Plant Archives Vol. 26, No. 1, 2026 pp. 2259-2265 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.313

EVALUATION OF FOLIAR-APPLIED MICRONUTRIENTS FOR IMPROVING GROWTH AND FLOWERING IN GLADIOLUS (*GLADIOLUS GRANDIFLORUS* L.) CV. CANDYMAN.

Aslam*, Prince, Deepika and Vikas Yadav
[1]Department of Horticulture, CCS Haryana Agricultural University, Hisar, Haryana, India
*Corresponding author E-mail: aslamhau2018@gmail.com
(Date of Receiving : 19-12-2025; Date of Revision : 26-02-2026; Date of Acceptance : 06-03-2026)

ABSTRACT

Gladiolus (*Gladiolus grandiflorus* L.), commonly known as the *"Queen of Bulbous Ornamentals,"* is one of the most important commercial cut flowers cultivated worldwide due to its elegant spikes, wide range of colours, large florets, and excellent vase life. It belongs to the family Iridaceae and is valued for its high aesthetic appeal and economic importance in the floriculture industry. The crop is extensively used for floral arrangements, bouquets, interior decoration, exhibitions, and ceremonial purposes. A field study was carried out during the year 2024–25 at the Precision Farming Development Centre, Department of Horticulture, CCS Haryana Agricultural University, Hisar, to assess the impact of various foliar applications of micronutrients on growth, flowering, corm production, and post-harvest performance of gladiolus (*Gladiolus grandiflorus* L.). The experiment comprised fifteen treatments, including individual and combined applications of $ZnSO_4$, H_3BO_3 and $FeSO_4$, laid out in a randomized block design. These findings collectively highlight the critical importance of adopting an integrated micronutrient management approach for improving the overall growth, flowering behaviour, and commercial performance of gladiolus. The consistently superior performance of treatment T_9 ($ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%) across almost all vegetative and reproductive parameters including maximum plant height, greater leaf area development, earlier spike emergence, earliest floret opening, enhanced spike and rachis length, increased number of florets per spike, larger floret size, and extended flowering duration clearly demonstrates the synergistic interaction among zinc, boron, and iron when applied together at higher concentrations. This synergism likely arises from the complementary physiological roles of these micronutrients: zinc regulates auxin biosynthesis, enzyme activation, and protein synthesis (Kumar & Arora, 2000); boron plays a vital role in cell wall stability, meristematic activity, and sugar translocation (Somkuwar *et al.*, 2023; Halder *et al.*, 2007); whereas iron is essential for chlorophyll formation and photosynthetic efficiency (Tagliavini & Rombolà, 2001; Mortvedt, 1991).

Keywords **:** Gladiolus, micronutrients, $ZnSO_4$, H_3BO_3, $FeSO_4$, foliar spray, flowering attributes.

Introduction

Gladiolus (*Gladiolus grandiflorus* L.) belongs to the family Iridaceae and the subfamily Crocoideae. It is native to South Africa. It is often referred to as the "queen of bulbous ornamentals" due to its widespread popularity among bulbous flowering plants. The modern cultivated gladiolus varieties are the result of hybridization among multiple species. Records indicate that gladiolus has been under cultivation since the early sixteenth century, while systematic breeding efforts began in the nineteenth century. This ornamental plant is highly valued for its adaptability, diverse floret colours, varied shapes and sizes, and extended shelf life. The commercial success of any ornamental crop largely depends on the availability of suitable cultivars that cater to consumer demand. Gladiolus is cultivated worldwide for its striking spikes, commonly used in bouquets, gardens, and landscapes. Large-scale commercial production for cut flowers is prominent in countries such as the USA, the Netherlands, Italy, France, Poland, Bulgaria, Brazil, Australia, and Israel. It ranks fourth in the global cut flower trade, following carnations, roses, and chrysanthemums. In India, it holds the third position in cut flower production and the sixth in loose flower production (Nath *et al*., 2020). Flowers are integral to various occasions, including weddings, religious ceremonies, and social gatherings. Gladiolus is relatively easy to cultivate and is ideal for bedding and exhibition purposes. In India, the total area under floriculture was recorded at 285 thousand hectares, with a production of 2,284 thousand metric tonnes of loose flowers and 947 thousand metric tonnes of cut flowers during 2023–24 (Anonymous, 2024a). In Haryana, floriculture covered an area of 1,830 hectares, yielding 31,015 metric tonnes of loose flowers and 791 lakh cut flower stems during the same period (Anonymous, 2024b). Gladiolus cultivation in India remains prominent. The major gladiolus-growing states in India include West Bengal, Uttar Pradesh, Odisha, Chhattisgarh, Maharashtra, Haryana, and Punjab. In Haryana alone, the crop covered 42 hectares in 2023–24, yielding 84 lakh cut flower stems, marking an increase from 45.8 lakh stems in the previous year (Anonymous, 2024c). India boasts a rich diversity of gladiolus varieties, including White Prosperity, Nova Lux, Snow Princess, Candyman, American Beauty, Eurovision, Punjab Flame, Punjab Glad-1, and Punjab Glad-2. Gladiolus spikes bear vibrant and delicate florets in a wide range of colours, from white to deep crimson, which open sequentially, extending their display duration. These spikes are extensively used in floral arrangements and bouquets. The plant thrives under open, 1 sunny conditions in well-drained sandy soils, with an optimum temperature range of 25-30°C and a photoperiod of 10-12 hours. In North India, planting is typically carried out between late October and November. Commercial propagation is achieved through corms and cormels, corms, which are compact vertical stems enclosed by a husk of dried leaves. Soil type and climate significantly influence the irrigation and fertilization requirements of gladiolus. Adequate fertilization ensures optimal flower yield and quality. For commercial cultivation, corms are planted in beds in sandy soils and on ridges or furrows in clay soils. A neutral soil pH range of 6-7 is considered ideal for gladiolus cultivation (Woltz, 1976; Boodley, 1981). Among various agronomic factors, mineral nutrition plays a crucial role in determining the yield and quality of gladiolus flowers. Gladiolus cultivation is an expensive enterprise requiring inputs such as land, water, planting material, fertilizers, and pesticides. Micronutrients play a significant role in plant growth and flower yield by stimulating and catalysing metabolic processes (Lahijie, 2012) and enhancing flower quality. Iron, zinc, and boron, in particular, are essential for plant growth and development, participating in redox reactions, enzyme structure formation, and nucleic acid metabolism (Khosa *et al*., 2011). Foliar application of micronutrients is an effective method to address plant-specific nutrient deficiencies, thereby accelerating growth and development (Said-Al Ahl and Mahmoud, 2010). Previous studies have demonstrated the beneficial effects of foliar micronutrient application in various flower crops, such as roses (Younis *et al*., 2013) and tuberoses (Tayade *et al*., 2018). Iron (Fe), zinc (Zn), and boron (B) are essential micronutrients that play pivotal roles in plant development, especially in floricultural crops like gladiolus. Iron deficiency, often observed in high-pH soils, leads to interveinal chlorosis in young leaves and can cause significant reductions in yield and quality (Tagliavini and Rombola, 2001). Foliar application of iron has proven effective in correcting chlorosis and enhancing crop performance (Mortvedt, 1991; Kumar *et al*., 2022). Zinc, on the other hand, functions as a cofactor for several enzymes and is involved in critical biosynthetic processes such as protein synthesis, photosynthesis, auxin metabolism, RNA and ribosome function, and cell division (Kumar and Arora, 2000). Its application has been reported to improve plant growth, leaf expansion, floret length, and floret number (Paradhan *et al*., 2004). Boron plays a crucial role in cell wall formation, sugar transport, and meristematic activity. Its application not only accelerates spike emergence but also enhances flower quality, floret size, and vase life (Somkuwar *et al*., 2023; Halder *et al*., 2007). Furthermore, combined foliar applications of boron and zinc have been shown to synergistically improve floral characteristics, including floret number per spike and flower diameter (Fahad *et al*., 2014).

Materials and Methods

Experimental details

The present investigation was carried out at the Precision Farming Development Centre (PFDC), Department of Horticulture, CCS Haryana Agricultural University, Hisar during the Rabi season of 2024–25. The experiment was conducted under field conditions using gladiolus cv. Candyman.

The experimental site is located in western Haryana at an altitude of 215 m above mean sea level and situated at 29.09°N latitude and 75.43°E longitude, representing a semi-arid agro-climatic zone. The experiment was laid out in a Randomized Block Design comprising 15 treatments with three replications, making a total of 45 experimental beds. Each bed measured 1.5 m × 1.5 m with a gross plot area of 2.25 m² and a net plot area of 1.25 m². Corms were planted at a spacing of 30 cm × 20 cm accommodating 20 corms per bed and planting was carried out on 20 November 2024.

The treatments consisted of individual and combined foliar applications of zinc sulphate, boric acid and ferrous sulphate. These included T_1 (control), T_2 ($ZnSO_4$ @0.2%), T_3 ($ZnSO_4$ @0.4%), T_4 (H_3BO_3 @0.1%), T_5 (H_3BO_3 @0.2%), T_6 ($FeSO_4$ @0.2%), T_7 ($FeSO_4$ @0.4%), T_8 ($ZnSO_4$ @0.2% + H_3BO_3 @0.1% + $FeSO_4$ @0.2%), T_9 ($ZnSO_4$@0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%), T_{10} ($ZnSO_4$ @0.2% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%), T_{11} ($ZnSO_4$ @0.2% + H_3BO_3 @0.2% + $FeSO_4$ @0.2%), T_{12} ($ZnSO_4$ @0.2% + H_3BO_3 @0.1% + $FeSO_4$ @0.4%), T_{13} ($ZnSO_4$ @0.4% + H_3BO_3 @0.1% + $FeSO_4$ @0.2%), T_{14} ($ZnSO_4$ @0.4% + H_3BO_3 @0.1% + $FeSO_4$ @0.4%) and T_{15} ($ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.2%).

The study aimed to evaluate the influence of micronutrient foliar sprays on vegetative growth, flowering behaviour and corm production of gladiolus under semi-arid conditions of Haryana.

The experimental site was the Precision Farming Development Centre (PFDC) of the Department of Horticulture, CCS Haryana Agricultural University, Hisar, which is located in western Haryana,

Observations for evaluation

Plant height (cm)

The height of five randomly selected plants was measured from the base of the plant to the highest growing tip of the spike when the fifth floret showed colour. Measurements were taken using a meter scale, and the average plant height was calculated.

Number of Leaves / plant

The number of leaves per plant was counted at 5^{th} floret opening stage of five randomly selected plants, and the average was calculated.

Width of leaf (cm)

The width of a leaf in gladiolus (cm) was measured by selecting the broadest part of a fully developed leaf, Digital vernier caliper was used to measure the distance between the two widest points perpendicular to the midrib.

Length of leaf (cm)

The length of a gladiolus leaf was measured using a simple manual method. Select a fully developed leaf and use a measuring scale or a flexible measuring tape. Place the scale at the base of the leaf where it emerges from the sheath and extend it along the midrib to the leaf tip.

Days Taken for Emergence of Spike

The duration from planting to the emergence of the first spike was meticulously recorded. This involved observing five randomly tagged plants and noting the individual number of days for each to exhibit the initial spike. The average of these five observations was then calculated to provide a representative measure of spike emergence time.

Days Taken to Basal/First Floret Opening

The number of days from planting to the opening of the basal/first floret was recorded from five tagged plants, and the average was computed.

Duration of flowering (days)

The flowering duration of each spike was determined by recording the number of days from the opening of the first floret to the wilting of the last floret. This observation was performed on five randomly tagged plants within each plot, and the average duration was subsequently calculated to represent the flowering period.

Number of florets / spike

To determine the average number of florets per spike, we carefully counted all the florets present on the spikes of five randomly tagged plants. We then calculated the average from these counts to get a representative measure for the entire plot.

Floret size (cm)

Using a vernier caliper, the diameter of the fifth floret was meticulously measured in two distinct diagonal directions immediately after it fully opened. The average of these two measurements was then calculated to represent the floret's diameter.

Spike length (cm)

The spike length of five tagged plants was measured from the base of the spike to the apical floret at the time of complete opening, and the average was calculated.

Rachis length (cm)

The length of the rachis was measured from the point of emergence of the first floret to the last floret on spikes of five tagged plants, and the average was calculated.

Number of spikes / plant

The number of spikes per plant in gladiolus was calculated by counting the total number of flowering spikes produced by a given number of plants and then averaging them.

Results and Discussion

Vegetative Parameters

Vegetative growth attributes collectively determine the photosynthetic efficiency and biomass accumulation in gladiolus, thereby influencing overall plant performance. The data pertaining to plant height, number of leaves per plant, leaf width and leaf length as affected by micronutrient treatments are presented in Table 3.

Table 1: Effect of foliar application of different micronutrients on vegetative parameters in gladiolus (cm).

Treatments	Plant height (cm)	Number of leaves per plant	Leaf width (cm)	Leaf length (cm)
T_1 : Control	105.23	9.50	2.19	38.75
T_2 : $ZnSO_4$ @0.2%	106.80	9.70	2.29	40.87
T_3 : $ZnSO_4$ @0.4%	111.23	10.10	2.47	43.70
T_4 : H_3BO_3 @0.1%	105.90	9.87	2.22	39.15
T_5 : H_3BO_3 @0.2%	106.40	9.80	2.24	40.00
T_6 : $FeSO_4$ @0.2%	106.67	9.80	2.27	40.80
T_7 : $FeSO_4$ @0.4%	107.43	9.90	2.30	41.37
T_8 : $ZnSO_4$ @0.2% + H_3BO_3 @0.1% + $FeSO_4$ @0.2%	113.13	10.20	2.48	44.02
T_9 : $ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%	120.40	10.97	2.83	51.80
T_{10} : $ZnSO_4$ @0.2% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%	114.70	10.47	2.56	46.88
T_{11} : $ZnSO_4$ @0.2% + H_3BO_3 @0.2% + $FeSO_4$ @0.2%	113.37	10.27	2.48	45.70
T_{12} : $ZnSO_4$ @0.2% + H_3BO_3 @0.1% + $FeSO_4$ @0.4%	114.23	10.37	2.52	46.85
T_{13} : $ZnSO_4$ @0.4% + H_3BO_3 @0.1% + $FeSO_4$ @0.2%	115.07	10.50	2.62	46.90
T_{14} : $ZnSO_4$ @0.4% + H_3BO_3 @0.1% + $FeSO_4$ @0.4%	116.37	10.60	2.69	48.10
T_{15} : $ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.2%	116.27	10.57	2.65	46.95
SE(m) ±	1.27	0.12	0.04	0.71
C.D. at 5%	3.71	0.35	0.13	2.07

The analysis revealed that micronutrient application significantly influenced all vegetative parameters. The maximum plant height (120.40 cm), highest number of leaves (10.97), maximum leaf width (2.83 cm) and longest leaves (51.80 cm) were recorded in T_9 ($ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%), which was significantly superior to all other treatments, indicating a strong synergistic effect of combined micronutrients applied at higher concentrations.

This was followed by T_{14} (116.37 cm, 10.60 leaves, 2.69 cm, 48.10 cm) and T_{15} (116.27 cm, 10.57 leaves, 2.65 cm, 46.95 cm), which were statistically at par with each other. These treatments were also at par with T_{13}, T_{10}, T_{12}, T_{11} and T_8 for most of the characters, indicating consistent improvement in vegetative growth due to combined application of Zn, B and Fe.

Among individual micronutrient applications, T_3 ($ZnSO_4$ @0.4%) recorded the best performance with plant height (111.23 cm), number of leaves (10.10), leaf width (2.47 cm) and leaf length (43.70 cm). It was significantly superior to T_7, T_2, T_6, T_5 and T_4 as the differences exceeded the respective critical differences (3.71 cm for plant height, 0.35 for leaves, 0.13 cm for leaf width and 2.07 cm for leaf length), suggesting zinc to be the most effective micronutrient when applied alone.

The lowest values for all parameters were observed in control T_1 (105.23 cm plant height, 9.50 leaves, 2.19 cm leaf width and 38.75 cm leaf length), which remained significantly inferior to most treatments, particularly the combined applications, confirming the essential role of micronutrient supplementation in enhancing vegetative growth and photosynthetic surface area in gladiolus.

Flowering Parameters

Flowering behaviour determines the commercial quality and market value of gladiolus spikes, as early spike emergence, timely floret opening, longer flowering duration and higher number of florets directly improve ornamental appeal and vase performance. The data regarding spike emergence, days to opening of first floret, duration of flowering and number of florets per spike as influenced by micronutrient treatments are presented in Table 4.

The analysis revealed that micronutrient application significantly affected all flowering parameters. The earliest spike emergence (93.07 days), minimum days to opening of first floret (100.90 days), longest flowering duration (18.13 days) and maximum number of florets per spike (12.30) were recorded in T_9

($ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%), which was significantly superior to all other treatments, indicating that combined application of Zn, B and Fe at higher concentrations accelerated flowering and improved spike quality.

This was followed by T_{14} (94.13 days, 103.77 days, 17.00 days, 11.80 florets) and T_{15} (94.83 days, 104.87 days, 16.83 days, 11.77 florets), which were statistically at par with each other. These treatments were also at par with T_{13}, T_{12}, T_{11} and T_{10} for most parameters, indicating consistent improvement in flowering behaviour due to combined micronutrient application.

Among individual micronutrient treatments, T_3 ($ZnSO_4$ @0.4%) showed the best response with earlier spike emergence (96.37 days), earlier floret opening (106.15 days), longer flowering duration (15.83 days) and higher number of florets (11.08). It was significantly superior to T_7, T_2, T_6, T_5 and T_4 as the differences exceeded the respective critical differences (2.42 days for spike emergence, 2.50 days for floret opening, 0.65 days for flowering duration and 0.42 florets), indicating zinc to be the most effective individual micronutrient for improving flowering.

Table 2: Effect of foliar application of different micronutrients on flowering parameters in gladiolus

Treatments	Spike emergence (days)	Days to opening of first floret	Duration of flowering (days)	Number of florets per spike
T_1 : Control	101.63	110.47	12.83	9.80
T_2 : $ZnSO_4$ @0.2%	99.30	108.93	15.47	10.57
T_3 : $ZnSO_4$ @0.4%	96.37	106.15	15.83	11.08
T_4 : H_3BO_3 @0.1%	100.27	109.78	14.03	10.07
T_5 : H_3BO_3 @0.2%	100.10	109.57	15.20	10.23
T_6 : $FeSO_4$ @0.2%	100.07	109.47	15.23	10.43
T_7 : $FeSO_4$ @0.4%	99.17	108.77	15.80	10.63
T_8 : $ZnSO_4$ @0.2% + H_3BO_3 @0.1% + $FeSO_4$ @0.2%	96.27	106.13	15.47	11.10
T_9 : $ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%	93.07	100.90	18.13	12.30
T_{10} : $ZnSO_4$ @0.2% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%	96.00	105.83	16.27	11.73
T_{11} : $ZnSO_4$ @0.2% + H_3BO_3 @0.2% + $FeSO_4$ @0.2%	96.17	106.07	15.93	11.57
T_{12} : $ZnSO_4$ @0.2% + H_3BO_3 @0.1% + $FeSO_4$ @0.4%	96.13	105.93	16.10	11.67
T_{13} : $ZnSO_4$ @0.4% + H_3BO_3 @0.1% + $FeSO_4$ @0.2%	95.27	105.33	16.73	11.77
T_{14} : $ZnSO_4$ @0.4% + H_3BO_3 @0.1% + $FeSO_4$ @0.4%	94.13	103.77	17.00	11.80
T_{15} : $ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.2%	94.83	104.87	16.83	11.77
SE(m) ±	0.83	0.86	0.22	0.14
C.D. at 5%	2.42	2.50	0.65	0.42

The maximum delay in spike emergence (101.63 days), late opening of first floret (110.47 days), minimum flowering duration (12.83 days) and lowest number of florets per spike (9.80) were observed in control T_1, which remained significantly inferior to most treatments, particularly the combined applications, confirming the crucial role of micronutrient supplementation in enhancing earliness and flowering quality of gladiolus.

Spike Quality Parameters

Spike quality parameters determine the commercial acceptability of gladiolus cut flowers, as larger florets, longer spikes and rachis along with higher spike production improve aesthetic value and market price. The data pertaining to floret size, spike length, rachis length and number of spikes per plant as influenced by micronutrient treatments are presented in Table 5.

Table 3: Effect of foliar application of different micronutrients on Spike quality parameters in gladiolus

Treatments details	Floret size (cm)	Spike length (cm)	Rachis length (cm)	Number of spikes per plant
T_1 : Control	9.11	53.27	39.67	1.17
T_2 : $ZnSO_4$ @0.2%	10.58	54.70	41.37	1.23
T_3 : $ZnSO_4$ @0.4%	11.18	57.30	43.47	1.15
T_4 : H_3BO_3 @0.1%	9.18	53.87	40.13	1.13
T_5 : H_3BO_3 @0.2%	9.90	55.13	40.77	1.17
T_6 : $FeSO_4$ @0.2%	10.84	54.20	40.93	1.23
T_7 : $FeSO_4$ @0.4%	10.60	54.73	41.70	1.15
T_8 : $ZnSO_4$ @0.2% + H_3BO_3 @0.1% + $FeSO_4$ @0.2%	11.19	57.37	43.60	1.23

T_9 : $ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%	11.99	63.83	50.90	1.42
T_{10} : $ZnSO_4$ @0.2% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%	11.20	58.47	45.87	1.23
T_{11} : $ZnSO_4$ @0.2% + H_3BO_3 @0.2% + $FeSO_4$ @0.2%	11.22	57.33	43.90	1.25
T_{12} : $ZnSO_4$ @0.2% + H_3BO_3 @0.1% + $FeSO_4$ @0.4%	11.21	58.47	44.97	1.32
T_{13} : $ZnSO_4$ @0.4% + H_3BO_3 @0.1% + $FeSO_4$ @0.2%	11.22	60.47	46.27	1.23
T_{14} : $ZnSO_4$ @0.4% + H_3BO_3 @0.1% + $FeSO_4$ @0.4%	11.36	61.33	47.83	1.27
T_{15} : $ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.2%	11.26	61.00	46.70	1.32
SE(m) ±	0.15	0.68	0.42	0.11
C.D. at 5%	0.45	1.98	1.23	N.S.

The analysis indicated that micronutrient application significantly influenced floret size, spike length and rachis length, whereas number of spikes per plant was found non-significant. The maximum floret size (11.99 cm), longest spike (63.83 cm) and maximum rachis length (50.90 cm) were recorded in T_9 ($ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%), which was significantly superior to all other treatments, indicating a strong synergistic effect of combined micronutrients at higher concentrations in improving spike quality.

This was followed by T_{14} (11.36 cm, 61.33 cm, 47.83 cm) and T_{15} (11.26 cm, 61.00 cm, 46.70 cm), which were statistically at par with each other. These treatments were also at par with T_{13}, T_{12}, T_{11} and T_{10} for most characters, indicating consistent improvement in spike quality due to combined application of Zn, B and Fe.

Among individual micronutrient applications, T_3 ($ZnSO_4$ @0.4%) recorded the best performance with floret size (11.18 cm), spike length (57.30 cm) and rachis length (43.47 cm) and was significantly superior to T_7, T_2, T_6, T_5 and T_4 as the differences exceeded the respective critical differences (0.45 cm for floret size, 1.98 cm for spike length and 1.23 cm for rachis length), showing zinc to be the most effective single micronutrient for improving spike characters.

The number of spikes per plant ranged from 1.13 to 1.42 and differences were non-significant; however, the highest value (1.42) was observed in T_9 while the lowest (1.13) was recorded in T_4, this may be attributed to the fact that foliar application was carried out after sufficient vegetative development, when spike initiation had already been physiologically determined in the corm. At this stage, micronutrients primarily enhanced assimilate translocation, floret development and spike elongation rather than inducing formation of additional spikes, which are largely governed by pre-formed buds and corm size.

The minimum values for floret size (9.11 cm), spike length (53.27 cm) and rachis length (39.67 cm) were observed in control T_1, which remained inferior to most treatments, particularly the combined applications, confirming the importance of micronutrient supplementation in improving cut flower quality in gladiolus.

Conclusion

Gladiolus (*Gladiolus grandiflorus* L.) is one of the most important commercial bulbous ornamental crops, valued for its attractive spikes, large florets, extended vase life, and wide adaptability under diverse agro-climatic conditions. The crop is highly responsive to nutrient management, particularly micronutrients, due to its rapid vegetative growth, high biomass production, and continuous demand for enzymatic and physiological regulation during spike initiation and floret development. Hence, foliar supplementation of essential micronutrients plays a decisive role in improving growth, flowering behaviour, and overall floral quality in gladiolus. The present study demonstrated that foliar application of micronutrients significantly enhanced the growth, flowering behaviour, and quality attributes of gladiolus cv. Candyman. Among all treatments, T_9 ($ZnSO_4$ @0.4% + H_3BO_3 @0.2% + $FeSO_4$ @0.4%) consistently produced the best results across almost all parameters. This treatment recorded the maximum plant height (120.40 cm), highest number of leaves (10.97), widest leaves (2.83 cm), longest leaves (51.80 cm), earliest spike emergence (93.07 days), earliest opening of first floret (100.90 days), longest flowering duration (18.13 days), highest number of florets per spike (12.30), largest floret size (11.99 cm), longest spike length (63.83 cm), and maximum rachis length (50.90 cm). These results clearly indicate a strong synergistic interaction of zinc, boron, and iron when applied together at higher concentrations. Overall, the combined foliar application of Zn, B, and Fe at higher concentrations proved most effective in maximizing growth, improving floral quality, and enhancing the commercial value of gladiolus cv. Candyman, thereby highlighting the importance of integrated micronutrient management in modern floriculture production systems.

References

Anonymous (2024a). Second Advance Estimates of Area and Production of Horticultural Crops 2023–24. National Horticulture Board, Ministry of Agriculture and Farmers Welfare, Government of India. Retrieved from https:// apeda.gov.in

Anonymous (2024b). Haryana Economic Survey 2023–24. Department of Economic and Statistical Analysis, Government of Haryana. Retrieved from https:// esaharyana.gov.in and https://www.scribd.com/document/ 769295395/Haryana-Economic-Survey-2023-24

Anonymous (2024c). Horticulture and Floriculture in Haryana: Current Status and Trends. PSC Notes Haryana. Retrieved from https://haryana.pscnotes.com

Boodley, J. W. (1981). The commercial greenhouse, Delmar Publishers Inc., Albany, New York, pp 568. https:// archive.org/details/commercialgreenh0000bood_d4w4

Fahad, S., Ahmad, K. M., Anjum, M. A., & Hussain, S. (2014). The effect of micronutrient (B, Zn, and Fe) foliar application on the growth, flowering, and corm production of gladiolus (*Gladiolus grandiflorus* L.) in calcareous soils. *Journal of Agriculture Science and Technology*, **16**(7), 1671-1682. http://jast.modares.ac.ir/article-23-4501 -en.html

Halder, N. K., Rafiuddin, M. D., Siddiky, M. A., Gomes, R., & Begam, K. A. (2007). Performance of gladiolus as influenced by boron and zinc. *Pakistan Journal of Biological Sciences*, **10**(4), 581-585. https://doi.org/ 10.3923/pjbs.2007.581.585.

Khosa, S. A., Younis, A., Rayit, S., Yasmeen, & Riaz, A. (2011). Effect of foliar application of macro and micro nutrients on growth and flowering of *Gerbera jamesonii* L. *American-Eurasian Journal of Agricultural and Environmental Sciences*, **11**(5), 736-757. https://www. cabidigitall ibrary.org/doi/full/10.5555/20123099630

Kumar, D., Sahu, T. L., Netam, N., Patel, S., Mandavi, G., & Kumar, N. (2022). Effect of foliar application of zinc and iron on growth and flowering of gladiolus cv. 'White Prosperity'. *The Pharma Innovation Journal*, **11**(2), 2587–2589. https://www.thepharmajournal.com/archives/ 2022/ vol11issue2/PartAI/11-2-130-123.pdf

Kumar, P., & Arora, J. S. (2000). Effect of micronutrients on gladiolus. *Journal of Ornamental Horticulture*, **3**(2), 91-93. https://www.indianjournals.com/ijor.aspx?target=ijor: joh&volume =3&issue=2&article=007

Lahijie, M.F. (2012). Application of micronutrients $FeSO_4$ and $ZnSO_4$ on the growth and development of gladiolus variety" Oscar". *International Journal of Agriculture and Crop Sciences*, **4**(11), 718-720. https://www.cabidigi tallibrary.org/doi/full/10.5555/20123364514

Mortvedt, J. J. (1991). Correcting iron deficiencies in annual and perennial plants: Present technologies and future prospects. *Plant and Soil*, **130**(1-2): 273-279. https://link. springer.com/article/ 10.1007/BF00011883

Nath, V., Sharma, S., & Singh, A. (2020). Response of different preservatives on vase life and quality of gladiolus flower. Yellow stone. *Plant Archives*, **20**(1), 1615-1618. https://plantarchives.org /20-1/1615-1618%20(5799).pdf

Paradhan, A., Das, J. N., Mishra, A. N., & Lenka, P. C. (2004). Effect of N and K on growth and yield of gladiolus. *Orissa Journal of Horticulture*, **32**(2), 74–77. https://www.cabidigitallibrary.org /doi/full/10.5555/20053 078124

Said-Al Ahl and A. Mahmoud (2010). Effect of Boron and / or iron foliar application on growth and essential oil of sweet basil (Ocimum basilicum L.) under salt stress. Ozean *J. Appl. Sci*., **3**, 97-111 https://www.researchgate.net/ publication/228443153_

Somkuwar, A., Singh, A., Sisodia, A., Lamsal, A., & Giri, S. (2023). Effect of boron on growth and flowering in gladiolus (*Gladiolus* sp.) cv. Malaviya Shatabdi. *Current Horticulture*, **11**(2), 58–61. https://doi.org/10.48165/chr. 2023.11.2.15

Tagliavini, M., and Rombolà, A. D. 2001. Iron deficiency and chlorosis in orchard and vineyard ecosystems. *European Journal of Agronomy*, **15**(2): 71-92. https://doi.org/10. 1016/S1161-0301(01)00125-3

Tayade, M., Badge and Nikam, B. (2018). Foliar application of zinc and iron as influenced on flowering and quality parameters of tuberose. *International Journal of Current Microbiology and Applied Sciences*, **7**(1), 2239-2243. https://doi.org/10.20546/ijcmas.2018.701.270

Woltz, S S, & Marousky, F J (1976). Fluoride leaf scorch of lily and gladiolus: soil acidity, superphosphate and diagnostic techniques. Fl. Flower Grower; (United States), 13:2. https://www.osti.gov/biblio/5226921

Younis, A., Riaz, A., Sajid, M., Mushtaq, N., Ahsan, M., Hameed, M., & Nadeem, M. (2013). Foliar application of macro-and micronutrients on the yield and quality of Rosa hybrida. Cardinal and Whisky Mac. *African Journal of Biotechnology*, **12**(7), 702-708. https://doi.org/10.5897/ AJB12.2226