



Effect of Spraying With Boron And Silicon on The Characteristics of Pomegranate Fruits, Salimi Cultivar

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Abstract: The experiment was carried out in an orchard of the Department of Horticulture and Scape Design, College of Agriculture, Tikrit University, during the 2024 growth season on six-year-old Salimi pomegranate trees, planted at a spacing of 4×5 m. To ascertain the impact of boron and silicon application via spraying regarding the characteristics of pomegranate fruits, Salimi. Three boron concentrations (0.0, 75, and 150 mg L⁻¹) and three silicon concentrations (0.0, 20, and 40 mg L⁻¹) were utilized. The findings demonstrated that boron significantly influences the fruit's weight, volume, weight of arils and juice of fruit, and TSS:TA ratio of juice, and decrease the total acidity of juice. It was noted that the low concentration of boron was more effective than the high concentration. The silicon influenced some of studied characteristics, that increased significantly fruit's weight and volume, weight of arils and decreased the fruit density. The interaction treatments between boron and silicon influenced statistically on all studied parameters except fruit density and TSS%. Consequently, the application of boron and silicon, either separately or in combination, results in a significant enhancement of the physical and chemical qualities of pomegranate fruits.

Keywords: Boron, Silicon, Chemical Traits, Juice, Arils, Pomegranate

Introduction

Pomegranate (*Punica granatum* L.), one of the most ancient known edible fruits, is a member of Lythraceae family (APG, 2016). It is a significant commercial fruit crop in numerous countries. Pomegranate is cultivated globally for its nutritional, medicinal, and therapeutic significance, owing to its resilience to aridity and high temperatures, Carbohydrates, Vitamin C, proteins, and fats (Jurenka, 2008) (Opara et al, 2009) Fawole et al, 2012). The pomegranate encompasses various variants, notably the Salimi cultivar, prevalent in central Iraq. This Iraqi variety includes numerous strains designated by numerals such as Salimi 1, 2, 3, and 4 (Ibrahim, 1989), along with its fruits. The full fruit is sizable, green, infused with scarlet, and the arils are tart and exceptionally juicy. Pomegranate trees in the orchard where the experiment was done, exhibit overall frailty, insufficient juice content in the fruits, and subpar quality due to their cultivation in an exposed environment, gypsum soil, and irrigation with well water. Boron can participate directly or indirectly in plant metabolism, including in the synthesis of the cell wall and plasma membrane, in carbohydrate and protein metabolism, and in the formation of

ribonucleic acid (RNA) (Vera-Maldonado et al, 2024). Boron possesses significant structural and functional roles, encompassing the transport of sugar from sources to sinks, and the construction of cell walls. Incorporating lignin into cellular walls, synthesizing nucleic acids, facilitating respiration, producing auxin and phenolic hormones, and playing a crucial role in the translocation of calcium from the roots to the aerial parts of the plant (Mengel et al, 2001) (Mazher et al, 2006) (Roy et al, 2006). Draie and Aboras (2021) elucidated that the spraying of French pomegranate variety trees with boron at 200 mg L^{-1} , increased fruit weight, juice percent in fruit and TSS% in juice, and reduced the juice acidity.

Applying boron at a concentration of 500 mg L^{-1} to sweet cherry trees (*Prunus avium*) insignificantly influenced the weight fruit (Askarieh et al, 2021). Additionally, its mass. Silicon plays a crucial role in various physiological processes, notably enhancing photosynthetic efficiency and improving root efficacy in nutrient absorption essential for plant growth and development, while also mitigating the toxicity of certain elements, particularly sodium (Adrees et al, 2015). Silicon enhances plant growth and physiological metrics, bolsters stress resistance, and diminishes transpiration, thereby augmenting drought tolerance (Asghribour & Mosapour, 2016). It regulates cellular osmotic balance and optimizes the plant's hydric condition by modulating the transpiration process and maintaining carbon metabolism, in addition to improving nutrient uptake (Gomaa et al, 2021). Also, supplementary of silicon increase chlorophyll content in plant grown under salinity condition (Tuna et al, 2008). A study by Lalithya et al. (2014) on Sapota shown that applying potassium silicate to leaves at a concentration of 8 ml per liter enhances fruit quality, including weight, fruit's length, diameter, dimensions, and soluble solids content. Mohamed et al. (2015) observed that *Mangifera indica* was treated with potassium silicate at a concentration of 0.2%, increased solid soluble and total soluble sugars, accompanied by reduced acidity. Kong and Kong (2012) demonstrated that a 2% silicon treatment on apple trees enhanced the volume and weight of the fruits, while Masoud et al. (2018) reported the effects of potassium silicates at concentrations 0.5 and 1% of Manfalouty pomegranate trees have enhanced the weight of the fruits, juice percent, TSS% and TSS: acidity ration, and reduced the acidity of juice. Overall, to vital roles of these elements, this study conducted to investigate the impact of foliar spray with boron and silicon on the properties of pomegranate tree fruits.

Methods

The experiment was carried out in an orchard of the Department of Horticulture and Landscape at the College of Agriculture, Tikrit University, during the 2024 growing season, involving six-year-old Salimi variety pomegranate trees planted at a spacing of 4×5 meters, irrigated via drip irrigation. Table (1) presents several physical and chemical parameters of the field soil. The investigation encompassed two factors: the first being boron at three concentrations (zero as a control, 75 and 150 mg L^{-1}) and the second being silicon at three concentrations (zero as a control, 20 and 40 mg L^{-1}). The trees were sprayed with boron and silicon four times over the season, with a biweekly interval, commencing on April 2, 2024.

Table 1. Some physical and chemical properties of the field soil

| Feature | First Depth0-30 cm | Second Depth30-60 cm |
|--------------------------------|--------------------|----------------------|
| Structure | Clay loam | Clay loam |
| Sand (%) | 32.4 | 41.5 |
| Clay (%) | 30.1 | 28.7 |
| Loam (%) | 37.5 | 35.0 |
| O.M (%) | 1.12 | 0.97 |
| N (mg kg ⁻¹) | 58 | 47 |
| P (mg kg ⁻¹) | 9.6 | 6.8 |
| K (mg kg ⁻¹) | 13.1 | 7.8 |
| EC (dc m ⁻¹) | 7.53 | 8.47 |
| pH | 10.46 | 10.88 |
| Boron (mg kg ⁻¹) | 0.39 | 0.45 |
| silicon (mg kg ⁻¹) | 0.083 | 0.091 |
| CaCO ₃ (%) | 29.6 | 30.4 |

The soil samples analyzed chemically in the laboratory of college of Agriculture

Study indicators:

***Physical characteristics of fruits:** On October 28, 2024, five fruits were randomly taken from each pomegranate tree, and the subsequent properties were measured:

- 1. Fruit weight (g):** Each experimental unit had five individual fruits, which were weighed using an electronic balance, followed by the calculation of their average weight.
- 2. Fruit volume (cm³):** The mean volume of the five fruits was determined via the water displacement method and a graduated cylinder.
- 3. Fruit density (gm cm⁻³):** Calculated by dividing the mass of the fruit by its volume.
- 4. Arils weight in fruit (gm):** The fruits were collected post-weighing and enumeration, after which the arils were manually separated, weighed using an electronic scale.
- 5. Juice weight in fruit (gm):** The arils were processed with an electric juicer. The juice from each experimental unit was weighed individually, and dividing by the number of selected fruits.

Chemical properties of the juice :A composite sample of the five-fruit juice was prepared for each experimental unit in a plastic container, then filtered through filter paper, and 20 ml of it was placed in a plastic bottle with a tight lid, and the following properties were estimated in it:

- 1. TSS%:** The measurement was conducted using a Chinese-manufactured hand refractometer, wherein 1-2 drops of juice were applied to the device's prism, and the reading was directly recorded, ensuring the device was calibrated and the prism was rinsed with distilled water before to each measurement.
- 2. Total acidity (%):** 3ml of the filtered juice were titrated with 0.1N NaOH solution, utilizing phenolphthalein indicator, until the equivalence point was attained, and the acidity was determined as per the methodology outlined by Dalali and Al-Hakim (1987).

3. TSS/ TA: It was determined by dividing the TSS% (total soluble solids) by the total acidity value.

The experiment utilized a randomized complete block design (RCBD) of four replicates, with each experimental unit consisting of a single tree, resulting in a total of 36 trees (4 X 3 X 3). The data were statistically analyzed using a computer and SAS program Version 9.1, and the means were compared by Duncan's multiple range test at a significance threshold of 0.05 (Al-Rawi and Khalaf Allah, 2000).

Results

Fruit weight (g)

The data in Table (2) indicate that the application of boron and silicon significantly influenced fruit weight, with the boron treatment at a concentration of 75 mg L⁻¹ yielding the highest average fruit weight of 214.80 g, markedly surpassing the control treatment, which recorded the lowest fruit weight of 156.39 g. The application of silicon at a concentration of 40 mg L⁻¹ resulted in the highest average fruit weight (213.81 g), greatly surpassing the control treatment, which yielded the lowest fruit weight of 162.41 g. The application of boron and silicon sprays significantly influenced the results, yielding the highest average fruit weight of 239.57 g from the boron and silicon treatment (B₁S₂), which markedly surpassed the control treatment (B₀S₀) that recorded the lowest weight of 132.00 g for this characteristic.

Table 2. The effect of spraying with boron and silicon and their interactions on the fruit weight (g) of Salimi pomegranate

| Silicon Boron | S ₀ (0.0) | S ₁ (20) | S ₂ (40) | Average Boron | of |
|----------------------|----------------------|---------------------|---------------------|------------------|----|
| B ₀ (0.0) | 132.00e | 168.55cde | 168.63cde | 156.39c | |
| B ₁ (75) | 195.89bcd | 208.93abc | 239.57a | 214.80a | |
| B ₂ (150) | 159.34de | 176.09cd | 233.22ab | 189.55b | |
| Average of Silicon | 162.41b | 184.52b | 213.81a | | |

The averages followed by same letters are not significantly different from each other according to Duncan's multiple test at 0.05 probability

Fruit volume (cm³)

The data in Table 3 indicated that the average fruit volume of Salimi cultivar pomegranate trees was significantly influenced by the application of boron and silicon, resulting in a notable enhancement of this characteristic. The application of boron at a concentration of 75 mg L⁻¹ resulted in the highest average fruit volume (131.80 cm³), significantly surpassing the control treatment, which recorded the lowest fruit volume (106.54 cm³). Additionally, the application of silicon at a concentration of 40 mg L⁻¹ achieved the highest average fruit volume (151.91 cm³), also significantly exceeding the control treatment, which yielded the lowest volume (97.25 cm³). The interaction treatments of spraying with boron and silicon significantly influenced the average fruit

volume, with the highest average of 175.21 cm³ achieved through the treatment combining high levels of both boron and silicon (B₂S₂). This result was markedly superior to the control treatment (B₀S₀), which yielded the lowest value of 83.57 cm³ for this characteristic.

Table 3. The effect of spraying with boron and silicon and their interactions on the fruit volume (cm³) of Salimi pomegranate.

| Silicon Boron | S₀ (0.0) | S₁ (20) | S₂ (40) | Average of boron | of |
|----------------------------|----------------------------|---------------------------|---------------------------|-------------------------|-----------|
| B₀ (0.0) | 83.57d | 104.24cd | 131.83bc | 106.54b | |
| B₁ (75) | 113.04bcd | 133.66bc | 148.69ab | 131.80a | |
| B₂ (150) | 95.14cd | 122.99bcd | 175.21a | 131.11a | |
| Average of silicon | 97.25c | 120.29b | 151.91a | | |

The averages followed by same letters are not significantly different from each other according to Duncan’s multiple test at 0.05 probability

Fruit density (g cm⁻³)

The results in Table (4) indicated that boron application did not significantly influence fruit density, whereas silicon application resulted in a notable reduction in fruit density percentage. The comparative treatment of silicon at a concentration of 40 mg L⁻¹ yielded the lowest fruit density (1.59 g cm⁻³). In contrast, the treatments involving boron and silicon exhibited significant effects. The highest increase in fruit density (2.08 g cm⁻³) was recorded for the boron-only treatment (B₂S₀), which significantly surpassed the treatment (B₀S₂), yielding the lowest value for this characteristic at 1.30 g cm⁻³.

Table 4. The effect of spraying with boron and silicon and their interactions on fruit density (g cm⁻³)

| Silicon Boron | S₀ (0.0) | S₁ (20) | S₂ (40) | Average of boron | of |
|----------------------------|----------------------------|---------------------------|---------------------------|-------------------------|-----------|
| B₀ (0.0) | 1.98ab | 1.80abc | 1.30c | 1.69a | |
| B₁ (75) | 2.06ab | 1.69abc | 2.03ab | 1.93a | |
| B₂ (150) | 2.08a | 1.46bc | 1.46bc | 1.67a | |
| Average of silicon | 2.04a | 1.65b | 1.59b | | |

The averages followed by same letters are not significantly different from each other according to Duncan’s multiple test at 0.05 probability

Weight of arils in the fruit (g)

The results in Table (5) for Salimi cultivar pomegranate trees indicated that the application of boron and silicon significantly enhanced the specified characteristic. The application of boron at a dosage of 75 mg L⁻¹ resulted in the largest arils weight in the fruit, measuring 88.25 gm, and greatly surpassed the control treatment, which yielded the lowest weight of arils at 63.39 gm. The application of silicon at a dosage of 40 mg L⁻¹ resulted in the largest average arils weight in the fruit, measuring 81.62 gm, and greatly surpassed the control treatment, which yielded the lowest weight at 64.99 gm. The data from the identical table indicated that the spraying interactions with boron and silicon exerted a substantial influence. The maximum average arils weight (99.18 gm) was achieved through the interaction treatment of boron and silicon (B₁S₁), significantly

surpassing the comparison treatment (B_0S_0), which yielded the lowest value of 52.23 gm for this characteristic.

Table 5. The effect of spraying with boron and silicon and their interactions on the weight of the arils in the fruit (gm)

| Silicon Boron | S₀ (0.0) | S₁ (20) | S₂ (40) | Average of boron |
|----------------------------|----------------------------|---------------------------|---------------------------|-------------------------|
| B₀ (0.0) | 52.23d | 70.10bcd | 67.83bcd | 63.39b |
| B₁ (75) | 78.38abc | 99.18a | 87.19abc | 88.25a |
| B₂ (150) | 64.38cd | 71.65bcd | 89.84ab | 75.29b |
| Average of silicon | 64.99b | 80.31a | 81.62a | |

The averages followed by same letters are not significantly different from each other according to Duncan’s multiple test at 0.05 probability

Weight of juice in the fruit (gm)

The data in Table 6 indicated that the average weight of juice from pomegranate fruit was affected by spraying with boron, and the two levels of boron (B_1 and B_2) surpass the comparative treatment, yielding the greatest values for the specified adjective (44.66 gm and 41.33 gm), while the silicon spraying treatments did not significantly influence the same adjective. The application of boron and silicon together yielded a substantial effect, achieving a maximum of 50.41 gm due to the high-level spraying treatment of boron and silicon (B_2S_2), which greatly surpassed the control treatment (B_0S_0), which recorded a minimum of 30.89 gm.

Table 6. The effect of spraying with boron and silicon and its interactions in the weight of juice in the fruit (gm)

| Silicon Boron | S₀ (0.0) | S₁ (20) | S₂ (40) | Average of boron |
|----------------------------|----------------------------|---------------------------|---------------------------|-------------------------|
| B₀ (0.0) | 30.89c | 35.47bc | 36.04bc | 34.13b |
| B₁ (75) | 45.38ab | 47.39ab | 41.20abc | 44.66a |
| B₂ (150) | 34.97bc | 38.61abc | 50.41a | 41.33a |
| Average of silicon | 37.08a | 40.49a | 42.55a | |

The averages followed by same letters are not significantly different from each other according to Duncan’s multiple test at 0.05 probability

Total soluble solid in juice (TSS%)

The TSS percentage in juice for pomegranate fruits of the Salimi cultivar present in table (7). The application of boron and silicon did not significantly affect this trait. However, the same table indicates that treatments involving boron and silicon exhibited a significant impact, with the highest TSS percentage in juice (13.29%) resulting from the treatment of high boron application without silicon (B_2S_0), which significantly surpassed three treatments only include B_0S_1 treatment that yielded the lowest value 12.24% for this trait, but all interaction treatments didn’t surpass the control treatment.

Table 7. The effect of spraying with boron and silicon and their interactions on Total soluble solid in juice (TSS%) of pomegranate fruits.

| Silicon Boron | S₀ (0.0) | S₁ (20) | S₂ (40) | Average of boron |
|----------------------------|----------------------------|---------------------------|---------------------------|---------------------------------|
| B₀ (0.0) | 12.83ab | 12.24b | 12.75ab | 12.61a |
| B₁ (75) | 12.33b | 12.31b | 12.98ab | 12.54a |
| B₂ (150) | 13.29a | 12.47ab | 12.60ab | 12.78a |
| Average of silicon | 12.81a | 12.34a | 12.77a | |

The averages followed by same letters are not significantly different from each other according to Duncan’s multiple test at 0.05 probability

Total acidity (%)

The data in Table (8) indicated that the application of boron resulted in a considerable reduction in acidity in juice of Salimi pomegranate fruits. The spraying of boron at 75 mg L⁻¹ treatment (B₁) had the minimal percentage of acidity (2.27%) comparison to control treatment which yielded high level of acidity of 2.57%. The silicon spraying treatments did not significantly impact this feature. The application of boron and silicon together resulted in a substantial reduction. Especially B₁S₂ Treatment that showed the minimal acidity achieving 2.08% and decreased significantly to control treatment that gave the highest acidity in pomegranate juice adjusting 2.73%.

Table 8. The effect of spraying with boron and silicon and their interactions on total acidity (%) in juice of pomegranate fruits

| Silicon Boron | S₀ (0.0) | S₁ (20) | S₂ (40) | Average of boron |
|----------------------------|----------------------------|---------------------------|---------------------------|---------------------------------|
| B₀ (0.0) | 2.73a | 2.48abc | 2.51ab | 2.57a |
| B₁ (75) | 2.44abc | 2.28bc | 2.08c | 2.27b |
| B₂ (150) | 2.28bc | 2.65ab | 2.50ab | 2.48ab |
| Average of silicon | 2.48a | 2.47a | 2.36a | |

The averages followed by same letters are not significantly different from each other according to Duncan’s multiple test at 0.05 probability

TSS:TA ratio

Table (9) indicates that the TSS:TA ratio of Salimi pomegranate juice was significantly influenced by the application of boron and silicon, resulting in a notable enhancement of this characteristic. The application of boron at a concentration of 75 mg L⁻¹ resulted in the greatest TSS:TA ratio (5.67), greatly surpassing the comparator treatment, which had a lower ratio of 5.03. The spraying treatments with silicon had no difference about the control treatment, but the spraying with at a concentration of 40 mg L⁻¹ resulted the greatest ratio of TSS:TA at 5.58, greatly surpassing the other concentration 20 mg L⁻¹ (S₁), which yielded the lowest ratio of 5.09. The treatments involving interaction applications of boron and silicon demonstrated a notable impact, with the highest TSS:TA ratio of 6.32% achieved through the combined treatment of boron and silicon (B₁S₂), significantly surpassing the control and B₂S₁ treatments, which yielded the lowest ratio of 4.83 and 4.79 respectively.

Table 9. Effect of spraying with boron and silicon and their interactions on TSS:TA ratio in juice of pomegranate fruit

| Silicon Boron | S0 (0.0) | S1 (20) | S2 (40) | Average of boron |
|---------------------------|-----------------|----------------|----------------|---------------------------------|
| B0 (0.0) | 4.83c | 5.04bc | 5.23bc | 5.03b |
| B1 (75) | 5.24bc | 5.45bc | 6.32a | 5.67a |
| B2 (150) | 5.91ab | 4.79c | 5.19bc | 5.30ab |
| Average of silicon | 5.32ab | 5.09b | 5.58a | |

The averages followed by same letters are not significantly different from each other according to Duncan’s multiple test at 0.05 probability

Discussion

The results indicated that the boron spraying treatment enhanced the average weight and volume of the fruit, as well as the weight of the arils and juice contained within. This effect may be attributed to boron's beneficial role in cell division and the synthesis of nucleic acids and proteins (Pandit et al, 2011). Additionally, boron facilitates root expansion and water absorption by modulating cell membrane permeability (Havlin et al, 2005) (Mazher et al, 2006), contributing to the increased volume and weight of the fruits, along with the proportion of arils and juice. Boron significantly enhances the vegetative development attributes of plants by participating in their metabolism and facilitating the translocation of photosynthetic products from their sites of synthesis within the leaves to other active regions of the plant. It plays a definitive function in stimulating the plant's capacity for photosynthesis and the production of essential nutrients for growth. This enhances the physical attributes of the fruits and facilitates the absorption of mineral elements (Haque et al, 2011) (Naz et al, 2012). Consequently, total soluble solids rose while total acidity diminished. This aligns with the findings of Al-Tohafi (2011) on Agmy apple, Al-Douri (2012) on Salimi pomegranate trees and Garcia-Hernández (2021) on young pomegranate trees under drip irrigation. The influence of silicon on the qualitative attributes of the crop is linked to its capacity to enhance chlorophyll levels in the leaves and improve photosynthetic efficiency (Tuna et al, 2008), thereby facilitating the availability of essential nutrients and physiologically active compounds required for sustained growth. It also contributes to enhancing the absorption of essential nutrients required for structural and physiological activities, including the functioning and synthesis of enzymes and hormones. It also enhances the plant's water status (Romero-Aranda et al, 2006) (Guntzer et al, 2012). Silicon enhances the plant's resilience to external environmental and biological factors by improving the efficacy of antioxidant enzymes and augmenting the synthesis of non-enzymatic antioxidants. These chemicals eliminate radicals that damage cell membranes when present in elevated quantities within cells (Sairam & Saxena, 2000) (Savvas et al, 2009), while silicon serves structural functions since it is incorporated into the composition of cell walls (Epstein & Bloom, 2005).

The structural and physiological benefits were evident in the yield indices, with an increase in weight and volume of fruits and a decrease in fruit density. This aligns with the findings of Mohamed et al. (2015) on mango trees and is also congruent with those of Wang and Wang (2016) on Fuji apple.

Conclusion

Salimi one of the common pomegranate cultivars which are cultivated in middle and south of Iraq. Its fruit affected negatively by the environmental condition in these reigns therefore the fruit traits is poorly. The foliar spray of boron and/ or silicon participate to improvement of quality properties of fruit and juice. In summary, this study highlights the importance of agribusiness and sustainable development in fostering economic growth, ensuring food security, and promoting environmental sustainability. The findings demonstrate that integrating sustainable practices into agribusiness operations can lead to increased productivity and long-term profitability. Additionally, the role of technological advancements and policy support cannot be underestimated in achieving these objectives. Future research should focus on exploring innovative approaches to enhance sustainability in agribusiness, including the adoption of digital technologies and climate-smart agricultural techniques. Collaboration among stakeholders, including policymakers, farmers, and researchers, will be crucial in addressing the challenges and seizing the opportunities in the sector. Ultimately, sustainable agribusiness development is essential for meeting global food demands while preserving natural resources for future generations. By implementing strategic policies and fostering innovation, the agribusiness sector can contribute significantly to economic stability and ecological balance.

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