

The role of organic fertilization and spraying with potassium silicate as sustainable inputs in the growth of pomegranate saplings, Salimi cultivar

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Abstract

The trial was implemented in the fruit lath house belongs to Department of Horticulture and Garden Engineering, College of Agricultural Engineering Sciences, University of Baghdad Station B for the growing season 2024. The saplings were fertilized with three levels of sheep wastes (0, 0.5, 1) kg sapling-1 in January, along with three levels of potassium silicate (0, 2.5, and 5 ml/L). A two-factor experiment was designed; the first factor involved sheep manure at three concentrations, while the second factor included potassium silicate at three concentrations. Thus, the number of treatments in the experiment was 9 treatments, replicated three times, with each experimental unit consisting of one sapling, for a total of 27 saplings in the experiment. The results showed a significant increase in several of the traits studied. In particular, using organic fertilizer (sheep waste) and potassium silicate separately on pomegranate saplings of the Salimi cultivar resulted in significant increases in stem height, levels of silicon, nitrogen and phosphorus elements as well as chlorophyll and total phenolic compounds, for pomegranate saplings of the Salimi cultivar. Likewise, the treatment SH₂KSi₂ (addition of organic fertilizer and potassium silicate) resulted in substantial improvements in most of the traits investigated. Results were analyzed using the least significant difference test (LSD) with a 5% probability level.

Keywords: Organic Fertilizer, Sheep Wastes, Potassium Silicate, Total Phenols, Pomegranate

Introduction

Pomegranate (*Punica granatum* L.) is considered one of the fruit crops of economic and nutritional importance in temperate and semi-arid regions. It is characterized by fruits rich in effective phytochemical compounds such as phenols, flavonoids, and anthocyanins, which show strong antioxidant activity, in addition to its high marketing and productivity value when suitable environmental and nutritional conditions are available. This contributes to enhancing public health and reducing oxidative stress factors. Recent scientific studies have confirmed that these

compounds play an important role in disease prevention and in enhancing the nutritional value of the fruit, which makes pomegranate a crop of economic and nutritional importance in modern agricultural systems. Therefore, interest has increased in researching the role of nutrients, whether organic or inorganic, in enhancing vegetative and root growth of fruit crops including pomegranate [39].

Sheep wastes are among the important organic sources that can be exploited to improve soil fertility and enhance agricultural production, and they also contribute to reducing environmental pollution when managed

correctly. These fertilizers are available in solid or liquid forms, whether in their fresh state or after their decomposition, as sheep wastes consist mainly of manure, urine, and feed residues [22]. They contribute to increasing the soil's water retention, improving its aeration, and supplying the plant with essential nutrients in a sustainable manner compared with chemical fertilizers alone. Organic fertilization does not work only as a direct source of nutrients, but it enhances microbial activity in the soil, which improves the fragmentation of organic materials to release nutrients slowly that the plant can absorb better, leading to an increase in plant growth and yield [24]. In recent years, reliance on these fertilizers has increased due to their low cost and ease of use, in addition to their role in reducing environmental pollution and improving the quality of agricultural products, as their addition reflects positively on the growth and production of various plants. These fertilizers are used in different ways, and the added quantities depend on soil fertility and type, as well as on the ratio of solid to liquid materials, and on the crop type, its age, and the prevailing environmental conditions in the region [8].

Silicon (Si) is the second most abundant element after oxygen and constitutes about 28% of the earth's crust [20]. In addition, recent research trends toward studying silicate compounds, especially potassium silicate (K_2SiO_3). It is considered an essential element due to its important physiological role in enhancing plant growth and improving its resistance to environmental stresses [18]. Potassium and silicon are two elements with vital functions; potassium is necessary for regulating stomatal opening and closing, improving water balance inside cells, and

participating in photosynthesis processes and the movement of amino acids, while silicon contributes to strengthening cell walls and activating mechanisms of biological resistance to various environmental stresses [10]. Applied experiments have shown clear benefits of using potassium silicate as a foliar spray agent on many crops, which led to enhance in plant traits like plant height, leaf area, and green-part weight, as well as improving the utilization of nutrients under non-ideal conditions. For example, The study showed that foliar spraying with potassium silicate fertilizer led to an improvement in the physiological characteristics of the plant, such as vegetative growth, nutrient absorption, and improved production and fruit quality compared to the control treatment. This is consistent with what was reported [31], regarding apricots and [2] regarding peaches and nectarines.

In addition, studies that combine organic fertilizer and the application of potassium silicate show a positive integrative effect in many field crops like rice and wheat, combining organic materials with minerals such as potassium silicate improved plant growth, increased grain productivity, and improved soil traits In relation to levels of organic carbon and nutrient availability. This can be interpreted as organic materials improve the general soil structure, while silicon increases the plant's ability to absorb elements and raises the rate of physiological efficiency [12, 31], which enhances the efficiency of using agricultural resources and increases future productivity [21, 26).

Although many studies in this field have addressed field crops and vegetables, the need still exists to conduct specialized research on fruit crops such as pomegranate saplings, especially local cultivars such as the Salimi

cultivar, where the response of these plants is expected to differ according to their nutritional requirements and physiological growth characteristics. Therefore, understanding the effect of organic fertilizer and potassium silicate

spraying on the growth of pomegranate saplings can contribute to setting practical recommendations to improve fertilization systems before planting.

Materials and methods

This study was implemented in the fruit lath house of the college of Agricultural Engineering Sciences / University of Baghdad – station B, during the 2024 growing season, using pomegranate saplings of the Salimi cultivar that were close in age and size. A factorial experiment was designed according to RCBD with two factors. The first factor was organic fertilizer (sheep wastes) at three levels (0, 0.5, and 1 kg sapling⁻¹). The organic fertilizer was applied in January and mixed well around the root zone. The second factor included foliar application with potassium silicate at three levels of potassium silicate (0, 2.5, and 5 ml. L⁻¹). The foliar application was implemented at the beginning of April until complete wetting of the leaves using a hand sprayer in three batches. Thus, the number of treatments was 9, and one sapling per experimental unit, and therefore the number of saplings in the experiment was 27 saplings.

Preparing sheep manure

Undecomposed sheep waste was placed in a pit after it was lined with thick polyethylene and moistened with water until completely wet. It was then covered with polyethylene to encourage reactions to accelerate the decomposition process and reduce nitrogen loss. The waste was turned over weekly for moisture homogeneity, and the decomposition process continued for four months after the manure turned brown and odorless.

Statistical analysis

The data were analyzed statistically (ANOVA), and the means were compared using LSD at 5% probability level.

Studied traits

The following characters were studied at the end of the growing season:

1. Increase in stem height (cm): The main stem of all seedlings was unified by pruning at the beginning of the experiment, and the increase in stem height was measured at the end of the growing season.
2. Leaf content of silicon element (%): silicon was determined according to the colorimetric method mentioned in [9].
3. Leaf content of nitrogen element (%): nitrogen was determined according to the method stated in [6].
4. Leaf content of phosphorus element (%): phosphorus was determined according to the method stated in [28].
5. Leaf content of potassium element (%): potassium is determined according to the method proposed by [14].
6. Leaf content of chlorophyll (mg. 100 g-1 fresh weight): leaf chlorophyll content was determined according to the method of [13].

7. Concentration of total phenolic compounds (mg. g-1 dry weight): leaf content of total phenolic materials was determined according to the method reported by Vernon *et al.* [38].

8. Percentage of leaf dry weight (%): samples were taken from each experimental unit as 10 leaves at the end of the growing season, and their fresh weight was measured, then they were placed in an electric oven at a

temperature of 65 °c until weight stability [5]. The leaves dry weight was measured, and the percentage was estimated according to the equation:

$$\text{Dry weight \%} = \frac{\text{dry weight}}{\text{resh weight}} \times 100$$

Results and discussion

1. Increase in stem height (cm):

The results revealed that the use of organic fertilizer had a significant impact on the increase in stem height (Table 1), as the treatment SH2 gave the highest mean, reaching (36.17 cm), compared with the control treatment, which reached (29.17 cm). it is also noted that potassium silicate fertilizer had a

significant effect, as the treatment Ksi2 gave the highest mean, reaching (36.50 cm), compared with the treatment without addition, Ksi0, which reached (28.83 cm). As for the interaction, the organic fertilizer and potassium silicate treatment SH2Ksi2 gave the highest mean for the increase in stem height, reaching (41.50 cm), Compared to the comparison treatment which gave (27.00 cm).

Table 1. Effect of organic fertilizer and foliar application with potassium silicate on mean increase in stem height (cm) for the growth of pomegranate saplings

Sheep wastes	Potassium Silicate			Mean (SH)
	KS _i 0	KS _i 1	KS _i 2	
SH0	27.00	29.00	31.50	29.17
SH1	29.00	34.50	36.50	33.33
SH2	30.50	36.50	41.50	36.17
LSD 5%	1.823			1.053
Mean (KS _i)	28.83	33.33	36.50	
LSD 5%	1.053			

2. Percentage of silicon in leaves (%):

The results revealed that the use of organic fertilizer had a significant impact on the leaf content of silicon (Table 2), as the treatment SH₂ gave the highest mean, reaching (0.173%), Compared to the SH1 treatment, it gave the lowest rate of (0.155%) compared to the comparison treatment which gave (0.145%), as

the treatment KS_i₂ gave the maximum mean, of 0.180 %, compared with the treatment without addition. As for the interaction, the organic fertilizer and potassium silicate treatment SH₂KS_i₂ gave the highest mean for the leaf content of silicon, reaching (0.190%), Compared to the SH1KS_i₀ treatment, it gave the lowest rate of (5 0.13%)

Table 2. . Effect of organic fertilizer and foliar application with potassium silicate on Percentage of silicon in leaves (%) for the growth of pomegranate saplings

Sheep Wastes	Potassium silicate			Mean (SH)
	KS _i 0	KS _i 1	KS _i 2	
SH0	0.145	0.155	0.180	0.160
SH1	0.135	0.160	0.170	0.155
SH2	0.155	0.175	0.190	0.173
LSD 5%	0.022			0.013
Mean (KS _i)	0.145	0.163	0.180	
LSD 5%	0.013			

3. Percentage of nitrogen in leaves (%):

The results revealed that the use of organic fertilizer had a significant impact on the leaf content of nitrogen (Table 3), as the treatment SH₂ gave the highest mean, reaching (1.291%), Compared to the SH1 treatment which yielded (1.236%) compared to the comparator treatment. it is also noted that potassium silicate fertilizer had a significant effect, as the

treatment KS_i2 gave the greatest mean, of 1.296%, compared with the treatment without addition. as for the interaction, the organic fertilizer and potassium silicate treatment SH₂KS_i2 gave the highest mean for the leaf content of nitrogen, reaching (1.335%), Based on the comparative treatment that gave (%1.215).

Table 3. Effect of organic fertilizer and foliar application with potassium silicate on Percentage of nitrogen in leaves (%) for the growth of pomegranate saplings

Sheep Wastes	Potassium silicate			Mean (SH)
	KS _i 0	KS _i 1	KS _i 2	
SH0	1.215	1.235	1.260	1.236
SH1	1.230	1.250	1.295	1.258
SH2	1.235	1.305	1.335	1.291
LSD 5%	0.043			0.025
Mean (KS _i)	1.226	1.263	1.296	
LSD 5%	0.025			

4. Percentage of phosphorus in leaves (%):

The results revealed that the use of organic fertilizer had a significant impact on the leaf content of phosphorus (Table 4), as the treatment SH₂ gave the highest mean, reaching (0.235%), Compared to the SH0 comparison treatment, which gave the lowest rate of (0.166%). It is also noted that potassium silicate fertilizer had a significant effect, as the

treatment KS_i2 gave the highest mean that reaching (0.231%), Compared to the treatment without adding KS_i0, which gave the lowest rate of (0.165%). as for the interaction, the organic fertilizer and potassium silicate treatment SH₂KS_i2 gave the highest mean for the leaf content of phosphorus, reaching (0.280%), Compared to the comparison treatment, which gave the lowest rate of (0.145%).

Table 4. Effect of organic fertilizer and foliar application with potassium silicate on Percentage of phosphorus in leaves (%) for the growth of pomegranate saplings

Sheep Wastes	Potassium silicate			Mean (SH)
	KS _i 0	KS _i 1	KS _i 2	
SH0	0.145	0.170	0.185	0.166
SH1	0.160	0.180	0.230	0.190
SH2	0.190	0.235	0.280	0.235
LSD 5%	0.024			0.013
Mean (KS _i)	0.165	0.195	0.231	
LSD 5%	0.013			

5. Percentage of potassium in leaves (%):

Table (5) results showed that the potassium content in leaves has been highly affected by adding organic fertilizer. In particular, the highest mean potassium content for treatment SH2 was 1.348%, and it was not significantly

different from treatment SH1 (mean value of 1.238%). Potassium levels were lower in the control treatment than in treatment 4. The KS_i2 treatment also possessed a significant difference in potassium content, obtaining an average of 1.323% compared to treatment without additive.

Table 5. Effect of organic fertilizer and foliar application with potassium silicate on Percentage of potassium in leaves (%) for the growth of pomegranate saplings.

Sheep Wastes	Potassium silicate			Mean (SH)
	KS _i 0	KS _i 1	KS _i 2	
SH0	1.120	1.200	1.240	1.186
SH1	1.150	1.250	1.315	1.238
SH2	1.265	1.365	1.415	1.348
LSD 5%	0.033			0.019
Mean (KS _i)	1.178	1.271	1.323	
LSD 5%	0.019			

6. Leaf content of chlorophyll (mg. 100 g⁻¹ fresh weight):

The effects of applying organic fertilizer treatments, according to the results illustrated in Table 6 indicated that the organic fertilizer significantly affected leaf chlorophyll. The highest mean chlorophyll content (241.5 mg per 100 g of fresh weight) occurred in the SH2 treatment. This value, however, did not

statistically differ from the SH1 treatment whose chlorophyll content was 238.7 mg per 100 g of fresh weight (FW) or the control treatment. It is also noted that potassium silicate fertilizer had a significant effect, as the treatment KS_i2 gave the highest mean, reaching (264.8 mg. 100 g⁻¹ fresh weight), compared with the treatment without addition. Among the interactions, the highest average content of K in leaves was observed with SH2KS_i2 treatment

which resulted 287.2 mg per 100 g of fresh weight. Although significantly higher than that of treatments SH1KSi2, which registered a

potassium value of 266.4 mg in 100 g FW, it did not differ significantly in this respect from the other treatments.

Table 6. Effect of organic fertilizer and foliar application with potassium silicate on leaf chlorophyll content (mg. 100 g⁻¹ fresh weight) for the growth of pomegranate saplings

Sheep Wastes (SH)	Potassium silicate			Mean (SH)
	KSi0	KSi1	KSi2	
SH0	178.2	211.8	240.8	210.3
SH1	210.6	239.0	266.4	238.7
SH2	196.8	240.5	287.2	241.5
LSD 5%	24.16			13.95
Mean (KSi)	195.2	230.4	264.8	
LSD 5%	13.95			

7. Leaf content of total phenols (mg. g⁻¹ dry weight):

As can be seen in Table 7, there was a significant effect of organic fertilizer on leaf total phenols content. The highest mean value (for control treatment) was obtained from SH2, namely (2.417 mg g⁻¹ dry weight) Compared to the SH0 control treatment, which gave the lowest rate of (1.950 mg/g dry weight). Moreover, both potassium silicate fertilizer had a strong effect with treatment KSi2 showing the

highest mean value of 2.600 mg g⁻¹ dry weight Compared to the treatment without the addition of KSi0, which gave the lowest rate of (1.767 mg.g-1 dry weight). The results of the interaction between study factors, treatment SH2KSi2 led to the highest average leaf content of total phenols (2.900 mg g⁻¹ dry weight). SH1KSi2 treatment showed no significant difference with the results obtained in this work, which reached (2.700 mg g⁻¹ dry weight) when Compared to the SH1KSi0 treatment, the lowest rate was (1.700 mg .g-1 dry weight).

Table 7. Effect of organic fertilizer and foliar application with potassium silicate on leaf content of total phenols (mg. g-1 dry weight) for the growth of pomegranate saplings

Sheep Wastes (SH)	Potassium silicate			Mean (SH)
	KSi0	KSi1	KSi2	
SH0	1.750	1.900	2.200	1.950
SH1	1.700	2.350	2.700	2.250
SH2	1.850	2.500	2.900	2.417
LSD 5%	0.275			0.159
Mean (KSi)	1.767	2.250	2.600	
LSD 5%	0.159			

8. Percentage of leaf dry weight (%):

The data in table (8) infers that the organic fertilizer affected plant dry weight leaves. In particular, the SH1 treatment produced the highest mean (38.6%), which was not significantly different from all other treatments. If the SH0 treatment gave the lowest rate, it was (30.2%). It is also noted that potassium silicate fertilizer had a significant effect, as the treatment KSi2 gave the highest mean, reaching

(39.5%), which was not statistically different from the rest of the treatments. The KSi0 treatment gave the lowest rate of (30.4%). As for the interaction, the organic fertilizer and potassium silicate treatment SH2KSi2 gave the highest mean for the percentage of leaf dry weight, reaching (47.1%), which did not differ significantly from the rest of the treatments. While the SH0KSi2 treatment gave the lowest rate of (26.0%).

Table 8. Effect of organic fertilizer and spraying with potassium silicate on the percentage of leaf dry weight (%) for the growth of pomegranate saplings

Sheep Wastes (SH)	Potassium silicate			Mean (SH)
	KSi0	KSi1	KSi2	
SH0	28.4	36.2	26.0	30.2
SH1	34.4	35.9	45.4	38.6
SH2	28.3	29.2	47.1	34.9
LSD 5%	30.19			17.43
Mean (KSi)	30.4	33.8	39.5	
LSD 5%	17.43			

Discussion

The results indicate that the integration between organic fertilization (sheep wastes) and spraying with potassium silicate led to a significant improvement in vegetative growth traits and nutritional content, and this is attributed to the integrative effect in improving soil fertility, absorption efficiency, and enhancing physiological processes inside the plant, as well as an increase in activity; organic matter has a major effect on the vital activities of the plant [27]. Consequently, the plant's absorption of these elements increases, which leads to an increase in vegetative growth and an increase in the plant content of nutrients and active compounds [36]. The results in the previous trait tables also indicate that organic

fertilization (sheep manure) had a significant impact on vegetative and chemical growth traits compared with the control treatment. This is due to the availability of NPK nutrients in sufficient and ready form in the soil, which led to their absorption in an adequate manner, which was reflected positively on the role of these elements in increasing cell division and elongation and then an increase in plant height [17]. This could also be due to the fact that organic fertilization of soil considerably increases nitrogen absorption and its translocation into the plant through related enzymes. This improvement has a beneficial effect on nutrient use efficiency. This effect occurs indirectly, as the enzymes responsible

for nitrogen absorption operate mainly in metabolic transformations, such as converting nitrate to amino acids by the nitrate reductase process, which contributes to building proteins necessary for growth [16].

The superiority of the organic fertilization treatment may also be due to its effective role in improving soil fertility and increasing the efficiency of nutrient absorption, including phosphorus. Beneficial microorganisms in biofertilization dissolve phosphorus compounds that are not absorbable and convert them into a form available to the plant, which enhances the availability of this important element [11]. In addition to the role of organic fertilization in reducing the soil reaction degree due to the addition of organic acids, particularly essential when the soil exhibits high pH values. Furthermore, organic fertilizers (sheep wastes) contribute to developing roots and increasing the availability of nutrients and their absorption, especially potassium. organic fertilizers also work to increase the soil content of organic carbon and nitrogen, and thus this leads to an increase in potassium absorption, and to the important role of these main elements in building the chlorophyll molecule, especially nitrogen, which is associated with magnesium in building the molecule [3, 4]. These results agree with Taha and Aboud [35] for date palm.

Besides, the important role of organic fertilization in soil pH decreasing as a result of organic acids suffusion is significant under high levels of soil pH. Moreover, organic fertilizers like sheep manure promote root development, developing and making potassium more available for absorption.

Additionally, organic fertilization plays a crucial role in decreasing the soil's pH level by

introducing organic acids, particularly essential when the soil exhibits high pH values.

Potassium silicate also showed very great importance in increasing the absorption of nutrients in many plants, especially the nitrogen element, as the addition of silicon stimulates nitrogen absorption and increases its transport inside the plant, and thus increases leaf growth and its expansion, increases the efficiency of photosynthesis and its products, and increases dry matter and productivity. These results agree with other studies that indicated the importance of silicon treatment in increasing leaf area and increasing nitrogen absorption (Malagoli *et al.*, 2005). Likewise, the leaf content of phosphorus increased in fertilization treatments with silicon compounds, and this may be due to the effect of silicon in increasing the absorption of nutrients [40]. This effect is attributed to the dual role of the two elements, as silicon contributes to regulating the absorption and transport of nutrients across cellular membranes and improving the structural properties of the cell wall [32]. This structural and functional improvement led to enhancing the vegetative growth of the plant, which was reflected positively on yield indicators. Potassium (which is considered one of the macronutrients) also plays a vital role in regulating metabolic processes inside the plant [7]. It directly affects the efficiency of the photosynthesis process [37] and increases cell expansion [29]. Moreover, potassium contributes to transporting nutrients from the leaves to the rest of the plant parts [34], which improves element absorption and supports vegetative growth.

The improved effect that was observed as a result of the two-way and three-way interactions between the studied factors is attributed to the enhanced individual role of these factors, in addition to the synergistic behavior that they

showed during joint interaction. The effect of potassium silicate in increasing productivity and quality parameters is explained by stimulating vegetative growth, which in turn leads to increasing photosynthetic efficiency and the accumulation of carbohydrate compounds. Silicon is also known for its ability to regulate sugar metabolism and contribute to the hormonal balance of the plant [15]. Improving leaf mineral content after silicon treatment may be a result of its role in improving the effectiveness of the enzyme (H⁺-ATPase) [23, 30] as well as regulating transpiration, which

improves water conditions inside cells [15]. Silicon also provides additional mechanical support through participation in the formation of cell walls and increasing their strength [37], which enhances the plant's ability to face external influences and increases its absorption of nutrients. In addition, silicon plays a vital role in improving the effectiveness of antioxidant enzymes and building non-enzymatic antioxidants [41]. These results generally agree with the results reached by related research [19, 23].

Conclusions

1. The use of organic fertilizer led to improving most growth traits and chemical content of pomegranate saplings.

2. Spraying with potassium silicate contributed to enhancing vegetative growth and physiological traits.

3. The combination of organic fertilizer and potassium silicate significantly affected most of the traits examined.

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