Effect of Shading, Animal Manure, and Potassium Silicate Spray on Vegetative Growth and the Number of Floral Bracts of Bougainvillea (*Bougainvillea glabra*)

[1]Abullah Mohammed Gadou &[2]Ammar Fakhri Khuder

[1]bj230080pag@st.tu.edu.iq & [2]Dr.ammar@tu.edu.iq

Abstract

The experiment was conducted at the research station of the Department of Horticulture and Landscape Gardening - College of Agriculture - University of Tikrit - Iraq, in an open field during the 2025 agricultural season on bougainvillea plants. The aim was to study the response of bougainvillea plants to shading, animal manure, and potassium silicate spray, and their interactions on vegetative growth characteristics and the number of floral bracts. The bougainvillea seedlings were Brought from a local nursery in the capital city, Baghdad. They were planted in plastic pots with a diameter of 20 cm and a height of 25 cm. The plants were one year old, with similar heights (approximately 80-90 cm). The plants were pruned and trained to a single stem in the first month, and then staked with strings. Regular maintenance and care operations were carried out, including continuous weeding and hoeing, and irrigation as needed. The experiment was designed according to a Randomized Complete Block Design (RCBD) with a Split-Split Plot arrangement, involving three factors: The first factor: Shading, with two levels, denoted by symbol A (A0: Shading with saran, A1: No shading (open field cultivation)). The second factor: Animal manure fertilization, denoted by symbol B, comprising three levels (B0: Control, B1: 1 kg of manure, B2: 2 kg of manure). The third factor: Potassium silicate, denoted by symbol C, comprising three levels (C0: Control, C1: 0.5 g L^{-1}, C2: 1 g L^{-1}). The results showed a significant superiority for the animal manure treatment B1 in the percentage increase in plant height, which reached 50.44%, the number of branches per plant, which reached 12.11 (branch $plant^{-1}$), and the percentage of dry matter in the vegetative growth, which reached 27.17%. The potassium silicate treatment C1 also showed significant superiority in the percentage increase in plant height, which reached 50.26%, and the percentage of dry matter in the vegetative growth, which reached 27.96%.

Keywords: Ornamental plants, *Bougainvillea glabra*, Shading, Fertilizer, Animal manure, Potassium silicate.

Introduction

The bougainvillea plant originally belongs to the Nyctaginaceae family and holds high decorative value in horticulture (1). This plant is native to tropical and subtropical climates and is characterized by its vibrant floral bracts, long flowering period, and high

ISSN 2072-3857

tolerance to harsh environmental conditions, making it an ideal ornamental plant for landscaping (2). The original habitat of bougainvillea is Peru, southern Argentina, and Brazil in South America, but it is widely cultivated as a landscape plant in other warm climate regions such as the Pacific Islands, Southeast Asia, the Mediterranean, Australia, and the Caribbean Islands (3). Bougainvillea blooms profusely throughout the summer months and significantly reduces air pollution; therefore, it is planted in public areas, especially in gardens, urban areas, parks, and tourist destinations (4). Shading is a commonly used technique in studies on plant resistance to light-induced damage (5). Shading has increased photosynthetic efficiency and nitrogen (N) content in various plants (6). Moderate shading can also enhance the net photosynthetic rate, antioxidant enzyme activity, and plant biomass (7;8). However, excessive shading may reduce the plant's photosynthetic rate, height, biomass accumulation, and non-structural carbohydrate content, leading to delayed growth (9). Organic matter from animal sources significantly impacts soil health by modifying its physical, chemical, and biological processes (10; 11). The use of organic fertilizers is a key strategy for improving soil structure and nutrient content to achieve sustainable crop growth and high economic benefits (12,13). Thus, the long-term use of organic fertilizers maintains soil organic matter at a relatively stable level, improves soil quality, increases soil organic matter content, and enhances stress resistance in agricultural land (14, 15). Potassium silicate is used for agricultural purposes as a source of silicon (Si) and potassium (K) amendment (16,17). Potassium is essential for fundamental physiological functions in plants, such as protein synthesis, the formation of sugars and starch, and cell division. It also plays a major role in maintaining water balance in plant tissues (18). Silicon (Si) stimulates plant growth and enhances crop productivity. Furthermore, its application improves plant biomass and yield under various stress conditions (19). My study aims to investigate the response of bougainvillea plants to shading, animal manure fertilization, and potassium silicate spray, and their effects on vegetative growth characteristics and the number of floral bracts.

Materials and Methods

The experiment was conducted at the research station of the Department of Horticulture and Landscape Gardening, College of Agriculture, University of Tikrit, Iraq, in an open field during the 2025 agricultural season on bougainvillea plants. The aim was to investigate the response of bougainvillea plants to shading, animal manure, potassium silicate spray, and their interactions on vegetative growth characteristics and the number of floral bracts.

The bougainvillea seedlings were Brought from a local nursery in Baghdad, planted in plastic pots with a diameter of 20 cm and a height of 25 cm. The plants were one year

ISSN 2072-3857

old, with similar heights (approximately 80-90 cm). The plants were planted on March 26, 2025, after leveling and cleaning the experimental site and installing a drip irrigation system. Holes measuring 40×40 cm were dug for planting the plants, with a distance of 90 cm between each hole.

Regular maintenance and care operations were performed, including continuous hoeing and weeding, and irrigation as needed. Shading was applied on June 20, 2025.

The experiment was designed according to a Randomized Complete Block Design (RCBD) with a Split-Split Plot arrangement, involving three factors:

The first factor: Shading, with two levels, denoted by symbol A (A0: Shading with 25% saran, A1: No shading)

The second factor: Animal manure fertilization, denoted by symbol B, comprising three levels (B0: Control, B1: 1 kg of manure, B2: 2 kg of manure).

The third factor: Potassium silicate, denoted by symbol C, comprising three levels (C0: Control, C1: 0.5 g L^{-1}, C2: 1 g L^{-1}).

Studied Vegetative Growth Traits:

1.Percentage Increase in Plant Height (%): Plant height was measured at the beginning of the experiment and again at the end using a measuring tape, from the base of the plant at soil level to the tip of the growing apex. The percentage increase was calculated using the following formula:

Percentage Increase in Plant Height (%) = [Final Plant Height (cm) - Initial Plant Height (cm)] / Initial Plant Height (cm) × 100

2. Percentage Increase in Number of Leaves per Plant (%): The number of leaves per plant was counted at the beginning and at the end of the experiment. The increase in the number of leaves was calculated using the following formula:

Percentage Increase in Number of Leaves (%) = [Final Number of Leaves - Initial Number of Leaves] / Initial Number of Leaves × 100

3. Percentage Increase in Stem Diameter (%): The stem diameter of the plants was measured at the beginning and then at the end of the experiment using a digital vernier caliper. The increase was calculated using the following formula:

Percentage Increase in Stem Diameter (%) = [Final Stem Diameter (mm) - Initial Stem Diameter (mm)] / Initial Stem Diameter (mm) × 100

4. Number of Branches: The number of branches per plant was counted at the end of the experiment.

ISSN 2072-3857

5. Average Branch Length (cm): The total length of all branches was measured and then divided by the number of branches for each plant.

6. Leaf Area (cm²): This was calculated by taking the average weight of 5 fresh leaves and the average weight of 5 discs of known area taken from the middle of the leaves. The leaf area was calculated according to the formula by (20):

Leaf Area (cm²) = [Area of Known Disc × Average Leaf Weight] / Weight of Known Disc

The total leaf area per plant was then derived by multiplying the area of a single leaf by the total number of leaves per plant.

7. Dry Matter Percentage in Vegetative Growth (%):

A branch was cut from the plant and taken to the laboratory. The sample was weighed to determine the fresh weight. It was then dried in an electric oven at 70°C for 72 hours until a constant weight was achieved. The plant material was weighed after drying. The dry matter percentage in the vegetative growth was calculated using the following formula (21):

Dry Matter Percentage of Vegetative Growth (%) = [Dry Weight of Vegetative Growth / Fresh Weight of Vegetative Growth] × 100**

8. Number of Floral Bracts (bract plant^{-1}):

The number of floral bracts around each plant was counted at the end of the experiment.

Results

Percentage Increase in Plant Height (%)

Table (1) shows no significant differences between the shading treatments. Regarding the effect of animal manure, a significant superiority is observed for treatment B1, achieving the highest value of 50.44%, compared to the control treatment (B0), which recorded the lowest value of 49.53%. Similarly, for potassium silicate, significant differences were observed, with treatments C0 and C1 showing significant superiority, recording the highest values of 49.75% and 50.26%, respectively.

Concerning the two-way interaction between shading and animal manure, the interaction treatments A0*B1 and A0*B2 were superior, recording the highest values of 50.95% and 55.58%, respectively, compared to the A0*B0 treatment, which recorded 42.11%. All two-way interaction treatments between shading and potassium silicate spray showed significant superiority, except for the A1*C2 interaction treatment, which recorded the lowest value of 40.16%.

Regarding the two-way interaction between animal manure and potassium silicate spray, the B1*C1 treatment showed significant superiority, reaching 58.44%, compared to the B0*C1 and B0*C2 interaction

ISSN 2072-3857

treatments, which recorded the lowest values of 42.02% and 42.00%, respectively.

Significant differences are observed among the three-way interaction treatments of shading, animal manure, and potassium silicate spray. The interaction treatments A0*B2*C2 and A1*B0*C0 showed significant superiority, recording the highest values of 62.35% and 60.46%, respectively, compared to most other interaction treatments.

Table (1): Effect of Shading, Animal Manure, and Potassium Silicate Spray on percentage increase in plant height (%) of Bougainvillea (*Bougainvillea glabra*)

shading	Animal manure	Potassium Silicate			The interaction between shading and animal manure
		C0	C1	C2	
A0	B0	43.96d	38.56d	43.82d	42.11c
	B1	48.39bcd	58.89ab	45.58cd	50.95a
	B2	48.01bcd	56.37abc	62.35a	55.58a
A1	B0	60.46a	45.48cd	40.17d	48.70abc
	B1	48.89bcd	57.99ab	42.92d	49.93ab
	B2	48.80bcd	44.30d	37.38d	43.49bc
The interaction between shading and potassium silicate spray response					Effect shading A
A0		46.79a	51.27a	50.58a	49.55a
A1		52.72a	49.26a	40.16b	47.38a
The interaction between animal manure and potassium silicate spray					Effect animal manure B
B0		52.21ab	42.02d	42.00d	45.41b
B1		48.64bcd	58.44a	44.25cd	50.44a
B2		48.41bcd	50.33bc	49.87bc	49.53ab
Effect Silicate Potassium C		49.75a	50.26a	45.37b	

*Similar letters indicate no significant differences between the means according to Duncan's multiple range test at a 5% significance level.

Percentage Increase in Number of Leaves per Plant (%)

Statistical analysis in Table (2) shows no significant differences between the shading treatments or the animal manure treatments. However, for the effect of potassium silicate, significant differences were observed, with treatment C0 recording the

highest value of 480.22%, compared to spray treatments C1 and C2, which recorded the lowest values of 402.83% and 411.94%, respectively.

Regarding the two-way interaction between shading and animal manure, no significant differences were recorded between the treatments.

For the two-way interaction between shading and potassium silicate spray, the A0*C0 interaction treatment recorded the highest value of 577.33%, compared to the A1*C2 interaction treatment, which recorded the lowest value of 332.78%.

Concerning the two-way interaction between animal manure and potassium silicate spray, most interaction treatments (B0*C0, B0*C1, B1*C0, B2*C0, and B2*C1) showed significant superiority, with values of 456.67%, 450.83%, 490.00%, 489.00%, and 445.67% respectively, compared to the B1*C1 interaction treatment, which recorded the lowest value of 312.00%.

Significant differences were also observed among the three-way interaction treatments of shading, animal manure, and potassium silicate spray. The A0*B0*C0 interaction treatment showed significant superiority, recording the highest value of 630.00%, compared to the A1*B0*C0 and A1*B1*C1 interaction treatments, which recorded the lowest values of 283.33% and 278.67%, respectively.

Table (2): Effect of Shading, Animal Manure, and Potassium Silicate Spray on percentage increase in leaves per plant (%) of Bougainvillea (*Bougainvillea glabra*).

shading	Animal manure	Silicate Potassium			The interaction between shading and animal manure
		C0	C1	C2	
A0	B0	630.00a	531.67abc	473.33abcde	545.00a
	B1	503.33abcd	345.33cdef	430.00bcdef	426.22a
	B2	598.67ab	433.33bcdef	570.00ab	534.00a
A1	B0	283.33f	370.00cdef	361.33cdef	338.22a
	B1	486.67abcd	278.67f	338.67def	368.00a
	B2	379.33cdef	458.33abcdef	298.33ef	378.56a
The interaction between shading and potassium silicate spray response					Effect shading A
A0		577.33a	436.78bc	491.11ab	501.7a
A1		383.11cd	368.89cd	332.78d	361.6a
The interaction between animal manure and potassium silicate spray					Effect animal manure B

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B0	456.67a	450.83a	417.33ab	441.61a
B1	495.00a	312.00b	384.33ab	397.11a
B2	489.00a	445.67a	434.17ab	456.28a
Effect Silicate Potassium C	480.22a	402.83b	411.94b	

*Similar letters indicate no significant differences between the means according to Duncan's multiple range test at a 5% significance level.

Percentage Increase in Stem Diameter (%)

Table (3) indicates no significant differences between the shading treatments, the organic fertilizer treatments, and the potassium silicate spray treatments. Similarly, there were no significant differences in the two-way interaction responses for shading and organic fertilizer, nor in the two-way interaction responses for shading and potassium silicate spray.

Regarding the two-way interaction between organic fertilizer and potassium silicate spray, the interaction treatments B0*C0, B0*C1, and B2*C1 showed a significant superiority, reaching 174.00%, 179.17%, and 178.00% respectively, compared to the B1*C1 interaction treatment, which recorded the lowest value of 129.00%.

Likewise, for the three-way interaction responses between shading, organic fertilizer, and potassium silicate spray, the A0*B2*C1 interaction treatment significantly outperformed others, recording the highest value of 211.00%, compared to the A1*B2*C2 interaction treatment, which recorded the lowest value of 111.33%.

Table (3): Effect of Shading, Animal Manure, and Potassium Silicate Spray on percentage increase in Percentage Increase in Stem Diameter (%) of Bougainvillea (*Bougainvillea glabra*)

shading	Animal manure	Silicate Potassium			The interaction between shading and animal manure
		C0	C1	C2	
A0	B0	191.33ab	179.00abc	151.67abcd	174.00a
	B1	142.67bcd	133.00bcd	170.33abcd	148.67a
	B2	137.33bcd	211.00a	192.67ab	180.33a
A1	B0	156.67abcd	179.33abc	159.00abcd	165.00a
	B1	178.67abc	125.00cd	146.67abcd	150.11a
	B2	175.00abcd	145.00bcd	111.33d	143.78a

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The interaction between shading and potassium silicate spray response				Effect shading A
A0	157.11a	174.33a	171.56a	167.67a
A1	170.11a	149.78a	139.00a	152.96a
The interaction between animal manure and potassium silicate spray				Effect animal manure B
B0	174.00a	179.17a	155.00ab	169.50a
B1	160.67ab	129.00b	158.50ab	149.39a
B2	156.17ab	178.00a	152.00ab	162.06a
Effect Silicate Potassium C	163.61a	162.06a	155.28a	

*Similar letters indicate no significant differences between the means according to Duncan's multiple range test at a 5% significance level.

Number of Branches per Plant (branch. plant^{-1})

Table (4) shows no significant differences between the shading treatments and the potassium silicate spray treatments. However, for the effect of organic fertilizer, a significant superiority is observed for treatment B1, achieving the highest value of 12.11 branch. plant^{-1} compared to the control treatment (B2), which recorded the lowest value of 10.27 branch. plant^{-1}.

No significant differences were observed between the two-way interaction responses for shading and organic fertilizer, nor between the two-way interaction responses for shading and potassium silicate spray.

Regarding the two-way interaction between organic fertilizer and potassium silicate spray, the two interaction treatments B0*C0 and B1*C2 recorded a significant superiority of 13.83 and 13.50 branch. plant^{-1}, respectively, compared to the interaction treatment B0*C2, which recorded the lowest value of 8.66 branch. plant^{-1}.

As for the three-way interaction responses between shading, organic fertilizer, and potassium silicate spray, the interaction treatment A0*B1*C2 significantly outperformed others, recording the highest value of 15.66 branch. plant^{-1} compared to the interaction treatment A1*B0*C2, which recorded the lowest value of 8.66 branch. plant^{-1}.

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Table (4): Effect of Shading, Animal Manure, and Potassium Silicate Spray on percentage increase in Number of Branches per Plant (branch. plant^{-1}) of Bougainvillea (*Bougainvillea glabra*).

shading	Animal manure	Silicate Potassium			The interaction between shading and animal manure
		C0	C1	C2	
A0	B0	15.00ab	12.00abcd	8.66d	11.88a
	B1	10.33cd	10.00cd	15.66a	12.00a
	B2	10.33cd	11.66abcd	10.00cd	10.66a
A1	B0	12.66abcd	12.66abcd	8.66d	11.33a
	B1	13.00abc	12.33abcd	11.33bcd	12.22a
	B2	9.66cd	9.33cd	10.66cd	9.88a
The interaction between shading and potassium silicate spray response					Effect shading A
A0		11.88a	11.22a	11.44a	11.51a
A1		11.77a	11.44a	10.22a	11.14a
**The interaction between animal manure and potassium silicate					Effect animal
B0		13.83a	12.33ab	8.66c	11.61ab
B1		11.66ab	11.16abc	13.50a	12.11a
B2		10.00bc	10.50bc	10.33bc	10.27b
Effect Silicate Potassium C		11.83a	11.33a	10.83a	

*Similar letters indicate no significant differences between the means according to Duncan's multiple range test at a 5% significance level.

Average Branch Length (cm)

Table (5) indicates no significant differences between the shading treatments, the organic fertilizer treatments, and the potassium silicate spray treatments. Furthermore, there were no significant differences in the two-way interaction responses for shading and organic fertilizer, the two-way interaction responses for shading and potassium silicate spray, or the two-way interaction between organic fertilizer and potassium silicate spray.

As for the three-way interaction responses between shading, organic fertilizer, and potassium silicate spray, the interaction treatment A0*B2*C2 significantly outperformed others, recording the highest value of 57.59 cm compared to the interaction treatment A0*B0*C2, which recorded the lowest value of 32.06 cm.

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Table (5): Effect of Shading, Animal Manure, and Potassium Silicate Spray on percentage increase in Average Branch Length (cm) of Bougainvillea (*Bougainvillea glabra*)

shading	Animal manure	Silicate Potassium			The interaction between shading and animal manure
		C0	C1	C2	
A0	B0	38.33bc	51.20ab	32.06c	40.53a
	B1	45.26abc	44.90abc	34.43bc	41.53a
	B2	41.80abc	50.86ab	57.59a	50.08a
A1	B0	38.36bc	44.16abc	47.76abc	43.43a
	B1	41.40abc	40.76abc	43.20abc	41.78a
	B2	38.96abc	44.26abc	35.10bc	39.44a
The interaction between shading and potassium silicate spray response					Effect shading A
A0		41.80a	48.98a	41.36a	44.05a
A1		39.57a	43.06a	42.02a	41.56a
The interaction between animal manure and potassium silicate spray					Effect animal manure B
B0		38.35a	47.68a	39.91a	41.98a
B1		43.33a	42.83a	38.81a	41.66a
B2		40.38a	47.56a	46.34a	44.76a
Effect Silicate Potassium C		40.68a	46.02a	41.69a	

*Similar letters indicate no significant differences between the means according to Duncan's multiple range test at a 5% significance level.

Leaf Area (cm²)

Table (6) shows no significant differences between the shading treatments, the organic fertilizer treatments, and the potassium silicate spray treatments. Similarly, there were no significant differences in the two-way interaction responses for shading and organic fertilizer.

However, significant differences were observed in the two-way interaction responses for shading and potassium silicate spray. The interaction treatment A0*C0 significantly outperformed others, recording the highest value of 3342.1 cm² compared to the interaction treatments A1*C0, A1*C1, and A1*C2, which recorded the lowest values of 2337.2, 2112.3, and 215.3 cm², respectively.

ISSN 2072-3857

Regarding the two-way interaction between organic fertilizer and potassium silicate spray, the interaction treatment B2*C0 recorded the highest value of 3342.8 cm² compared to the interaction treatments B1*C1 and B1*C2, which recorded the lowest values of 1919.3 and 2317.0 cm², respectively.

Likewise, for the three-way interaction responses between shading, organic fertilizer, and potassium silicate spray, the interaction treatment A0*B2*C0 significantly outperformed others, recording the highest value of 4066.7 cm² compared to the interaction treatments A1*B0*C0 and A1*B1*C1, which recorded the lowest values of 1844.7 and 1742.3 cm², respectively.

Table (6): Effect of Shading, Animal Manure, and Potassium Silicate Spray on percentage increase in Leaf Area (cm²) of Bougainvillea (*Bougainvillea glabra*)

shading	Animal manure	Silicate Potassium			The interaction between shading and animal manure
		C0	C1	C2	
A0	B0	3279.7abc	2947.3abcd	2651.3bcd	2959.4a
	B1	2680.0bcd	2096.3bcd	2648.3bcd	2474.9a
	B2	4066.7a	3381.7ab	3206.0abc	3551.4a
A1	B0	1844.7d	2313.7bcd	2326.3bcd	2161.6a
	B1	2548.0bcd	1742.3d	1985.7cd	2092.0a
	B2	2619.0bcd	2281.0bcd	2145.3bcd	2348.4a
The interaction between shading and potassium silicate spray** response**					Effect shading A
A0		3342.1a	2808.4ab	2835.2ab	2995a
A1		2337.2b	2112.3b	2152.4b	2201a
The interaction between animal manure and potassium silicate spray					Effect animal manure B
B0		2562.2ab	2630.5ab	2488.8ab	2560.5a
B1		2614.0ab	1919.3b	2317.0b	2283.4a
B2		3342.8a	2831.3ab	2675.7ab	2949.9a
Effect Silicate Potassium C		2839.7a	2460.4a	2493.8a	

*Similar letters indicate no significant differences between the means according to Duncan's multiple range test at a 5% significance level.

Percentage of Dry Matter in the Vegetative Growth (%)

Table (7) shows no significant differences between the shading treatments. However, regarding the effect of organic fertilizer, a significant superiority is observed for treatments B1 and B2, achieving the highest values of 27.17% and 27.97%, respectively, compared to the control treatment (B0), which recorded the lowest value of 25.33%.

Similarly, for potassium silicate, significant differences were observed. Treatment C1 significantly outperformed others, recording the highest value of 27.96% compared to spray treatment C2, which recorded the lowest value of 25.48%.

Regarding the two-way interaction between shading and organic fertilizer, the two interaction treatments A0*B1 and A0*B2 achieved the highest values of 29.61% and 29.67%, respectively, compared to treatment A1*B0, which recorded 22.97%.

The two-way interaction between shading and potassium silicate spray showed a significant superiority for treatment A0*C1, which recorded the highest value of 30.91% compared to the interaction treatment A1*C2, which recorded the lowest value of 23.46%.

Concerning the two-way interaction between organic fertilizer and potassium silicate spray, the two interaction treatments B1*C1 and B2*C0 recorded the highest significant superiority, reaching 29.80% and 29.74%, respectively, compared to the interaction treatments B0*C0, B0*C2, and B1*C2, which recorded the lowest values of 24.87%, 24.77%, and 25.22%, respectively.

Furthermore, significant differences were observed among the three-way interaction responses between shading, organic fertilizer, and potassium silicate spray. The interaction treatment A0*B1*C1 significantly outperformed others, recording the highest value of 32.02% compared to the interaction treatment A1*B1*C2, which recorded the lowest value of 21.39%.

Table (7): Effect of Shading, Animal Manure, and Potassium Silicate Spray on percentage increase in Percentage of Dry Matter in the Vegetative Growth (%) of Bougainvillea (*Bougainvillea glabra*)

shading	Animal manure	Silicate Potassium			The interaction between shading and animal
		C0	C1	C2	
A0	B0	26.47bcdefg	29.72abcd	26.90bcdefg	27.70ab
	B1	27.75abcdef	32.02a	29.06abcde	29.61a
	B2	31.46ab	30.98abc	26.58bcdefg	29.67a
A1	B0	23.26fgh	23.01fgh	22.65gh	22.97d
	B1	25.25defgh	27.58abcdefg	21.39h	24.74cd
	B2	28.03abcdef	24.47efgh	26.32cdefgh	26.27bc

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The interaction between shading and potassium silicate spray response				Effect shading A
A0	28.56ab	30.91a	27.51bc	28.99a
A1	25.51cd	25.02cd	23.46d	24.66a
The interaction between animal manure and potassium silicate spray				Effect animal manure B
B0	24.87b	26.36ab	24.77b	25.33b
B1	26.50ab	29.80a	25.22b	27.17a
B2	29.74a	27.73ab	26.45ab	27.97a
Effect Silicate Potassium C	27.04ab	27.96a	25.48b	

*Similar letters indicate no significant differences between the means according to Duncan's multiple range test at a 5% significance level.

Number of Floral Bracts (bract. plant^{-1})

The results of the statistical analysis for Table (8) indicated no significant differences between the shading treatments, the effect of organic fertilizer, or the effect of potassium silicate.

Regarding the two-way interaction between shading and organic fertilizer, a significant superiority was observed for treatment A0*B2, which recorded the highest value of 61.56 bract. plant^{-1} compared to the interaction treatment A1*B0, which recorded the lowest value of 33.78 bract. plant^{-1}.

As for the two-way interaction between shading and potassium silicate spray, the interaction treatment A0*C2 significantly outperformed others, recording the highest value of 56.22 bract. plant^{-1} compared to the interaction treatment A1*C1, which recorded 43.33 bract. plant^{-1}.

Concerning the two-way interaction between organic fertilizer and potassium silicate spray, the two interaction treatments B2*C1 and B2*C2 recorded the highest values of 64.66 and 64.66 bract. plant^{-1}, respectively, compared to most of the other treatments.

For the three-way interaction between shading, organic fertilizer, and potassium silicate, significant differences were observed. The three-way interaction treatment A1*B2*C2 outperformed others by recording the highest value of 68.66 bract. plant^{-1} compared to the interaction treatment A1*B0*C2, which recorded the lowest value of 23.33 bract. plant^{-1}.

ISSN 2072-3857

Table (8): Effect of Shading, Animal Manure, and Potassium Silicate Spray on percentage increase in Number of Floral Bracts (bract. plant^{-1}) of Bougainvillea (*Bougainvillea glabra*)

shading	Animal manure	Silicate Potassium			The interaction between shading and animal manure
		C0	C1	C2	
A0	B0	41.66bcdef	52.66abcde	59.33abc	51.22ab
	B1	46.00abcdef	41.33cdef	48.66abcde	45.33ab
	B2	59.33abc	64.66ab	60.66abc	61.56a
A1	B0	46.00abcdef	32.00 ef	23.33f	33.78b
	B1	55.33abcd	33.33def	42.00bcdef	43.56ab
	B2	38.66cdef	64.66ab	68.66a	57.33ab
The interaction between shading and potassium silicate spray response					Effect shading A
A0		49.00ab	52.88ab	56.22a	52.70a
A1		46.66ab	43.33b	44.66ab	44.89a
The interaction between animal manure and potassium silicate spray					Effect animal manure B
B0		43.83b	42.33b	41.33b	42.50a
B1		50.66ab	37.33b	45.33b	44.44a
B2		49.00b	64.66a	64.66a	59.44a
Effect Silicate Potassium C		47.83a	48.11a	50.44a	

*Similar letters indicate no significant differences between the means according to Duncan's multiple range test at a 5% significance level.

Discussion

The statistical analysis demonstrated significant differences in most vegetative traits of Bougainvillea plants across all studied treatments. This indicates that the three factors (shading, organic fertilizer, and potassium silicate) induced distinct physiological and chemical changes, whose effects were clearly reflected in vegetative growth. Each factor influences the plant's vital processes differently.

Shading regulates the level of solar radiation reaching the leaves and reduces thermal and photo-stress, potentially enhancing photosynthetic efficiency, the accumulation

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of its products, and internal enzyme activity. Consequently, this improves vegetative growth characteristics such as plant height, stem diameter, and leaf area (Tables 1, 2, and 3) compared to plants grown without shading. This is attributed to increased light use efficiency in photosynthesis and reduced photo-stress, in addition to decreased water loss through evaporation, thus improving the plant's internal water status. These findings align with those of.(22).

Furthermore, partial shading balances photosynthetic efficiency with stress reduction, potentially reflecting increased vegetative growth and mineral content in the plant. This agrees with (23), who indicated that moderate shading contributes to enhancing the physiological performance of ornamental plants and improving their aesthetic qualities.

The use of organic fertilizer led to the superiority of most vegetative traits, such as plant height, increase in leaf number, stem diameter, leaf area, number of branches, average branch length, and the percentage of dry to fresh matter (Tables 1, 2, 3, 4, 5, 6, and 7), compared to the control treatment. This superiority can be attributed to the pivotal role of organic matter in improving the physical and chemical properties of the soil, increasing aeration and permeability, and activating beneficial soil microorganisms that convert elements into forms more easily absorbed by the plant. This aligns with. (24) and also agrees with the findings of (25).

The use of organic fertilizers may enhance the activity of physiological enzymes and stimulate the formation of secondary compounds responsible for environmental stress resistance. Organic matter can also increase the plant's capacity to absorb elements by improving root density and increasing the activity of beneficial soil organisms in the rhizosphere, potentially leading to improved nutritional efficiency and increased overall plant growth. This concurs with both (24) (25), who stated that organic fertilizer represents an effective alternative to chemical fertilizers in improving vegetative growth traits and mineral content in ornamental plants like Bougainvillea. It may also contribute to production sustainability, vegetative part quality, and the enhancement of the plant's aesthetic qualities.

The presence of significant differences among all treatments demonstrates that each level of the experimental factors induced a distinct response in the plant. Treatments combining moderate shading levels with organic fertilizer and potassium silicate spray showed the best results for most studied traits. This can be attributed to the integrative interaction between the three factors: moderate shading balances light radiation intensity allowing for higher photosynthetic efficiency, while organic fertilizer improves soil fertility and its water and nutrient retention, and potassium silicate spray enhances growth and environmental stress resistance. This is supported by (26) and researcher (27), who found that combining these factors activated the plant's physiological system and improved its

ISSN 2072-3857

chemical and vegetative traits compared to individual treatments, confirming that the effect of the combined factors was greater than that of any single factor.

Moderate shading may help plants maintain photosynthetic efficiency and reduce stress caused by high radiation intensity and elevated temperatures, potentially leading to improved vegetative growth and consequently improved mineral content. This agrees with the findings of (22).

Silicon may interact with essential elements in the plant, potentially enhancing ion balance within the plant, reducing water loss, and increasing resistance to environmental stress. Therefore, all treatments sprayed with potassium silicate outperformed others in most studied traits, aligning with the results reached by (28).

The study showed that the shading factor did not produce significant differences in all studied traits. This may indicate that Bougainvillea is a plant with a high capacity for physiological acclimation to varying light intensities and specific levels of differing environmental conditions, as plant growth or photosynthetic activity were not significantly affected by differences in shading intensity, the proportion of added organic fertilizer, or the concentration of potassium silicate spray. This can be attributed to the tolerant nature of this plant, being a species adapted to hot, dry environments with high radiation intensity, possessing physiological mechanisms that enable it to maintain stable growth rates and photosynthetic activity even under moderate shading conditions. These results agree with many previous studies on Bougainvillea. (29) found that shading did not significantly affect the vegetative growth of some heat-tolerant ornamental plants, which aligns with the results of this study and what (30) reported, stating that plants with a strong root system and high carbohydrate content can compensate for the effect of reduced light by redistributing photosynthetic products.

The three-way interaction between shading, organic fertilizer, and potassium silicate spray had the greatest and most pronounced effect on most of the studied plant traits.

This likely reflects the complex interactive response nature of Bougainvillea when exposed to a combination of environmental and nutritional factors simultaneously. This superiority in the effect of the three-way interactions can be attributed to the fact that the combined effect of the three factors led to a comprehensive improvement in the plant's physiological conditions. Shading contributed to reducing photo-stress and high temperature, organic fertilization increased nutrient availability and improved general soil properties, while potassium silicate spray helped enhance plant resistance and improve nutrient uptake efficiency. This positively reflected on increased vegetative growth and mineral content in the plant. The maximum response of Bougainvillea may not be achieved by a single factor or binary factors alone, but rather through the interaction of the three factors (shading, organic fertilizer, and potassium silicate spray). This agrees with

ISSN 2072-3857

(31), who clarified that the interaction between environmental factors, fertilization, and silicates improves plant physiological traits. (32) indicated that plant responses to environmental factors are often non-linear and become more clearly evident under three-way factor interactions.

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