EFFECT OF DIFF. SUBS. AND SPRAYING WITH K2SIO3 ON THE ROOT AND VEGETATIVE GROWTH OF L. W. PLANTS IN BAGHDAD CITY

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ABSTRACT

This study was aimed to investigate the response of two types of ornamental herbaceous plants (*Wedelia trilobata* and *Jacobaea maritima 'Cirrus'*) to different agricultural environments and the application of potassium silicates to the living walls system LWS (Felt layer system) under the climate conditions of Baghdad city. Each experiment involved the cultivation of a different plant species, and the study duration was from September 15, 2021, to August 1, 2022. A Strip-Plot Design experiment was conducted using two factors: factor M with four levels of substrates (50% peatmoss and perlite (M1), 50% Vermicompost and perlite (M2), 50% Water hyacinth compost and perlite (M3), 50% wheat straw compost and perlite (M4)) and factor S with three levels of foliar spray of potassium silicate (0, 1.5, and 3 ml L^{-1}) S1, S2 and S3 respectively. The results differed according to the different substrates, and the study indicators were superior using potassium silicate concentrations compared to the comparison treatment.

Key words: Vertical gardens; growing media; roots ; external vertical greenery systems ; felt.

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تأثير الركائز المختلفة والرش بسيليكات البوتاسيوم في النمو الجذري والخضري لنباتات الجدران الحية في مدينة بغداد

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المستخلص

هدفت الدراسة إلى معرفة مدى استجابة نوعين من نباتات الزينة العشبية (*Wedelia trilobata* و *Jacobaea maritima 'Cirrus'*) على الركائز الزراعية المختلفة وتطبيق سيليكات البوتاسيوم في نظام الجدران الحية LWS (نظام اللباد) تحت الظروف المناخية لمدينة بغداد، تضمنت كل تجربة زراعة نوع نباتي مختلف، وكانت مدة الدراسة من 15 أيلول 2021 إلى 1 آب 2022. تم إجراء تجربة حسب تصميم القطاعات المنشقة باستخدام عاملين: العامل M بأربعة مستويات من الركائز (50٪ بيتموس و بيرلايت (M1) ، 50٪ سماد دودة الأرض و بيرلايت (M2)، 50٪ سماد زهرة النيل و بيرلايت (M3)، 50٪ سماد قش القمح و بيرلايت(M4)) ، و العامل S فشمل الرش بثلاث مستويات من سيليكات البوتاسيوم (0 و 1.5 و 3 مل.لتر$^{-1}$) S0 و S1 و S2 على التوالي، وقيست الصفات الآتية: (منحنى النمو، المحتوى المائي النسبي للأوراق، طول أطول جذر، عدد الجذور الثانوية، النسبة المئوية للمادة الجافة للجذور، النسبة المئوية لرطوبة الركائز، درجة حرارة الركائز)، واختلفت النتائج باختلاف الركائز وتفوقت مؤشرات الدراسة باستخدام تراكيز سيليكات البوتاسيوم مقارنة بمعاملة المقارنة.

الكلمات المفتاحية: الحدائق العمودية ؛ أوساط النمو ؛ الجذور ؛ أنظمة التخضير العمودية الخارجية ؛ لباد ؛ مسجل البيانات.

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INTRODUCTION

Urbanization is one of the most significant issues of the 21st century. The increase in concrete buildings has led to a reduction in open spaces and green areas surrounding them, resulting in a decrease in urban green spaces (14). Additionally, it has caused an increase in the levels of carbon dioxide in urban areas. In May 2016, the World Health Organization announced that more than 80% of urban areas had exceeded the maximum limits of air pollution levels, leading to the urban heat island effect (27, 32). The capital city of Baghdad has witnessed a decline in the areas planted with vegetation from 0.025 km² to 0.013 km² between 2001 and 2020. This has negatively affected the climate of the city, with temperature rates increasing from 26-47 degrees Celsius in 2001 to 32-56 degrees Celsius in 2020. The highest temperatures were recorded in urban areas with no plant cover (41). In the past, plants were employed in architecture through the concept of gardens, Public parks and private gardens are considered essential components and important tools for improving urban life quality. These green spaces should possess environmental characteristics that provide human comfort, renew vitality, and enhance social interaction. The use of plants in architecture has a long history, and gardens have been used as a means of improving the built environment for thousands of years. Today, architects and landscape designers continue to integrate plants into their designs to create more sustainable and livable cities. The surface area of a building's façade is usually larger than its surface area, reaching more than twenty times its surface area in high-rise buildings. Therefore, the use of green walls has a greater impact on the building environment and improves its thermal properties (46 , 47). Not only that, but green walls also perform some functions such as thermal and acoustic insulation, reducing the urban heat island effect, improving air quality, and adding aesthetic value, as well as having a positive impact on human psychology (14). The success of plant growth in vertical garden systems depends mainly on growth media, plant selection, and growth containers (49). Perlite is a chemically inert and non-degradable material that is lightweight and small in size, appearing as white granules. It is formed by rapidly heating volcanic rocks (760-1100°C), which causes its volume to expand 7-16 times due to trapped water evaporating from the inside. Perlite is characterized by low density, large surface area, and water-holding capacity (Markoska, 2018). Its unique particle structure allows it to retain moisture and nutrients in the closed cells and provide a stable environment for plant roots, ensuring good watering throughout the root zone. Perlite also acts as an insulator to reduce fluctuations in soil temperature. Its particle quality provides quick drainage of excess moisture and allows for good ventilation and oxygen intake (15). According to (13), vermicompost resulted in an average increase of 26% in commercial crop yield, (13 % in total plant biomass, 78 % in plant shoot biomass, and 57% in plant roots biomass). The maximum positive effect on plant growth was observed when vermicompost accounted for 30-50% of the soil volume. (6) was also found that earthworm compost had a significant effect on the vegetative and root growth parameters of Beta vulgaris L. Eichhornia crassipes, also known as water hyacinth, is one of the worst invasive alien species in the world, with a significant impact on food security, agricultural production, and the environment (34). Utilizing it in organic fertilizer production is one way to mitigate its negative impact, as it plays a vital role in enriching the chemical, physical, and biological properties of soil, including water retention, soil aggregation, density, porosity, nutrient availability, pH, cation exchange capacity, and microorganism population, as well as bioremediation of heavy metals (11, 50). The selection of plant species and Substrate and location is one of the crucial factors that determine the success or failure of a vertical garden design and construction. It is necessary to follow a set of criteria based on the requirements of those species in terms of light, heat, water, nutrients, and growth. The characteristics of the selected plants should be compatible with the climate in which the vertical garden is located, as this will affect their healthy development. Additionally, the chosen plants should be lightweight with spread-out roots, and preferably evergreen, so that the vertical garden can perform its function throughout the year. Ornamental grasses and perennial plants with high tolerance for environmental pollution are preferred. The selection of plant species, growing medium, and planting location is important for the living wall as it affects the spatial root growth of the plants (33). Silicon (Si) is one of the most important sources of chemical elements in nature (18, 52). (44) found that foliar application of potassium silicate (5 g L^{-1}) on Dahlia variabilis L. cv. Arizona plants had a significant effect on the number of leaves, plant height, duration of floral spikes, and number of flowers per plant compared to the control treatment (foliar spray with zero concentration of potassium silicate). Furthermore, it led to an increase in nitrogen, potassium, and magnesium content, as well as chlorophyll content in the leaves. Similarly, (29) reported that foliar spraying of white eggplant plants with potassium silicate K2SiO (25% SiO2 and 10% K2O) at three concentrations (0.75, 1.00, 1.50 mg L^{-1}) resulted in increased vegetative growth and yield of the plants. This study was aimed to investigate the response of some herbaceous plants to different substrates and the application of potassium silicate in a living wall agriculture system.

MATERIAIS AND METHODS

A study consisting of three experiments were conducted during the winter season of 2021 and the summer season of 2022 at Al Batool Park, which is located at 60th Street, the Al-Kadhimiya Municipality in Iraq. The planting system consisted of panels made of waste fabrics, specifically jute, and PVC foam sheets mounted on iron frames. Two layers of fabric were sewn together with dimensions of 100 x 70 cm, leaving a 3 cm space for the vertical ribs and a 1.5 cm space for the horizontal ribs for stabilization purposes. The fabric contained pockets with dimensions of 27 x 16 cm, created by making a cut in the upper rib of each pocket. An 8 cm space was left between each pocket in the longitudinal lines for agriculture. Iron frames with dimensions of 310 x 100 cm were prepared and the 100 x 70 cm agricultural bags were attached to the iron frames, leaving a 10 cm space between each bag. The panels were then attached to the fence of the park. Four types of degraded substrate were used, including peatmoss, vermicompost, Water hyacinth compost, and reinforced wheat straw compost. Each type of growing medium was mixed with perlite in a volumetric ratio of 50:50 after being analyzed to determine its physical and chemical components (Table 1).

Table 1. Chemical characteristics of the substrates used in the living wall

Trait measure	The unit	M1	M2	M3	M4
EC 1:5	Dm M-1	0.48	2.08	21.8	6.30
pH 1:5	——	7.94	8.04	7.91	7.50
C/N ratio	——	18.65	25.45	25,64	28.14
organic carbon	mg kg-1 soil	19.023	70.242	53.844	81.8874
total nitrogen N	%	1.02	2.76	2.10	2.91
total phosphorus P	%	1.18	2.01	0.40	0.68
total potassium K	%	1.98	2.59	1.69	2.31
total magnesium Mg	%	0.23	0.4135	0.3521	0.4212
CEC	centimole-charge/kg-1	2.69	1.95	1.65	1.02

The substrate, including peat moss + perlite (50:50%), vermicompost + perlite (50:50%), Water hyacinth compost + perlite (50:50%), and reinforced wheat straw compost + perlite (50:50%), were placed inside these pockets, and seedlings of *Wedelia trilobata* and *Jacobaea maritima 'Cirrus'* were prepared with uniform sizes and then planted inside these pockets. An open-source irrigation system using a series of Xeri bug emitters (made by American company Rain Bird) had installed with a discharge rate of 1.89 liters per hour. The emitters were mounted on top of the canvas and placed at the same intervals as the crops (intra-row spacing). Water was supplied to the emitters through a drip irrigation tube (made by Jordanian company Al-Alamiya) with a diameter of 16 mm and a thickness of 0.9 mm. The tube was connected to a drip timer (best Flora made in Germany) and then connected to a water source. The study involved two factors. The first factor included four types of substrates, denoted by (M), as follows: peat moss + perlite (50:50%) (M1), vermicompost + perlite (50:50%) (M2), Water hyacinth compost + perlite (50:50%) (M3), and wheat straw compost + perlite (50:50%) (M4). The second factor included spraying the shoots with three levels of potassium silicate, denoted by (S), as follows: (0 mL^{-1}) (S0), (1.5 mL^{-1}) (S1), and (3 mL^{-1}) (S2). The potassium silicate used in the experiment was prepared by AGRI Sciences and was sprayed per season. The first season included three sprays, with the first on 10/15/2021, the second on 11/1/2021, and the third on 11-15-2021. In the second season, potassium silicate was sprayed on 2/1/2022, followed by the second spray on 3/1/2022 and then the third on 1/4/2022. The study consisted of three experiments, each with a different plant species. Each experiment included treatments of four substrates and three concentrations of potassium silicates. The plants were distributed after their lengths were standardized to (18 cm) . and sprayed with potassium silicate during the day. All plants substrates were fertilized with NPK fertilizer (20-20-20 + TE) once a month during the growing season. Each experiment of the three included 12 treatments according to The Strip-Plot Design (7) with three replicates. The levels of the potassium silicate spraying factor (S) were randomly distributed among the blocks, where each block contained all levels of (S) factor. The substrates (M) were distributed in strips along the block that contained all levels of the (S) factor. Each experimental unit consisted of four plants, resulting in a total of 108 experimental units for each of the three experiments, and a total of 432 plants. Thus, each experiment included 144 plants (36 experimental units). Data were analyzed using RStudio (Build 576) (2022.07.2) and the means were compared at the least significant difference at the 5% probability level (7).

Vegetative growth treats: Growth curve, Leaf relative water content (RWC): Measured according to (1).

Root treats: longest root length measurement, number of secondary roots, Roots dry matter percentage.

Growing media measurements: Since there is no method available to estimate the Moisture of the substrates (used in the research) in a continuous manner that is compatible with the size of the cultivation pockets. two electronic devices were designed and programmed as data loggers for each of the two agricultural experiments. Each device consisted of an open-source electronic circuit board (Arduino Uno SMD) with a precise controller (ATmega328P), an electronic clock (DS3231 Precision RTC Module), four capacitive soil moisture sensors, and four temperature sensors for measuring soil temperature (also DS3231 Precision RTC Module). The device also featured a built-in temperature sensor in the electronic clock (DS3231) for measuring outdoor temperature, and a timer for scheduling the data logger's operation and shutdown periods. A 16 GB SDRAM memory was included for data storage, and the device was connected to a solar energy system that included a solar panel and lithium batteries to ensure 24/7 operation. The data logger was programmed using the Arduino IDE program, specifically designed for programming Arduino boards. The device was mounted in a white waterproof box on the living wall system , with the moisture and soil temperature sensors placed near the root area, and the outside temperature sensor placed inside the box. Where the following data was recorded: Substrate Moisture percentage, Substrate temperature, Outside temperature measurement.

RESUITS AND DISCUSSION

The first experiment: Vegetative growth treats: Leaves relative water content (RWC%): winter season: Table (2) shows the two experimental treatments, Substrates and potassium silicate spray, had a significant impact on the relative water content of *Wedelia trilobata* in the winter season. The results showed that treatments M3 (Water hyacinth compost media) and M2 (vermicompost media) significantly outperformed the other treatments, recording (73.77% and 73.70%, respectively). On the other hand, treatment M1 (peatmoss media) recorded the lowest value, with (65.63%). Regarding the potassium silicate spray treatment, the results showed that treatment S2 performed significantly better than the control treatment, recording (74.27%). Meanwhile, the lowest significant value was recorded by the control treatment with no spray (S0), which recorded (67.44%). Treatment S1 recorded an intermediate percent between the highest and lowest values, with (70.21%). The interaction between the two factors, treatments M3S2 and M2S2 significantly outperformed the other treatments, recording (76.80% and 76.46%, respectively). This represents an increase of

(23.73% and 23.18%, respectively) over the lowest values, which were recorded by treatment M1S0, with (62.07%).

Table 2. Effect of different substrates (M) and potassium silicate (S) spraying and their interactions on (*Wedelia trilobata*) plant

Treatments			Longest root length (cm)	Secondary roots number	Roots dry matter percentage (%)	Leaf RWC (%) in winter	Leaf RWC (%) in summer
Growing Media (M)	M1		24.38	34.33	25.83	65.63	70.40
	M2		31.69	38.44	28.48	73.70	78.78
	M3		28.99	36.67	27.78	73.77	79.88
	M4		23.69	35.11	23.76	69.46	74.49
L.S.D (0.05)			2.52	3.35	4.09	0.82	4.88
Potassium silicate spray levels	S0		23.71	31.50	25.17	67.44	72.18
	S1		26.60	37.17	26.35	70.21	76.42
	S2		31.26	39.75	27.87	74.27	79.06
L.S.D (0.05)			3.82	3.92	1.58	0.47	2.84
Interaction M*S	M1	S0	20.73	28.33	23.49	62.07	68.31
		S1	24.65	37.00	26.38	64.17	70.65
		S2	27.75	37.67	27.61	70.66	72.23
	M2	S0	27.52	36.00	28.24	70.52	76.00
		S1	30.73	39.00	27.56	74.13	79.04
		S2	36.83	40.33	29.64	76.46	81.30
	M3	S0	25.57	29.33	27.37	70.33	75.72
		S1	27.65	38.00	27.34	74.17	80.68
		S2	33.76	42.67	28.64	76.80	83.24
	M4	S0	21.02	32.33	21.58	66.84	68.70
		S1	23.35	34.67	24.11	68.38	75.31
		S2	26.70	38.33	25.59	73.17	79.46
L.S.D (0.05)			4.74	5.20	5.10	1.06	7.96

Summer season: As shown by the results of the summer season, the treatment of Water hyacinth compost M3 had significant superiority over the other treatments, recording a value of (79.88)%. Meanwhile, the treatment of peatmoss M1 recorded the lowest value, giving (70.40)%. The results also revealed that the treatment, S2 and S1, showed significant superiority over the other treatments, recording (79.06 and 76.42)%, respectively. On the other hand, the comparison treatment, S0, recorded the lowest significant value, giving (72.18)%. The interaction between the experimental factors, the results showed that the treatments of M3S2, M2S2, and M3S1 had significant superiority over the other treatments, recording (83.24, 81.30, and 80.68)%, respectively. These values increased significantly by (21.86, 19.02, and 18.11)%, respectively, compared to the lowest significant means recorded by the treatments M1S0 and M4S0, which gave (68.31 and 68.70)%, respectively.

Second: Root treats: longest root length measurement: Treatment M2 significantly outperformed the other treatments, with length of 31.69 cm. On the other hand, treatments M1 and M4 had the lowest values, with root length of 24.38 and 23.69 cm, respectively. As for the treatment S2, outperformed treatments S1 and S0, with plant heights of 31.26, 26.60, and 23.71 cm, respectively. For the interaction between the two treatments, treatment M2S2 showed a significant superiority over the other treatments, with root length value 36.83 cm, followed by treatment M3S2, which did not differ significantly from it and gave a root length 33.76 cm. However, treatment M1S0 had the lowest value, with root length of 20.73 cm.

Number of secondary roots: Treatment M2 showed a statistically significant superiority over the other treatments, with a value of 38.44 sub-root ¹, while treatment M1 had the lowest value at 34.33 sub-root ¹. Treatments M3 and M4 had intermediate values that were not significantly different from each other, producing 36.67 and 35.11 sub-root ¹, respectively. Regarding the potassium silicate spraying, the results showed that treatments S2 and S1 were significantly superior, with values of 39.75 and 37.17 sub-root ¹, respectively, compared to the control treatment S0, which only received distilled water and had the lowest significant difference with a value of 31.50 sub-root $^{-1}$. The pairwise interaction showed that treatment M3S2 was significantly superior to the other treatments, with a value of 42.67 sub-root $^{-1}$, followed by treatment M2S2, which was not significantly different from it and had a value of 40.33 sub-root $^{-1}$. Treatment M1S0 and treatment M3S0 had the lowest values, with 28.33 and 29.33 sub-root ^{1}, respectively.

Roots dry matter percentage: The results indicate that treatment M2 had a significant difference to other treatments, reaching a percentage of (28.48%). On the other hand, treatment M4 recorded the lowest value of dry matter at (23.76%). Treatments M3 and M1 had, percentages values of (27.78% and 25.83%), respectively. As for the potassium silicate spraying treatment, the results showed that treatment S2 had a significant superiority, recording a percentage of (27.87%). Treatment S0 (spraying with distilled water only) recorded the lowest significant value at (25.17%). Treatment S1 had intermediate values, recording a percentage of (26.35%). The interaction between the two treatments, M2S2 and M3S2 had a significant superiority over the other treatments, recording percentages of (29.64% and 28.64%), respectively. On the other hand, treatments M1S0 and M4S0 recorded the lowest values, with percentages of (23.49% and 21.58%), respectively.

Growing media and Outside temperature measurements: Figure 1 shows the relative moisture levels for the substrates which planting with ***Wedelia trilobata* plant** in the living wall, on a weekly basis throughout the duration of the experiment. The results indicate that the M3 media (Water hyacinth compost) recorded the highest relative moisture rate compared to the other media throughout the experiment, except for the first month after planting. It was followed by the M2 media (vermicompost), then the M4 media (wheat straw compost), and finally the M media (peat moss), which was higher than the M4 substrate until the 10th week, then decreased before rising again higher than the M4 substrate after the 26th week. The water retention of the pillar indicates the availability of water and nutrients for absorption by the roots, thereby increasing plant metabolism, growth, and vegetative growth tables (Figure 3) reflect this. Figure 2 showed the temperature of the substrates used in the experiment, as well as the temperature of the experimental environment. The temperature of the substrates decreased almost 8 degrees Celsius compared to the outside temperature. The temperature of the substrates was similar among themselves, but the minimum temperature of the substrates approached the minimum temperature of the local environment. However, the temperature of the media decreased compared to the outside temperature in the summer season, resulting the temperature of substrates are lower than the outside environment. The growth curve of ***Wedelia trilobata*** plant Figure (3) shows can be depicted by a growth curve with three stages, starting from the date of planting the seedlings on September 15, 2021, all of which had a length of 18 cm, until the end of the experiment on August 15, 2022. The graph illustrates that the growth of ***Wedelia trilobata*** plants varied depending on the experimental conditions and the months of growth. It is notable that the growth rate reached its minimum during the period from November 1, 2021, to January 1, 2022, in the winter season, and from June 1, 2022, to August 15, 2022, in the summer season. Additionally, the experimental factors M3S2, M4S2, and M2S2 showed better growth in the initial months of the winter season, while M2S2, M3S2, and M2S1 performed better at the end of the experiment. The lowest average plant length in the winter season was recorded for M1S0 and M4S0, whereas the lowest average plant length at the end of the experiment was observed for M1S1 and M1S0.It is interesting to note that the *Wedelia trilobata* plant exhibited a faster growth rate than Jacobaea plants, with an average monthly increase in length of 12.14. in (Figure 3).

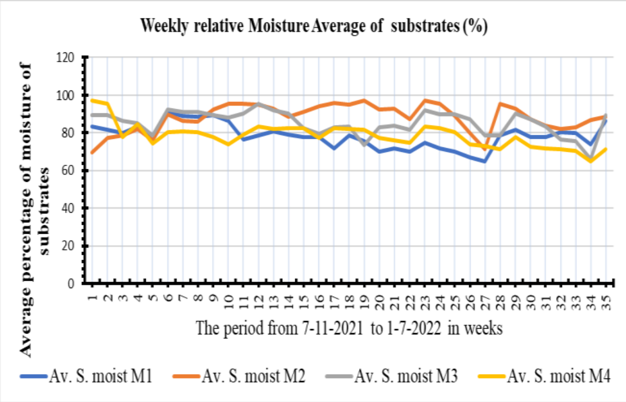


Fig 1. weekly relative Moisture Average of substrates (%) for summer and winter seasons of *Wedelia trilobata* plant

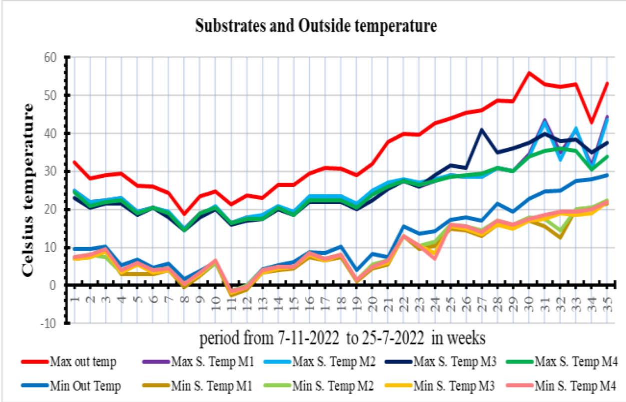
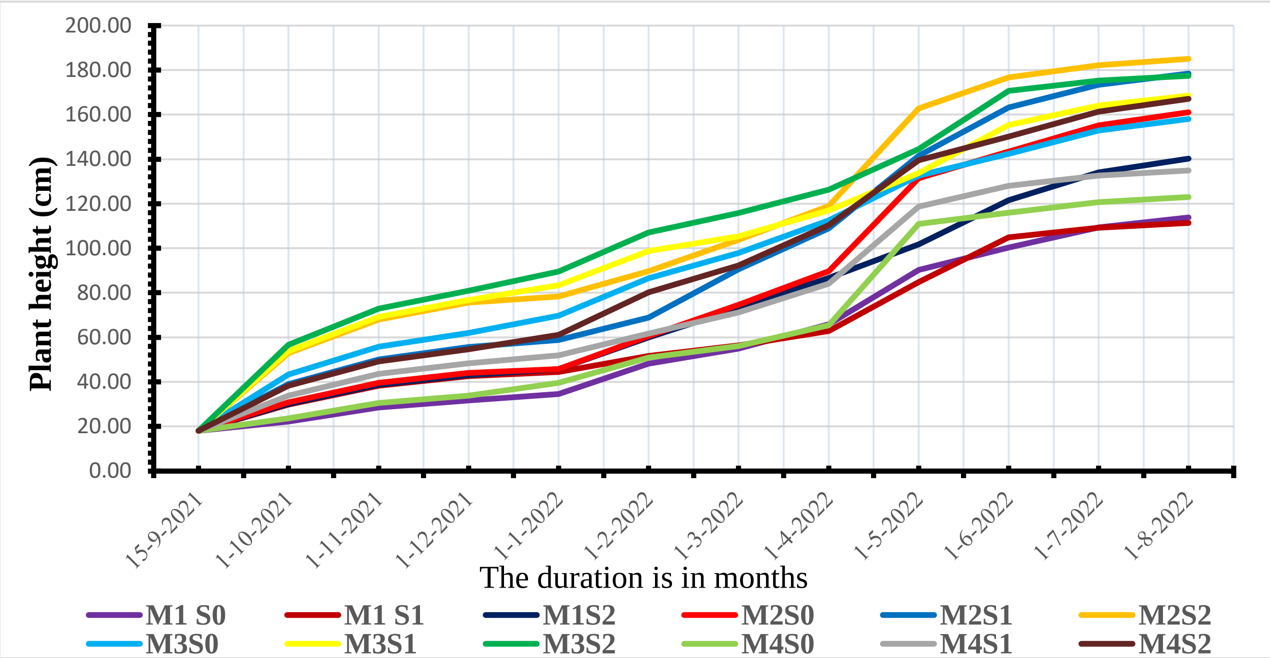


Fig 2. Weekly maximum and minimum temperatures (°C) for winter and summer seasons of *Wedelia trilobata* plant

Growth Curve:



Treatments : Potassium Silicate (S): S0 (0 mL⁻¹), S1 (1.5 mL⁻¹), S3 (3 mL⁻¹)
Substrates: M1 (peatmoss), M2 (vermicompost), M3 (Water hyacinth compost), M4 (wheat straw compost)

Fig 3. Growth curve of *Wedelia trilobata* from the beginning of its growth to the end of the experiment

The second experiment: vegetative growth treats: Leaves relative water content (RWC%): winter season: Table 3 shows that the two experimental treatments, substrates and potassium silicate spray, had a significant impact on the relative water content of *Jacobaea maritima* plants. Results indicated that treatment M2, using vermicompost, and M3, using compost from the water hyacinth, outperformed the other treatments, with percent of 54.50% and 53.91%, respectively. Following these, treatment M4, which used wheat straw compost, recorded a percent of 50.32%. Treatment M1, using the peat moss medium, had the lowest percent at 48.40%. As for the potassium silicate spray treatment, results shows that treatment S2, had a significant superiority with a percent of 54.41%, while the lowest significant percent was recorded by treatment S0, and treatment S1, recorded percent of 49.54% and 51.39%, respectively. In terms of the two-factor interaction, treatments M2S2 and M3S2 showed significant superiority over the other treatments, with values of 56.65% and 56.39%, respectively, representing an increase of 22.70% and 22.14%, respectively, compared to the lowest significant means recorded by treatment M1S0 at 46.17%.

Table 3. Effect of different substrates (M) and potassium silicate (S) spraying and their interactions on *(Jacobaea maritima 'Cirrus')* plant

Treatments			Longest root length (cm)	Secondary roots number	Roots dry matter percentage (%)	Leaf RWC (%) in winter	Leaf RWC (%) in summer
Growing Media (M)	M1		23.22	99.67	23.95	48.40	47.18
	M2		29.97	181.67	27.68	54.50	56.94
	M3		29.36	196.44	27.28	53.91	55.16
	M4		21.19	175.44	23.46	50.32	51.23
L.S.D (0.05)			5.74	42.45	3.24	0.93	1.62
Potassium silicate spray levels	S0		24.31	118.50	24.03	49.54	50.07
	S1		25.62	189.58	27.19	51.39	52.14
	S2		27.88	181.83	25.55	54.41	55.67
L.S.D (0.05)			4.77	52.63	2.56	1.94	2.41
Interaction M*S	M1	S0	21.90	72.00	22.39	46.17	44.88
		S1	22.08	100.00	23.86	47.85	46.46
		S2	25.68	127.00	25.58	51.16	50.19
	M2	S0	25.03	108.00	26.47	52.11	54.82
		S1	30.15	236.00	30.67	54.73	57.03
		S2	34.73	201.00	25.91	56.65	58.96
	M3	S0	29.15	136.00	25.40	51.79	52.68
		S1	27.40	242.00	30.17	53.54	54.81
		S2	31.52	211.30	26.28	56.39	58.00
	M4	S0	21.17	158.00	21.86	48.07	47.90
		S1	22.85	180.33	24.07	49.45	50.28
		S2	19.57	188.00	24.43	53.44	55.52
L.S.D (0.05)			4.44	53.43	2.35	0.90	2.40

Summer season: The statistical analysis results for the summer season, as shown in the same table, had a significant superiority of vermicompost treatment (M2) over the other treatments, with a percentage of 56.94%. This was followed by the treatment of Water hyacinth compost (M3) which recorded a percentage of 55.16%. On the other hand, treatment of Peatmoss (M1) produced the lowest percent of 47.18%. In terms of the potassium silicate spray treatment, the results showed a significant superiority of the treatment (S2), recording a percentage of 55.67%. Meanwhile, the lowest significant percent was recorded by the treatments (S0) and (S1), which produced percentages of 50.07% and 52.14% respectively. The interaction between the study factors, the M2S2 and M3S2 treatments showed a significant superiority over the other treatments, recording percentages of 58.96% and 58.00% respectively. These percents increased by 31.37% and 29.23% respectively, compared to the lowest significant means recorded by the M1S0 treatment, which gave a percentage of 44.88%.

Root treats: Longest root length measurement: Among all the treatments, the M2 and M3 treatment shows the highest significant difference, with plant root lengths of 29.97 cm and 29.36 cm respectively. the lowest length was recorded in M1 and M4 treatments, with plant root lengths of 23.22 cm and 21.19 cm respectively, with no significant difference between them. The treatment S2 recording the highest value of 27.88 cm, and the lowest length of 24.31 cm in the control treatment S0, the results indicated no significant differences. However, the interaction between the two study factors revealed that the treatment M2S2 outperformed the other treatments significantly, with plant root length of 34.73 cm, while the M4S2 treatment showed the lowest value of 19.57 cm.

Number of secondary roots: The results showed that treatments M3, M2, and M4 had significantly affect compare treatment M1, with respective values of 196.44, 181.67, and 175 sub-root ^{1}. compared to the lowest value of 99.67 sub-root ^{1} recorded in treatment M1. Additionally, the results indicated that treatments S1 and S2, significantly outperformed compare to treatment S0, with respective values of 189.58 and 181 sub-root $^{-1}$., compared to the lowest value of 118 sub-root $^{-1}$. recorded in treatment S0. The interaction between the agricultural environment and potassium silicate spray treatments showed that treatment M3S1 significantly outperformed all other treatments, with a value of 242.00 sub-root ^{1}, while treatment M1S0 recorded the lowest value of 72.00 sub-root $^{-1}$.

Roots dry matter percentage: The results showed that treatment M2 and treatment M3, had a statistically significant superiority over the other treatments, reaching (27.68% and 27.28%, respectively). Meanwhile, treatment M1, which used peat moss, and treatment M4, which used wheat straw compost media, had the lowest values at (23.95% and 23.46%, respectively), and did not differ significantly from each other. As for the potassium silicate foliar spray treatment (S), the results showed that treatment S1, had a statistically significant superiority, reaching (27.19%), while the lowest value was recorded in the comparison treatment S0, which was (24.03%). Treatment S2, had a median value between the highest and lowest values, which was (25.55%). In terms of the interaction between the two factors, treatments M2S1 and M3S1 had a statistically significant superiority over the other treatments, reaching (30.67% and 30.17%, respectively). They showed an increase of (40.31% and 38.01%, respectively) over the lowest mean value, which was recorded in treatment M4S0 at (21.86%).

Growing media and Outside temperature measurements: Figure 4. showed the relative moisture levels in the organic substrates which planted with *Jacobaea maritima 'Cirrus'* during the experiment. The treatment M2 (vermicompost) recorded higher relative moisture levels than the other treatment, while M1 had the lowest levels throughout the experiment. The growth indicators for both shoot and root in M2 were higher than the other treatment due to the availability and absorption of water by the plant, thus enhancing plant growth. Decreasing relative moisture levels correspond to a decrease in substrates temperature, which leads to reduced absorption and growth rates (Figure 5.). Figure 5 showed decrease in the temperature of the substrates than the temperature of the experimental environment especially during the winter season, where the temperatures of the substrates approached those of the ambient temperature. However, during the summer season, the temperature of the M1 compost (peat moss) increased compared to the other treatment, both in terms of maximum and minimum temperatures. The minimum temperatures were similar to the ambient temperature, except during the summer season, where the temperature of the growing was lower than the outside temperature. Figure (6) showed the growth curve of *Jacobaea maritima 'Cirrus'*, which remarkably the height growth rate was slow, with a monthly increase percentage of 52%. treatments M2S2, M2S1, and M3S1 outperformed other treatments in terms of plant height growth during the winter season. Growth was observed stopped between 11/15/2021 and 6/15/2022, exception of M2S2, M3S2, and M3S1 treatments, which continued to grow. Interestingly, these treatments also exhibited superior height growth compared to the other treatments. Growth was also observed to stop around 6/15/2022 until end of the experiment, except for the M2S2, M3S2, and M3S1 treatments, which stopped around 7/15/2022.

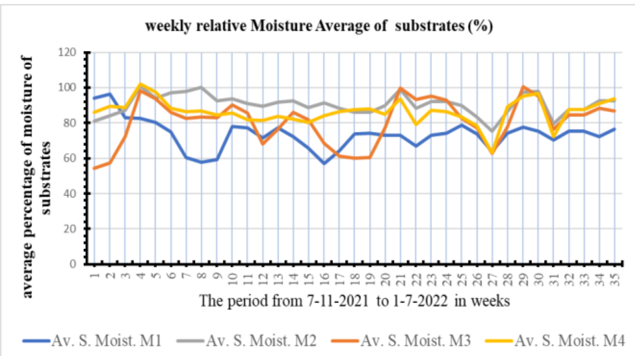


Fig 4. weekly relative Moisture Average of substrates (%) for summer and winter seasons of *Jacobaea maritima 'Cirrus'* plant

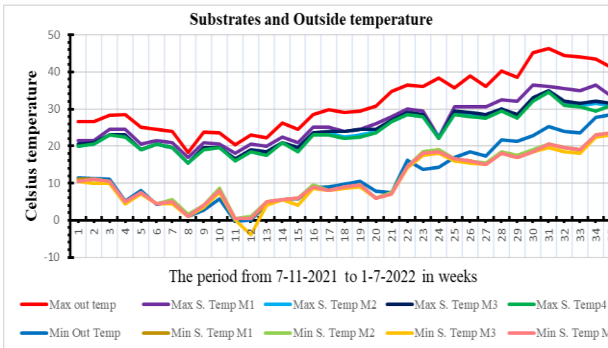
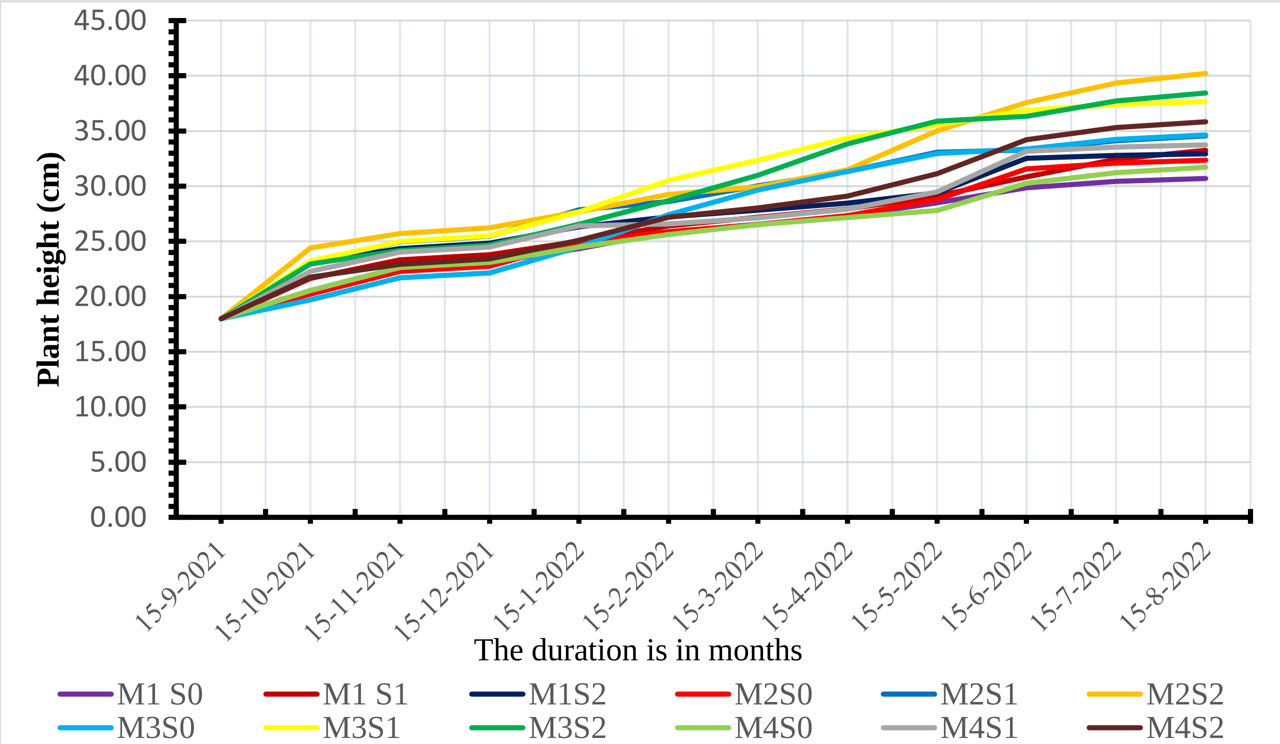


Fig 5. Weekly maximum and minimum temperatures (°C) for winter and summer seasons of *Jacobaea maritima 'Cirrus'* plant

Growth Curve:



Treatments : Potassium Silicate (S): S0 (0 mL⁻¹), S1 (1.5 mL⁻¹), S3 (3 mL⁻¹)
Substrates: M1 (peatmoss), M2 (vermicompost), M3 (Water hyacinth compost), M4 (wheat straw compost)

Fig 6. Growth curve of *Jacobaea maritima 'Cirrus'* from the beginning of its growth to the end of the experiment

Photo 1. The living wall at the end of the experiment

The results of root growth of *Wedelia trilobata* (Table 2) and *Jacobaea maritima 'Cirrus'* (Table 3), demonstrate that the substrates used in the vertical gardening system (vermi compost and Water hyacinth compost) achieved higher averages for the mentioned traits compared to Wheat straw media and peatmoss. Despite the good characteristics of vermicompost and Water hyacinth compost as agricultural media, such as maintaining plant health and providing water and nutrients, and having the ability to gas exchange in the root zone, adequate oxygen levels, and sufficient interparticle distances, the choice of appropriate media is one of the crucial factors that affect the cultivation of ornamental plants (19). The vermicompost media may have provided the plants with the necessary macro and micronutrients essential for plant growth and development (Table 1), as well as the different hormones, enzymes, organic and amino acids absorbed from the roots (16). Moreover, it supplies the media with a vast array of bacteria that perform various functions important for the plant, including providing the media and the plant with growth regulators, nutrients, growth hormones, and soil pest-resistant materials, which restore the media's vitality. All of this has had a significant impact on the root growth of *Wedelia trilobata* (Table 2) and *Jacobaea maritima 'Cirrus'* (Table 3). Earthworms indirectly stimulate microbial biomass and activity by aerating the soil and breaking down solid materials, thereby increasing the available surface area of organic materials for beneficial microorganisms. This, in turn, affects the formation of microbial communities, including those that fix nitrogen and those that provide plants with antibiotics from bacteria belonging to the genera Proteobacteria, Chlorobi, Achromobacter, and Rhizobiales. Furthermore, vermicomposting can protect plants from diseases by promoting their growth and providing them with antibiotics from associated bacteria. (Domínguez et al., 2019; 30). In addition, vermicompost has the ability to retain water (Figure 1, 4) and maintain a stable temperature (Figure 2, 5) despite climate fluctuations. This encourages root growth by increasing root length and branching, as well as the percentage of dry matter (Table 2, 3). vermicompost and Water hyacinth may slowly provide nutrients, but steadily improves the physical properties of the soil over time. This results in better absorption of nutrients by cultivated plants. It may also lead to a decrease in soil acidity, as microorganisms release nutrients from the compost. This improved soil condition has resulted in better root growth, longer branching, and increased dry matter percentage in *Wedelia trilobata* (Table 2) and *Jacobaea maritima 'Cirrus'* (Table 3). Furthermore, improved water and nutrient absorption has led to increased vegetative growth in *Wedelia trilobata* (Figure 3) and *Jacobaea maritima 'Cirrus'* (Figure 6). Also, Water hyacinth compost is a good and effective medium that facilitates better fixation of the root system and root space (Table 2, 3). and may improve the gas exchange of CO_2 and O_2 for root respiration and healthy plant growth and development (55). Additionally, Water hyacinth compost is rich in essential nutrients such as nitrogen, phosphorus, potassium, micronutrients, calcium, and sodium (35) (Table 1). These nutrients can positively affect plant metabolic processes (48), resulting in increased vegetative growth and vitamin content (53), particularly nitrogen and phosphorus, which are essential for chlorophyll formation and plant growth. It also elevates the percentage of leaves Carbohydrates, and that is a good indicator of increasing the fresh and dry weight of leaves (3), The compost of Water hyacinth, it has low electrical conductivity (EC) of 250-600 parts per million, is rich in humic acid, potassium, and phosphorus. It has the ability to retain moisture (Figure 1, 4) ,and its its contain high levels of organic matter and is highly porous, which can enhance moisture retention in the soil (23) (Figure 1, 4). It can also improve nutrient solubility and root growth (Table 2, 3) and absorption. Perhaps the compost contains more microorganisms (42), which can improve soil aeration and lead to better root growth. According to (12), the Water hyacinth has a wide range of applications, including the production of biofertilizers and the utilization of their products such as growth-promoting hormones, facilitating the availability of major and minor elements to plants. using Wheat straw compost were compared to those of using vermicompost and Water hyacinth compost. Although the analysis of Wheat straw compost was good (Table 1) and supported with nutrients, observations from Figures (3) and (6) show that growth in the beginning was similar to the other two composts, but later the vermicompost and Water hyacinth compost outperformed the Wheat straw compost. The reason for this may be due to the effect of allelopathic compounds released from the wheat straw. several phenolic compounds like Hydroquinone, its concentration is high compared to other compounds, which is known to have an effect on stomatal behavior and distribution of guard cells. The inhibitory effect and growth reduction may be due to this compound. Other phenolic compounds were also found in Wheat straw and also Quercetic, Rutin, P-Hydroxy benzoic acid, Salicylic acid, and are soluble in water during plant irrigation, which may have affected plant growth. (54, 58) and (18), found that these compounds may cause a decrease in leaf area and root growth of *Wedelia trilobata* (Table 2 and Figure 3) and *Jacobaea maritima* 'Cirrus' (Table 3 and Figure 6). slows growth of plants roots may be attributed to the restriction of DNA building in meristematic cells of the root, a change in the effectiveness of mitochondria, and alterations in the division coefficient of cells (30). Moreover, the shape of the cortical cells of the root may differ due to the impact of allelopathic compounds on water relations and hormone equilibrium, varying according to the genetic makeup of the plant species grown in this media, such as *Wedelia trilobata* and *Jacobaea maritima* '*Cirrus'*. This finding is consistent with the results of (22), who discovered that the addition of wheat residues at a concentration of 5% resulted in an inhibitory effect on essential traits, such as relative water content and root diameter. The small container used for soilless agriculture quickly saturates during watering, limiting its capacity to store water. Therefore, the effective medium particles and micropores must have a physical structure that can maintain an appropriate balance between air and water content to prevent root suffocation and drought stress (4). These characteristics may have been present in the media used in this experiment, resulting in the successful growth of the planted crops. The small container used for soilless cultivation quickly saturates during irrigation, limiting water capacity. Therefore, the particles and fine structures of the media must be capable of maintaining a suitable balance between air and water content to prevent root suffocation and dehydration stress (4). These characteristics may have been present in the media used in our experiment, leading to the success and growth of the planted crops. In media such as peatmoss, wood materials, straw, and paper, the increased activity of microorganisms may lead to nitrogen freezing. This is because mineral nitrogen from nutrient solution is used during the mineralization of organic matter, reducing the availability of nitrogen for the plant. This, in turn, may lead to a reduction in growth specifications due to nitrogen freezing and low oxygen in the roots, resulting in an increase in phenolic acid content in the plant and weakening it (24). Therefore, nutrients are added to these media to meet the nutritional requirements of the plants. The use of growing medium, perlite, may have aided in retaining water around the roots (Figures 1, 4) and maintaining root temperature (Figures 2, 5). This can be attributed to the unique shape of perlite particles and the small cracks on their surface. These characteristics make moisture, oxygen, and nutrients easily available to the plant. Additionally, the numerous small cracks on the surface of the particles allow them to retain water during drainage and evaporation, making them accessible to the roots and providing a more stable environment around the roots regardless of weather conditions or root growth stage. Perlite also acts as an insulator to reduce fluctuations in soil temperature. It ensures even watering of the entire root zone, resulting in healthy plant growth. Furthermore, perlite is sterile and does not transmit diseases. It is a neutral medium with a pH of 7 (15). As for the treatments S1 and S2, they improved the vegetative and root growth characteristics, as observed in the figures for *Wedelia trilobata* plant (Figure 3) and *Jacobaea maritima 'Cirrus'* plant (Figure 6) for the vegetative characteristics, and in Tables 2 and 3 for the root characteristics. Plants that were not treated with this substance showed a decrease in the mentioned characteristics' averages, possibly due to reduced photosynthesis, increased growth inhibitors, decreased internal hormones, and a smaller leaf area (37). potassium silicates may have led to an increase in internal levels of gibberellins, which helped elongate cells and increase plant height (31), has been shown to improve both vegetative and root growth characteristics in plants, as observed in the *Wedelia trilobata* (Figure 3), *Jacobaea maritima 'Cirrus'*(Figure 6). In addition to changing the levels of important nutrients such as N and Ca, along with the concentration of key proteins such as Importin alpa-1b, Serin phosphatase, and Thieonin + Thioredoxin, which contribute to increasing levels of biologically active gibberellins GA1 and GA4 in cell elongation (38). Additionally, silicon has played a protective role in plants against UV radiation by increasing the level of photosynthesis and antioxidants, thereby increasing plant biomass (43). The increased potassium uptake may be attributed to the growing activity of the root plasma membrane pump ATPase H (45). Silicon has been shown to increase photosynthesis, nutrient and water uptake (Table 2, 3), as well as promote healthy plant growth and differentiation (Figure 3, 6) (2; 20; 21). Silicon also helps to reduce the cell wall rigidity of root cells, increasing water and nutrient uptake and leading to increased root mass and dry matter accumulation, ultimately improving the root system development and enhancing the plant's ability to withstand thermal stress (10). Potassium is an essential nutrient for plants that plays a crucial role in photosynthesis, respiration, and many other vital plant functions. It activates more than 80 enzymes that aid in numerous important activities within the plant. Potassium is particularly important in maintaining water balance, turgor pressure, stomatal opening and closing, carbohydrate accumulation and transport, and thereby providing greater tolerance to stressful conditions, such as high or low temperature (59). The decrease in water loss observed in plants sprayed with potassium silicates may be attributed to the reduction of transpiration in plants, as the accumulation of silicon in the lower epidermal cells of the plant reduces water loss from these cells (17; 25). This is evidenced by an increase in relative water content and turgor weight in these plants (Table 2, 3). Perhaps the use of potassium silicates resulted in increased activity of antioxidant enzymes such as POD, CAT, and SOD under thermal stress conditions, both in summer and winter (Figure 2, 5). This is consistent with (9), who confirmed that spraying silicon on leaves led to enhanced plant growth and improved plant ability to withstand various abiotic stresses, such as heat waves. Plants possess strategies to alleviate stress and stimulate physiological and molecular mechanisms to adapt to changing environments. Stress alters the physiological, biochemical, and molecular balance of the plant, including membrane integrity loss, disturbed enzyme activity, reduced photosynthetic efficiency, nutrient uptake, water relations, and disrupted osmotic regulation. Hormonal balance is also affected by stress (36). Under non-biological stress conditions, silicon regulates plant growth and development by modulating the levels of the plant hormone 3-Indol Acetic Acid (IAA) (39). Additionally, some studies have shown that enhanced lateral root formation via increased IAA and plant growth-promoting rhizobacteria (PGPR) can increase root biomass and protect roots from inhibitory effects (5, 56, 57). and enhances nutrient uptake and utilization, especially under non-biological stress conditions (40). silicon can affect the plant-water relationship, cell wall flexibility and thickness, cell membrane integrity, root cell elasticity, and absorption, resulting in an increase in root biomass and dry matter (Table 2, 3), and an improvement in plant growth (51). In non-silicon-treated plants, root inhibition may be associated with the reduction of root tips/apex growth due to the stiffening of plant cell walls. Heat stress may stimulate oxidative stress, such as the production of oxygen species that cause cell damage (26). This can result in membrane lipid peroxidation, which often leads to membrane loss or changes in permeability, affecting metabolic processes and leading to proline formation. Proline plays a significant role in osmotic adjustment, maintaining enzyme stability, and stabilizing the cell membrane. Its accumulation can lead to increase tolerance to various stresses (8). Finally, it can be concluded that the use of chemical protection has led to improve plant growth in vertical outdoor gardens exposed to varying outdoor temperatures. The results obtained recommend the use of potassium silicates as a foliar application to protect and improve plant growth.

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