EFFECT OF SILICON, CALCIUM AND BORON ON APPLE LEAF MINERALS CONTENT

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ABSTRACT

This experiment was carried out at the apple orchard - College of Agricultural Engineering Science - University of Baghdad during the growing seasons 2017 and 2018. A factorial experiment was conducted within a Randomized Complete Block Design using three replicates and two factors, factor (S) which stands for trees sprayed with potassium silicate as a source of silicon at four levels (0, 2, 4 and 6 ml L^{-1}), while factor (C) represents trees sprayed with a Calcium and Boron combination using three concentrations (0, 0.5 g L^{-1} Ca-EDTA +10 mg L^{-1} B, and 1 g L^{-1} Ca-EDTA+20 mg L^{-1} B). Main results showed that silicon had a significant effect on Nitrogen, Phosphorus, Potassium, Calcium, Boron, and Silicon, especially concentrations 4 and 6 ml L^{-1} for both seasons, Calcium Boron combination also affected studied traits specially treatment (1 g calcium + 20 mg L^{-1} boron) for both seasons, also the dual interaction treatment S3C3 and S4C3 gave the highest rates for most studied characteristics for both seasons.

Key word: plant nutrition, fruit trees, growing season, minerals level

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تاثير السليكون والكالسيوم والبورون في محتوى اوراق التفاح من العناصر الغذائية

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المستخلص

نفذ البحث في بستان التفاح الواقع في كلية علوم الهندسة الزراعية – جامعة بغداد ، خلال الموسمين 2017 و 2018 بهدف دراسة تأثير رش السليكون وتوليفة الكالسيوم بورون في محتوى اللاوراق من العناصر الغذائية، نفذت تجربة عاملية وفق تصميم القطاعات الكاملة المعشاة (RCBD) وبثلاث مكررات. العامل الاول هو رش سليكات البوتاسيوم باربع تراكيز هي (0، 2 ، 4، 6) مل لتر$^{-1}$ والعامل الثاني يشتمل رش توليفة الكالسيوم بورون بثلاثة تراكيز 0 و(0.5 غم لتر$^{-1}$ Ca-EDTA نصف توصية الشركة + 10 ملغم لتر$^{-1}$ B) و (1غم لتر$^{-1}$ Ca-EDTA التوصية + 20 ملغم لتر$^{-1}$ B)، وبثلاثة مكررات وبذلك نتجت 36 وحدة تجريبية (4*3*3) علما أن الوحدة التجريبية تحوي شجرة واحدة، تشير اهم النتائج الى ان السليكون اثر معنويا في زيادة النتروجين والفسفور والبوتاسيوم والكالسيوم والبورون والسليكون خصوصا التركيز 4 و 6 مل لتر$^{-1}$ ولسنتي الدراسة، كذلك اثر الكالسيوم بورون في الصفات المدروسة خضوضا المعاملة (1غم كالسيوم +20 ملغم لتر$^{-1}$ بورون) ولسنتي الدراسة، كما تميزت معاملات التداخل S3C3 و S4C3 في اعطاء اعلى المعدلات لمعظم الصفات ولسنتي الدراسة.

الكلمات المفتاحية :تغذية نبات، اشجار الفاكهة، موسم النمو، مستويات المعادن.

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INTRODUCTION

Silicon (Si) is the second most abundant element in the earth's crust after oxygen, with a percentage of 26%. In normal conditions, silicon does not have a free form, it is linked with other elements, consisting more complex compounds like rocks. Silicon is mainly found as Silicon dioxide (Silica) and Silicates which contain Silicon, Oxygen and minerals (34). Soil rocks that contain Silicon are resistant to weathering and decomposition, therefor Silicon concentrations are low in soil solutions (5). The soluble form of Silicon in soil solutions are an unsaturated monosilicic acid (H_4SiO_4) at a concentration of 3-17 mg / L^{-1} in pH less than 9 (20), and an amorphous biological form of silicon called phytolith (8). According to FAO reports, approximately 210-224 tons of Silicon is removed from the world's agricultural soils every year because silicon-containing fertilizers aren’t applied to the soil and the low use of organic fertilizers, silicon soil content has decreased in a way that may affect plant production. Epstein and Bloom (10) reported that Silicon is a semi-essential element for plants because deficiency causes abnormal growth, development and reproduction. Silicone improves plant defense mechanisms against environmental and biological influences and thus positively reflects the quantity and quality of the crop. Some studies have pointed at the important effect of Silicon on apple trees, which increased the content of chlorophyll in leaves and increased the efficiency of photosynthesis (21). It also stimulates the development of roots (22). Silicon also reduces physiological disorders in fruit like bitter bite and fruit cracking also reducing water loss from leaves and fruit (12). Calcium is one of the most important nutrients affecting the quality of fruits, where there are many physiological symptoms associated with the lack of this element called calcium related disorders (39). Calcium concentrations are high at the first stages of fruit formation and gradually decrease with increament of growth rate (7). The main issue with Calcium is its difficulty transferring between cells and the best solution to overcome these symptoms in fruits is to foliar apply the element to quickly increase its concentration in the leaves and fruits (29, 37), results may vary depending on the type of fertilizer used, the concentration of the element in the fertilizer, the technique used in spraying, the number of times sprayed and spraying date. Boron is an immobile element in plants. It has been shown importance for plant growth since 1910 (14). The importance of Boron lies in cell building and physiological roles of interacting with calcium in cell wall structures (30). It has a fundamental role in cell division and vegetative growth, deficiency causes failure of plant growth, Boron furthermore forms complexes with sugar compounds and facilitates their movement within the plant, also Boron regulates plant hormones (3), and increases yield by controlling the development of the Pollen tube (32). Abd El-Megeed and Medan (1) reported that foliar application of chelated Calcium (0.2%) and Boric acid (0.1%) on peach trees led to significant increasing in shoot length, leaf area, crop yield, fruit hardiness, TSS, total acidity and vitamin C compared to the control treatment.

MATERIALS AND METHODS

The experiment was carried out in 4 years old Anna apple orchard trees grafted on quince rootstocks, located at the Collage of Agricultural Engineering Sciences - University of Baghdad and consists of three lines, each line includes 15 trees, the distance between each line was 4m and the distance between trees was within 2.5m. The factorial experiment within RCBD included 3 replicates and two factors, factor (S) which stands for trees sprayed with K_2SiO_3 as a source of silicon (26.5% Si2O and 12.65% K_2O) at four concentrations (0,2, 4 and 6 ml L^{-1}), while factor (C) represents trees sprayed with a mixture containing Calcium Ca-EDTA (9.7% Ca) and Boron with H_3BO_3 (17 % B) at 3 concentrations (0, 0.5 g L^{-1} Ca-EDTA + 10 mg L^{-1} B, and 1 g L^{-1} Ca-EDTA + 20 mg L^{-1} B). All the treatments were applied on the 1st of April, 1st of May, and 1st of June 2017 and 2018.

Studied characteristics

***** Nitrogen was estimated using a micro-Kjeldahl method (16).

* Phosphorus and Boron are estimated using a Spectrophotometer by the methods listed in (31).

*Potassium and Calcium are estimated by the Flame photometer according to the method proposed by (15).

*The amount of Silicon was estimated according to the color method mentioned in (9).

RESULTS AND DISCUSSION

1- Leaf Nitrogen content (%)

The results in Table 1. reveal that Silicon has significantly increased leaf Nitrogen content, treatment S3 recorded the highest rates for both seasons (2.25, 1.90) % respectively. Calcium and Boron combinations also affected increasing Nitrogen levels. Treatment C3 recorded the highest rate for both seasons (2.37, 1.92) % respectively. The interaction treatment between Silicon, Calcium and Boron also affected Nitrogen content in plant leaves, treatment S3C3 recorded the highest rate for both seasons (2.51, 1.94) % respectively.

Table 1. Effect of Silicon, Calcium and Boron on leaf Nitrogen content (%)

	2017				2018			
S	C			means	C			means
	1	2	3		1	2	3	
1	1.48	2.04	2.24	1.92	1.81	1.86	1.89	1.86
2	2.00	1.49	2.50	2.00	1.85	1.90	1.92	1.89
3	2.24	1.99	2.51	2.25	1.86	1.91	1.94	1.90
4	2.01	2.06	2.23	2.10	1.87	1.89	1.93	1.90
means	1.93	1.89	2.37		1.85	1.89	1.92	
LSD	S=0.17	C= 0.15	S*C= 0.30		S=0.03	C= 0.03	S*C= 0.06	

2- Leaf Phosphorus content (%)

The results in Table 2. reveal that Silicon significantly increased phosphorus content in leaves, treatment S2 and S3 recorded the highest rate in the first season (0.22) % while treatment S4 recorded the highest rate in the second season (0.29) % Calcium and Boron combination had an effect on increasing the leaf phosphorus content, treatment C3 in the first season and C2 in the second season recorded the highest rate (0.22, 0.28) % respectively. The interaction effect between Silicon, Calcium and Boron also affected Phosphorus content in plant leaves, treatment S3C3 recorded the highest rate in the first season while treatment S3C2 recorded the highest rate in the second season (0.23, 0.33) % respectively.

Table 2. Effect of Silicon, Calcium and Boron on leaf phosphorus content (%)

	2017				2018			
S	C			means	C			means
	1	2	3		1	2	3	
1	0.13	0.21	0.22	0.19	0.21	0.25	0.25	0.24
2	0.23	0.20	0.23	0.22	0.22	0.26	0.27	0.25
3	0.20	0.22	0.23	0.22	0.23	0.30	0.31	0.28
4	0.21	0.22	0.20	0.21	0.25	0.33	0.31	0.29
means	0.19	0.21	0.22		0.22	0.28	0.28	
LSD	S=0.01	C= 0.01	S*C= 0.03		S=0.02	C=0.01	S*C= 0.03	

3- Leaf Potassium content (%)

The results in Table 3. reveal that Silicon significantly increased the Potassium content in leaves, treatment S4 recorded the highest rates for both seasons (1.37, 1.90) % respectively. Calcium and Boron interaction treatments also affected Potassium leaf content, treatment C3 for both seasons recorded the highest rate (1.23, 1.84) % respectively. The interaction between Silicon, Calcium and Boron treatments also increased the potassium content in plant leaves. Treatment S4C3 from season one and treatment S4C2 from season two recorded the highest rate (1.38, 1.92) % respectively.

Table 3. Effect of Silicon, Calcium and Boron in leaf potassium content (%)

	2017				2018			
S	C			means	C			means
	1	2	3		1	2	3	
1	1.02	1.10	1.15	1.09	1.66	1.71	1.76	1.71
2	1.20	1.05	1.07	1.11	1.78	1.81	1.82	1.80
3	1.27	1.33	1.30	1.30	1.85	1.86	1.90	1.87
4	1.35	1.38	1.38	1.37	1.89	1.92	1.90	1.90
means	1.21	1.21	1.23		1.79	1.82	1.84	
LSD	S=0.05	C=0.04	S*C= 0.09		S=0.03	C=0.03	S*C= 0.06	

4- Leaf Calcium content (%): The results in Table 4. reveal that Silicon significantly increases calcium content in leaves, treatment S4 recorded the highest rate for the first season (1.14) % while treatment S3 recorded the highest rate for the second season (0.75) %.

Calcium and Boron interaction treatments also affected leaf Calcium content, treatment C3 recorded the highest rate for both seasons (1.21, 0.77) % respectively. The interaction between Silicon Calcium and Boron treatments also increased the Calcium content in plant leaves, treatment S4C3 for the first season recorded the highest rate (1.34) % while treatment S3C3 recorded the highest rate for the second season (0.83) %.

Table 4. Effect of Silicon, Calcium and Boron on leaf Calcium content (%)

	2017				2018			
S	C			Average	C			Average
	1	2	3		1	2	3	
1	0.60	0.83	1.10	0.84	0.55	0.58	0.68	0.61
2	0.73	0.82	1.24	0.93	0.56	0.74	0.76	0.69
3	0.77	1.25	1.17	1.06	0.62	0.79	0.83	0.75
4	0.78	1.30	1.34	1.14	0.61	0.79	0.80	0.73
Average	0.72	1.05	1.21		0.59	0.72	0.77	
LSD	S=0.12	C= 0.10	S*C= 0.21		S= 0.03	C= 0.02	S*C= 0.05	

5- Leaf Boron content (ppm)

The results in Table 5. reveal that Silicon significantly increased Boron content in leaves. Treatment S4 recorded the highest rate for the first season (36.02) ppm while treatment S3 recorded the highest rate for the second season (14.84) ppm. Calcium and Boron combination treatments also affected leaf Boron content, treatment C3 recorded the highest rate for both seasons (36.57, 18.01) ppm respectively. The interaction between Silicon, Calcium and Boron combination treatments also increased Boron content in plant leaves, treatment S4C3 for the first season recorded the highest rate (46.35) ppm as for the second season treatment S3C3 recorded the highest rate reaching (18.61) ppm..

Table 5. Effect of Silicon, Calcium and Boron on leaf Boron content (ppm)

	2017				2018			
S	C			means	C			means
	1	2	3		1	2	3	
1	21.58	26.81	27.72	25.37	10.51	13.30	17.56	13.79
2	23.99	44.91	37.10	35.33	11.21	13.61	18.15	14.33
3	22.55	27.41	35.03	28.33	11.72	14.18	18.61	14.84
4	24.52	37.08	46.45	36.02	12.28	13.75	17.71	14.58
means	23.16	34.05	36.57		11.43	13.71	18.01	
LSD	S=1.85	C= 1.60	S*C= 3.21		S=1.19	C= 1.03	S*C= 2.06	

6- Leaf Silicon content (ppm)

The results from Table 6. reveal that Silicon treatments significantly increased Silicon content in leaves, treatment S3 recorded the highest rate for the first season (113.31) ppm while treatment S4 recorded the highest rate for the second season (111.49) ppm. Calcium and Boron combination treatments also affected leaf Silicon content, treatment C3 recorded the highest rate for both seasons (94.60, 87.88) ppm respectively. The interaction treatments between Silicon, Calcium and Boron also increased the Silicon content in plant leaves, treatment S3C3 for the first season recorded the highest rate (114.31) ppm while treatment S4C1 recorded the highest rate for the second season (120.38) ppm.

Table 6. Effect of Silicon, Calcium and Boron on leaf Silicon content (ppm)

	2017				2018			
S	C			means	C			means
	1	2	3		1	2	3	
1	49.80	57.29	59.61	55.57	54.77	63.60	65.93	61.43
2	101.17	107.62	101.08	103.29	73.58	78.92	82.15	78.22
3	112.90	112.71	114.31	113.31	85.20	90.07	100.84	92.03
4	102.17	98.42	103.39	101.33	120.38	111.49	102.60	111.49
means	91.51	94.01	94.60		83.48	86.02	87.88	
LSD	S=1.436	C= 1.244	S*C= 2.487		S= 4.003	C= 3.467	S*C= 6.933	

The increment effect in leaf mineral content due to Silicon treatments might be caused by its role in improving the effectiveness of the (H^+-ATPase) enzyme (23, 19), or its role in improving cell water conditions by regulating transpiration (13). Silicon also plays a vital role in improving the effectiveness of antioxidant enzymes and building non-enzymatic antioxidants (38) providing further mechanical support for the plant towards external influences due to its participation in the composition of the cellular walls which increases its strength (33), leading to improve plant growth and absorb more nutrients. These results are consistent with the findings of (17). Calcium plays a key role in the stability and permeability of plasma membranes, and in the transmission of signals within the plant, especially in the cases of thermal and water environmental stress (6). Also, it has a regulatory role similar to hormonal effects as it regulates the work of ionic pumps, the work of the pumps is to control the absorption and movement of ions within plant cells, (11). These results are consistent with (27, 1, and 28). Boron has many important structural and physiological roles in plants, it participates in the construction of cellular walls, adding lignin, the manufacture of nucleic acids, the synthesis of Auxins and Phenols and has an important role in the transfer of Calcium from the root to the leaves as well as its role in the transfer and storage of Carbohydrates (25, 26 and 35), As well as activating the Nitrate-reducing enzyme (4), Boron plays a role in maintaining water balance (24) and the role and stability of cellular membranes (14).These results are consistent with (18, 2).

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