The effect of potassium silicate treatment and cutting the growing crown on pot production of chrysanthemum

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Abstract

This research was performed in the lath house of the Department of Horticulture and Landscape Architecture at Tikrit University, College of Agriculture, during the 2024 agricultural season. The objective was to examine the influence of two primary variables: the removal of the apical meristem and the application of varying amounts of potassium silicate on the growth and flowering of potted chrysanthemum (Dendranthema × grandiflorum). This study employed a randomized complete block design (R.C.B.D.). Data statistical analysis was conducted utilizing SAS software, and means were compared employing Duncan's test at a 5% significance level. The findings indicated that the cutting treatment resulted in substantial enhancements in vegetative traits, with an average plant height of 18.56 cm, a leaf count of 174.63 leaves per plant, and a leaf area of 153.96 cm². The 150 mg L^{-1} potassium silicate treatment surpassed others, achieving the highest measurements for plant height (18.25 cm), leaf count (172.48 leaves), and leaf area (152.86 cm²). The interaction between the two components (cutting × concentration) was markedly significant, with the 150 mg L^{-1} + cutting treatment yielding the highest values for most traits: plant height (19.93 cm), leaf number (210.27 leaves per plant), and leaf area (175.23 cm²). This treatment yielded the maximum number of inflorescences (43.53 per plant), the largest inflorescence diameter (55.76 mm), and the longest flowering duration (64.70 days). The same treatment surpassed the other treatments in nitrogen (2.048%), phosphorus (0.645%), potassium (1.844%), and silicon (0.584%). The maximum chlorophyll content measured was 2.034 mg/kg. The findings suggest that employing an intercropping treatment alongside cuttings of the growing tip and potassium silicate at a concentration of 150 mg/L is an efficacious agricultural strategy for enhancing the vegetative, floral, and chemical development of the chrysanthemum plant. The researcher advocates for the implementation of this technique to yield superior plants in controlled growing environments.

introduction

The chrysanthemum (Dendranthema x grandiflorum) is a flowering plant belonging to the Asteraceae family. It is recognized for its many floral hues, encompassing white, yellow, red, and orange. It is extensively grown globally for decorative purposes, especially in gardens, residences, and festivals. It holds considerable cultural and symbolic importance, especially in China and Japan, where it is seen as a symbol of good fortune and longevity, and is featured in numerous traditional festivals [1 . [

Dendranthema serves numerous attractive purposes, such as cut flowers, individual blooms for bouquets, flowering potted plants, and landscaping in containers. It enhances outdoor gardens during periods of floral scarcity [2.[

Urban growth and heightened construction, resulting in the loss of green spaces and gardens, have led to a growing demand for potted blooming and foliage plants. This is due to its application in home design, as the

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varied hues of its blossoms contribute dynamism and vibrancy to the environment. It is distinguished by its aromatic fragrance and aesthetic appeal, enhancing the formation of a pleasant and visually appealing indoor atmosphere [3 .[

Fertilization is a material employed to supply nutrients to plants. It is often sprayed to the soil and occasionally to the foliage. Soil, comprising solid particles and organic materials, serves as the principal source of nutrients for plants and underpins the process of plant nutrition. Nevertheless, under specific conditions, plants may lack adequate nutrients from the soil, resulting in diminished output. Consequently, the application of fertilizers has become imperative [4 .[

Potassium silicate is regarded as a contributor to plant growth by facilitating the absorption of water and nutrients. Silica fortifies plant cell walls, so augmenting the plant's resilience to environmental conditions, including drought and elevated temperatures. This results in enhanced root development and a greater capacity for nutrient absorption in plants [5]. Numerous researchers have underscored the significance of potassium fertilizers as a principal source of potassium for plant development [6,7,8]. Potassium is a crucial nutrient for the regulation of numerous key activities in plants. It is an essential element of over 60 enzymes that regulate plant development and productivity, particularly under environmental stress conditions [8]. Potassium has been reported to promote flowering and alleviate environmental stress effects [9]. [10] demonstrated in their research on Acacia Senna surattensis that the application of potassium-rich NPK fertilizer markedly enhanced the quantity of vegetative and floral branches, plant height, flower weight, and chlorophyll concentration. Moreover, potassium silicate ($KSiO3$) serves as an excellent source of silicon (Si) for cut flower plants, particularly Chrysanthemum plants. Utilized as a foliar spray, it enhances resistance to biological stresses (including diseases and aphids) and abiotic stresses (such as salinity and drought), resulting in improved plant growth [11], enhanced flowering traits [12], and superior plant chemical composition [13]. Pinching is among the most advantageous horticultural techniques for the effective cultivation of cut flowers and potted plants. This operation is executed to promote the development of lateral branches by disrupting the apical dominance of the plant. The supremacy and vigorous development of the terminal bud inhibit the formation of the axillary buds underneath it. This phenomenon results from the elevated amounts of auxins present in the axillary buds. These buds possess intrinsic auxins as well as supplementary auxins derived from the terminal bud. An excess of auxin beyond a specific concentration suppresses bud growth, leading to the development of a limited number of branches and inflorescences [14,15,16]. In a study aimed at assessing the impact of pinching on the growth and flowering of Zinnia elegans (L), [17] reported that pinching the apical meristem led to a notable reduction in plant height (32.70 cm), a substantial increase in stem diameter (4.125 mm), a considerable rise in leaf count (54.87 leaves/plant), and a significant enhancement in leaf area (835.9 cm^2). The objective of the study was to assess the impact of potassium silicate and the pinching of the apical meristem on the growth and yield of the Chrysanthemum plant cultivated in pots.

Materials and Methods

The study was performed in the arboreal canopy of the Department of Horticulture and Landscape Engineering at the College of Agriculture, Tikrit University, from July 2023 to January 2024. Seedlings were planted on July 1, 2024, in plastic pots measuring volume: 12.2 liters. One seedling was sown in each container. The planting media, composed of peat moss, sand, and soil, was utilized in a 1:1:1 ratio.

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The soil was analyzed and the table shows the chemical and physical properties.

Table (1) chemical and physical properties

Characteristics	**Unit**	**Value**
Sand	%	31
Silt	%	30
Clay	%	39
Texture	clayey sandy mixture	
Soil acidity		7.09
E.c.	ds/m^2	3.24
Organic matter	mg/kg	1.32
Nitrate	mg/kg	13.3
Ammonium	mg/kg	14.11
Available phosphorus	mg/kg	18.7
Potassium	mg/kg	2.97

The therapy had two factors: the first was pinching, which had two levels—pinching and no pinching—and the second was potassium concentrations at four levels (0, 50, 100, and 150 mg/kg .(

The factorial experiment was conducted using a randomized complete block design (RCBD), with each experimental unit comprising five pots .

The findings were processed with SAS software and evaluated using Duncan's multiple range test at a 5% significance level for comparing treatment means [18 .[

The subsequent characteristics were examined :

Plant height (cm): The height of the plant was measured from the soil surface to the apex of the tallest branch in the pot utilizing a measuring tape .

The total number of leaves per plant was calculated, and the average was determined .

The leaf area (leaf/plant-1) was quantified using the gravimetric approach as described by [19 .[

The spread area of the plant (cm) was determined by measuring the distance between the two most distant spots with a measuring tape after the inflorescences had fully opened in multiple directions, and the average value was recorded [20.[

The wet and dry weights of the shoot and root systems (g) were quantified as described in [21]. The number of inflorescences per plant was determined by tallying the total count of inflorescences at full bloom .

The inflorescence diameter (cm) was measured for five plants using a digital vernier, determining the distance between the two most distant locations, followed by the calculation of the average .

The age of blooming (in days) was determined by counting the days from the emergence of the first inflorescence to the wilting of two-thirds of the inflorescences. In other terms, almost 50% of the inflorescences in the pot exhibit color loss[22 . [

The duration till the initial inflorescence opens (in days) is determined by calculating the interval from the transplanting date to the emergence of the first inflorescence on the plant [23 .[

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Proportion of nitrogen, phosphorus, and potassium in foliage: The proportion of these factors was assessed as documented in [24,25,21 . [

Quantification of silicon in foliar tissue (mg/kg) Silicon was quantified using Atomic Absorption

Spectroscopy (AAS) as per [26]. The chlorophyll content in fresh leaves was quantified utilizing the technique established by [27.[

Results and discussion

The data presented in Table (2) indicate that the pinching treatment had a beneficial impact on the vegetative and root growth characteristics of the plant. The mean plant height rose to 18.56 cm, in contrast to 15.69 cm without pinching. The area of spread expanded to 21.62 cm, the leaf count reached 174.63, and the leaf area amounted to 153.96 cm². The vegetative mass percentage rose to 24.029%, while the root mass climbed to 14.580%. The application of potassium silicate exhibited a distinct impact on the examined attributes. A dosage of 150 mg/kg elevated plant height to 18.25 cm, expanded the spreading area to 21.28 cm, increased the number of leaves to 172.48, and augmented the leaf area to 152.86 cm². The vegetative mass constituted 24.067%, while the root mass accounted for 14.477%, in contrast to the control treatment, which exhibited the lowest values .

The interaction between turfing and silicate concentrations was strong and distinctly observable in turfed plants treated with 150 mg/kg potassium silicate. The maximum measurements for plant height were 19.93 cm, the spread area was 23.00 cm, the leaf count was 210.27, and the leaf area was 175.23 cm², indicating a synergistic interaction between the two treatments. The proportion of vegetative dry matter rose to 23.853%, whereas the proportion of root dry matter increased to 14.383%. Moreover, the data indicates that the interaction between the absence of turfing and potassium silicate concentrations exerted a substantial effect, though to a lesser extent than the turfing treatment. This suggests that potassium silicate significantly influences plant development, particularly when used in conjunction with pricking. Unpricked plants treated with 150 mg/kg of potassium silicate exhibited enhanced characteristics. Pricking demonstrated a substantial impact on enhancing vegetative development characteristics of plants, including height, leaf count, leaf area, and dry matter percentage. This phenomenon is ascribed to the disruption of apical dominance due to the excision of the developing tip, which facilitates the development of lateral buds and enhances photosynthetic efficiency [28,29[

Pruning has demonstrated a substantial impact on enhancing vegetative growth characteristics in plants, including height, leaf count, leaf area, and dry matter percentage. This phenomenon is ascribed to the disruption of apical dominance following the excision of the developing tip, which promotes the development of lateral buds and enhances photosynthetic efficiency due to the expanded active leaf area [28; 29]. Pruning influences metabolic processes by reallocating carbon and energy resources within the plant, channelling these resources towards lateral and vegetative growth, hence augmenting the synthesis of proteins and sugars in the developing regions. Unexpectedly, the combination of pruning and potassium silicate enhanced plant height, despite pruning alone typically resulting in a relative reduction in vertical growth. This difference is ascribed to the beneficial interaction between silicon and potassium found in potassium silicate. Silicon functions as a biostimulant that boosts photosynthetic efficiency, improves cell membrane stability, facilitates nutrient absorption, and mitigates the impacts of abiotic stressors, including drought and salinity [30.[

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Potassium is an essential element in metabolic activities, facilitating the activation of over 60 enzymes in plant cells, especially those involved in protein synthesis, stomatal regulation, and glucose transport. This augments ATP production and elevates the rates of photosynthesis and cellular respiration [31]. It was noted that elevated concentrations of potassium silicate resulted in a progressive enhancement of growth parameters, indicating its contribution to cell wall development (via silicon deposition in epidermal and vascular tissues), increased root pliability, and improved water and nutrient utilisation in plants [32; 33]. The interplay between Pruning and silicate applications exhibited a distinct cumulative effect, with the combined treatment (Pruning + 150 mg/kg silicate) yielding the highest values for all examined traits, thereby affirming the complementarity of the physiological and metabolic effects derived from both treatments, in terms of promoting growth and enhancing metabolism .

Table (2) The effect of pruning and treatment with potassium silicate on the vegetative and root growth characteristics of the Chrysanthemum plant.

Pruning	potassium silicate	Plant Height (cm)	Plant Spread Area (cm)	Number of Leaves (leaf per plant)	Leaf Area (cm2)	Percentage of Dry Matter of the Leaf System (%)	Percentage of Dry Matter of the Root System (%)
No-pruning	0 mg kg	14.75 g	12.83 f	88.70 g	98.40 f	22.693 b	13.885 c
	50 mg kg	15.50 fg	16.62 e	112.03 f	110.48 e	24.045 ab	14.340 b
	100 mg kg	15.95 ef	18.07 e	118.37 ef	127.11 d	24.117 ab	14.542 ab
	150 mg kg	16.57 de	19.55 d	134.70 de	130.50 d	24.280 ab	14.570 ab
Pruning	0 mg kg	17.45 cd	20.03 cd	148.43 cd	137.52 cd	23.687 ab	14.627 ab
	50 mg kg	18.16 bc	21.13 bc	157.70 c	146.22 c	23.498 ab	14.747 a
	100 mg kg	18.70 b	22.30 ab	182.10 b	156.86 b	25.077 a	14.565 ab
	150 mg kg	19.93 a	23.00 a	210.27 a	175.23 a	23.853 ab	14.383 ab
Average Pruning	No-pruning	15.69 b	16.77 b	113.45 b	116.62 b	23.784 b	14.334 b
	Pruning	18.56 a	21.62 a	174.63 a	153.96 a	24.029 a	14.580 a
average potassium silicate	0 mg kg	16.10 c	16.43 d	118.57 d	117.96 d	23.190 b	14.256 b
	50 mg kg	16.83 b	18.88 c	134.87 c	128.35 c	23.772 ab	14.543 a
	100 mg kg	17.33 b	20.18 b	150.23 b	141.99 b	24.597 a	14.553 a
	150 mg kg	18.25 a	21.28 a	172.48 a	152.86 a	24.067 ab	14.477 ab

*Values with similar letters for each individual factor or their interactions are not significantly different from each other according to Duncan's multiple range test at the 5% probability level.

Table (3) demonstrates that the pruning treatment resulted in a notable enhancement of floral features relative to the non-pruning treatment. This encompassed an increase in inflorescence quantity, inflorescence diameter, and flowering age, while concurrently decreasing the duration necessary for the initial inflorescence to bloom. The count of inflorescences in trimmed plants was 39.60, in contrast to 32.37 in unpruned plants. The

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inflorescence diameter rose from 50.23 mm to 53.43 mm, and the flowering age extended from 58.53 to 62.82 days, indicating that pruning enhances branching and floral growth. Potassium silicate concentrations shown a progressive impact on enhancing floral features. The quantity of inflorescences rose with higher concentrations, attaining 39.28 inflorescences at a dose of 150 mg/kg. The inflorescence diameter rose to 53.71 mm, while the duration of staminate phase prolonged to 62.47 days. Simultaneously, the duration for the initial inflorescence to emerge diminished from 134.32 days at zero concentration to 138.07 days at the maximum concentration. The interaction between staminate and potassium silicate concentrations was considerable, resulting in notable enhancements in floral features, especially in staminate plants treated with 150 mg/kg. This treatment resulted in the biggest quantity of inflorescences, totaling 43.53, the greatest inflorescence diameter at 55.76 mm, the duration until the first inflorescence opening at 140.47 days, and a staminate age of 64.70 days. Conversely, the interaction between the absence of fertilization and silicate concentrations demonstrated an enhancement in characteristics, albeit to a lesser degree than the interaction involving fertilization. The quantity of inflorescences and their diameter augmented without fertilization at a concentration of 150 mg/kg, demonstrating that potassium silicate fertilization enhances floral development even in the lack of fertilization. The study results indicated that pruning markedly enhanced the plant's floral attributes, augmenting the quantity of inflorescences, inflorescence width, and inflorescence longevity, while reducing the duration needed for the initial inflorescence to bloom. This enhancement is ascribed to the impact of pruning in reallocating metabolic chemicals and resources from the apical meristem to the lateral buds, hence more efficiently promoting the growth and development of flower buds. Pruning diminishes hormonal competition, particularly auxins, from the apical meristem, hence promoting flower development in the lateral growth regions [34]. This physiological change is correlated with heightened activity of enzymes that facilitate the synthesis of phytohormones, including gibberellins and cytokinins, which enhance flower growth.

The results indicated that potassium silicate positively influences inflorescence production, enhances inflorescence diameter, accelerates blooming time, and extends floral longevity. This can be elucidated by silicon's function in enhancing metabolic processes related to blooming, fortifying cell walls, augmenting photosynthetic efficiency, and controlling water balance. This enhances plant physiological nourishment throughout essential flowering phases. Moreover, silicon improves plant resilience to both biotic and abiotic stimuli, hence ensuring a steady physiological environment for floral development [35.[

The integration of pruning and potassium silicate at a dose of 150 mg/kg produced optimal outcomes for all floral characteristics, demonstrating a significant synergistic effect between the two variables. The cumulative effect results from the physiological complementarity between pruning-induced floral branching stimulation and the essential role of potassium silicate in enhancing the plant's metabolic environment. Consequently, the combined application of pruning and silica is advocated as a component of contemporary agricultural management practices to enhance both the quality and quantity of flowers in economically significant potted plants .

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Table (3) Effect of pruning and treatment with potassium silicate on flower growth characteristics

Pruning	potassium silicate	Number of inflorescences (plant inflorescence)	Inflorescence diameter (mm)	Number of days until first inflorescence opens (days)	Coordination age (days)
No-pruning	0 mg kg	29.37 f	48.02 d	132.27 f	56.83 f
	50 mg kg	31.27 f	50.01 cd	133.60 e	57.73 ef
	100 mg kg	33.80 e	51.21 bc	134.63 de	59.33 de
	150 mg kg	35.03 de	51.67 bc	135.67 cd	60.23 cd
Pruning	0 mg kg	36.67 cd	51.94 bc	136.37 c	61.13 cd
	50 mg kg	38.60 bc	52.61 b	137.60 b	61.73 bc
	100 mg kg	39.57 b	53.42 b	138.73 b	63.70 ab
	150 mg kg	43.53 a	55.76 a	140.47 a	64.70 a
Average Pruning	No-pruning	32.37 b	50.23 b	134.04 b	58.53 b
	Pruning	39.60 a	53.43 a	138.29 a	62.82 a
average potassium silicate	0 mg kg	33.02 c	49.98 c	134.32 d	58.98 b
	50 mg kg	34.93 b	51.31 bc	135.60 c	59.73 b
	100 mg kg	36.68 b	52.32 ab	136.68 b	61.52 a
	150 mg kg	39.28 a	53.71 a	138.07 a	62.47 a

*Values with similar letters for each individual factor or their interactions are not significantly different from each other according to Duncan's multiple range test at the 5% probability level.

Table (4) indicates that the pruning treatment resulted in a substantial enhancement of leaf nutrition and chlorophyll content, in contrast to the no-pruning condition. Nitrogen concentration rose from 1.627% to 1.677%, phosphorus from 0.594% to 0.638%, and potassium from 1.564% to 1.684%. The silicon uptake by the leaves rose from 0.432 mg/kg to 0.554 mg/kg, while chlorophyll content elevated from 1.660 to 1.964 mg/100g. Potassium silicate concentrations have demonstrated efficacy in incrementally enhancing the levels of elements and chlorophyll, with the peak nitrogen concentration at 100 mg/kg, 1.898%, phosphorus at 0.642 mg/kg, potassium at 100 mg/kg, 1.765%, and silicon and chlorophyll at 150 mg/kg, 0.554 mg/kg and 1.876 mg/100 g, respectively. The interaction between pruning and potassium silicate concentrations was significant, yielding the highest values in pruned plants treated with 150 mg/kg, with nitrogen content at 2.048%, phosphorus at 0.645%, potassium at 1.844%, silicon at 0.584 mg/kg, and chlorophyll content at 2.034 mg/100 g. The interaction between the absence of pruning and varying amounts of potassium silicate demonstrated a notable enhancement, though to a smaller degree. Unpruned plants at 100 mg/kg exhibited nitrogen content of 1.947%, phosphorus content of 0.639%, potassium content of 2.047%, silicon content of 0.523%, and chlorophyll content of 1.879 mg/100 g .

The experimental results indicated that both pinching and potassium silicate concentrations significantly influenced the majority of the examined features in Dawoodi plants, either independently or through their interaction .

The findings indicated that pinching enhanced the leaf concentrations of macronutrients

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(nitrogen, phosphorus, potassium) and micronutrients, particularly silicon, alongside a notable rise in total chlorophyll content. This enhancement is ascribed to heightened metabolic and physiological activity in constrained plants due to the disruption of apical dominance. This promotes lateral bud development and expands leaf area, thereby improving the efficacy of water and nutrient uptake from the soil[34]. Encouraging lateral growth increases the metabolic demand for nutrients, hence enhancing the leaf content of critical elements necessary for crucial functions.

Conversely, potassium silicate effectively increased the concentration of these elements, especially potassium and silicon, as it serves as a direct source of them. Furthermore, silicon enhances the effectiveness of root nutrient absorption by altering their shape and promoting the development of root hairs, so augmenting the plant's capacity to utilise soil-derived nutrients [26]. Silicon improves nutrient availability in the plant by enhancing their transport and distribution across distinct tissues .

Besides its nutritional benefits, silicon treatment has shown a definitive impact on enhancing plant physiology, especially under conditions of environmental stress. The treatment diminished water loss by modulating stomatal aperture, enhancing proline accumulation, and augmenting chlorophyll content, all of which are recognised indications of enhanced plant resilience to drought and thermal stress [36; 37]. This results from the development of a gelatinous silica layer linked to cell walls, which increases plant tissue rigidity and diminishes transpiration, hence enhancing water efficiency and production [38]. The integrated treatments (pinching + potassium silicate) exhibited the greatest values in the examined chemical parameters, especially in chlorophyll and macronutrient levels, which directly corresponded to the enhanced vegetative development and blooming resulting from these treatments. This is elucidated by the physiological integration between the transfer of metabolic resources due to pinching and the essential functions of silicon and potassium in facilitating fundamental biological activities.

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Table (4) The effect of pruning and treatment with potassium silicate on the leaf content of nutrients and plant pigment (chlorophyll(

Pruning	potassium silicate	Chlorophyll (mg/kg)	N%	P%	K%	Si%
No-pruning	0 mg kg	1.507 d	1.439 f	0.578 d	1.248 c	0.365 e
	50 mg kg	1.537 d	1.778 d	0.578 d	1.542 b	0.429 c
	100 mg kg	1.879 b	1.947 b	0.581 d	2.047 a	0.410 d
	150 mg kg	1.717 c	1.343 g	0.639 b	1.419 bc	0.523 b
Pruning	0 mg kg	1.909 b	1.281 h	0.603 c	1.565 b	0.523 b
	50 mg kg	2.066 a	1.528 e	0.669 a	1.844 a	0.530 b
	100 mg kg	1.848 b	1.849 c	0.635 b	1.484 b	0.579 a
	150 mg kg	2.034 a	2.048 a	0.645 b	1.844 a	0.584 a
Average Pruning	No-pruning	1.660 b	1.627 b	0.594 b	1.564 b	0.432 b
	Pruning	1.964 a	1.677 a	0.638 a	1.684 a	0.554 a
average potassium silicate	0 mg kg	1.708 c	1.360 d	0.590 d	1.407 b	0.444 d
	50 mg kg	1.802 b	1.653 c	0.624 b	1.693 a	0.479 c
	100 mg kg	1.864 a	1.898 a	0.608 c	1.765 a	0.495 b
	150 mg kg	1.876 a	1.695 b	0.642 a	1.631 a	0.554 a

*Values with similar letters for each individual factor or their interactions are not significantly different from each other according to Duncan's multiple range test at the 5% probability level.

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