination of wonderful cultivar gave the highest effects on fruit weight compared to other combination either Manfalouty or Higazy cultivar. The heaviest weight was recorded on wonderful pomegranate trees that sprayed with combined of nano-boron and nano-calcium. Whereas the maximum arils percentage was detected on Manfalouty cultivars that sprayed with nano-boron plus nano-calcium compared to other studied pomegranate cultivars.

Table 8. Effect of nano-boron and nano-calcium foliar spraying on juice volume of some pomegranate cultivars during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	32.18	30.65	31.53	31.45	32.64	31.87	32.31	32.27	32.43	31.22	32.88	32.18
Nano-boron at 0.1% spraying	36.15	34.89	36.10	35.71	36.65	36.25	36.67	36.52	36.41	35.52	37.33	36.42
Nano-boron at 0.2% spraying	36.52	35.31	36.18	35.98	37.11	36.68	36.75	36.85	36.80	35.96	37.41	36.72
Nano-calcium spraying 1%	36.95	35.53	36.48	36.32	37.45	36.81	37.36	37.21	37.19	36.11	38.05	37.12
Nano-calcium spraying 2%	37.26	35.80	36.39	36.48	37.81	37.12	37.26	37.40	37.58	36.41	37.91	37.30
B 0.1 + Ca 1% spraying	37.45	36.11	36.83	36.80	37.68	37.50	37.69	37.62	37.42	36.75	38.26	37.48
Mean	36.09	34.72	35.57		36.56	36.04	36.34		36.31	35.53	36.97	
LSD	A: N.S	B: 1.98	AB:N.S.		A: N.S.	B: 1.29	AB:N.S.		A: N.S.	B: 2.05	AB: N.S.	

Table 9. Effect of nano-boron and nano-calcium foliar spraying on peel anthocyanin of some pomegranate cultivars during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	56.83	54.81	41.56	51.07	57.63	56.58	44.11	52.77	57.26	55.16	44.23	52.22
Nano-boron at 0.1% spraying	60.12	57.48	43.55	53.72	60.91	59.31	46.35	55.52	60.35	57.97	46.41	54.91
Nano-boron at 0.2% spraying	60.78	57.93	43.74	54.15	61.05	54.40	46.46	55.64	60.54	58.62	46.65	55.27
Nano-calcium spraying 1%	60.39	57.81	43.91	54.04	61.63	60.28	46.81	56.24	60.25	57.83	46.34	54.81
Nano-calcium spraying 2%	61.11	57.65	43.68	54.15	61.66	60.25	46.73	56.21	60.76	58.18	46.50	55.14
B 0.1 + Ca 1% spraying	61.25	58.11	44.03	54.46	61.90	60.46	46.92	56.42	60.85	58.38	46.63	55.29
Mean	60.08	57.30	43.42		60.79	59.38	46.23		60.00	57.69	46.13	
LSD	A: 1.40	B: 1.98	AB:3.43		A: 1.60	B: 2.27	AB:3.93		A: 1.80	B: 2.54	AB: 4.39	

Table (10): Effect of nano-boron and nano-calcium foliar spraying on TSS% of some pomegranate juice during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	14.92	13.71	14.67	14.43	14.61	13.55	14.25	14.14	15.10	13.44	14.58	14.37
Nano-boron at 0.1% spraying	15.62	14.35	15.28	15.08	15.36	14.18	14.91	14.82	15.84	14.10	15.16	15.03
Nano-boron at 0.2% spraying	15.74	14.46	15.44	15.21	15.41	14.25	15.10	14.92	15.90	14.21	15.35	15.15
Nano-calcium spraying 1%	15.65	14.32	15.41	15.13	15.33	14.10	14.96	14.80	15.81	14.08	15.41	15.10
Nano-calcium spraying 2%	15.92	14.63	15.65	15.40	15.67	14.46	15.18	15.10	16.11	14.46	15.56	15.38
B 0.1 + Ca 1% spraying	15.89	14.81	15.73	15.48	15.73	14.58	15.10	15.14	16.05	14.55	15.67	15.42
Mean	15.62	14.30	15.36		15.35	14.19	14.92		15.80	14.14	15.29	
LSD	A: 0.36	B: 0.50	AB:0.87		A: 0.38	B: 0.53	AB:0.92		A: 0.31	B: 0.43	AB: 0.76	

Table 11. Effect of nano-boron and nano-calcium foliar spraying on reducing sugars of some pomegranate juice during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	11.21	10.71	10.78	10.90	11.24	10.91	10.68	10.94	11.48	10.82	10.91	11.07
Nano-boron at 0.1% spraying	11.79	11.25	11.18	11.41	11.83	11.42	11.21	11.49	12.05	11.34	11.54	11.64
Nano-boron at 0.2% spraying	11.83	11.36	11.31	11.50	11.76	11.48	11.35	11.53	11.94	11.35	11.60	11.63
Nano-calcium spraying 1%	11.68	11.32	11.22	11.41	11.92	11.40	11.30	11.54	12.17	11.26	11.63	11.69
Nano-calcium spraying 2%	11.96	11.48	11.39	11.61	12.10	11.56	11.41	11.69	12.25	11.47	11.65	11.79
B 0.1 + Ca 1% spraying	12.08	11.55	11.52	11.72	12.10	11.75	11.46	11.77	12.31	11.54	11.72	11.86
Mean	11.76	11.28	11.23		11.83	11.42	11.24		12.03	11.30	11.51	
LSD	A: 0.21	B: 0.30	AB:0.52		A: 0.21	B: 0.29	AB:0.51		A: 0.23	B: 0.33	AB: 0.57	

Table 12. Effect of nano-boron and nano-calcium foliar spraying on juice anthocyanin of some pomegranate cultivars during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	60.33	57.18	47.61	55.04	62.18	60.06	49.63	57.29	60.90	58.61	49.35	56.29
Nano-boron at 0.1% spraying	64.98	61.26	50.33	58.86	65.84	62.98	51.44	60.09	65.91	63.13	53.11	60.72
Nano-boron at 0.2% spraying	65.71	61.65	50.53	59.30	66.11	63.16	51.63	60.30	66.18	63.85	53.39	61.14
Nano-calcium spraying 1%	65.34	61.73	50.67	59.25	66.64	63.89	51.94	60.82	66.22	63.63	53.18	61.01
Nano-calcium spraying 2%	66.29	61.46	50.73	59.49	66.75	63.95	52.08	60.93	66.35	63.41	53.51	61.09
B 0.1 + Ca 1% spraying	66.18	61.85	50.89	59.64	67.65	65.19	53.13	61.99	66.29	63.58	53.30	61.06
Mean	64.87	60.85	50.12		65.87	63.21	51.65		65.31	62.70	52.64	
LSD	A: 1.70	B: 2.41	AB:4.17		A: 1.95	B: 2.75	AB:4.76		A: 1.80	B: 2.53	AB: 4.41	

Table 13. Effect of nano-boron and nano-calcium foliar spraying on acidity of some pomegranate juice during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	1.59	1.63	1.89	1.71	1.63	1.65	1.96	1.71	1.53	1.60	1.88	1.67
Nano-boron at 0.1% spraying	1.47	1.50	1.75	1.58	1.51	1.52	1.72	1.61	1.41	1.46	1.70	1.52
Nano-boron at 0.2% spraying	1.45	1.47	1.72	1.55	1.50	1.51	1.75	1.59	1.40	1.44	1.62	1.49
Nano-calcium spraying 1%	1.42	1.45	1.69	1.52	1.46	1.46	1.76	1.56	1.35	1.41	1.56	1.44
Nano-calcium spraying 2%	1.39	1.41	1.63	1.48	1.43	1.44	1.68	1.52	1.36	1.38	1.53	1.42
B 0.1 + Ca 1% spraying	1.38	1.42	1.65	1.48	1.45	1.46	1.70	1.54	1.35	1.36	1.52	1.41
Mean	1.45	1.48	1.72		1.51	1.78	0.94		1.40	1.44	1.63	
LSD	A: 0.024	B:0.034	AB:0.059		A: 0.030	B: 0.042	AB:0.064		A: 0.027	B:0.038	AB:0.066	

Table 14. Effect of nano-boron and nano-calcium foliar spraying on V.C contents of some pomegranate cultivars during 2018, 2019 and 2020 seasons

A / B	2018				2019				2020			
	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean	Manfalouty	Higazy	Wonderful	Mean
Water spray (Cont.)	23.65	18.21	17.75	19.87	23.32	17.58	17.22	19.37	24.18	18.11	17.75	20.08
Nano-boron at 0.1% spraying	25.31	19.68	19.29	21.43	25.06	19.10	18.74	20.97	25.89	19.48	19.52	21.63
Nano-boron at 0.2% spraying	25.50	19.95	19.62	21.69	25.25	19.31	19.06	21.21	26.10	19.73	19.85	21.89
Nano-calcium spraying 1%	25.63	19.81	19.43	21.62	25.45	19.23	18.94	21.21	26.22	19.62	19.61	21.82
Nano-calcium spraying 2%	25.73	19.98	19.60	21.77	25.49	19.27	19.00	21.25	26.31	19.78	19.75	21.95
B 0.1 + Ca 1% spraying	25.83	20.17	19.65	21.88	25.50	19.45	19.25	21.40	26.44	19.81	19.72	21.99
Mean	25.28	19.63	19.22		25.01	18.99	18.70		25.86	19.42	19.40	
LSD	A: 0.44	B: 0.61	AB:1.07		A: 0.35	B: 0.50	AB:0.87		A: 0.47	B: 0.66	AB: 1.14	

Also, the highest values of total soluble solids, reducing sugar, anthocyanin and V.C contents were detected on Manfalouty fruit that treated with combined of nano-boron and nano-calcium compared to Higazy and Wonderful fruits.

Hence, the cost wise evaluation of the application of nano-boron and nano-calcium spraying is in favor, as a mixture of them. Such spraying programs are very important for the production of pomegranate fruits, because the improve in the fruit quality induce an increase in packable yield.

Discussion

Boron disorder is widespread micronutrient problem in agriculture, which leads to reduce yield and lack crop quality (Barker and Pilbeam, 2006). Boron roles in plants involve effects on fruit set and yield, and is indirectly responsible for the energized dehydrogenase enzymes, sugar translocation, nucleic acids and plant hormones (Brady and Weil, 1996; El-Sheikh *et al*., 2007 and Marschner, 2012).

Calcium provides cell wall rigidity by crosslinking of pectic chains of the middle lamella. Disintegration of cell walls and the collapse of the affected tissues are typical symptom of calcium deficiency. The proportion of calcium pectate in cell walls is very important for fruit ripening. The increase of fruit calcium content leads to the increase fruit firmness and delays fruit ripening or prevents calcium-related disorders. Moreover, the role of Ca preventing in the formation of abscission zone between fruit pedicles and bearing branches as well as regulating

the activity of enzymes and photosynthesis. Hence, could result in controlling fruit splitting percentage (Tony and John, 1994).

Increasing yield due to spray of boron and calcium may be back to increase number and weight of fruits, to reduce fruit cracking. The lowering of fruit cracking may be return to the physiological boron role in the synthesis of pectic substances in the cell wall, which support the tissues and prevented fruit cracking. Calcium role in bound the tissues of the middle lamella play an important role in decreasing the fruit cracking. These finding could be due to synergies of boron that may support in calcium metabolism in cell wall, elongation and cell division. Similar findings were reported by Sheikh and Manjula (2012), Korkmaz *et al.* (2016) and Goargiuos (2016).

Conclusion

Results revealed that foliar spraying nano-boron, nano-calcium in pomegranate trees thrice at middle of May, June and August. The foliar application nano-boron at 10 ppm + nano-calcium at 0.1% was found most suitable for increase vegetative growth getting maximum fruit, fruit yield and fruit quality as well as net return.

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تأثير الرش الورقي للأسمدة النانومترية للبورون والكالسيوم على نمو وإثمار بعض أصناف الرمان

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الملخص

أجريت هذه الدراسة بمزرعة كلية الزراعة – جامعة أسيوط – مصر خلال ثلاث مواسم 2018، 2019، 2020 بهدف دراسة تأثير رش الأسمدة النانومترية للبورون والكالسيوم على النمو الخضري والمحصول وخصائص الثمار لكل من أشجار الرمان المنفلوطي والحجازي والوندرفول. حيث صممت تجربة بنظام القطاعات المنشقة مرة واحدة في توزيع كامل العشوائية حيث مثلت الأصناف بالقطع الرئيسية ومعاملة الرش بالقطع الثانوية، حيث تضمنت التجربة ستة معاملات من نانو بورون 10 أو 20 جزء في المليون والنانو كالسيوم 1 أو 2% والنانو بورون 10 جزء في المليون +الكالسيوم 1% والرش بالماء للمقارنة

وقد أوضحت النتائج ما يلي

أدي الرش بالنانو بورون أو النانو كالسيوم سواء فردياً أو معاً إلي زيادة معنوية في صفات النمو الخضري والمحصول/ شجرة مع نقص معنوي في نسبة تشقق الثمار مقارنة بالرش بالماء معاملة المقارنة.

سجلت أعلي القيم من النمو الخضري أو المحصول وأقل القيم لتشقق الثمار نتيجة رش النانو بورون مع النانو كالسيوم في كل الأصناف تحت الدراسة.

لم تسجل فروق معنوية لصفات النمو الخضري أو المحصول أو تشقق الثمار نتيجة الرش الفردي أو المختلط من النانو بورون أو النانو كالسيوم.

سببت جميع المعاملات زيادة جوهرية في صفات الثمار من حيث وزن الثمار ونسبة اللب وحجم العصير وكذلك مكونات الثمار من المواد الصلبة الذائبة والسكريات وصبغة الانثوسيانين وفيتامين C مقارنة بالرش بالماء (معاملة المقارنة)، سجلت أعلي القياسات الخضرية أو وزن المحصول/شجرة وكذلك تشقق الثمار بالصنف الوندرفول ثم يليه الحجازي ثم المنفلوطي. بينما كانت أعلي القيم لصفات الثمار وقلة التشقق بالصنف المنفلوطي.

أظهرت معاملات التفاعل أن جميع المعاملات مع الصنف الوندرفول سجلت أعلي القيم للنمو الخضري والمحصول بينما سجلت أعلي القيم لصفات الثمار للصنف المنفلوطي.

من نتائج هذه الدراسة نوصي بأهمية رش النانو بورون أو النانو كالسيوم سواء بصورة فردية أو معاً ثلاث مرات خلال موسم النمو بداية من منتصف مايو ويونيو وأغسطس وذلك لتحسين النمو الخضري وإنتاج محصول عال ذو خصائص جيدة مع تقليل نسبة التشقق لثمار الرمان المنفلوطي – الحجازي والوندرفول.