International Journal of Advanced Biochemistry Research 2026; SP-10(1): 784-789

International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(1): 784-789
www.biochemjournal.com
Received: 26-10-2025
Accepted: 29-11-2025

Chanchal Tiwari
Department of Horticulture, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Ranjan K Srivastava
Department of Horticulture, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

BD Bhuj
Department of Horticulture, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Satish Chand
Department of Horticulture, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Ajaya Srivastava
Department of Soil Science, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Gurdeep Bains
Department of Plant Physiology, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Ajay Kumar
Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Corresponding Author:
Chanchal Tiwari
Department of Horticulture, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Enhancing growth and flowering of tuberose (*Agave amica* Medik. cv. 'Mexican single') through integrated soil and foliar applications of silica oxide (SiO_2) under *tarai* conditions

Chanchal Tiwari, Ranjan K Srivastava, BD Bhuj, Satish Chand, Ajaya Srivastava, Gurdeep Bains and Ajay Kumar

DOI: https://www.doi.org/10.33545/26174693.2026.v10.i1Sj.7074

Abstract

A field experiment was conducted to evaluate the impact of silica oxide (SiO_2) applied through both soil and foliar routes on vegetative growth and floral traits of tuberose (*Agave amica* Medik. cv. 'Mexican Single'). Five soil applications of silica oxide (SiO_2) (0, 2.9, 5.9, 8.8, and 11.8 g/m²) with four foliar concentrations (0%, 1%, 2%, and 3%) were applied in a factorial randomized block design with three replications. Observations were recorded on vegetative parameters: leaf number, plant height, basal leaf length, and floral parameters: spike diameter, rachis length, and total number of florets per spike. Results showed that increasing SiO_2 levels in combinations significantly improved all vegetative and floral parameters. The highest values were recorded in the treatment combination of 8.8 g/m² soil + 3% foliar SiO_2. Statistical analysis confirmed highly significant interaction effects between soil and foliar Si levels on most traits. These findings suggest that the integrated application of SiO_2 can enhance the quality and productivity of tuberose flowers.

Keywords: Silica oxide, soil application, foliar spray, tuberose, vegetative growth, floral traits

Introduction

Tuberose (*Agave amica* Medik. also known as *Polianthes tuberosa* L.) is a prominent ornamental bulbous plant grown widely for its attractive, fragrant white flowers. It holds high economic value in the floriculture industry due to its uses as cut, loose flowers, landscaping and the extraction of essential oils (Shahzad *et al.*, 2022) [14]. However, its commercial productivity is often limited by poor soil fertility and abiotic stress factors, which affect its vegetative growth and flowering behaviour (Karimian *et al.*, 2021) [8].

Silicon (Si) is not classified as an essential plant nutrient but is considered a beneficial element, particularly for enhancing plant resilience against various stresses. When applied silicon contributes to improved cell wall integrity, water balance, nutrient uptake and photosynthetic efficiency (Ye *et al.*, 2023) [16]. Numerous studies have shown that Si plays a vital role in improving both vegetative and reproductive parameters in several crops, including ornamentals. It has been observed to enhance structural strength, spike quality, flower yield and resistance to diseases (Sattar *et al.*, 2019 and Al-Rahbi & Hasan, 2021) [13, 1].

Despite increasing interest in the application of Si in floriculture, limited research has been conducted on the combined effects of soil and foliar SiO_2 treatments on tuberose. Most previous studies have focused on different forms and methods of applications (Attia and Elhawat 2021 and Shahzad *et al.*, 2022) [3, 14]. The 'Mexican Single' being one of the important cultivar, known for its single row florets with good spike length and high market preference, may benefit from an integrated application approach.

The present study was designed to evaluate the influence of different levels of soil and foliar applied silica oxide on the vegetative growth and floral performance of tuberose under *tarai* climatic conditions. The aim was to determine the most effective combination for improving overall plant development and floral yield.

Materials and Methods

The field experiment was conducted during 2023-24 at the Model Floriculture Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The experimental site comprised sandy loam soil with good water retention and proper drainage. A Factorial Randomized Block Design (FRBD) was employed with three replications, incorporating two factors: soil and foliar application of silica oxide (SiO_2). The study included 20 treatment combinations resulting from five soil application levels (0, 2.9, 5.9, 8.8 and 11.8 g/m²) and four foliar concentrations at (0, 1, 2 and 3%).

The soil application of silica oxide was incorporated at the time of planting, while foliar sprays were applied at 30, 60 and 90 days after planting (DAP). Uniform and healthy bulbs of tuberose (*Agave amica* Medik.) cv. 'Mexican Single' were planted at a spacing of 25 × 25 cm. Standard agronomic practices, including irrigation, weed management and plant protection, were uniformly followed. Fertilizer was applied at the recommended NPK rate of 120:60:60 kg/ha using urea, single super phosphate and muriate of potash.

Data were recorded for key vegetative parameters: plant height, number of leaves and leaf length at 30, 60 and 90 DAP. Floral traits included the number of spikes per plant, Rachis length, number of florets per spike and spike diameter.

Statistical Analysis

The collected data were statistically analyzed using analysis of variance (ANOVA), suitable for factorial RBD. Treatment means were compared using the critical difference (CD) at a 5% level of significance. Software tools such as OPSTAT, R Studio and Microsoft Excel were used for calculations and data visualization.

Results

Number of leaves

The combined treatments of SiO_2, significantly improved leaf production at all stages. At 30 DAP, the greatest leaf count was 7.78 per plant in S_3F_2 (soil 8.8 g/m² + foliar 2% SiO_2), compared to just 6.02 leaves in the control S_0F_1 (0 g/m² + 1% SiO_2). At 60 DAP, the maximum (13.44) number of leaves was observed in S_3F_3, whereas the minimum (9.00 leaves) was in S_0F_1. By 90 DAP, S_4F_2 produced the highest number of leaves (32.33), with S_3F_3 (31.56) and S_2F_2 (31.11) closely following, while the lowest count (21.89) was recorded in S_1F_3. Overall, higher soil and foliar Si applications resulted in more leaves, with intermediate combinations approaching the top values.

Plant height

The plant height showed a steady increase with the application of SiO_2 treatments. At 30 DAP, the tallest plants (28.40 cm), observed in S_2F_3, followed by S_3F_2 (28.25) and S_4F_0 (27.92), while the shortest (21.28 cm) was recorded in S_2F_2. At 60 DAP, S_3F_0 produced the greatest height (31.30 cm), followed closely by S_3F_2 (30.10 cm), whereas the lowest height (24.00 cm) was observed in S_2F_2. At the 90 DAP, the maximum height (54.49 cm) was observed in S_4F_2, which was statistically at par with S_3F_3 (54.21 cm) and S_1F_1 (54.08 cm). Whereas the minimum height (47.47 cm) was observed in S_2F_0. The plants receiving the combination treatment of SiO_2, particularly S_3F_3 and S_4F_2, attained the greatest plant heights compared to controls, which remained shorter.

Leaf length

The application of SiO_2 influenced the leaf length at both early and mid-growth stages. At 30 DAP, the longest leaf length (22.71 cm) was observed in S_2F_3, significantly higher than the rest of the treatments and followed by S_4F_1 (20.31 cm) and S_3F_0 (20.31 cm), where the lowest leaf length was observed in S_2F_2 (14.56). At the 60 DAP stage, the longest leaf length values were recorded in S_3F_3 (35.88 cm), followed by S_3F_2 (35.21 cm), S_4F_4 (34.91 cm) and S_2F_1 (34.90 cm), which were close to the maximum value. The lowest leaf length was recorded in S_2F_0 (30.15 cm). These results indicate that intermediate soil application of Si (5.9-8.8 g/m²) combined with higher foliar applications favoured the leaf elongation, whereas low or excessive combinations yielded shorter leaf length.

Number of spikes per plant

The number of flower spikes per plant varied modestly among the treatments. The highest spike count (12.22 spikes/plant) was recorded in S_4F_4, with S_3F_3 (12.12 spikes) and S_4F_2 also nearly as high (12.11 spikes). The lowest count occurred in S_1F_0 (8.55 spikes). Most SiO_2-treated plots produced more spikes than the untreated and control ones (S_0F_0, 9.11 spikes). Overall, the higher soil rate (S_3 and S_4) with high foliar Si tended to maximise the spike production.

Spike diameter

Spike diameter increased with combined SiO_2 treatment. The largest mean spike diameter (8.75 mm) was recorded in S_2F_3, followed by S_2F_1 and S_2F_2 (8.70 mm, each). In contrast, the lowest spike diameter (7.72 mm) was observed in S_1F_2, followed by S_0F_0 (7.73 mm). Thus, the results showed that the higher soil and foliar SiO_2 combination application resulted in the thickest flower spikes, while control or other lower SiO_2 applications produced smaller spike diameters.

Rachis length

Silica oxide (SiO_2) combined applications also improved the rachis length. The maximum rachis length (30.00 cm) was recorded in S_3F_3, which was at par with S_4F_3 (29.90 cm) and S_1F_3 (29.68 cm). These values were found significantly greater than the shortest rachis length, which was recorded in S_1F_0 (26.32 cm), followed by the other lower SiO_2 applications (S_0F_1) and control. The intermediate lengths were recorded in other treatments in S_2 and S_3 combinations. In summary, moderate to high soil Si treatments combined with higher foliar Si elongated the rachis length most effectively.

Number of florets per spike: The highest floret count per spike responded strongly to SiO_2 applications. The highest number (40.50 florets) was recorded in S_3F_1. Closely trailing with S_3F_3 (39.33 florets), S_4F_2 (39.00), and S_2F_3 (38.83), all near the maximum number of florets. The lowest florets (33.50) were observed in S_0F_1, with S_0F_0 (35.67) also relatively low. Thus, plants treated with SiO_2 application showed a notably higher number of florets, with S_3F_1 recorded the highest and the (S_0F_1) remaining the lowest.

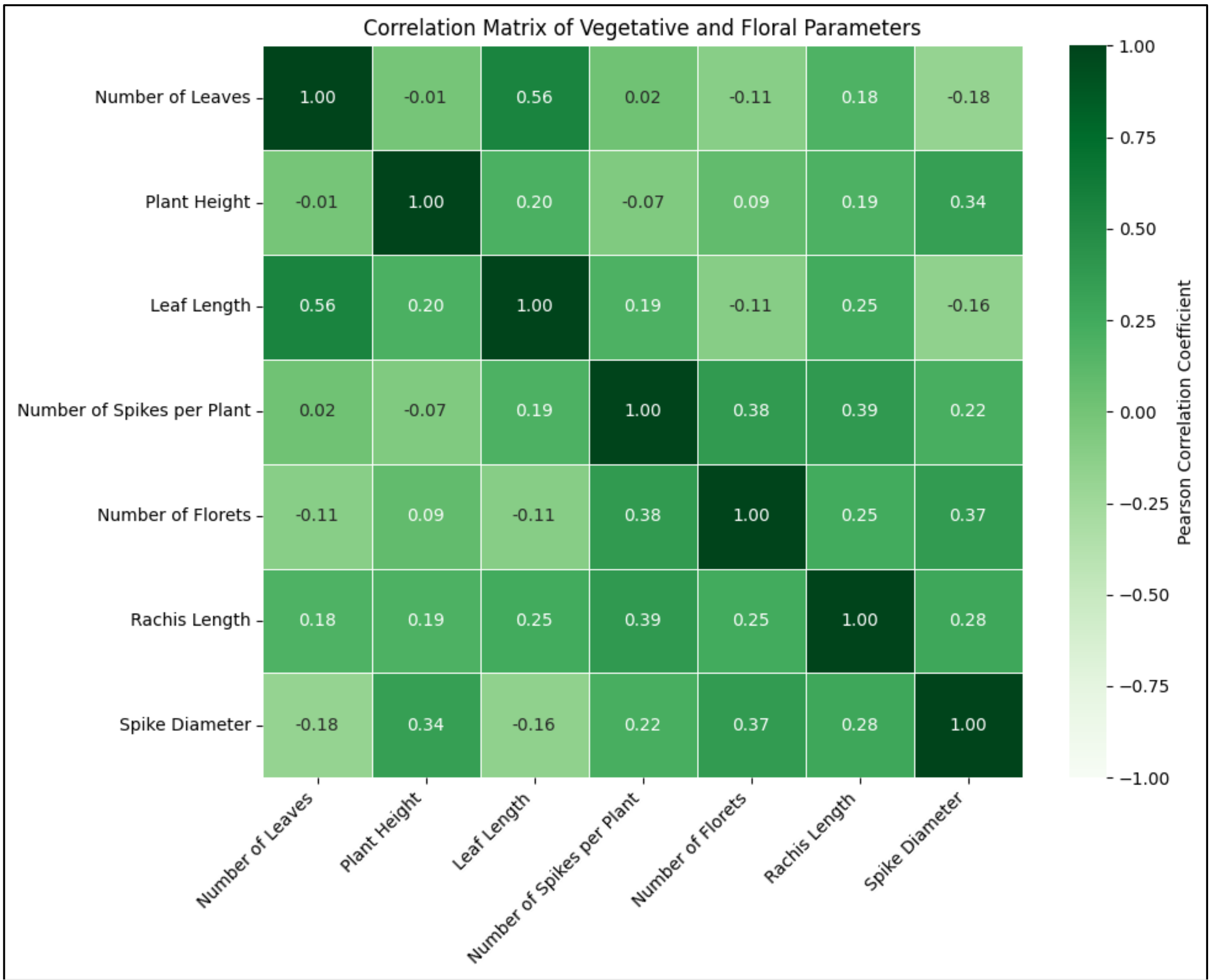

Fig 1: Heatmap showing Pearson correlations among key growth and flowering traits of tuberose based on pooled mean data across all soil and foliar silica oxide SiO_2)treatments.

Figure 1. This heatmap illustrates the Pearson correlation coefficients among seven selected growth and flowering traits of tuberose based on pooled mean data across all soil and foliar treatment combinations. Traits included are number of leaves, plant height, leaf length, spike diameter, rachis length, number of spikes per plant, and number of florets per spike. These parameters were selected based on their agronomic significance and measurable variation under combined silica oxide application.
(The values range from-1 to +1: +1 indicates a perfect positive correlation (both traits increase together), while -1 indicates a perfect negative correlation (one increases while the other decreases) and 0 indicates no correlation.

Effect of Trait Interactions under Silica Oxide Treatments

The correlation matrix demonstrates a coherent pattern of strong positive associations among vegetative and floral traits of tuberose under integrated soil and foliar applications of silica oxide (SiO_2). The number of leaves and plant height, as primary vegetative indicators, were positively correlated with critical floral attributes such as spike diameter, rachis length, number of florets per spike and spikes per plant. This trend indicates that enhanced vegetative growth serves as a foundational contributor to reproductive success. The observed inter-trait relationships suggest that silica application not only reinforces cell wall integrity and physiological activity but also facilitates efficient translocation of assimilates toward the sink. These findings provide compelling evidence for the integrative role of SiO_2 in synchronising vegetative vigour with floral productivity, highlighting its potential as a bio-stimulant in optimizing morphological and yield-related parameters in tuberose cultivation.

Discussion

The present study highlights the beneficial impact of silica oxide (SiO_2) on enhancing both vegetative and reproductive traits in tuberose (*Agave amica* Medik.) cv. 'Mexican Single'. These findings are in line with earlier reports on silicon's role in improving ornamental crop performance. Improved leaf number and plant height observed under Si treatments likely result from enhanced cell division, silica deposition and structural reinforcement, which collectively promote better light interception and photosynthetic activity (Ma & Yamaji, 2006; Flavia *et al.*, 2017) [10, 6]. Silicon (Si) supplementation often boosts vegetative vigour in ornamentals. In tuberose (*Polianthes tuberosa* L.), for example, foliar SiO_2 (150 mg L^{-1}) increased plant height and leaf number Shahzad *et al.* (2022) [14]. Likewise, root-or foliar-applied SiNP (200-400 mg L^{-1}) raised tuberose leaf biomass and flowering-stem length, indicating larger leaves and taller plants Karimian *et al.* (2021) [8]. In gladiolus, the combined application of soil and foliar application of Si dramatically enhanced growth (Fartiyal *et al.*, 2023) [7] found that Si-treated gladiolus had significantly greater plant height, spike length, rachis length and number of leaves than controls. Thakur *et al.* (2025) [15] similarly reported that 100 kg ha^{-1} soil Si plus foliar Si (3% SiO_2) produced the tallest gladiolus plants (103.9 cm) and the earliest spike emergence. In chrysanthemum, Puspitasari *et al.* (2019) [12] showed that Si application stiffened stems and accelerated flowering, reflecting stronger vegetative growth. Attia and Elhawat (2021)[3] reported that marigold (*Tagetes erecta*) also responded positively to the soil-applied Si (200 mg L^{-1}) increased plant height and branch number, while foliar Si further amplified flower traits. In summary, Si consistently increased leaf size and number, plant height and stem robustness across these crops. This is attributed to Si deposition in cell walls and enhanced physiology, as exogenous Si thickens leaves and stems, elevates chlorophyll, nutrient uptake and thus boosts photosynthetic capacity.

Silica also improves reproductive growth. In tuberose, soil Si (diatomite) lengthened flower spikes and increased floret number and weight. Karimian *et al.* (2021) [8] in tuberose found that both root and foliar Si raised tuberose flowering-stem length and floret count. In gladiolus, combined Si treatments yielded longer spikes and more/bigger florets (Fartiyal *et al.*, 2023) [7] observed that the combined application of soil and foliar Si produced the longest spikes (78.11) as compared to the control (67.58 cm) and a higher floret count. Thakur *et al.* (2025) [15] in gladiolus also reported that basal Si application at the rate of (100 kg·ha^{-1}) not only increased spike length (79.9 cm) but also led to the earliest spike emergence (102 days) compared to control (122 days). Attia and Elhawat (2021) [3] reported that the combined Si nanoparticle application dramatically extended the flowering period and flower quality in marigold. They found that the soil and foliar SiNP at the rate of (600 + 200 mg L^{-1}) produced the highest number of flowers, largest flower diameter, greatest floral biomass and longest flowering duration. In the case of chrysanthemum, Puspitasari *et al.* (2019) [12] found that the application of silicon benefited the blooms at the rate of 62.2 mg L^{-1}, which improved the longevity of chrysanthemum flowers and increased stem strength, suggesting earlier and more robust flowering. All these studies show that Si often increases floret number, spike length and flower diameter in many floricultural crops, and faster flowering and longer vase life have been reported.

The above enhancements are grounded in Si's multifaceted physiology. Silicon is known to deposit as amorphous silica (phytoliths) in cell walls and cuticles, reinforcing tissues (Epstein, 1994) [5]. Ye *et al.* (2023) [16] found that exogenous Si thickens leaf and stem tissues, significantly increases chlorophyll content and optimises leaf arrangement, which improves light capture and photosynthetic rate. It also increases chloroplast size and mesophyll cell wall thickness, enhancing mesophyll conductance and photosynthesis. Greater photosynthesis provides more carbohydrates to support extra leaf production, taller stems and more flowers. Silicon also helps in modulating water relations, as it forms a "cuticle-double Si layer" in leaves that reduces cuticular and stomatal transpiration, thus improving water-use efficiency under stress conditions. Niemczyk *et al.* (2024) [11] similarly reported that Si causes partial stomatal closure and better water balance, helping in minimizing the drought-induced water loss.

Moreover, Si enhances stress tolerance via biochemical defenses. In salt-stressed tuberose, Shahzad *et al.* (2022) [14] found that Si-treated plants maintained higher antioxidant enzyme activities. These antioxidants protect cells from oxidative damage, preserving photosynthetic function and cellular integrity under stress. Silicon also promotes nutrient uptake, as reported by Ye *et al.* (2023) [16]. They found that the Si increases root N, P and K uptake and prolongs root function, supplying more resources for growth. Some studies even suggest Si can also influence hormone levels (e.g. increasing gibberellins) that help in stem elongation and flowering characters as inferred in Gazania, Salvia and verbena (Khudair and Albbas, 2021; Debicz and Katarzyna 2011 and Aslam *et al.* 2014) [9, 4, 2].

In summary, combined soil and foliar Si treatments likely enhanced 'Mexican Single' tuberose growth by building stronger, more photosynthetically efficient foliage and stems, improving water status and activating stress defences. These improvements translated into more leaves, taller plants, longer leaves and inflorescence axes, thicker flower spikes and higher floret counts, trends consistent with those reported in tuberose, gladiolus, chrysanthemum, marigold and other ornamentals. Such evidence underpins the positive role of SiO_2 in enhancing both vegetative vigour and reproductive development in cut-flower crops.

Table 1: Effect of soil and foliar applications of silica oxide (SiO_2) on number of leaves per plant at 30, 60 and 90 days after planting (DAP) in tuberose (*Agave amica* Medik. cv. 'Mexican Single').

Number of leaves															
	(30 DAP)					**(60 DAP)**					**(90 DAP)**				
Soil × Foliar	**F_0**	**F_1**	**F_2**	**F_3**	**Mean(S)**	**F_0**	**F_1**	**F_2**	**F_3**	**Mean (S)**	**F_0**	**F_1**	**F_2**	**F_3**	**Mean (S)**
S_0	6.56	6.02	6.56	6.88	6.51	10.00	9.00	10.11	11.89	10.25	26.11	23.56	22.22	23.33	23.81
S_1	6.44	7.33	6.33	6.67	6.69	10.67	11.89	11.44	12.56	11.64	27.11	26.44	26.00	21.89	25.36
S_2	7.67	6.78	6.22	6.67	6.83	11.67	12.89	12.67	12.89	12.53	24.55	26.56	31.11	30.56	28.19
S_3	6.56	6.28	7.78	6.56	6.79	11.11	11.00	12.89	13.44	12.11	28.22	29.22	27.78	31.56	29.20
S_4	7.22	6.44	7.22	6.96	6.96	11.78	12.78	12.56	12.00	12.28	22.78	24.44	32.33	29.44	27.25
Mean (F)	6.89	6.57	6.82	6.75		11.05	11.51	11.93	12.56		25.76	26.04	27.89	27.36	
SE(m) ±															
SE(m) (S)	0.083					0.082					0.162				
SE(m) (F)	0.074					0.073					0.145				
SE(m) (S×F)	0.166					0.163					0.325				
CD (p = 0.05)															
CD at 5% (S)	0.163					0.235					0.467				
CD at 5% (F)	0.146					0.21					0.417				
CD at 5% (S×F)	0.326					0.469					0.933				

Table 2: Effect of soil and foliar applications of silica oxide (SiO_2) on Plant height at 30, 60 and 90 days after planting (DAP) in tuberose (*Agave amica* Medik. cv. 'Mexican Single').

Plant height (cm)															
	(30 DAP)					(60 DAP)					(90 DAP)				
Soil × Foliar	**F_0**	**F_1**	**F_2**	**F_3**	**Mean(S)**	**F_0**	**F_1**	**F_2**	**F_3**	**Mean (S)**	**F_0**	**F_1**	**F_2**	**F_3**	**Mean (S)**
S_0	26.87	23.98	25.24	22.65	24.69	30.1	26.5	30.1	26.8	28.4	50.84	49.99	50.06	51.27	50.54
S_1	25.17	22.84	24.68	22.44	23.78	29.1	26.9	28.2	26.6	27.7	48.10	54.08	49.56	51.75	50.87
S_2	26.30	26.03	21.28	28.40	25.50	28.0	28.1	24.0	29.1	27.3	47.47	50.98	49.16	51.76	49.84
S_3	27.16	23.42	28.25	22.97	25.45	31.3	28.5	30.7	28.4	29.7	49.02	51.56	52.66	54.21	51.86
S_4	27.92	25.99	26.05	23.61	25.89	28.7	29.7	28.0	26.6	28.3	50.93	51.06	54.49	52.95	52.36
Mean (F)	26.68	24.45	25.10	24.02		29.4	28.0	28.2	27.5		49.27	51.53	51.19	52.39	
SE(m) ±															
SE(m) (S)	0.163					0.209					0.363				
SE(m) (F)	0.146					0.187					0.325				
SE(m) (S×F)	0.326					0.417					0.726				
CD (p = 0.05)															
CD at 5% (S)	0.469					0.6					1.043				
CD at 5% (F)	0.419					0.537					0.933				
CD at 5% (S×F)	0.937					1.2					2.086				

Table 3: Effect of soil and foliar applications of silica oxide (SiO_2) on Leaf length at 30 and 60 days after planting (DAP) in tuberose (*Agave amica* Medik. cv. 'Mexican Single').

Leaf length (cm)										
	(30 DAP)					(60 DAP)				
Soil × Foliar	**F_0**	**F_1**	**F_2**	**F_3**	**Mean(S)**	**F_0**	**F_1**	**F_2**	**F_3**	**Mean (S)**
S_0	19.31	16.84	17.69	18.28	18.03	33.88	33.19	30.40	34.27	32.93
S_1	15.79	18.96	16.12	16.28	16.79	32.29	33.94	32.01	33.88	33.03
S_2	16.69	17.31	14.56	22.71	17.82	30.15	34.90	30.67	34.40	32.53
S_3	19.92	17.58	18.63	16.57	18.17	34.00	33.12	35.21	35.88	34.55
S_4	17.45	20.31	16.75	18.52	18.26	33.31	34.73	34.32	34.91	34.32
Mean (F)	17.83	18.20	16.75	18.47		32.73	33.98	32.52	34.67	
SE(m) ±										
SE(m) (S)	0.133					0.309				
SE(m) (F)	0.119					0.276				
SE(m) (S×F)	0.266					0.618				
CD (p = 0.05)										
CD at 5% (S)	0.382					0.888				
CD at 5% (F)	0.342					0.794				
CD at 5% (S×F)	0.764					1.776				

Table 4: Effect of soil and foliar applications of silica oxide (SiO_2) on Spike parameters in tuberose (*Agave amica* Medik. cv. 'Mexican Single').

spike parameters															
	Number of spikes/plant					Diameter of spike (mm)					Rachis length (cm)				
Soil × Foliar	**F_0**	**F_1**	**F_2**	**F_3**	**Mean(S)**	**F_0**	**F_1**	**F_2**	**F_3**	**Mean (S)**	**F_0**	**F_1**	**F_2**	**F_3**	**Mean (S)**
S_0	9.11	8.89	9.22	10.22	9.36	7.73	8.58	8.39	8.17	8.22	26.51	26.38	27.20	27.51	26.51
S_1	8.55	9.55	10.22	10.78	9.78	8.16	8.07	7.72	8.00	7.99	26.32	27.58	26.50	29.68	26.32
S_2	9.45	9.89	10.78	11.33	10.36	8.11	8.70	8.70	8.75	8.56	27.05	26.96	27.98	28.84	27.05
S_3	10.00	10.44	11.56	12.12	11.03	8.01	7.99	8.10	8.28	8.10	26.73	28.85	28.15	30.00	26.73
S_4	10.11	10.89	12.11	12.22	11.33	7.92	7.75	8.07	8.15	7.98	26.97	27.18	28.63	29.90	26.97
Mean (F)	9.45	9.93	10.78	11.34		7.99	8.22	8.20	8.27		26.72	27.39	27.69	29.19	26.72
SE(m) ±															
SE(m) (S)	0.089					0.052					0.198				
SE(m) (F)	0.079					0.047					0.177				
SE(m) (S×F)	0.178					0.104					0.396				
CD (p = 0.05)															
CD at 5% (S)	0.255					0.15					0.57				
CD at 5% (F)	0.228					0.134					0.51				
CD at 5% (S×F)	0.511					0.299					1.139				

Table 4: Effect of soil and foliar applications of silica oxide (SiO_2) on the number of florets/spike in tuberose (*Agave amica* Medik. cv. 'Mexican Single').

Number of florets/spike					
Soil × Foliar	**F_0**	**F_1**	**F_2**	**F_3**	**Mean (S)**
S_0	35.67	33.50	34.33	34.83	34.58
S_1	34.50	38.50	35.50	37.33	36.46
S_2	36.17	35.17	38.67	38.83	37.21
S_3	35.50	40.50	37.00	39.33	38.08
S_4	37.83	35.33	39.00	38.67	37.71
Mean (F)	35.93	36.60	36.90	37.80	
SE(m) ±					
SE(m) ± (S)			0.427		
SE(m) ± (F)			0.382		
SE(m) ± (S×F)			0.854		
CD (p = 0.05)					
CD at 5% (S)			1.228		
CD at 5% (F)			1.098		
CD at 5% (S×F)			2.455		

Conclusion

The present study demonstrated that the combined application of silica oxide through soil and foliar application significantly enhanced the vegetative and floral attributes of tuberose (*Agave amica Medik.* cv. 'Mexican Single') under *tarai* conditions. Higher levels of SiO_2, particularly the treatment S_4F_4 (8.8 g/m² soil + 3% foliar), consistently resulted in increased number of leaves, plant height, basal leaf length, rachis length, spike diameter and total number of florets per spike. The significant interaction effects observed between soil and foliar SiO_2 applications suggested that an integrated approach is more effective than either method alone. The improvement in vegetative growth could be attributed to better cell wall strength, enhanced nutrient uptake and improved water use efficiency, while floral enhancements were likely due to increased assimilate partitioning and spike development. These findings suggested that silica oxide can be a valuable input for improving the growth and marketable yield of tuberose. The combined application of 8.8 g/m² soil-applied and 3% foliar-applied SiO_2 can be recommended as an effective treatment for maximizing both vegetative and floral characters.

References

1. Al-Rahbi KNA, Hasan AH. Effect of silicon on the growth and flowering of some ornamental plants: a review. J Ornamental Plants. 2021;11(4):245-256.
2. Aslam SM, Khan T, Ali S, Nafees M, Wahid F. Response of marigold cultivars to different humic acid levels. Int J Acad Res Rev. 2018;3(4):85-97.
3. Attia FAR, Elhawat N. Effect of silica nanoparticles and micronutrients on growth, flowering and vase life of marigold (*Tagetes erecta* L.). J Plant Prod. 2021;12(1):37-47.
4. Debicz R, Pawlikowska A, Wróblewska K, Babelewski P. Influence of foliar treatment with silicon contained in the Actisil Hydro Plus preparation on the growth, flowering and chemical composition of *Gazania rigens* (L.) Gaertn., *Salvia farinacea* Benth and *Verbena hybrida* Voss. J Elem. 2016;21(3):681-692.
5. Epstein E. The anomaly of silicon in plant biology. Proc Natl Acad Sci U S A. 1994;91:11-17.
6. Flavia R, Silva JAT, Santos CF. Effects of silicon application on plant rigidity and nutrient balance in floriculture species. Plant Sci Today. 2017;4(1):34-40.
7. Fartiyal P, Bhuj BD, Srivastava R, Kumar A, Singh NK, Kumar A, Singh R. Effect of silica oxide concentrations on vegetative growth and flowering attributes of gladiolus cv. Rose Supreme under Tarai conditions of Uttarakhand. Pharma Innov J. 2023;12(8):344-355.
8. Karimian E, Dehestani-Ardakani M, Moradi P. The impact of root and foliar application of silicon on the growth and flowering of tuberose (*Polianthes tuberosa* L.). J Ornamental Plants. 2021;11(1):61-70.
9. Khudair TY, Albbas FAA. Effect of silicon and humic acid on vegetative and flowering growth traits in gazania plant (*Gazania splendens*). Int J Agric Stat Sci. 2021;17(1):73-80.
10. Ma JF, Yamaji N. Silicon uptake and accumulation in higher plants. Trends Plant Sci. 2006;11(8):392-397.
11. Niemczyk H, Tokarz K, Kulus D. The influence of silicon on the physiological and biochemical traits of ornamental plants under water-deficit conditions. Horticulturae. 2024;10(1):289.
12. Puspitasari RD, Nuringtyas TR, Purwanto YA. The role of silicon in the improvement of morphological and physiological characteristics of chrysanthemum (*Chrysanthemum morifolium*) grown in the lowlands. IOP Conf Ser Earth Environ Sci. 2019;391:012058.
13. Sattar A, Cheema MA, Sher A, Ijaz M, Ul-Allah S, Wahid MA. Silicon nutrition enhances growth and yield of wheat under heat stress. Plant Physiol Biochem. 2019;143:235-242.
14. Shahzad S, Ali S, Ahmad R, Ercisli S, Anjum MA. Foliar application of silicon enhances growth, flower yield, quality and postharvest life of tuberose (*Polianthes tuberosa* L.) under saline conditions by improving antioxidant defence mechanism. Silicon. 2022;14(6):1511-1518.
15. Thakur A, Yadav GC, Dey Y. Integrated nutrient management using silicon and organic sources enhances growth and flowering in gladiolus (*Gladiolus grandiflorus*). Indian J Hortic. 2025;82(1):1477-1485.
16. Ye M, Yu J, Wang J, Liu X. Mechanisms of silicon-mediated improvements in leaf anatomy and photosynthesis in higher plants: a review. Front Plant Sci. 2023;14:1093448.