



Effect of Spraying With Calcium and Potassium Silicate on Some Growth Characteristics and Yield of Pomegranate Trees of the cv. (Wonderful)

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ABSTRACT

The experiment was conducted during the 2024 growing season on five-year-old, healthy pomegranate trees in a local orchard in Qaladiza, Sulaymaniyah Governorate, Kurdistan, Iraq, to examine the effect of foliar spray with three levels of calcium (0, 2, 4 ml.l⁻¹) and three levels of potassium silicate (0, 1.5, 3 ml.l⁻¹), along with their interactions, on the growth and yield of pomegranate trees. Results showed that the most significant increases occurred with the highest treatment levels and the interaction of calcium and potassium silicate, especially at high concentrations (4 ml.l⁻¹ calcium and 3 ml.l⁻¹ potassium silicate). Based on the earlier findings, this study concluded that the majority of the vegetative, yield, and chemical properties of pomegranates (cv. Wonderful) were considerably impacted by the application of calcium and potassium silicate as foliar treatments, as well as their interaction, leading to increases in chemical components, yield, and vegetative growth. These enhancements led to notable improvements in most measured parameters, including leaf nitrogen content (2.083%), calcium (0.889%), and potassium (0.990%), leaf area (7.378 cm²), leaf chlorophyll content (47.257 SPAD), fruit cracking (40.76%), Total Soluble Solid (17.100%), anthocyanin (5.706%), and peel content of nitrogen (2.030%), peel content of calcium (10.649%), and peel content of potassium (1.387%).

Keywords: Pomegranate, Calcium, Potassium silicate, Foliar spray, Yield.

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INTRODUCTION

Since ancient times, pomegranates (*Punica granatum* L.) have been cultivated for their numerous health benefits, durability, and value. As one of the first five fruit crops domesticated around 2000 BC, the pomegranate has played a vital role in agricultural history [1]. The plant is native to regions extending beyond Iran, including the northern Indian Himalayas and the Mediterranean and Middle Eastern countries, which are today the world's leading pomegranate producers and growers [2]. The maturity and consumer quality assessments of pomegranates depend on their physicochemical and mechanical traits, such as sugar content, acidity, flavour, skin colour, bruising, discoloration, and deformities. This makes pomegranates a "non-climacteric fruit" [3] [4].

Fruit cracking occurs when the internal pressures within the fruit surpass the strength of its cell walls and outer covering, or rind in the case of pomegranates. This results in a crack while the fruit remains on the plant, threatening the plant's structure and mechanical strength and potentially causing a significant decline in pomegranate yield [5]. Pomegranate splits and cracks create open wounds that lead to shrivelling and moisture loss, reducing fruit quality and post-harvest shelf life. Additionally, these cracks make the fruit more susceptible to insect and microbial attacks. [6] [7].

Cracking happens because the peel and flesh grow at different rates, a process that is worsened by temperature fluctuations and water pressure changes [8]. Physiologically, since pomegranates are sensitive to soil moisture, humidity, and transpiration, moisture imbalance is recognized as a key cause of cracking [9]. While completely preventing fruit cracking may be difficult, several treatments remain unexplored, including the possible use of calcium and potassium silicate, along with other molecular and mechanical strategies [10].

Since calcium is a vital component of pectin, which helps bind plant cells together and maintain proper cellular integrity, it plays an essential role in the development and functioning of plants. Adequate calcium levels lead to fruits

with tougher rinds and outer cells, enhancing their resistance to mechanical damage, increasing yields, and improving quality after harvest [11]. Calcium deficiency often causes weaker cell walls, compromising the outer rind's integrity and structural resilience, which makes pomegranates more susceptible to both biotic and abiotic stresses and shattering. Low calcium levels are linked to physiological disorders [12] [13].

Pomegranates can be sprayed with calcium both before and after to prevent physiological deterioration, delaying maturity and improving fruit quality [14], controlling the water intake by plant roots and minimizing pomegranate shattering [15], improving its fruit quality, productivity, and nutritional status [16].

Another important mineral that can help prevent fruit cracking and enhance overall fruit quality is potassium silicate, which strengthens plant tissues and reduces water loss. Potassium silicate also increases the flexibility of the pericarp, total aril weight, and fruit juice content, and helps maintain optimal moisture levels. All these benefits are further supported by potassium silicate [17]. In plants, potassium is essential for photosynthesis, respiration, ion transport and absorption, protein synthesis, and enzyme activation [18], increasing the pomegranate fruit output, quality, and set and reserve percentages [19]. Potassium could be involved in the transfer and buildup of sugars in fruit [13], and it plays a crucial role in maintaining the turgidity of the cell membrane and its capacity for protein production by controlling the osmotic pressure [20]. Because it is a component of plant structure and has regulatory roles in protein synthesis, carbohydrate metabolism, enzyme activation, stomatal regulation, photosynthesis, increases in abiotic stress tolerance, membrane potential regulation, sugar transport, stress acclimatization, and plant growth, potassium is one of the essential elements [21] [22] [23]. Under salinity conditions, K^+ sustains ion homeostasis and controls the osmotic balance [24] [25], and controls the stomatal opening under drought circumstances and aids plants to adapt under water stress [26]. The role of the element potassium is vital in growing the fruit size since it protects cell water contents and it is viewed as a co-factor in chlorophyll production, photosynthesis processes and boosting the peel colour of fruits [27].

The research objectives of this study are threefold, focusing on the effects of foliar spraying with calcium and potassium silicate on pomegranate fruit cracking. Fruit cracking, one of the biggest problems in pomegranate production, must be measured to understand the impact and effects of calcium and potassium silicate foliar spraying. In addition to the treatments applied, the overall quality of the pomegranates should be evaluated considering the factors that influence fruit cracking. This is important because the study will examine the combined effects of potassium silicate on water balance and calcium's role in enhancing structural integrity and fruit quality. The study will also assess the growth of treated and untreated plants and determine whether calcium and potassium silicate help reduce cracking, improve fruit quality, and increase overall yield.

Material and Methods

Experimental Site

Experimented during the 2024 growing season in a local orchard near Qaladize town, Iraq, located at latitude 36.2371 N, longitude 45.0189 E, and an elevation of 538 meters above sea level. The experiment focused on a pomegranate tree (*Punica granatum* L. cv. Wonderful), which was five years old and cultivated with 2x3 meter spacing. All trees had uniform vigour, were trained to five stems, and were irrigated using a stream system.

Experimental Design and Statistical Analysis

We applied a foliar spray of calcium and potassium silicate for this experiment. The study was structured using a randomized complete block design (RCBD) with three replications, each consisting of one tree as the experimental unit. Therefore, the total number of trees used is 27 (3 x 3 x 3). The mean values were compared using Duncan's multiple range test (DMRT) at a 0.05 probability level [28]. The data were analysed with SAS [29].

Treatment

This study was conducted to examine the effect of foliar application of calcium, with solutions prepared at concentrations of (0, 2, and 4 ml.l^{-1}), as well as potassium silicate the solutions were applied at concentrations of (0, 1.5, and 3 ml.l^{-1}) on the growth and yield characteristics of 5-year-old pomegranate trees. Each pomegranate tree was sprayed three times at different intervals during the growing season. The first spray was on 3/7/2024 after fruit set at 6 P.M., the second on 18/7/2024, and the third on 2/8/2024, with 15 days between each spray.

Studied characteristics

We take all use measurement after harvesting of fruit at 25/10/2024 for all determine vegetative characteristics.

Leaf content (Nitrogen, Calcium and Potassium silicate %)

It will be determined by collecting 40 leaves randomly from the top mid and bottom at the different sides of a tree. The leaves were collected and washed well with water to remove any residue after washing dried. After that, the

samples were placed in the oven at (70 °C) for 72 hours, till reaches the constant weight, and grind then 0.5 g weight of each sample was digested using H₂SO₄ and HClO₄ [30] to estimate the elements of (Nitrogen, Calcium and Potassium) in the leaves, according to [31]. According to the following procedures:

1 – Percentage of Nitrogen by the modified Microkjeldahl method.

2– Percentage of calcium by using Olsen methods by using the color method by using spectrophotometer at long wave 410 nm.

3 – Percentage of potassium by using flame photometer.

Leaf Area (cm²)

Thirty leaves from each tree were randomly collected from the canopy's top, middle, and bottom. Leaf area was measured non-destructively using Easy Leaf Area image software on Windows [32].

Leaf Chlorophyll content (SPAD)

Chlorophyll content of leaves was measured using a SPAD meter. Data were obtained from 40 leaves randomly collected from the top, middle, and bottom of the tree canopy, as well as from different sides; each leaf was measured with a SPAD unit. The SPAD meter used was model 502 [33].

Tree yield (kg)

It was determined using the following equation:

Tree yield = Number of fruits per tree × Average weight of each fruit

According to [34].

Fruit cracking %

The percentage of cracked fruits was calculated by dividing the number of cracked fruits by the total number of fruits per tree [35].

$$\text{Cracked \%} = \frac{\text{Number of cracked fruit / tree}}{\text{Total number of fruit / tree}} \times 100$$

Fruit size (cm³)

The average size was determined using a numerical cylinder filled with water. The size of the fruit is equal to the volume of displaced water [36].

Total soluble solids (TSS %)

Before placing a drop of juice in a Digital Hand refractometer, it should be cleaned and washed. With drooped distilled water, a drop of juice will be placed on the Refractometer. The device's direct reading was taken [37].

Anthocyanin pigment content in the berry juice (mg per 100 ml juice)

According to [38].

$$\text{Anthocyanin content (\%)} = \frac{\text{Abs } 535 * V_e * T_v}{V_u * W_{ts}} \times 100$$

Abs = Reading of the spectrophotometer

Ve = Volume of extracts

TV = Total Volume

Vu = Volume of extracts

Wts = Weight of the sample

Peel content of the nutrients in (Nitrogen, Calcium, and Potassium)

Peel content (of the nutrients in Nitrogen, Calcium, and Potassium silicate) was determined by drying the peel, then placing the peel in the massaging packet and sealing the packet in several places before transferring it to the laboratory. The samples were then placed in an oven at 70 °C for 72 hours until reaching a constant weight to assess the nutrient content in the peel for Nitrogen, Calcium, and Potassium silicate. silicate according [34].

Result

The following table demonstrates the effect of foliar application of Calcium and Potassium silicate separately and their interaction on pomegranate trees, aiming to assess the impact of these fertilizers individually and combined on the parameters outlined in the materials and methods.

Table (1): Effect of Calcium and Potassium silicate application and their interactions on vegetative characteristic on pomegranate tree cv. "Wonderful"

Treatments		N %	Ca %	K %	Leaf area	Leaf Chlorophyll
Calcium (ml .l ⁻¹)	0	1.624 b	0.658 c	0.563 c	6.618 a	43.328 b
	2	1.858 a	0.706 b	0.737 b	6.918 a	44.123 b
	4	2.035 a	0.752 a	0.855 a	7.035 a	45.867 a
Potassium silicate (ml .l ⁻¹)	0	1.803 a	0.639 c	0.607 c	6.884 a	42.681 b
	1.5	1.823 a	0.695 b	0.717 b	7.013 a	44.975 a
	3	1.892 a	0.783 a	0.831 a	6.674 a	45.663 a
0	0	1.413 c	0.561 c	0.410 e	6.242 b	39.940 c
	1.5	1.623 bc	0.705 b	0.556 d	7.044 ab	44.817 ab
	3	1.836 ab	0.709 b	0.723 bc	6.568 ab	45.230 ab
2	0	1.913 ab	0.677 b	0.656 cd	7.031 ab	43.473 b
	1.5	1.896 ab	0.690 b	0.776 b	6.652 ab	44.393 ab
	3	1.766 ab	0.751 b	0.780 b	7.071 ab	44.503 ab
4	0	2.083 a	0.680 b	0.756 bc	7.378 a	44.630 ab
	1.5	1.950 ab	0.689 b	0.820 b	7.344 ab	45.717 ab
	3	2.073 a	0.889 a	0.990 a	6.384 ab	47.257 a

*Values within each column followed by the same letter are not significantly different from each other according to Duncan's Multiple Range Test at a 5% level.

Leaf content of (Nitrogen %)

According to Table (1), foliar application of Ca significantly influenced the leaf nitrogen (N) content. The highest leaf N content (2.035%) was observed at the level of 4 ml.l⁻¹, while the lowest (1.624%) was recorded in the controls. Additionally, foliar application of K did not significantly affect the leaf N content. The highest N value (1.892%) was found at 3 ml.l⁻¹ of K, whereas the lowest (1.803%) was from the control treatment. The interaction between Ca and K showed significant effects on leaf N%. Specifically, at 4 ml.l⁻¹ of Ca and 0 ml.l⁻¹ of K, the highest leaf N content (2.083%) was noted, and the lowest (1.413%) was observed in the control.

Leaf content of (Calcium %)

According to Table (1), the foliar application of Ca significantly affected the leaf content of Ca. The highest leaf Ca content (0.783%) was recorded at the 4 ml.l⁻¹ level, while the lowest (0.561%) was observed in the control. The table clearly shows that the interaction between Ca and K significantly influenced the leaf Ca content. Results indicate that foliar application of Ca and K on pomegranate trees significantly impacted the leaf Ca levels. The highest Ca content (0.889%) was found at the combination of 4 ml.l⁻¹ Ca and 3 ml.l⁻¹ K, whereas the lowest was recorded in the control treatment.

Leaf content of (Potassium silicate %)

It's clear from Table (1) that foliar application of K significantly influenced the leaf content of P. The highest K level (0.831%) was observed at (3 ml.l⁻¹), while the lowest (0.607%) was seen in the control treatment. The combination of foliar spray with Ca and K led to a notable increase in leaf K content. The maximum value (0.990%) was recorded at (4 ml.l⁻¹) of Ca and (3 ml.l⁻¹) of K. The lowest value was from the control, measuring (0.410%).

Leaf Area (cm²)

The results from Table (1) indicate that foliar spraying with Ca and K on the pomegranate tree was not significantly different from the control. However, the results also showed that a combination of Ca and K was applied as foliar to the pomegranate tree, significantly influencing leaf area. The most successful result recorded was 7.378 cm at a level of 4 ml.l⁻¹ of Ca and 0 ml.l⁻¹ of K, while the lowest value of 6.242 cm was observed in the control.

Leaf chlorophyll content SPAD.

According to the table (1), the foliar application of Ca significantly influenced leaf chlorophyll content. The highest leaf chlorophyll content (45.867 SPAD) was recorded at the level of (4 ml.l⁻¹), while the lowest (43.328 SPAD) was observed in the control. Additionally, the foliar application of K significantly affected leaf chlorophyll content. The highest value (45.633 SPAD) was observed at (3 ml.l⁻¹), while the lowest (42.681 SPAD) was in the control treatment. Combining foliar spray with Ca and K resulted in a significant increase in leaf chlorophyll content. The maximum value (47.257 SPAD) was recorded at levels of (4 ml.l⁻¹) Ca and (3 ml.l⁻¹) K, whereas the lowest (39.940 SPAD) was in the control treatment.

Table (2): Effect of Calcium and Potassium silicate application and their interactions on yield characteristic on pomegranate tree cv. "Wonderful"

Treatments		Tree yield (Kg)	Fruit cracking (%)	Fruit size (cm)
Calcium (ml .l ⁻¹)	0	14.85 a	60.94 a	180.46 a
	2	15.75 a	44.49 b	179.96 a
	4	17.40 a	41.88 b	167.83 a
Potassium silicate (ml .l ⁻¹)	0	14.64 a	57.07 a	177.37 a
	1.5	17.20 a	45.65 b	171.76 a
	3	16.17 a	44.58 b	179.13 a
0	0	10.88 a	85.48 a	156.45 a
	1.5	17.98 a	49.37 b	204.67 a
	3	15.69 a	47.97 b	180.28 a
2	0	14.90 a	44.98 b	209.55 a
	1.5	17.35 a	44.35 b	151.45 a
	3	15.02 a	44.13 b	178.89 a
4	0	18.14 a	40.76 b	166.11 a
	1.5	16.26 a	43.22 b	159.16 a
	3	17.80 a	41.65 b	178.22 a

*Values within each column followed by the same letter are not significantly different from each other according to Duncan's Multiple Range Test at a 5% level.

Tree yield (Kg)

The results from Table (2), indicate that foliar spraying with Ca and K on the pomegranate tree was not significantly different from the control. Likewise, the interaction between them had no significant effect on the tree yield.

Fruit cracking (%)

According to Table (2), the foliar application of Ca significantly influenced fruit cracking. The highest fruit cracking (60.94%) was observed at the level (0 ml.l⁻¹), while the lowest (41.88 %) occurred at level (4 ml.l⁻¹). Additionally, foliar application of K significantly affected fruit cracking. The highest value (57.07 %) was recorded at (0 ml.l⁻¹) and the lowest (44.58%) was observed at (3 ml.l⁻¹). Both Ca and K had significant effects on fruit cracking. It was found that the combination of Ca and K significantly impacted fruit cracking when applied to the pomegranate trees with this mixture. The highest result (85.48%) was recorded at (0 ml.l⁻¹) of Ca and (0 ml.l⁻¹) of K, while the lowest (40.76%) was observed at (4 ml.l⁻¹) of Ca and (0 ml.l⁻¹) of K.

Fruit size (cm³)

The results from Table (2), indicate that foliar spraying with Ca and K on the pomegranate tree was not significantly different from the control. Similarly, the interaction between them had no significant effect on fruit size.

Table (3): Effect of Calcium and Potassium silicate application and their interactions on chemical characteristic on pomegranate tree cv. "Wonderful"

Treatments		TSS %	Anthocyanin	N %	Ca %	K %
Calcium (ml .l ⁻¹)	0	15.97 a	3.924 b	1.666 b	7.556 b	1.084 b
	2	16.33 a	5.222 a	1.894 a	9.590 a	1.233 a
	4	16.45 a	5.353 a	2.008 a	9.790 a	1.285 a
Potassium silicate (ml .l ⁻¹)	0	15.62 b	4.640 b	1.775 b	8.662 b	1.070 b
	1.5	16.30 a	4.705 b	1.913 a	9.430 a	1.236 a
	3	16.84 a	5.154 a	1.881 ab	8.844 ab	1.296 a
0	0	14.56 b	3.090 e	1.400 d	7.103 e	0.827 c
	1.5	16.26 a	3.863 d	1.746 c	7.895 de	1.235 ab
	3	17.10 a	4.820 bc	1.853 abc	7.671 de	1.190 ab
2	0	15.93 a	5.706 a	1.896 abc	9.403 bc	1.141 b
	1.5	16.50 a	4.633 c	2.006 a	10.649 a	1.247 ab
	3	16.56 a	5.326 ab	1.780 bc	8.719 cd	1.312 ab
4	0	16.36 a	5.123 abc	2.030 a	9.481 bc	1.241 ab
	1.5	16.13 a	5.620 a	1.986 ab	9.747 abc	1.226 ab
	3	16.86 a	5.316 ab	2.010 a	10.144 ab	1.387 a

*Values within each column followed by the same letter are not significantly different from each other according to Duncan's Multiple Range Test at a 5% level.

Total Soluble Solids (TSS %)

The results from Table (3) indicate that foliar spraying with Ca on the pomegranate tree was not significantly different from the control. Furthermore, TSS levels were significantly influenced by foliar application of K. The highest TSS value (16.844%) was recorded at a level of 3 ml.l⁻¹, while the lowest (15.622%) was observed in the control treatment. The interaction between foliar application of Ca and K, as shown in Table 3, significantly affected TSS%. The highest value (17.100%) was noted at 0 ml.l⁻¹ of Ca and 3 ml.l⁻¹ of K, whereas the lowest value was in the control treatment, which was 14.566%.

Anthocyanin (mg.100ml⁻¹ juice)

Table (3) shows that the foliar application of Ca significantly affected anthocyanin content. The highest anthocyanin level (5.353%) was recorded at the 4 ml.l⁻¹ level, while the lowest (3.924%) was observed in the control treatment. Additionally, anthocyanin levels were significantly impacted by foliar application of K. The highest value (5.154%) was found at 3 ml.l⁻¹, and the lowest (4.640%) was from the control. The combination of Ca and K significantly affected anthocyanins in pomegranate juice. As shown in Table (3), the maximum result (5.706 mg per 100 ml⁻¹ juice) was obtained from a concentration of 2 ml.l⁻¹ Ca and 0 ml.l⁻¹ K. Conversely, the lowest value was in the control treatment, at 3.090 mg per 100 ml⁻¹ juice.

Peel Content (Nitrogen)

According to Table (3), the foliar application of Ca significantly affected the peel nitrogen content. The highest nitrogen content (2.008%) was recorded at the 4 ml.l⁻¹ level, while the lowest (1.666%) was observed in the control treatment. Additionally, foliar application of K significantly influenced the peel nitrogen content. The highest value (1.913%) was recorded at 1.5 ml.l⁻¹, whereas the lowest (1.775%) was from the control. Furthermore, Table (3) shows that the interaction between Ca and K in pomegranate trees caused a significant increase in peel nitrogen content. The maximum value (2.030%) was found at the concentration of 4 ml.l⁻¹ Ca with 0 ml.l⁻¹ K, while the minimum was observed in the control.

Peel Content (Calcium)

According to the table (3), the foliar application of Ca significantly affected the peel calcium content. The highest leaf calcium content (9.790%) was recorded at the level (4 ml.l⁻¹), while the lowest (7.556%) was noted in the control. Data from table (3) showed that spraying pomegranate trees with Ca and K together significantly increased the peel calcium content. The highest value (10.649%) was observed with a concentration of (2 ml.l⁻¹) Ca and (1.5 ml.l⁻¹) K, compared to the control, which had the lowest value (7.103%).

Peel content (Potassium)

It's clear from table (3) that foliar application of K significantly influenced the peel content of potassium. The highest K value (1.296%) was recorded at level (3 ml.l⁻¹), while the lowest (1.070%) was from the control treatment. Additionally, the interaction between Ca and K specifically, 4 ml.l⁻¹ of Ca with 3 ml.l⁻¹ of K significantly affected the peel potassium content, with the maximum value (1.387%) and the minimum being from the control treatment (0.827%).

Discussion

Fruit suffers sunburn damage when summer temperatures rise above 45 °C, which can reduce yield by up to 40% [39] [40]. Conversely, a drop in leaf temperature may improve net photosynthesis by reducing the amount of time stomata close and the rate of respiration during the day, especially in hot, dry regions [41]. High solar radiation, high temperatures, and low humidity all contribute to the physiological condition known as sunburn, which reduces fruit yield and quality by burning the fruit's surface and changing the colour of the peel by forming large black spots on the fruit's skin [42]. As a result, there are significant financial losses as well as a decline in the fruits' visual quality [43]. Fruit cracking, which is brought on by moisture imbalances and vitamin deficiencies, is one of the most prevalent physiological issues [13] [44].

According to the data in Table (1) on pomegranate vegetative growth characteristics, it is clear that spraying pomegranate trees with Ca and K significantly affected the leaf content of N, Ca, , K and leaf chlorophyll and increase it, especially with Ca and K at the rate 4 ml.l⁻¹ and 3 ml.l⁻¹ respectively [45][46].

In the subject of the effect of Ca and K on yield and chemical content, it is clear from tables (2) and 3 that foliar application of Ca and K influenced the yield and chemical characteristics. For example, fruit size, fruit weight, and juice percentage of 100 arils, which lead to an increase in yield production. Moreover, applying Ca and K increased some chemical contents in the fruit, such as TSS/TA, anthocyanin, and vitamin [47][48].

A vital secondary macronutrient, calcium (Ca), is essential for the physiological and biochemical processes in plants. This is especially true for pomegranates, as calcium plays a key role in maintaining vital functions like controlling plant growth [49]. Additionally, calcium is crucial for cellular structure because it helps keep cells functional and structurally intact while reducing damage to the cell membrane, which shields cells from stressors such as salinity and dehydration. The selective transport of sodium ions, which can displace Ca ions from membranes, is balanced by Ca "very low mobility inside plant cells" [50]. Its importance in horticultural crops, where it is closely linked to fruit quality, disease resistance, and post-harvest shelf life, illustrates how critical it is for the plant's structural integrity, cellular signalling, and overall metabolic functions as a secondary macronutrient [13]. Like other fruit crops, pomegranate plants need a strong vegetative growth phase to support flowering, fruit setting, and yield. Calcium is vital for this process because it influences several physiological functions. Foliar sprays are an important tool used in agriculture to address nutrient deficiencies. As previously noted, these sprays can enhance vegetative growth and help the plant develop resistance to various stresses and conditions that may limit root absorption [51]. The effects of calcium foliar sprays on vegetative growth and fruit yield have been studied, but the primary focus remains on altering the plant's chemical composition. Since nutrient management practices during the pomegranate's lifecycle where calcium plays a major role directly impact the fruit's size, weight, flavour, nutritional value, and shelf life [49].

Potassium silicate foliar spraying enhances water use efficiency, strengthens plant cell walls, facilitates nutrient absorption, and protects the plant from environmental stressors. It is an effective method for increasing vegetative growth in pomegranate cultivation [52]. One key benefit of potassium silicate foliar spraying is its impact on water use efficiency. Potassium is vital for regulating stomatal opening, maintaining ion homeostasis, and balancing osmotic pressure under salinity and drought conditions, helping plants adapt to water stress [13]. This process is fundamental for the plant's functions, as it balances gas exchange and water conservation, promoting higher photosynthetic efficiency and better growth. When silicon is applied as potassium silicate, it reinforces cell walls and boosts the plant's capacity to maintain turgor pressure, preventing dehydration and enabling better tolerance to water scarcity. This is especially beneficial during drought and hot weather, as water stress can inhibit vegetative growth and increase crack formation [53]. Considering abiotic stress factors and challenges such as drought, high salinity, and extreme temperatures in pomegranate cultivation, potassium silicate (K₂SiO₃) positively affects vegetative growth and reduces risks to yield and fruit quality [54]. Consequently, potassium silicate functions by improving osmotic regulation and carbohydrate metabolism while supporting structural defence and metabolic stability, which directly influence fruit development. Since traditional fertilizers may be less effective due to poor soil structure or high salinity, foliar application of silicon from potassium silicate proves especially beneficial [55]. Regarding biochemical aspects, potassium silicate spraying influences the internal chemical makeup of the fruit, affecting sugar content, TSS, and overall flavour profile, as potassium supports efficient carbohydrate translocation from source leaves to sink tissues [56]. To enhance the sugar and acid balance determining sweetness and tartness potassium silicate treatment increases reducing sugars and improves the sugar-to-acid ratio, making the fruit more appealing for fresh eating and juice processing. It is also crucial for maintaining the plant's overall vigor and its response to stress, which is vital for pomegranate health, especially in dry, hot climates prone to sunburn and cracking [54]. Furthermore, potassium silicate promotes the biosynthesis of antioxidant enzymes, neutralizes reactive oxygen species that can damage cellular structures and nutrients, and elevates secondary metabolites such as phenolic compounds and flavonoids, enhancing the fruit's antioxidant capacity and shelf life [52].

However, potassium's role in promoting the translocation of complex carbohydrates may alter the fruits' osmotic

pressure and increase their weight and size. The tree's yield will increase as a result of the crop's greater weight and size [45].

Conclusion

Based on the previous results, this research concludes that applying Calcium and potassium silicate separately as foliar treatments, as well as their interaction, significantly affected most of the vegetative, yield, and chemical characteristics of pomegranate (cv. Wonderful). The best overall effects were observed at concentrations of 4 ml.l⁻¹ of Calcium and 3 ml.l⁻¹ of potassium silicate, resulting in improvements in vegetative growth, yield, and chemical components.

References

- [1]. Besharat A, Xiangping G, Abad KK, Zadeh HS., 2024. Invitro Propagation of Pomegranate (*Punica granatum* L.) Cv. Wonderful Cultivar. Journal of Natural Science Review. 2(Special. Issue), pp.476-85.
- [2]. Tinebra I, Scuderi D, Sortino G, Mazzaglia A, Farina V., 2021. Pomegranate cultivation in mediterranean climate: plant adaptation and fruit quality of 'mollar de elche' and 'wonderful'cultivars. Agronomy, 11(1), p.156.
- [3]. Ginzberg I, Faigenboim A., 2022. Ripening of pomegranate skin as revealed by developmental transcriptomics. Cells, 11(14), p.2215.
- [4]. Salem AM, Gad HA, Al-Sayed E, El-Ahmady SH., 2022. Recent trends on the quality assessment of Pomegranate: A detailed review. Archives of pharmaceutical sciences ain shams university, 6(1), pp.114-140.
- [5]. Ko K, Dadmohammadi Y, Abbaspourrad A., 2021. Nutritional and bioactive components of pomegranate waste used in food and cosmetic applications: A review. Foods, 10(3), p.657.
- [6]. Davarpanah, S., Aakari, M., Babalar, M., Zarei, M. and Aghayeh, R., 2018. Effect of Foliar Application of Phosphorus, Potassium and Iron on Physical and Chemical Properties of Pomegranate Fruit.
- [7]. Raimondo ML, Lops F, Tarantino A, Bellantuono N, Carlucci A, Bimbo F., 2025. The Current State of Italian Pomegranate Production: Agronomic, Crop Protection, Economic, and Managerial Perspectives. Agronomy, 15(4), p.826.
- [8]. Joshi M, Schmilovitch ZE, Ginzberg I., 2021. Pomegranate fruit growth and skin characteristics in hot and dry climate. Frontiers in Plant Science, 12, p.725479.
- [9]. Jubeir S, Hassan MA, Tarkan S., 2025. Phenomenon of fruit cracking, causes, and methods of control. Damascus University Journal for Agricultural Science, 41(1).
- [10]. Fischer G, Balaguera-López HE, Alvarez-Herrera J., 2021. Causes of fruit cracking in the era of climate change. A review. Agronomía Colombiana, 39(2), pp.196-207.
- [11]. Parsa Z, Roozbehi S, Hosseiniarahi M, Radi M, Amiri S., 2021. Integration of pomegranate peel extract (PPE) with calcium sulphate (CaSO₄): A friendly treatment for extending shelf-life and maintaining postharvest quality of sweet cherry fruit. Journal of Food Processing and Preservation, 45(1), p.e 15089.
- [12]. De Bang TC, Husted S, Laursen KH, Person DP, Schjoerring JK., 2021. The molecular-physiological functions of mineral macronutrients and their consequences for deficiency symptoms in plants. New Phytologist, 229(5), pp.2446-2469.
- [13]. Al-Saif AM, Mosa WF, Saleh AA, Ali MM, Sas-Paszt L, Abada HS, Abdel-Sattar M., 2022. Yield and fruit quality response of pomegranate (*Punica granatum*) to foliar spray of potassium, calcium and kaolin. Horticulturae, 8(10), p.946.
- [14]. Bonomelli C, Ruiz R., 2010. Effects of foliar and soil calcium application on yield and quality of table grape cv. 'Thompson Seedless'. Journal of Plant Nutrition. 13;33(3): pp.299-314.
- [15]. Sharma N, Belsare C., 2011. Effect of plant bio-regulators and nutrients on fruit cracking and quality in pomegranate (*Punica granatum* L.) 'G-137' in Himachal Pradesh. Acta Horticulturae. 18;890(48): pp.347-52.
- [16]. Khalil HA, Aly HS., 2013. Cracking and fruit quality of pomegranate (*Punica granatum* L.) as affected by pre-harvest sprays of some growth regulators and mineral nutrients. Journal of Horticultural Science and Ornamental Plants. 5(2): pp.71-76.
- [17]. MM Abdelghany A., 2024. Impacts of foliar spraying with potassium citrate on pomegranate trees. Fayoum Journal of Agricultural Research and Development, 38(2), pp.240-50.
- [18]. Barker AV, Pilbeam DJ, editors., 2015. Handbook of plant nutrition. CRC press.
- [19]. Fageria NK, Dos Santos AB, De Moraes MF., 2010. Yield, potassium uptake, and use efficiency in upland rice genotypes. Communications in Soil Science and Plant Analysis. 41(22): pp. 2676-2684.
- [20]. Almeida DM, Oliveira MM, Saibo NJ., 2017. Regulation of Na⁺ and K⁺ homeostasis in plants: towards

- improved salt stress tolerance in crop plants. Genetics and molecular biology. 40(1 suppl 1): pp.326-345.
- [21]. Sanyal SK, Rajasheker G, Kishor PK, Kumar SA, Kumari PH, Saritha KV, Rathnagiri P, Pandey GK., 2020. Role of protein phosphatases in signaling, potassium transport, and abiotic stress responses. In Protein phosphatases and stress management in plants: Functional genomic perspective (pp. 203-232). Cham: Springer International Publishing.
 - [22]. Sardans J, Peñuelas J., 2021. Potassium control of plant functions: Ecological and agricultural implications. Plants. 10(2): p.419.
 - [23]. Hasanuzzaman M, Bhuyan MB, Nahar K, Hossain MS, Mahmud JA, Hossen MS, Masud AA, Moumita, Fujita M., 2018. Potassium: a vital regulator of plant responses and tolerance to abiotic stresses. Agronomy. 8(3): p.31.
 - [24]. Assaha DV, Ueda A, Saneoka H, Al-Yahyai R, Yaish MW., 2017. The role of Na⁺ and K⁺ transporters in salt stress adaptation in glycophytes. Frontiers in physiology. 8: p.509.
 - [25]. Kumar P, Kumar T, Singh S, Tuteja N, Prasad R, Singh J., 2020. Potassium: A key modulator for cell homeostasis. Journal of Biotechnology. 324: pp.198-210.
 - [26]. Aksu G, Altay H., 2020. The effects of potassium applications on drought stress in sugar beet. Sugar Tech. 22(6):1092-1102.
 - [27]. Norozi M, VALIZADEH KB, Karimi R, Nikoogoftar SM., 2019. Effects of foliar application of potassium and zinc on pistachio (*Pistacia vera* L.) fruit yield. 6(1): pp.113-123.
 - [28]. KhM AR, Khalaf-Allah AM., 2000. Design and analysis of agricultural experiments. Dar Al-Kutub Foundation for Printing and Publishing. University of Mosul. Iraq, p.81.
 - [29]. SAS Institute., 2015. SAS Certification Prep Guide: Advanced Programming for SAS9. SAS Institute.
 - [30]. Joslyn, M.A., 1970. Methods in food analysis (2). Acad. Press, N.Y. London. Inc.1020.Plain Street. Marsh Field 02050 London. P.P 514
 - [31]. Bhargava, B. S., and H. B. Reghupathi., 1999. Analysis of plant materials for macro and micronutrients. in: tendon, h. l. s. (ed), metods of analysis of soil, plants, waters and fertilizers. Binnig Printers l-14, Lajpat. Nagar New Delhi, p.110024.
 - [32]. Schneider CA, Rasband WS, Eliceiri KW., 2021. NIH Image to ImageJ: 25 years of image analysis. Nature methods, 9(7), pp.671-675.
 - [33]. Loh F, Grabosky J, Bassuk N., 2000. 191 Use of the minolta SPAD-502 to determine chlorophyll concentration in Ficus benjamina L. and Populus deltoides Marsh leaf tissue. HortScience, 35(3), pp.423D-424.
 - [34]. Hasan DM, Kader JS., 2022. response of pomegranate trees cv. sawa to foliar application with npk fertilizer and licorice root extract. journal of kirkuk university for agricultural sciences, 13(3).
 - [35]. Hegazi A, Samra NR, El-Baz EE, Khalil BM, Gawish MS., 2014. improving fruit quality of manfaloty and wonderfull pomegranates by using bagging and some spray treatments with gibberellic acid, calcium chloride and kaolin. Journal of plant production, 5(5), pp.779-792.
 - [36]. Taha SM., 2008. Effect of spraying with gibberellic acid and cycosil and three extracts from marine plants in some vegetative and floral traits and components of two types of strawberry (*Fragaria* × *ananassa* Duch). Salahaddin, Iraq, Faculty of Agriculture, University of Salahaddin, PhD Diss.
 - [37]. de Moraes Barros HR, de Castro Ferreira TA, Genovese MI., 2012. Antioxidant capacity and mineral content of pulp and peel from commercial cultivars of citrus from Brazil. Food chemistry, 134(4), pp.1892-1898.
 - [38]. Bar-Ya'akov I, Tian L, Amir R, Holland D., 2019. Primary metabolites, anthocyanins, and hydrolyzable tannins in the pomegranate fruit. Frontiers in plant science, 10, p.620.
 - [39]. Melgarejo P, Martinez JJ, Hernández FC, Martinez-Font R, Barrows P, Erez A., 2004. Kaolin treatment to reduce pomegranate sunburn. Scientia Horticulturae. 100(1-4): pp.349-353.
 - [40]. Yazici K, Kaynak L., 2006. Effects of kaolin and shading treatments on sunburn on fruit of Hicaznar cultivar of pomegranate (*Punica granatum* L. cv. Hicaznar). InI International Symposium on Pomegranate and Minor Mediterranean Fruits 818 (pp. 167-174).
 - [41]. Glenn DM, Puterka GJ, Drake SR, Unruh TR, Knight AL, Baherle P, Prado E, Baugher TA., 2001. Particle film application influences apple leaf physiology, fruit yield, and fruit quality. Journal of the American Society for Horticultural Science. 126(2): pp.175-181.
 - [42]. Pareek S, Valero D, Serrano M., 2015. Postharvest biology and technology of pomegranate. Journal of the Science of Food and Agriculture. 95(12): pp.2360-2379.
 - [43]. Finkel T, Holbrook NJ., 2000. Oxidants, oxidative stress and the biology of ageing. nature. 408(6809): pp.239-247.

- [44]. Abd El-Rhman IE., 2010. Physiological studies on cracking phenomena of pomegranates. J. Appl. Sci. Res. 6(6): pp.696-703.
- [45]. Zayan MA, Mikhael GB, Okba SK., 2016. Treatments for improving tree growth, yield and fruit quality and for reducing double fruit and deep suture incidence in "Desert red" peach trees. International Journal of Horticultural Science, 22(3-4), pp.7-19.
- [46]. Hamza LM, Hassan HK, Aubeid IA., 2019. The impact of naphthalene, acetic acid and organic fertilizer on seedlings growth of pomegranate (*Punica granatum* L.) Salimi cultivar, 19(1), pp.345-351.
- [47]. ValizadehKaji B, Naeini MR., 2024. Physicochemical characteristics of pomegranate fruits as affected by foliar application of potassium and zinc. Journal of Plant Nutrition, 47(12), pp.2038-2055.
- [48]. Gawade SN, Kale AP, Shaikh JA, Sharma RC., 2018. Study on nutrient package for pomegranate (*Punica granatum* L.), 52(2), pp.199-202.
- [49]. Weng X, Li H, Ren C, Zhou Y, Zhu W, Zhang S, Liu L., 2022. Calcium regulates growth and nutrient absorption in poplar seedlings. Frontiers in plant science, 13, p.887098.
- [50]. Rashedy AA, Abd-ElNafea MH, Khedr EH., 2022. Co-application of proline or calcium and humic acid enhances productivity of salt stressed pomegranate by improving nutritional status and osmoregulation mechanisms. Scientific Reports, 12(1), p.14285.
- [51]. Dass A, Rajanna GA, Babu S, Lal SK, Choudhary AK, Singh R, Rathore SS, Kaur R, Dhar S, Singh T, Raj R., 2022. Foliar application of macro-and micronutrients improves the productivity, economic returns, and resource-use efficiency of soybean in a semiarid climate. Sustainability, 14(10), p.5825.
- [52]. Moradi S, Zamani Z, Fatahi R, Saba MK, Paliaga S, Laudicina VA, Inglese P, Liguori G., 2024. Fruit quality, antioxidant, and mineral attributes of pomegranate cv. Ghoghagh, influenced by shading and spray applications of potassium sulfate and sodium silicate. Scientific Reports, 14(1), p.14831.
- [53]. Kumar A, Tandon C, Singh R, Kumar V, Choudhary V, Singh G, Singh AP, Tiwari V., 2025. Study of fruit cracking's physiological and biochemical mechanisms: A review, 8(2), pp.346-349.
- [54]. Mosa WF, Behiry SI, Ali HM, Abdelkhalek A, Sas-Paszt L, Al-Huqail AA, Ali MM, Salem MZ., 2022. Pomegranate trees quality under drought conditions using potassium silicate, nanosilver, and selenium spray with valorization of peels as fungicide extracts. Scientific Reports, 12(1), p.6363.
- [55]. Laane HM. The effects of foliar sprays with different silicon compounds. Plants., 2018. 7(2), p.45.
- [56]. Al-Huqail AA, Kumar P, Eid EM, Adelodun B, Abou Fayssal S, Singh J, Arya AK, Goala M, Kumar V, Širić I., 2022. Risk assessment of heavy metals contamination in soil and two rice (*Oryza sativa* L.) varieties irrigated with paper mill effluent. Agriculture, 12(11), p.1864.

تأثير الرش الورقي بالكالسيوم وسليكات البوتاسيوم في بعض في صفات النمو و حاصل اشجار الرمان صنف (وندر فول)

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الخلاصة

أجريت هذه الدراسة خلال موسم النمو لعام 2024 على أشجار الرمان للصنف ووندر فول، التي يبلغ عمرها 5 سنوات، في بستان محلي في قلادزة بمحافظة السليمانية في إقليم كردستان العراق، بهدف دراسة تأثير الرش الورقي بثلاث مستويات من الكالسيوم (0، 2، 4 مل لتر-1) وثلاثة مستويات من سليكات البوتاسيوم (0، 1.5، 3 مل لتر-1) وتداخلهما في النمو وإنتاجية أشجار الرمان. أظهرت النتائج أن زيادة مستويات الكالسيوم وسليكات البوتاسيوم، خاصة عند أعلى التراكيز (4 مل لتر-1 كالسيوم و 3 مل لتر-1 سليكات البوتاسيوم)، أدت إلى زيادات معنوية في معظم الصفات المدروسة، حيث أعطت أعلى القيم في محتوى الأوراق من النتروجين (2.083%) والكالسيوم (0.889%) والبوتاسيوم (0.990%)، وكذلك نسبة تشقق الثمار (40.76%)، ونسبة المواد الصلبة الذائبة الكلية (17.100) (TSS %)، والأنثوسيانين (5.706%)، ومحتوى القشرة من النتروجين (2.030%) والكالسيوم (10.649%) والبوتاسيوم (1.387%).

الكلمات المفتاحية: مستويات الزنك، تركيزات (BA)، الرش، النمو الخضري، صنفين من نبات الزينبا.