

Role of Boron-Nanoparticles to Improve Fruiting Properties, Chemical Constituents and Accumulation of Bioactive Compounds of *Citrus sinensis L.* Trees

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Abstract - Boron is an essential plant micronutrient taken up via the roots mostly in the form of boric acid. Its important role in plant metabolism involves the stabilization of molecules with cis-diol groups. The element is involved in the cell wall and membrane structure and functioning; therefore, it participates in numerous ions, metabolite, and hormone transport reactions. This study was carried out to assess the effects of the foliar application of nano-fertilizers of boron (B) on balady orange (*Citrus sinensis L.*) growth, tree nutritional status, yield, fruit quality and chemical constituents of *Citrus sinensis L.* trees grown under Egypt conditions.

This study was conducted during 2016/2017 and 2017/2018 seasons to examine the effect of using boron via Nano-system at 50 to 200 ppm versus application of it through borax or boric acid at 0.0125 to 0.05% on growth, tree nutritional status, yield and fruit quality. Using boron via nanotechnology system at 50 to 200 ppm was materially superior that using boron via borax or boric acid each at 0.0125 to 0.05% in enhancing growth aspects, photosynthetic pigments, nutrients, yield and both physical and chemical characteristics of the fruits. Generally, all sources of boron lead to enhance all the investigated parameters over the control. No material promotion on all the studied measurements were unaffected among the higher two concentrations of each boron source. Carrying out three spraying of nano boron at 10 ppm is suggested to be beneficial for maximizing yield and producing better fruit quality of *Citrus sinensis L.* trees grown under Minia Region conditions.

Keywords: Borax, Boric acid, nano-boron, *Citrus sinensis L.* trees, Growth, yield, fruit quality.

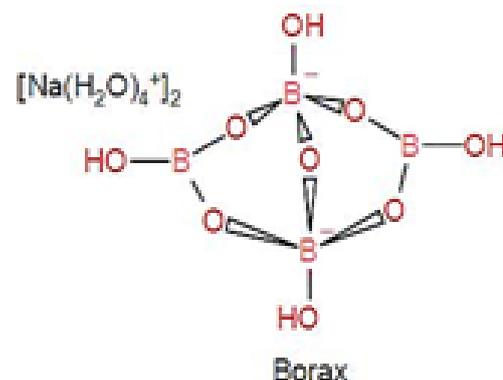
I. INTRODUCTION

Boron is a unique element since it can form strong complexes with different molecules carrying cis-diol groups in appropriate spatial configurations (Makkeet *et al.*, 1985). Complexes of B with apiose, ribose, nicotinamide adenine dinucleotide (NAD), S-adenosyl methionine (SAM),

phenolics, mannitol, sorbitol, sucrose, amino acids and larger molecules such as glycopeptides and glycoproteins have been detected at least *in vitro* (Nielsen and Meacham, 2011).

Plants need B mainly for growth and elasticity of the cell wall and production of pectin (Herrera-Rodriguez *et al.*, 2010). There is a large proportion of B in the cell wall. There is no strong evidence that B is present in other structural or metabolic processes. But there is evidence of B role in other processes, such as the protection of the plasma membrane. There are some reports that B deficiency alters plasma membrane permeability, but the mechanism is still unknown. It has been suggested that some membrane molecules, such as hydroxylated ligands, are responsible for B function in plasma membrane (Camacho-Cristobal *et al.*, 2008).

Plants absorb B from soil as boric acid. Depending on the availability of B, absorption of boric acid is accomplished by three mechanisms: (i) passive diffusion in the lipid double layer, (ii) facilitated transfer through protein channels – these proteins are vital, at low concentrations of B, to absorb B into root cells (Herrera-Rodriguez *et al.*, 2010) – and (iii) activated absorption. It consumes energy through a system with high affinity to B that is activated in response to B deficiency. B deficiency induces an uptake mechanism, which results in a concentration gradient, while in the available conditions this mechanism is not induced and absorption of B is carried out passively (Dannelet *et al.*, 2002).



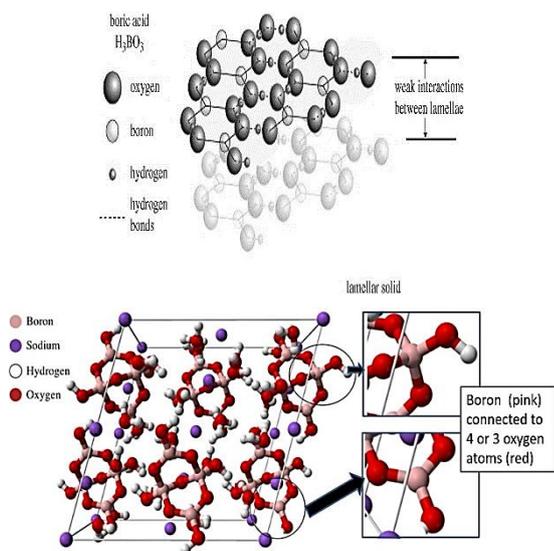


Figure 1: Structure of Borax and Boric acid

Yield decline of *Citrus sinensis L.* grown under Minia region conditions (20Kg/ tree) is considered to be a serious and major problem that faces citrus growers. Trails were established for finding out the best horticultural practices that solve this problem /issue.

Vitamin C is a known antioxidant that helps to safeguard body cells from reactive oxygen species (ROS) which are formed by the immune cells to kill pathogens. There are many ways in which vitamin C effects on innate and adaptive immunity. For example, it is shown that the development (Jariwalla and Harakeh,1996) and the function (Hotchkiss *et al.*,2013)of the white blood cells (WBCs), lymphocytes, phagocytes, and neutrophils are directly associated with vitamin C. Vitamin C-stimulated functions include motility of the cells,18 chemotaxis and phagocytosis (Hotchkiss *et al.*,2013). Another function of vitamin C is to stimulate Neutrophils, which then attack foreign bacteria and viruses, and also affect lymphocytes and other phagocytes (Schwageret *et al.*, 2015). To support the effect of vitamin C on neutrophil activity, a group of people whose vitamin C levels were suboptimal (< 50 $\mu\text{mol} / \text{L}$), were given Vitamin C rich fruit. It resulted in improved neutrophil chemotaxis and oxidant generation (Bozonet *et al.*, 2015).

When B enters the xylem, it begins to move, following the transpirational flow, to the shoot (Shelpet *al.*, 1995). In addition, B can move through phloem to reproductive and vegetative tissues (Matoh and Ochiai, 2005), although the movement through this conductive system varies amongst different species (Brownand Hu, 1996; Brown and Shelp, 1997). In plants that transfer sugar alcohols through phloem, a rapid and significant transfer of B has been observed (Brown and Hu, 1996). It is reported that transgenic tobacco and rice containing high sorbitol in the phloem sap have a greater

capacity for transferring B through phloem to young tissues (Brown *et al.*, 1999). All of these results indicate the probability of B transfer in the phloem, which involves the formation of B-diol compounds with sugar-bearing alcohols ascarrier molecules (Brownand Hu, 1996; Hu and Brown, 1997). However, B phloem transport also occurs, especially to young tissues, inother plant species (e.g., broccoli, lupine, wheat, rapeseed, and sunflower) that are not able to produce thesehydrocarbons (sugary alcohols), although this transfer is not as effective as sugar alcohol producers (Shelpet *al.*, 1998). The molecular mechanism underlying this transfer is still unknown. Research has identified aboric acid channel (NIP6; 1), which plays a role in the transfer of B from xylem to phloem, in condition of Bdeficiency in Arabidopsis thaliana (Tanaka *et al.*, 2008).

Nanotechnology is a promising field of interdisciplinary research. It opens up a wide array of opportunities in various fields like medicine, pharmaceuticals, electronic and agriculture. The potential uses and benefits of nanotechnology are enormous. The current global population is nearly 7 billion with 50% living in Asia. A large proportion of those living in developing countries face daily food shortages as a result of environmental impacts or political instability, while in the developed world there is surplus of food. For developing countries, the drive is to develop drought and pest resistant crops, which also maximize yield. The potential of nanotechnology to revolutionize the health care, textile, materials, information and communication technology, and energy sectors has been well publicized. The application of nanotechnology to agriculture and food industries is also getting attention nowadays. Investments in agriculture and food nanotechnologies carry increasing weight because their potential benefits range from improved food quality and safety to reduced agricultural inputs and improved processing and nutrition (Raiet *al.*, 2012). While most investment is made primarily in developed countries, research advancements provide glimpses of potential applications in agricultural, food and water safety that could have significant impacts on rural populations in developing countries. This study is concentrated on modern strategies and potential of nano-materials in sustainable agriculture management as modern approaches of nanotechnology. (Prasad *et al.*, 2014 and Cicek and Nadaroglu, 2015).

Using boron and other micronutrients via nanotechnology system is very important for enhancing nutrient uptake and quick one of deficiency of these nutrients. Uses of nutrients via nano systems cause a great control on nutrient absorption and uptake of nutrients and prevent the accumulation of nutrients in plant tissues and portent our environment from pollution (Mukhopadhyay, 2014 and Manjunathaet *al.*, 2016).

Boron is very essential for fruit crops because its beneficial impacts on improving germination of pollen grains, fruit setting, water retention, biosynthesis and translocations of sugars and hormones. The activation of enzymes and decreasing disorders, soil pH and soil salinity (Pericaet *et al.*, 2001, Ahmed *et al.*, 2009 and Marschner, 2012).

Using boron in the form of normal boron (Gamal, 2013; Mohamed and Mohammed, 2013; Refaai, 2014, Roshdy and Refaai, 2016 and Hassan, 2017) and nano-boron (Refaai, 2014; Abdalla, 2018; Ahmed, 2017 and Abou-Baker-Basma, 2019) was very effective in improving growth, yield and fruit quality of fruit crops. Most studies showed that nano-system was superior than using normal one in this respect. The merit of this study was testing the effect of using nano-boron versus normal one on fruiting of *Citrus sinensis L.* trees grown under Upper Egypt conditions.

II. MATERIALS AND METHODS

This study was carried out during two consecutive experimental 2016 and 2017 seasons on uniform in vigour 30 years old balady orange trees (*Citrus sinensis L.*) onto sour orange rootstock. The selected trees are grown in a Malawi Agric. Res. & experiment Station, at Malawi district Minia governorate (about 300 Km south of Cairo). The trees planted at a spacing of 4x6 meters. The soil of the orchard is well drained clay in texture with a water table not less than two meters deep. Surface irrigation system was carried out using Nile water. Soil analysis was carried out using the procedures outlined according to (Carter, 1993) shown in Table (1).

Table 1: Analysis of the soil at trial location

Constituents	Values
Sand%	10.0
Silt%	15.0
Clay%	75.0
Texture	clay
O.M.%	0.24
pH (1:2.5 extract)	8.11
E.C (1:2.5 extract) (memos/cm/25c)	1.14
CaCO ₃ %	1.22
Available N%	0.04
Available P (Olsen method, ppm)	1.50
Available K (ammonium acetate, ppm)	50.5

The selected trees were subject to the normal horticultural practices that already applied in the orchard except those dealing with Nano and Normal boron.

This investigation consisted of ten treatments arranged as follows:

1. Control.
2. Spraying Boric acid at 0.025%.
3. Spraying Borax at 0.0125%.

4. Spraying Boric acid at 0.05%.
5. Spraying Borax at 0.025%.
6. Spraying Borax at 0.05%.
7. Spraying Boric acid at 0.0125%.
8. Spraying Nano- Boron at 50 ppm.
9. Spraying Nano- Boron at 100 ppm.
10. Spraying Nano-Boron at 200 ppm.

Each treatment was replicated three times, one tree per each. All sources of Boron were sprayed three times at growth start (2nd of Mar.), just after fruit setting (last week of Apr.) and two months later (last week of June). Triton B as a wetting agent was added to all treatments at 0.05% and spraying was done till runoff.

Complete randomized block design (CRBD) was adopted which the experiment included ten Treatments and each treatment was replicated three times, one tree per each during both seasons and statistical analysis was done and treatments means were compared using new L.S.D. at 5% (Snedecor and Cochran, 1980).

Generally, the following measurements were recorded during the two seasons of study.

1. Vegetative growth Characteristics Four branches for each tree were labeled (1st of Mar.) for measuring mean shoot length and leaf area (cm²) in spring growth flush. Twenty leaves from non-fruiting shoots in the spring growth cycle (according to summer, 1985) namely shoot length, number of leaves / shoots, shoot.
2. Thickness and leaf area (cm²) by (Ahmed and Morsy, 1999).
3. Leaf pigments namely chlorophylls a & b total chlorophylls and total carotenoids (as mg/1g F.W.) (Von-Wettstein, 1957).
4. Total carbohydrates (A.O.A.C., 2006).
5. Leaf chemical components namely N. P. K. S and Ca (as %) (Cottenieet al., 1982, Joneset al., 1991, Chapman and Pratt, 1965 and Summer, 1985).
6. Micro nutrients namely Mn, Zn, Fe and Cu by using atomic absorption spectrophotometer (Page et al., 1980).
7. Boron was measured by using Hot Water (A.O.A.C, 2000).
8. Percentages of initial fruit setting and fruit retention.
9. Number of fruits per tree and yield /tree (Kg) was calculated (1st week of April).
10. Physical and chemical characteristics of the fruit namely fruit weight (g) and dimension (height and diameter as cm), percentages of juice and fruit peel weight, fruit peel thickness (as cm), T.S.S%, total acidity% (as g. citric acid/100 ml juice) T.S.S./acid, total and reducing sugars% (lane and Eynon, 1965) vitamin C content (mg/100 ml juice) (A.O.A.C, 2000).

All the obtained data during the course of this study in the two successive seasons were tabulated and subjected to the proper statistical analysis. The differences between various

treatment means were compared using New L.S.D. parameter at 5% (according to Mead *et al.* 1993).

III. RESULTS & DISCUSSION

1. Vegetative growth aspects

It is clear from the data in **Table(2)** that foliar application of boron via borax and boric acid each at 0.0125 to 0.05% and non-boron at 50 to 200 ppm was significantly responsible for stimulating shoot length and leaf area of *Citrus sinensis L.* trees relative to the control. The promotion was related to the increase in concentrations of the three sources of boron. Increasing concentrations of borax and boric acid from 0.0125 to 0.05% and nano-boron from 100 to 200 ppm was of meaningless effect on such two growth aspects. The best source of boron was nano-system followed by boric acid and borax occupied the last position.

Table 2: Effect of spraying Borax, boric acid and nano-boron on main shoot length, leaf area and some photosynthetic pigments of *Citrus sinensis L.* trees during 2016-2017 and 2017-2018 seasons

Treatments	Main Shoot length (cm)		Leaf area (cm ²)		Chlorophyll a (mg/g F.W.)		Chlorophyll b (mg/g F.W.)		Total Chlorophyll (mg/g F.W.)	
	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
Control	5.1	4.9	25.0	24.9	4.5	4.6	1.4	1.4	5.9	.0
Borax at 0.0125	5.5	5.6	25.5	25.5	4.9	5.0	1.6	1.6	6.5	6.6
Borax at 0.025%	6.0	6.1	26.0	26.1	5.4	5.5	1.9	2.0	7.3	7.5
Borax at 0.05%	6.1	6.1	26.1	26.2	5.5	5.5	2.0	2.0	7.5	7.5
Boric acid at 0.0125	6.5	6.4	26.4	26.7	6.0	5.9	2.3	2.5	8.3	8.4
Boric acid at 0.025%	7.0	6.9	26.8	27.3	6.5	6.5	2.5	2.8	9.0	9.3
Boric acid at 0.05%	7.0	7.0	26.9	27.4	6.5	6.6	2.5	2.9	9.0	9.5
Nano-Boron at 50 ppm	7.4	7.3	27.5	28.0	7.0	7.1	3.0	3.2	10.0	10.3
Nano-Boron at 100 ppm	8.0	7.6	28.1	28.5	7.6	7.5	3.3	3.5	10.9	11.0
Nano-Boron at 200 ppm	8.1	7.6	28.2	28.6	7.6	7.6	3.3	3.6	10.9	11.2
New LSD at 5 %	0.4	0.3	0.4	0.4	0.3	0.4	0.2	0.2	0.5	0.4

In this respect significant differences on such two growth aspects were detected among the three sources of boron. The maximum values were detected on the trees that received three sprays of nano boron at 200 ppm. The untreated trees produced the minimum values. These results were true during both seasons.

2. Leaf Chemical components

Data in **Table (2&3)** clearly exhibit that photosynthetic pigments namely chlorophylls a & b, total chlorophylls, total carotenoids, N,P,K,Mg,Zn,Mn,B and Fe were significantly enhancing in response to treating the trees with all sources of boron compared to the control. Using nano-boron at 50 to 200 ppm was significantly superior than using boric acid and borax each at 0.0125 to 0.05% in improving these chemical components. Treating the trees with boric acid was significantly favorable than using borax in these respects. Significant differences on these leaf components were observed among all boron sources and concentrations except among the higher two concentrate of each source namely 0.025 to 0.05% for both borax and boric acid and 100 to 200 ppm for nano-boron. Treating the trees with nano-boron at 200 ppm gave the maximum values. The untreated trees with boron gave the lowest values. The boron treatments had no significant effect on the leaf content of Cu. These results were true during both seasons.

Table 3: Effect of spraying Borax, boric acid and nano-boron on Total carotenoids and percentages of N, P, K and Mg in the Leaves of *Citrus sinensis L.* trees during 2016-2017 and 2017-2018 seasons

Treatments	Total carotenoids (mg/g F.W.)		Leaf N%		Leaf P%		Leaf K%		Leaf Mg%	
	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
Control	1.5	1.3	1.56	1.55	0.161	0.152	1.11	1.07	0.51	0.49
Borax at 0.0125	1.8	1.9	1.62	1.62	0.172	0.163	1.17	1.16	0.55	0.53
Borax at 0.025%	2.0	2.2	1.71	1.69	0.184	0.174	1.23	1.22	0.60	0.57
Borax at 0.05%	2.1	2.2	1.72	1.70	0.186	0.175	1.24	1.23	0.61	0.57
Boric acid at 0.0125	2.5	2.5	1.86	1.79	0.199	0.190	1.32	1.31	0.67	0.61
Boric acid at 0.025%	2.9	3.0	1.97	1.95	0.211	0.201	1.40	1.39	0.72	0.66
Boric acid at 0.05%	3.0	3.0	1.98	1.96	0.212	0.202	1.41	1.40	0.72	0.67
Nano-Boron at 50 ppm	3.3	3.3	2.15	2.11	0.230	0.222	1.52	1.50	0.77	0.75
Nano-Boron at 100 ppm	3.6	3.7	2.22	2.19	0.250	0.240	1.59	1.57	0.82	0.80
Nano-Boron at 200 ppm	3.6	3.8	2.23	2.20	0.252	0.241	1.60	1.57	0.83	0.81
New LSD at 5 %	0.3	0.3	0.06	0.05	0.009	0.010	0.04	0.05	0.03	0.03

3. Percentages of initial fruit setting and fruit retention

Data in **Table (4)** indicate that spraying *Citrus sinensis L.* trees with borax and boric acid each at 0.0125 to 0.05% and nano-boron at 50 to 200 ppm significantly improved both initial fruit setting and fruit retention compared to the control. There was a gradual promotion on such two parameters with increasing concentrations of borax and boric acid from 0.0125 to 0.05% and nano-boron from 50 to 200 ppm significant differences on such two measurements were observed among all boron sources. Increasing concentrations of borax and boric acid from 0.025 to 0.05% and nano-boron from 100 to 200 ppm failed to show significant promotion on such two parameters. The best source of boron was nano-boron followed by boric acid and borax occupied the last position in this respect. The maximum values of initial fruit setting (21.9 & 22.0 %) and fruit retention (2.8 & 2.8%) from economical point of view were recorded on the tree treated with nano-boron at 100 ppm during both seasons, respectively. The untreated trees produced the lowest values of initial fruit setting (14.1 & 12.9%) and fruit retention (0.5 & 0.5%) during two seasons, respectively. Similar trend was noticed during both seasons.

Table 4: Effect of spraying Borax, boric acid and nano-boron on the leaf content of Zn, Mn, Fe, Cu and B (as ppm) of *Citrus sinensis L.* trees during 2016-2017 and 2017-2018 seasons

Treatments	Leaf Zn (ppm)		Leaf Mn (ppm)		Leaf Fe (ppm)		Leaf Cu (ppm)		Leaf B (ppm)	
	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
Control	51.0	50.8	52.2	51.9	54.1	53.9	1.2	1.3	1.1	1.2
Borax at 0.0125	53.1	53.0	54.3	54.0	56.1	55.9	1.2	1.3	2.0	1.9
Borax at 0.025%	55.5	55.5	56.4	56.9	58.3	58.4	1.2	1.3	2.3	2.4
Borax at 0.05%	55.6	55.6	56.5	57.0	58.4	58.5	1.3	1.3	2.3	2.4
Boric acid at 0.0125	58.0	58.5	59.0	60.0	60.9	61.0	1.3	1.3	2.6	2.8
Boric acid at 0.025%	60.9	60.9	61.5	62.0	63.0	63.9	1.3	1.3	2.9	3.1
Boric acid at 0.05%	61.0	61.0	61.6	62.2	63.1	64.0	1.3	1.3	3.0	3.2
Nano-Boron at 50 ppm	64.0	64.9	64.0	64.5	65.6	66.3	1.3	1.3	3.5	3.5
Nano-Boron at 100 ppm	67.0	68.0	66.0	67.0	68.0	69.0	1.3	1.3	3.8	3.9
Nano-Boron at 200 ppm	67.2	68.2	66.3	67.1	68.1	69.2	1.3	1.3	3.9	4.0
New LSD at 5 %	1.90	2.00	1.90	1.80	1.90	2.10	NS	NS	0.2	1.2

4. Yield/ tree

As shown in **Table (5)** yield expressed in number of fruits/tree and weight (Kg.) was significantly improved due to treating the trees with boron in all sources compared to the control. Treating the trees with nano-boron, boric acid and borax in descending order was significant very effective in improving the yield. No significant promotion on the yield was observed among the higher two concentrations of each sources of boron. Varying boron sources had significant differences on the yield from economical point of view; it is suggested to use nano-boron at 100 ppm for producing higher yield.

Table 5: Effect of spraying Borax, boric acid and nano-boron on the percentage of initial fruit setting, Fruit retention, Yield and number of fruit / trees of *Citrus sinensis L.* trees during 2016-2017 and 2017-2018 seasons

Treatments	Initial fruit setting %		Fruit retention %		No. of fruit / Tree		Yield/tree (Kg.)	
	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
Control	14.1	12.9	0.5	0.5	200.0	192.0	22.2	21.2
Borax at 0.0125	15.2	14.9	0.9	0.8	212.0	205.0	24.2	23.3
Borax at 0.025%	16.3	16.3	1.5	1.1	224.0	218.0	26.4	25.8
Borax at 0.05%	16.5	16.4	1.5	1.1	225.0	219.0	26.7	26.0
Boric acid at 0.0125	17.9	18.0	1.9	1.4	240.0	236.0	29.3	28.8
Boric acid at 0.025%	19.0	19.2	2.3	1.7	255.0	236.0	32.1	29.8
Boric acid at 0.05%	19.0	19.3	2.3	1.7	256.0	237.0	32.3	30.0
Nano-Boron at 50 ppm	20.0	20.5	2.7	2.0	270.0	265.0	35.1	34.6
Nano-Boron at 100 ppm	21.9	22.0	2.8	2.3	281.0	281.0	37.4	37.7
Nano-Boron at 200 ppm	22.0	22.0	2.8	2.3	282.0	282.0	37.6	37.9
New LSD at 5 %	0.90	1.00	0.4	0.3	10.10	11.30	1.10	1.00

Under such promised treatment yield per tree reached (37.4 & 37.7 Kg.) during both seasons, respectively the untreated trees produced (22.2 & 21.2 Kg.) yield during 2016-2017 and 2017-2018 seasons respectively the percentage of increment on the yield due to using 100 ppm nano-boron over the control reached (68.5 & 77.8) during both seasons, respectively the same trend was revealed during both seasons.

5. Physical and chemical characteristic of the fruits

It is obvious from the data in **Tables (6&7)** that supplying *Citrus sinensis L.* trees three times with borax or boric acid each at 0.0125 to 0.05% or nano-boron at 50 to 200 ppm significantly was very effective in improving fruit quality in terms of increasing

fruit weight and dimensions, T.S.S., Total and reducing sugars and Vitamin C and decreasing fruit peel weight and thickness and total acidity relative to the control.

Table 6: Effect of spraying Borax, boric acid and nano-boron on some physical characteristics of the fruit of *Citrus sinensis* L. trees during 2016-2017 and 2017-2018 seasons

Treatments	Av. Fruit Weight (g.)		Av. Fruit diameter (Cm.)		Av. Fruit height (cm.)		Fruit peel weight %		Fruit peel thickness (cm.)	
	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
Control	111.0	110.5	5.40	5.55	6.00	6.11	14.0	14.2	0.41	0.42
Borax at 0.0125	114.0	113.9	5.52	5.67	6.10	6.22	14.5	14.5	0.37	0.39
Borax at 0.025%	118.0	118.3	5.64	5.80	6.20	6.33	15.0	15.0	0.33	0.36
Borax at 0.05%	118.5	118.6	5.65	5.81	6.21	6.33	15.0	15.1	0.32	0.35
Boric acid at 0.0125	122.0	122.0	5.77	5.94	6.33	6.42	15.5	15.6	0.28	0.32
Boric acid at 0.025%	126.0	126.3	5.90	6.07	6.42	6.50	16.0	16.1	0.24	0.29
Boric acid at 0.05%	126.3	126.4	5.91	6.08	6.43	6.51	16.1	16.2	0.24	0.28
Nano-Boron at 50 ppm	130.0	130.5	6.14	6.20	6.56	6.60	16.6	16.7	0.20	0.24
Nano-Boron at 100 ppm	133.0	134.0	6.27	6.33	6.67	6.68	17.1	17.2	0.19	0.20
Nano-Boron at 200 ppm	133.5	134.5	6.28	6.34	6.68	6.69	17.5	17.3	0.19	0.20
New LSD at 5 %	2.20	2.50	0.11	0.10	0.09	0.08	0.40	0.30	0.04	0.03

The promotion on fruit quality was significantly in proportional to the increase in concentration of each boron source except among the higher two concentrations. The promotion on fruit quality was significantly depended on using nano-boron, boric acid and borax, in descending order. The best results were obtained on the trees that treated three times with nano-boron at 100 ppm. The untreated trees produced unbetter fruit quality characteristics. These results were true during both seasons.

Table 7: Effect of spraying Borax, boric acid and nano-boron some chemical characteristics of the fruit of *Citrus sinensis* L. trees during 2016-2017 and 2017-2018 seasons

Treatments	T.S.S.%		Total sugars%		Reducing sugars%		Total acidity%		Vitamin C (mg/ 100 ml J.W.)	
	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018	2016/2017	2017/2018
Control	11.0	11.5	7.5	8.0	3.1	3.2	1.375	1.438	36.1	37.2
Borax at 0.0125	11.4	11.9	7.8	8.4	3.3	3.5	1.359	1.420	38.0	38.3
Borax at 0.025%	11.9	12.2	8.2	8.8	3.6	3.8	1.340	1.391	39.5	40.0
Borax at 0.05%	12.0	12.3	8.3	8.9	3.7	3.8	1.338	1.390	39.7	40.3
Boric acid at 0.0125	12.4	12.6	8.7	9.4	4.0	4.2	1.320	1.360	41.0	42.0
Boric acid at 0.025%	12.9	13.0	9.0	9.8	4.2	4.6	1.301	1.320	42.9	43.3
Boric acid at 0.05%	13.0	13.0	9.1	9.9	4.2	4.7	1.299	1.319	43.0	43.4
Nano-Boron at 50 ppm	13.4	13.4	9.5	10.3	4.5	4.9	1.277	1.291	44.5	45.0
Nano-Boron at 100 ppm	13.7	13.8	10.0	10.7	4.8	5.1	1.250	1.264	46.0	46.1
Nano-Boron at 200 ppm	13.7	13.9	10.1	10.8	4.9	5.1	1.247	1.260	46.3	46.2
New LSD at 5 %	0.30	0.30	0.30	0.30	0.2	0.2	0.014	0.011	1.10	0.90

6. Discussion

The beneficial effects of using boron on growth, tree nutritional status, yield and fruit quality might be attributed to its positive action on enhancing germination of pollens, initial fruit setting, fruit retention, water retention, biosynthesis and translocation of sugars and natural hormones, cell division and the tolerance of trees to drought and salinity stresses (Marschner, 2012). The superiority of boron especially when applied via nanotechnology on a formational result might be attributed to the essential roles of nano boron enhancing the efficiency of uptake of elements and the lowest leaching of nutrients (Rai *et al.*, 2012, Prasad *et al.*, 2014 and Cicek and Nadaroglu, 2015).

These results are in agreement with those obtained by (Abd El-Rahman, 2003; Khayyat *et al.*, 2007; Tariq *et al.*, 2007; Gamal, 2013; Refaai, 2014; Roshdy and Refaai, 2016 and Hassan, 2017) who worked on normal nano and (Refaai, 2014; Abdalla, 2018; Ahmed, 2017 and Abou-Baker-Basma, 2019) who worked on nano-boron.

IV. CONCLUSION

Carrying out three spraying of nano boron at 10 ppm is suggested to be beneficial for maximizing yield and producing better fruit quality of *Citrus sinensis* L. trees grown under Minia Region conditions.

REFERENCES

- [1] Abdalla, O.G. (2018): Response of Zaghloul date palms to the use of some microelements through nanotechnology. *M.Sc. thesis Fac. of Agric. Minia Univ. Egypt.*
- [2] Abd El-Rahman, A.M. (2003): Effect of some nutrients and growth substances application on fruiting, yield and fruit quality of Washington Navel

- orange trees. *Bull. Fac. Agric. Cairo Univ.*, 54: 175-188.
- [3] Abou-Baker- Bassma, A.D. (2019): Reducing the adverse effect of salinity on growth and fruiting of superior grapes by using nano-technology soils conditions. *M.Sc. thesis fac. Agric. Minia Univ. Egypt*.
- [4] Ahmed, W., A. Niaz, S. Kanawal and A. Rahmatullah (2009): Role of Boron in Plant Growth: A Review. *J. Agric. Res.*, 47(3): 329-338. ISSN: 0368-1157.
- [5] Ahmed, F.F. and Morsy, M.H. (1999): A new method for measuring leaf area in different fruit species. *Minia J. of Agric. Res. & Develop.*, vol. (19): 97-105.
- [6] Ahmed, M.M.M. (2017): physiological studies on fertilization of Flame seedless grapevines by nano-technology system. *M.Sc. thesis Fac. Of Agric. Minia Univ. Egypt*.
- [7] Association of Official Agricultural Chemist (A.O.A.C.) (2000): official Methods of Analysis (A.O.A.C.), 12th Ed., Benjamin Franklin Station, Washington D.C., U.S.A. pp. 490-510.
- [8] Carter, M.R. (1993): Soil Sampling and Methods Analysis. *Xandian Soc. Soil Sci. lewis Publishers, London, Tokyo*, ISBN- 100873718615.
- [9] Chapman, H.D and Pratt, P.E. (1965): Methods of Analysis foe soil, Plant and Water. *Univ. of Calif. Division of Agric. Sci.* 172-173.
- [10] Cicek, S., &Nadaroglu, H. (2015): The use of nanotechnology in the Agriculture. *Advances in nano research*, 3(4), 207-223.
- [11] Cottenie A; Verloo, M.; Velghe, M. and Camerlynck, R. (1982): Chemical Analysis of plant and soil. Ghent, Belgium, *Laboratory of Analytical and Agro-chemistry. State Univ.* pp. 200-210.
- [12] Gamal, A. P.O. (2013): Fruiting of Washington Navel Orange trees in relation to application of Seaweed Extract Boron and citric acid Ph.D. *Thesis Fac. Of Agric. Minia Univ., Egypt*.
- [13] Hassan, H.S.I. (2017): Effect of spraying calcium, boric acid and silicon on growth, yield and fruit quality of Balady Mandarin Trees. *Ph.D thesis. Fac. Of Agric. Minia Univ. Egypt*.
- [14] Jones, J. R. B.; Wolf, B. and Mills, H.A. (1991): Plant Analysis Handbook, Micro- Macro publishing Inc., *Georgia U.S.A. Chapter 7* pp. 45-88.
- [15] Khayyat, M.; Tafazoli, E.; Eshghi, S. and Rajae, S. (2007): Effect of Nitrogen, boron, potassium and Zinc on yield and fruit quality of date palm. *Amer. Eurasian J. Agric. & Environ. Sci.* 12(3): 289-296.
- [16] Lane, J.H. and Eynon, L. (1965): Determination of reducing sugars by means of Fehling's solutions with methylene blue as indicator. *A.O.A.O. Washington D. C., U.S.A.*
- [17] Marschner, P. (2012): Mineral Nutrition of Higher plants. Marschner (Ed.) Academic press. Third edition. Mineral Nutrition. *Yield and source-sink Relationships*. pp. 115-116. Elsevier.
- [18] Manjunatha, S.B., Biradar, D. P. and Aladakatti, Y.R. (2016): Nanotechnology and its applications in agriculture: A review. *J. Farm Sci.*, 29(1): (1-13)2016.
- [19] Mead, R., Curnow, R.N. and Harted, A.M. (1993): Statistical methods in Agricultural and Experimental Biology. *2nd Ed. Chapman & Hall, London* pp. 10-44.
- [20] Mohamed, A.Y. and Mohamed, H.H. (2013): The synergistic effects of using turmeric with various nutrients on fruiting of Sewy date palms. *Hort. Sci. J. of Suiz Canal Univ.* Vol. (1): 287-291.
- [21] Mukhopadhyay, S.S. (2014): Nanotechnology in agriculture prospects and constraints. *Nanotechnology, science and applications*, 7, 63-71.
- [22] Page, A.L.; Miller, R.H. and Keeney, D.R. (1982): Methods of Soil Analysis. *Part 2 Amer Soc. Of Agron, Madison, U.S.A.* pp. 10-17.
- [23] Peach, K. and Tracey, I.M.V. (1968): Modern Methods of plant Analysis, Vol. 11 p. 36-38.
- [24] Percia, B.N.; Gerve, C.; Hu, H. and Broan, P. H. (2001): Boron Transport and soluble carbohydrate concentrations in olive. *Amer. Soc. Hort. Sci.* 126:291-296.
- [25] Prasad, R.; Kumar, V. and Prasad, K.S. (2014): Nanotechnology in sustainable agriculture: present concerns and future aspects. *Afr. J. Biotech.* 13(6): 705-713.
- [26] Rai, V.; Acharya, S., Dey, N. (2012): Implications of nano-biosensors in agriculture. *J. Biomater. Nano-biotechnol.* 3 315-324. 10.4236/jbnt.2012.322039.
- [27] Refaai, M.M. (2014): Response of Zaghoul date palms grown under Minia region conditions to spraying wheat seed sprout extract and Nano-boron. *Stem Cell* 5(4); 22-25.
- [28] Roshdy, Kh. A. and Refaai, M.M. (2016): Effect of nanotechnology fertilization on growth and fruiting of zaghoul date palms. *Plant Production, Mansoura Univ.*, Vol. 7(1): 93-98, 2016.
- [29] Summer, M.E. (1985): Diagnosis and Recommendation Integrated system (DRIS) as a guide to orchard fertilization. *Hort. Abst.* 55(8): 7502.
- [30] Tariq, M.; Sharif, M.; Shah, Z. and Khan, R. (2007): Effect of foliar application of micronutrients on the yield and quality of sweet orange. *Pakistan J. of Bio. Sci.* 10 (11): 1823-1825.

- [31] Von-Wettstein, D.V. (1957): Chlorophyll- Lethale under submikro shop ischeformilkechrel der plastidenceli, prp. *Trop. Res. Amer. Soc. Hort. Sci.* 20 pp. 427-433.
- [32] Shelp, B.J.; Marentes, E.; Kithaka, A.M. and Vivekanandan, P. (1995): Boron mobility in plants. *Physiol. Plant.* 94 (2): 356-361.
- [33] Matoh, T. and Ochiai, K. (2005): Distribution and partitioning of newly taken-up boron in sunflower. *Plant Soil* 278 (1/2): 351-360.
- [34] Brown, P.H. and Hu, H. (1996): Phloem mobility of boron is species dependent: evidence for phloem mobility in sorbitol-rich species. *Ann. Bot.* 77 (5): 497-506.
- [35] Brown, P.H. and Shelp, B.J. (1997): Boron mobility in plants. *Plant Soil* 193 (1-2): 85-101.
- [36] Brown, P.H., Bellaloui, N., Hu, H., and Dandekar, A. (1999): Transgenically enhanced sorbitol synthesis facilitates phloem boron transport and increases tolerance of tobacco to boron deficiency. *Plant Physiol.* 19 (1): 17-20.
- [37] Hu, H. and Brown, P.H. (1997): Absorption of boron by plant roots. *Plant Soil* 193 (1/2): 49-58.
- [38] Shelp, B.J.; Kithaka, A.M.; Vanderpool, R.A. et al., (1998): Xylem-to-phloem transfer of boron in broccoli and lupin during early reproductive growth. *Physiologia Plantarum* 104 (4): 533-540. <https://doi.org/10.1034/j.1399-3054.1998.1040403.x>.
- [39] Tanaka, M., Wallace, I.S., Takano, J. et al., (2008): NIP6;1 is a boric acid channel for preferential transport of boron to growing shoot tissues in Arabidopsis. *Plant Cell* 20 (10): 2860-2875.
- [40] Herrera-Rodriguez, M.B.; Gonzalez-Fontes, A. and Rexach, J. et al., (2010): Role of boron in vascular plants and response mechanisms to boron stresses. *Plant Stress* 4 (2): 115-122.
- [41] Camacho Cristobal, J.J., Rexach, J., and Gonzalez-Fontes, A. (2008): Boron in plants: deficiency and toxicity. *J. Integr. Plant Biol.* 50 (10): 1247-1255.
- [42] Dannel, F., Pfeffer, H., and Romheld, V. (2002): Update on boron in higher plants, uptake, primary translocation and compartmentation. *Plant Biol.* 4 (2): 193-204.
- [43] Makkee M, Kieboom APG, van Bekkum H. (1985): Studies on borate esters III. Borate esters of D-mannitol, D-glucitol, D-fructose and D-glucose in water. *Recueil des Travaux Chimiques des Pays-Bas* 104: 230-235.
- [44] Nielsen, F.H. and Meacham, S.L. (2011): Growing evidence for human health benefits of boron. *Journal of Evidence-Based Integrative Medicine* 16: 169-180.
- [45] Jariwalla R.J. and Harakeh S. (1996): Antiviral and immune modulatory activities of ascorbic acid. In: Harris JR, ed. *Subcellular Biochemistry. Ascorbic Acid: Biochemistry and Biomedical Cell Biology.* New York: Plenum Press: 215-231.
- [46] Bozonet SM, Carr AC, Pullar JM, et al., (2015): Enhanced human neutrophil vitamin C status, chemotaxis and oxidant generation following dietary supplementation with vitamin C-rich SunGold kiwifruit. *Nutrients.* 7(4):2574-2588.
- [47] Schwager J, Bompard A, Weber P, et al., (2015): Ascorbic acid modulates cell migration in differentiated HL-60 cells and peripheral blood leukocytes. *Mol Nutr Food Res.*; 59(8):1513-1523.
- [48] Hotchkiss RS, Monneret G, Payen D. (2013): Sepsis-induced immune suppression: From cellular dysfunctions to immunotherapy. *Nat. Rev. Immunol.* 13:862-874. doi: 10.1038/nri3552.

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