

Effect of Potassium silicate and organic fertilization on vegetative traits of some ornamental shrubs under salt stress

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Abstract

The experiment was conducted in lathhouse belonging to the Babylon Agriculture Directorate Khanfara Nursery from November 2024 until October 2025. To study the effect of Potassium silicate and organic fertilization on vegetative traits of some ornamental shrubs under salt stress, the experiment included three factors: salt stress (three salinity levels of irrigation water, 3.6 dSm⁻¹, designated S1, S2, and S3); the second factor, humic acid at three concentrations (0, 5, and 10 g.L⁻¹, designated H1, H2, and H3); and the third factor, potassium silicate spray (52.8% silicon dioxide, SiO₂) at three concentrations (0, 150, and 200 mg.L⁻¹, designated Si₁, Si₂, and Si₃). The research was conducted as a 3x3x3 factorial experiment with a randomized complete block design (RCBC). With three replicates, the arithmetic means were compared using the least significant difference (LSD) test. The results were as follows: The salt stress treatment at a concentration of 6 ds m⁻¹ resulted in the lowest average height for Tecoma and Rose of Jelly plants (123.33 and 118.33 cm, respectively), the lowest number of leaves (32.72 and 45.72 leaves per plant, respectively), the lowest leaf area (2871.33 and 1904.21 cm², respectively), the lowest stem diameter (144.17 and 1.75 cm, respectively), and the lowest number of branches (6.16 and 6.44 branches.plant⁻¹, respectively). The humic acid spray treatment at a concentration of 10 g L⁻¹ was excelled, resulting in the highest average plant height for Tecoma and Hibiscus (140.91 and 147.93 cm, respectively). The average number of leaves was (45.48, 65.11) leaves/plant, the average leaf area was (5748.33 and 4348.12 cm²), the average stem diameter was (194.68, 2.16 cm), and the average number of branches was (7.94, 9.14) branches.plant⁻¹. Regarding potassium silicate spraying, the treatment with a concentration of 200 mg.L⁻¹ resulted in the highest average plant height (140.97, 147.39 cm), average number of leaves (44.48, 62.17) leaves/plant, average leaf area (4405.53 and 3448.41 cm²), average stem diameter (183.69, 2.11 cm), and average number of branches (8.98, 8.84) branches.plant⁻¹. The triple interaction coefficient was recorded between (Without salt stress + spraying with humic acid at a concentration of 10 g.L⁻¹ + spraying with potassium silicate at a concentration of 200 mg.L⁻¹) Highest average for the studied traits.

Keyword: humic acid, Hibiscus, Tecoma, Potassium silicate, **salt stress**

Introduction

Hibiscus (*Hibiscus rosa sinensis* L - is an evergreen flowering ornamental shrub belonging to the Malvaceae family. It has taproot roots, simple, heart-shaped leaves with serrated edges, and a dark green, glossy color. It can reach 20 cm in length and 5-15 cm in width. Its native habitat is Southeast Asia, China (Torkashvand and Shadparvar, 2012). It is used in medicinal applications due to its content of antioxidants such as taraxeryl and ascorbic acid (vitamin C). It is effective against some fungi and has many other

medicinal properties (Mukhopadhyay , 2018). Tecoma stans, however, belongs to the Bigoniaceae family, which includes many species, most of which are evergreen trees (Singh et al., 2021). The original habitat of this tree is South America, and it has spread to many other countries, which indicates its ability to withstand different climatic conditions (Mesquida et al., 2017). It is also considered an ornamental plant that can be cut, shaped, and arranged into arches within gardens (Singh et al., 2024). Tecoma plants are often grown in groups to highlight their aesthetic value as a flowering ornamental tree with a light, aromatic fragrance (Anand and Basavaraju et al., 2021).

In addition to its botanical importance as an ornamental tree, Tecoma is also considered a medicinal plant because it contains active ingredients that have been used in various medical fields (Jassim and Khuder., 2022). The growth of ornamental plants is affected by many environmental factors, most importantly soil and water salinity. These are environmental stressors that negatively impact the growth and flowering of ornamental plants (Singh et al., 2024). Salinity has two types of effects on plants: primary effects, such as reducing the water potential of the growing medium and causing disturbances in ionic balance; and secondary effects, which include inhibiting cell expansion, affecting photosynthesis, inhibiting cellular metabolism and the production of reactive oxygen species, disrupting hormonal balance, and affecting metabolism. Protein (Yang and Fu, 2023)

To reduce the impact of salt stress on plants, plants are treated with humic acid, a complex compound that arises from the gradual decomposition of organic matter by various microorganisms. Humus is formed as a result of the transformation of plant residues under the influence of microbial biochemical reactions. Humic acids play a role in improving soil fertility and are important for plant growth and development due to their content of numerous macro- and micronutrients. When added to the soil and absorbed by the root system, they improve vegetative growth (El-Shanhorey et al., 2014). Silicon is also highly beneficial to plant growth, as clearly observed in plants growing under salt stress conditions, from a physiological perspective. Silicon has demonstrated its beneficial effect on plant growth and development by increasing the yield of various crops. In addition, silicon improves plant tolerance to salt stress, and its use may help reduce the plant's need for irrigation (Hassan et al, 2025). The advantages can be summarized as follows: Silicon plays a key role in plant salinity tolerance. From another perspective, its effect on water absorption and water channels within the plant has been observed. Recently, clear results have been achieved in silicon's mitigation of osmotic stress resulting from salinity. Research aim to Effect of Potassium silicate and organic fertilization on vegetative traits of some ornamental shrubs under salt stress.

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Materials and Methods

Experiment Location:

The experiment was conducted in the wooden shade structure belonging to the Babil Agriculture Directorate/Khanfara Nursery from November 2024 to October 2025. To study the effect of amino acids and organic fertilization on the morphological and physiological characteristics of some ornamental shrubs under salt stress

Preparing the seedlings for planting

Ornamental shrub seedlings (Beautiful Rose and Tecoma) of uniform height (1 m) were purchased from a private nursery in Babylon Governorate. They were grown in plastic bags measuring (25*30) cm. The seedlings were transferred to plastic pots with a capacity of (10) kg containing a mixture of river mulch and peat moss (2:1). 250 seedlings of each plant, as uniform in growth and size as possible, were selected and subjected to the same cultivation practices for all treatments. Soil analysis was performed to determine some of its physical and chemical properties according to the methods described in Black (1965) and Page et al. (1882) at the laboratory of the College of Agriculture, Al-Qasim Green University (Table 1).

Table (1) Chemical and Physical Properties of the Soil Used in the Experiment

traits	values	units
Soil pH	7.40	
Organic Matter	3.21	mg.kg ⁻¹ soil
Electrical Conductivity (EC)	2.87	dsm ⁻¹
Nitrogen	15.71	mg.kg ⁻¹ soil

traits	values	units
Phosphorus	11.75	
Potassium	147.82	
Soil separators		
Sand	774.13	g.kg⁻¹
silt	143.11	
Clay	82.76	
texture	sandy loam	

3-3-Experimental Factors

First Factor: Salinity Stress

For the purpose of conducting irrigation operations in the experiment, three salinity levels were prepared for the irrigation water by mixing drainage water with an EC of 35 dSm⁻¹ with tap water with an EC of 1 dSm⁻¹. The drainage water was collected from a drain near the experimental location and stored in a sealed plastic tank. The salinity levels of the irrigation water used in each irrigation were measured using an EC meter. The irrigation treatments included:

(river water, 3.6 dSm⁻¹) and were designated (S1, S2, S3). Factor Two: Humic Acid

H-850 humic acid, manufactured by COSMOCEL, was used. It contains 68% humic acid, 17% fulvic acid, 6.58% nitrogen, 0.65% phosphorus, and 4.96% potassium, and was available in three concentrations: 0, 5, and 10 g.L, designated H1, H2, and H3, respectively. Spraying began 15 days after the start of the experiment and was repeated every 15 days until the experiment concluded. Spraying was carried out using a knapsack sprayer in the early morning until the plants were completely wetted. A few drops of liquid soap were added as a spreading agent to the spray solution to reduce surface tension, ensure complete wettability, and increase the efficiency of the spray solution in penetrating the outer surface of the leaf.

Factor Three: Silicon Spraying

Potassium silicate was sprayed as a silicon source (52.8% silicon dioxide, SiO₂) at three concentrations (0, 150, and 200 mg L⁻¹), designated as Si₁, Si₂, and Si₃. Spraying began 20 days after the start of the experiment and was repeated every 15 days until the end of the experiment, alternating with humic acid spraying.

Experimental Design

The research was conducted as a factorial experiment (3x3x3) using a Randomized Complete Block Design (RCBC). There were three replicates, with each replicate containing 81 seedlings (3 seedlings per experimental unit). Means were compared using the Least Significant Difference (LSD) test at a probability level of 0.05 with the Genstat software. (Al-Sahouki, 1990) 3-6- Studied traits:

Plant Height (cm)

The plant height was measured from the top of the potting soil to the top of the plant using a metric measuring tape for all plants in the experimental unit. The average was then calculated for each treatment and for both plants.

Number of Leaves (leaf.plant⁻¹)

The number of leaves was counted for each plant in the experimental unit, and the average was calculated for each treatment and for both plants.

Leaf Area (cm²)

Five leaves were randomly collected from the experimental unit plants. For each plant, the leaf area was measured using an area meter scanner with the ADC Bioscientific Ltd software. The result was then calculated according to the following equation:

$$\text{Leaf Area per Plant (cm}^2\text{)} = \text{Average Area per Leaf (cm}^2\text{)} \times \text{Number of Leaves per Plant}$$

Average Stem Diameter (cm)

Measurement was performed using an electronic caliper (Microvernia). The average was calculated for each experimental unit and each plant.

Results and Discussion

Plant Height (cm)

The results in Table (2) show that salt stress has a significant effect on plant height. The salt stress treatment at a concentration of 6 ds.m⁻¹ resulted in the lowest height for Tecoma and Hibiscus plants, reaching (123.33 and 118.33 cm), respectively, the no-salt treatment resulted in the highest plant height for Tecoma and Hibiscus , reaching (149.19 and 165.80 cm), respectively. The results also showed that humic acid spraying had a significant effect on plant height. The treatment using humic acid at a concentration of 10 g.L⁻¹ resulted in the highest average plant height for Tecoma and Hibiscus , reaching (140.91 and 147.93 cm), respectively.

The control treatment (without humic acid spray) recorded the lowest plant height for Tecoma and Hibiscus (127.56 cm, 129.77 cm, respectively). Regarding potassium silicate spraying, the treatment with 200 mg L⁻¹ of potassium silicate resulted in the highest plant height (140.97 cm, 147.39 cm), while the control treatment (without potassium silicate spraying) recorded the lowest plant height for Tecoma and Hibiscus (129.76 cm, 135.11 cm). Table 2 also shows that Bi- interaction significantly affects plant height in Tecoma and Hibiscus . The interaction treatment consisting of (no salt stress + humic acid spray at a concentration of 10 g L⁻¹) recorded the highest plant height for Tecoma and Hibiscus (160.51 cm). The highest average height for Tecoma and Hibiscus plants was recorded at 178.60 cm, respectively. The interaction treatment consisting of no salt stress and spraying with potassium silicate at a concentration of 200 mg.L⁻¹ resulted in the highest average height for Tecoma and Hibiscus plants, reaching 149.19 and 165.80 cm, respectively. The interaction treatment combining spraying with potassium silicate at a concentration of 200 mg.L⁻¹ and spraying with humic acid at a concentration of 10 g.L⁻¹ resulted in the highest average height for Tecoma and Hibiscus plants, reaching 146.10 and 152.60 cm, respectively. The highest average height for Tecoma and Hibiscus plants was recorded at 146.10 and 152.60 cm, respectively. The results in the same table also showed that the interaction between the experimental factors had a significant effect on plant height. The triple interaction treatment (no salt stress + humic acid spray at a concentration of 10 g.L⁻¹ + potassium silicate spray at a concentration of 200 mg.L⁻¹) recorded the highest average height for Tecoma and Hibiscus plants, reaching 167.26 and 1178.60 cm, respectively., the interaction treatment (salt stress at a concentration of 6 dS.m⁻¹ + no humic acid spray + no potassium silicate spray) recorded the lowest average height for Tecoma and Hibiscus plants, reaching 109.54 and 115.40 cm, respectively.

Table (2) Effect of salt stress, humic acid spray, and potassium silicate spray, and their interactions, on the height of Tecoma and Hibiscus plants (cm).

salt stress (S) DS.m-1	humic acid (H)	Tecoma				Hibiscus			
		(SI) Potassium silicate spray			S x H	Potassium silicate spray (SI)			S x H
		Si 1	Si 2	Si 3		Si 1	Si 2	Si 3	
S1	H1	116.41	141.78	145.20	134.46	132.50	155.20	158.80	148.83
	H2	148.91	156.81	158.97	154.90	161.50	171.80	176.40	169.90
	H3	149.38	164.89	167.26	160.51	167.60	182.30	185.90	178.60
S2	H1	132.20	136.08	140.41	136.23	133.00	131.70	136.4	133.70
	H2	133.82	137.64	140.77	137.41	140.2	145	150.3	145.17
	H3	135.07	139.06	142.34	138.82	142.70	147.10	149.30	146.37
S3	H1	109.54	118.59	120.84	116.32	115.40	119.00	120.90	118.43
	H2	121.98	124.34	126.58	124.30	121.70	123.80	125.20	123.57
	H3	123.46	128.35	132.41	128.07	117.10	127.00	129.90	124.67
L.S.D 0.05		(S*H*SI) 2.79			1.61	(S*H*SI) 2.46			1.23
					S				S
interaction SxSi	S1	135.94	154.49	157.14	149.19	153.90	169.80	173.70	165.80
	S2	128.84	133.70	135.93	132.82	135.00	138.70	141.30	138.33

salt stress	humic	Tecoma				Hibiscus			
	S3	120.62	123.76	125.61	123.33	106.70	123.30	125.00	118.33
L.S.D 0.05		11.6				1.23			
		H				H			
interaction HxSi	H1	119.38	130.48	132.82	127.56	115.70	135.30	138.30	129.77
	H2	134.90	139.60	142.11	138.87	142.50	144.70	146.90	144.70
	H3	135.97	140.67	146.10	140.91	141.10	150.10	152.60	147.93
L.S.D 0.05		1.61				1.23			
Potassium silicate spray (Si)		129.76	138.02	140.97		135.11	144.32	147.39	
L.S.D 0.05		0.929				0.49			

Number of leaves (leaf.plant⁻¹)

Table (3) shows that salt stress has a significant effect on the number of leaves. The salt stress treatment at a concentration of 6 dS.m⁻¹ resulted in the lowest number of leaves for both Tecoma and Hibiscus plants, reaching (32.72 and 45.72) leaf.plant⁻¹, respectively., the no-salt treatment resulted in the highest number of leaves for both Tecoma and Hibiscus plants, reaching (51.85 and 73.37) leaf.plant⁻¹, respectively. The results also showed that humic acid spraying had a significant effect on the number of leaves. The treatment using humic acid at a concentration of 10 g.L⁻¹ resulted in the highest average number of leaves for both Tecoma and Hibiscus plants, reaching (45.48 and 65.11) leaf.plant⁻¹, respectively.

The control treatment (without humic acid spray) recorded the lowest number of leaves for Tecoma and Hibiscus plants, at 34.75 and 52.13 leaves per plant, respectively. Regarding potassium silicate spraying, the treatment with a concentration of 200 mg.L resulted in the highest average number of leaves, at 44.48 and 62.17 leaves per plant, respectively. The control treatment (without potassium silicate spraying) recorded the lowest average number of leaves for Tecoma and Hibiscus plants, at 37.22 and 52.69 leaves per plant, respectively. Regarding Bi- interaction, the treatment consisting of (no salt stress + 10 g.L⁻¹ humic acid spray) recorded the highest average leaf count for Tecoma and Hibiscus plants, reaching (61.62 and 90.07) leaf.plant⁻¹, respectively. Meanwhile, the treatment consisting of (no salt stress + 200 mg.L⁻¹ potassium silicate spray) recorded the highest average leaf count for Tecoma and Hibiscus plants, reaching (57.11 and 79.95) leaf.plant⁻¹, respectively.

The interaction between (spraying potassium silicate at a concentration of 200 mg.L + spraying humic acid at a concentration of 10 g.L) resulted in the highest average number of leaves for Tecoma and Hibiscus plants (48.03 and 69.93, respectively). The same table also showed that the interaction between experimental factors had a significant effect on the number of leaves. The three-way interaction between (no salt stress + spraying humic acid at a concentration of 10 g.L + spraying potassium silicate at a concentration of 200 mg.L) resulted in the highest average number of leaves for Tecoma and Hibiscus plants (61.62 and 90.07 leaves per plant, respectively)., the interaction between (salt stress at a concentration of 6 dS.m⁻² + no spraying humic acid + no spraying potassium silicate) resulted in the lowest average number of leaves for Tecoma plants. The height of the Tecoma and Hibiscus reached (26.76, 39.17) leaves per plant, respectively.

Table (3) Effect of salt stress, humic acid spray, and potassium silicate, and their interactions, on the height of Tecoma and Hibiscus plants (cm).

salt stress (S) DS.m-1	humic acid (H)	Tecoma				Hibiscus			
		(SI) Potassium silicate spray			S x H	Potassium silicate spray (SI)			S x H
		Si 1	Si 2	Si 3		Si 1	Si 2	Si 3	
S1	H1	26.51	39.57	41.08	35.72	35.30	48.93	50.41	44.88
	H2	49.80	52.45	53.62	51.96	74.55	79.55	80.38	78.16
	H3	55.45	58.56	61.62	58.54	76.46	85.74	90.07	84.09
S2	H1	34.24	40.63	42.44	39.10	52.66	53.03	58.71	54.80
	H2	40.60	44.75	46.78	44.04	58.24	60.56	67.75	62.18
	H3	41.41	46.08	48.84	45.44	52.97	60.04	63.38	58.80

salt stress	humic	Tecoma				Hibiscus			
S3	H1	21.57	28.81	29.91	26.76	30.26	43.04	44.21	39.17
	H2	30.93	33.39	35.31	33.21	45.58	46.98	47.57	46.71
	H3	32.70	37.74	39.14	36.53	40.56	49.98	50.75	47.10
L.S.D 0.05		(S*H*SI) 1.39				(S*H*SI) 2.98			
					S				S
interaction SxSi	S1	43.25	55.19	57.11	51.85	62.10	78.07	79.95	73.37
	S2	38.29	39.04	42.26	39.86	56.48	57.11	58.87	57.49
	S3	30.07	33.68	34.42	32.72	42.98	46.67	47.51	45.72
L.S.D 0.05		0.80				1.72			
					H				H
interaction HxSi	H1	29.57	34.57	40.11	34.75	43.72	54.88	57.78	52.13
	H2	41.72	45.31	46.59	44.54	59.46	62.36	65.23	62.35
	H3	42.12	46.3	48.03	45.48	59.02	66.37	69.93	65.11
L.S.D 0.05		0.80				1.72			
Potassium silicate spray (Si)		37.22	42.40	44.48		52.69	59.55	62.17	
L.S.D 0.05		0.46				0.99			

Leaf Area (cm²)

Table 4 shows that salt stress has a significant effect on leaf area (cm²). The salt stress treatment with a concentration of 6 dS.m⁻¹ resulted in the lowest leaf area for both Tecoma and Hibiscus plants, reaching (2871.33 and 1904.21 cm², respectively). Conversely, the treatment without salinity resulted in the highest leaf area for both Tecoma and Hibiscus plants, reaching (5748.33 and 4348.12 cm², respectively). The results also showed that humic acid spraying had a significant effect on leaf area. The treatment with humic acid at a concentration of 10 g.L⁻¹ resulted in the highest leaf area for Tecoma and Hibiscus plants (5748.33 and 4348.12 cm², respectively). The control treatment (without humic acid spraying) resulted in the lowest leaf area for Tecoma and Hibiscus plants (3906.33 and 3234.63 cm², respectively). Regarding potassium silicate spraying, the treatment with potassium silicate at a concentration of 200 mg.L⁻¹ resulted in the highest leaf area (4405.53 and 3448.41 cm²). The control treatment (without potassium silicate spraying) resulted in the lowest leaf area for Tecoma and Hibiscus plants (3487.21 and 2511.64 cm², respectively). Regarding Bi- interaction, the treatment consisting of (no salt stress + 10 g.L⁻¹ humic acid spray) recorded the highest leaf area for Tecoma and Hibiscus plants, at 6381.00 and 4544.04 cm², respectively. The treatment consisting of (no salt stress + 200 mg.L⁻¹ potassium silicate spray) recorded the highest leaf area for Tecoma and Hibiscus plants, at 5613.00 and 4239.22 cm², respectively. The treatment consisting of (200 mg.L⁻¹ potassium silicate spray + 10 g.L⁻¹ humic acid spray) recorded the highest leaf area for Tecoma and Hibiscus plants, at 4630.00 and 3654.35 cm². The results in the same table also showed that the interaction between experimental factors had a significant effect on leaf area. The triple interaction treatment (no salt stress + humic acid spray at a concentration of 10 g.L⁻¹ + potassium silicate spray at a concentration of 200 mg.L⁻¹) resulted in the highest leaf area for Tecoma and Hibiscus plants, reaching 6381.00 and 4544.04 cm², respectively. Conversely, the interaction treatment (salt stress at a concentration of 6 dS.m⁻¹ + no humic acid spray + no potassium silicate spray) resulted in the lowest leaf area for Tecoma and Hibiscus plants, reaching 1830.00 and 1521.57 cm², respectively.

Table (4) Effect of salt stress, spraying of humic acid and potassium silicate and their interactions on the leaf area of Tecoma and Hibiscus plants (cm²)

salt stress (S) DS.m-1	humic acid (H)	Tecoma				Hibiscus			
		(SI) Potassium silicate spray			S x H	Potassium silicate spray (SI)			S x H
		Si 1	Si 2	Si 3		Si 1	Si 2	Si 3	
S1	H1	1947.24	3795.25	3961.41	3234.63	3059.00	4183.00	4477.00	3906.33
	H2	4048.66	4192.25	4212.21	4151.04	4685.00	5326.00	5981.00	5330.67

salt stress	humic	Tecoma				Hibiscus			
	H3	4128.20	4372.12	4544.04	4348.12	4785.00	6079.00	6381.00	5748.33
S2	H1	1624.88	3057.71	3240.71	2641.10	3625.12	3700.00	3871.00	3732.04
	H2	1709.07	3494.20	3726.72	2976.66	3962.00	4093.00	4228.00	4094.33
	H3	1990.31	3497.77	3619.55	3035.88	3296.00	4059.00	4136.00	3830.33
S3	H1	1521.57	2073.84	2117.22	1904.21	1830.00	3387.00	3397.00	2871.33
	H2	2271.02	2651.58	2761.42	2561.34	3455.00	3551.00	3618.00	3541.33
	H3	2454.23	2971.38	2999.98	2808.53	3253.00	3674.00	3787.00	3571.33
L.S.D 0.05		(S*H*SI) 26.57				(S*H*SI) 53.8			
		S				S			
interaction SxSi	S1	3232.81	4119.88	4239.22	3863.97	3767.00	5196.00	5613.00	4858.67
	S2	2317.83	2985.91	3349.90	2884.55	2744.00	3798.00	3940.00	3494.00
	S3	2224.16	2565.60	2626.21	2471.99	3256.00	3537.00	3600.00	3464.33
L.S.D 0.05		15.34				8.86			
		H				H			
interaction HxSi	H1	2175.51	2497.99	3106.45	2593.32	2524.00	2897.00	3915.00	3112.00
	H2	2850.97	3271.29	3566.78	3229.68	4034.00	4324.00	4509.00	4289.00
	H3	3178.11	3360.07	3654.35	3397.51	4033.00	4488.00	4630.00	4383.67
L.S.D 0.05		15.34				8.86			
Potassium silicate spray (Si)		2511.64	3260.46	3448.41		3487.21	4152.80	4405.53	
L.S.D 0.05		8.86				17.3			

Average Stem Diameter (cm)

Table (5) shows that salt stress has a significant effect on stem diameter. The salt stress treatment at a concentration of 6 dS.m⁻¹ resulted in the lowest stem diameters for Tecoma and Hibiscus plants, reaching (144.17 cm and 1.75 cm, respectively)., the no-salinity treatment (S1) resulted in the highest stem diameters for Tecoma and Hibiscus plants, reaching (223.47 cm and 2.41 cm, respectively). The results also showed that humic acid spraying had a significant effect on stem diameter. The treatment with humic acid at a concentration of 10 g.L⁻¹ resulted in the highest average stem diameter for Tecoma and Hibiscus plants (194.68 cm and 2.16 cm, respectively). The control treatment (without humic acid spraying) resulted in the lowest average stem diameter for Tecoma and Hibiscus plants (152.56 cm and 1.87 cm, respectively). Regarding potassium silicate spraying, the treatment with potassium silicate at a concentration of 200 mg.L⁻¹ resulted in the highest average stem diameter (183.69 cm and 2.11 cm). The control treatment (without potassium silicate spraying) resulted in the lowest average stem diameter for Tecoma and Hibiscus plants (165.49 cm and 1.97 cm, respectively). Regarding Bi- interaction, the treatment consisting of (no salt stress + 10 g.L⁻¹ humic acid spray) recorded the highest average stem diameter for Tecoma and Hibiscus plants (243.76 cm and 2.63 cm, respectively). Similarly, the treatment consisting of (no salt stress + 200 mg.L⁻¹ potassium silicate spray) recorded the highest average stem diameter for Tecoma and Hibiscus plants (239.43 cm and 2.63 cm, respectively). Finally, the treatment combining (200 mg.L⁻¹ potassium silicate spray + 10 g.L⁻¹ humic acid spray) recorded the highest average stem diameter for both Tecoma and Hibiscus plants (274.32 cm and 2.88 cm, respectively). The results in the same table also showed that the interaction between the experimental factors had a significant effect on stem diameter. The triple interaction treatment (no salt stress + humic acid spray at a concentration of 10 g.L⁻¹ + potassium silicate spray at a concentration of 200 mg.L⁻¹) recorded the highest average stem diameter for Tecoma and Hibiscus plants, reaching 274.32 and 2.88 cm, respectively. Conversely, the interaction treatment (high salt stress + no humic acid spray + no potassium silicate spray) recorded the lowest average stem diameter for Tecoma and Hibiscus plants, reaching 123.82 and 1.52 cm, respectively.

Table (5) Effect of salt stress, humic acid spray, and potassium silicate, and their interactions, on the stem diameter of Tecoma and Hibiscus plants (cm).

salt stress	humic	Tecoma		Hibiscus	
(S) DS.m-1	acid	(SI) Potassium silicate spray	S x H	(SI) Potassium silicate spray	S x H

	(H)	Si 1	Si 2	Si 3		Si 1	Si 2	Si 3	
S1	H1	114.73	195.05	200.22	170.00	1.43	2.24	2.37	2.01
	H2	205.53	230.23	243.76	226.51	2.46	2.56	2.63	2.55
	H3	218.4	245.11	274.32	245.94	2.50	2.65	2.88	2.68
S2	H1	158.15	123.82	161.04	147.67	1.97	1.98	2.02	1.99
	H2	179.21	126.74	191.23	165.73	2.12	2.10	2.22	2.14
	H3	180.91	185.37	131.39	165.89	2.07	1.63	1.52	1.74
S3	H1	135.17	140.07	144.76	140.00	1.67	1.50	1.66	1.61
	H2	146.88	142.54	149.04	146.15	1.74	1.78	1.82	1.78
	H3	150.45	152.55	157.41	153.47	1.82	1.91	1.90	1.87
L.S.D 0.05		(S*H*SI) 4.60			2.66	(S*H*SI) 0.14			0.08
					S				S
interaction SxSi	S1	179.55	223.47	239.43	214.15	2.13	2.48	2.63	2.41
	S2	172.76	145.31	161.22	159.76	2.05	1.91	1.92	1.96
	S3	144.17	145.06	150.40	146.54	1.74	1.73	1.79	1.75
L.S.D 0.05		2.66			1.53	0.08			0.05
					H				H
interaction HxSi	H1	136.02	152.98	168.67	152.56	1.69	1.91	2.02	1.87
	H2	177.20	166.50	194.68	179.46	2.11	2.15	2.22	2.16
	H3	183.25	194.35	187.71	188.44	2.13	2.06	2.10	2.10
L.S.D 0.05		2.66			1.53	0.08			0.05
Potassium silicate spray (SI)		165.49	171.28	183.69		1.9741	2.0389	2.1126	
L.S.D 0.05		1.53				0.05			

Number of branches (branch.plant⁻¹)

The results in Table (6) showed that salt stress had a significant effect on the number of branches. The salt stress treatment at a concentration of 6 ds.m⁻¹ recorded the lowest number of branches for Tecoma and Hibiscus plants, reaching (6.16, 6.44) branches.plant⁻¹ respectively, while the treatment without salinity recorded the highest number of branches for Tecoma and Hibiscus plants, reaching (9.60, 9.46) branches.plant⁻¹ respectively. The results also showed that humic acid spraying had a significant effect on the number of branches. The treatment with humic acid spraying at a concentration of 10 g.L resulted in the highest average number of branches for Tecoma and Hibiscus plants, reaching (7.94) and (9.14) branches/plant, respectively. The control treatment (without humic acid spraying) recorded the lowest number of branches for both Tecoma and Hibiscus plants, at (6.68) and (6.58) branches/plant, respectively. Regarding potassium silicate spraying, the treatment with potassium silicate spraying at a concentration of 200 mg.L resulted in the highest average number of branches, reaching (8.98) and (8.84) branches/plant, respectively. The control treatment (without potassium silicate spraying) recorded the lowest average number of branches for both Tecoma and Hibiscus plants, at (7.05) and (6.83) branches/plant, respectively. Regarding the dual interaction, the interaction treatment consisting of (no salt stress + spraying with humic acid at a concentration of 10 g.L) recorded the highest average number of branches in Tecoma and Hibiscus plants, reaching (12.24, 13.63) branches/plant, respectively. Meanwhile, the interaction treatment consisting of (no salt stress + spraying with potassium silicate at a concentration of 200 mg.L) recorded the highest average number of branches in Tecoma and Hibiscus plants, reaching (10.89, 10.82) branches/plant, respectively. The interaction treatment between (spraying with potassium silicate at a concentration of 200 mg.L) and spraying with humic acid at a concentration of 10 g.L recorded the highest average number of branches in Tecoma and Hibiscus plants, reaching (8.77, 10.73) branches/plant, respectively. The results in the same table also showed that the interaction between the experimental factors had a significant effect on the number of branches. The three-way interaction between (no salt stress + humic acid spray at a concentration of 10 g.L⁻¹ + potassium silicate spray at a concentration of 200 mg.L⁻¹) recorded the highest average number of branches for Tecoma and Hibiscus plants, reaching (12.24 and 13.63), respectively. Conversely, the interaction between (salt stress at a concentration of 6 dS.m⁻¹ + no

humic acid spray + no potassium silicate spray) recorded the lowest average number of branches for Tecoma and Hibiscus plants, reaching (6.05 and 5.02), respectively.

Table (6) Effect of salt stress, humic acid spray, and potassium silicate spray, and their interactions on the number of branches for Tecoma and Hibiscus plants (branch . plant⁻¹).

salt stress (S) DS.m-1	humic acid (H)	Tecoma				Hibiscus			
		(SI) Potassium silicate spray			S x H	Potassium silicate spray (SI)			S x H
		Si 1	Si 2	Si 3		Si 1	Si 2	Si 3	
S1	H1	5.89	8.92	9.08	7.96	4.90	5.82	6.12	5.61
	H2	.188	9.16	10.36	9.23	7.19	8.45	9.69	8.44
	H3	9.82	10.62	12.24	10.89	10.27	11.80	13.63	11.90
S2	H1	6.66	7.37	9.08	7.70	5.13	5.52	6.62	5.76
	H2	7.03	8.60	9.79	8.47	7.70	8.62	9.91	8.74
	H3	9.42	9.71	10.61	9.91	8.37	9.70	10.69	9.59
S3	H1	5.07	6.02	7.06	6.05	4.15	5.09	5.83	5.02
	H2	6.22	7.41	8.83	7.49	6.55	7.42	7.50	7.16
	H3	6.45	7.11	7.45	7.00	7.21	7.72	8.77	7.90
L.S.D 0.05		(S*H*SI) 0.40			0.232	(S*H*SI) 1.37			0.80
					S				S
interaction SxSi	S1	8.02	9.90	10.89	9.60	8.20	9.36	10.82	9.46
	S2	7.56	7.83	8.04	7.81	7.74	8.28	8.73	8.25
	S3	5.19	6.51	6.78	6.16	5.56	6.74	7.03	6.44
L.S.D 0.05		0.232			0.13	0.80			0.46
					H				H
interaction HxSi	H1	6.21	6.77	7.07	6.68	5.73	6.81	7.19	6.58
	H2	6.81	7.39	8.66	7.62	6.48	8.16	9.37	8.00
	H3	7.23	7.81	8.77	7.94	7.28	9.41	3710.	9.14
L.S.D 0.05		0.232			0.13	0.80			0.46
Potassium silicate spray (Si)		7.05	8.08	8.98		6.83	7.93	8.84	
L.S.D 0.05		0.13				0.46			

The decrease in vegetative and root growth indicators with increased salinity in irrigation water (Tables 2-6) may be due to the direct effects of increased soil salinity in inhibiting enzyme activity, leading to disruptions in nutrient balance, cell membrane function, and overall plant metabolism. This, in turn, affects carbon synthesis and respiration. Furthermore, humic acid contains phosphorus, which plays a vital role in the formation of organic compounds produced by photosynthesis (Parihar et al,2015). It promotes carbohydrate formation and provides the plant with the energy necessary for vital processes, such as ATP and ADP, thus enhancing plant growth and improving photosynthetic efficiency. Alternatively, the decrease may be due to the indirect effects of increased salinity on the physical and chemical properties of the soil, and consequently, its impact on plant growth in these saline environments. Increased osmotic potential leads to a decrease in the plant's ability to absorb water and a reduction in cell swelling, affecting cell wall flexibility, expansion, and elongation(Balasubramaniam et al,2023). This results in a decrease in CO₂ entering through the stomata, an increase in the production of reactive oxygen species, an imbalance in the ionosphere, and a decrease in chlorophyll content, ultimately leading to reduced fruit production. Carbohydrates, proteins, and plant hormones all lead to a decrease in plant height, stem diameter, and reduction of leaf surface area (Tables 2-3-4). The decrease in vegetative growth indicators when soil salinity concentrations increase is due to a reduction in soil water potential, which affects the efficiency of plants in their ability to absorb water and mineral ions necessary for the division and elongation of plant

tissues, leading to a decrease in plant length, number of aerial stems, and number of leaves (Carillo et al, 2011). The results also showed the effect of humic acid on vegetative characteristics (Tables 2-6). The humic acid spray treatment was significantly superior. This is attributed to the important role of humic acid in biological processes, which it plays by improving soil fertility and increasing the availability of nitrogen, phosphorus, potassium, iron, and magnesium, as well as increasing their uptake by the plant. This affects various biological activities such as cell division and elongation of meristematic tissues, and the synthesis of proteins and nucleic acids (Ren et al., 2022). Consequently, it promotes good vegetative growth and nutrient uptake by the plant, which in turn affects various biological activities within the plant (Ennab et al., 2023). Humic acid also increases the soil's ability to chelate mineral elements, especially micronutrients, which primarily encourage the enzymes necessary for the formation of auxins and gibberellins. These become nutrient-attracting centers that promote cell division and increase in cambium size, cell division and elongation of meristematic tissues, and the synthesis of proteins and nucleic acids, thus contributing to the formation of Good vegetative growth is promoted, and humic acid encourages enzyme activity and the transport of carbon dioxide products (Ibraheem et al., 2023), leading to increased plant height, number of leaves, leaf area, and number of branches (Table.)

The results shown in the same tables (2-6) indicate that the silicon concentrations used resulted in significant increases in the studied root growth characteristics, especially the 200 mg/L concentration. This may be due to silicon spraying improving vegetative growth characteristics by increasing gibberellin levels in the plant, which is responsible for stimulating growth. Alternatively, it may be due to an increase in chlorophyll content in the leaves, which promotes the synthesis of sugars used in plant growth (Parimala and Singh, 2022). Another possibility is that silicon increased root growth, thus enhancing nutrient uptake and contributing to plant growth (Debicz et al., 2016). The increased plant height may also be attributed to silicon's role in elongation. Strengthening plant roots leads to increased nutrient uptake from the soil solution (Ma and Yamaji, 2006). This may be due to silicon's role in enhancing nutrient and water absorption, thus accelerating growth (Epstein, 2001). Silicon's significant role in improving plant growth and development may also contribute to this effect. It enhances mechanical strength, light absorption, and resistance to various biotic and abiotic stresses, leading to improved vegetative growth characteristics. Furthermore, foliar application of silicon increases plant hardiness due to increased nitrogen levels, further enhancing vegetative growth (Mahmoud et al., 2022). Silicon-mediated stress tolerance results from two main processes: physical and mechanical protection through silicon dioxide (SiO₂) deposition, and metabolic changes triggered by biochemical responses (Bhat, 2019). The increased leaf area and number of leaves resulting from silicon application may also be attributed to its role in photosynthesis, increasing chlorophyll content and photosynthetic efficiency. (Abdelaal et al., 2020).

Conclusions:

Salt stress has a significant effect on the growth of Tecoma and Rose of Jelly seedlings and their content of minerals and enzymes. Spraying with humic acid has a significant effect, especially at a concentration of 10 g/L, which recorded the highest rates for most of the studied traits. Spraying with potassium silicate also plays a significant role in reducing the effects of salt stress on Tecoma and Rose of Jelly seedlings. The concentration of 200 mg/L showed a significant advantage and recorded the highest rates for most vegetative, root, and flowering growth traits, as well as the leaf content of nutrients and enzymes.

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