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Research Article

Effect of Humic Acid Levels on the Production of Gladiolus Cultivars

Ahmad Naeem[1†], Noor Ul Amin[1], Hamza Ali[2†*], Masood Ahmad[1*], Abdul Mateen Khattak[1], Amna Shafi[3], Ateeq Ur Rehman[1], and Habib Ur Rehman[4]

[1]Department of Horticulture, Faculty of Crop Production Sciences, The University of Agriculture Peshawar, 25120, Pakistan

[2]State Key Laboratory for Crop Stress Resistance and High-Efficiency Production, College of Horticulture, Northwest A&F University, Yangling, Shaanxi 712100, China

[3]Agriculture Research Institute Tarnab, Peshawar, Pakistan

[4]Muhammad Nawaz Shareef University of Agriculture, Multan, Pakistan

Abstract: Gladiolus is a valuable ornamental crop, widely cultivated for its aesthetic appeal and commercial demand. However, its growth and flowering performance are often hindered by poor soil fertility and suboptimal nutrient management, which needs to be optimized for its commercial production under the agroclimatic conditions of Peshawar, Pakistan. Humic acid is a natural organic substance and is known to enhance soil properties and improve plant growth. Therefore, this experiment was conducted under RCBD split plot arrangement to evaluate the different humic acid levels and their influence on five different gladiolus cultivars. Results indicated that both humic acid and cultivars significantly influenced vegetative and reproductive attributes. The humic acid at the rate of 4 kg ha^{-1} treatment was most effective, resulting in improved emergence, number of leaves, leaf area, spike emergence, 1st floret opening, florets per spike, field flower persistence, vase life, corm weight, and number of cormels. Enhanced performance was attributed to better nutrient uptake, chlorophyll synthesis, hormonal balance, and source–sink relationships under humic acid supplementation. Among cultivars, 'White Prosperity' showed superior vegetative growth and cormel production, while 'Priscilla' had longer vase life and heavier corms, indicating genetic differences in nutrient use and reproductive efficiency. The results show that humic acid not only promotes vegetative growth but also accelerates floral initiation, increases floret production, delays senescence, and enhances postharvest quality. It is concluded that humic acid at the rate of 4 kg ha^{-1}, in cultivars White Prosperity and Priscilla, was optimal for commercial gladiolus cultivation under Peshawar's agro-climatic conditions.

Keywords: Bulbous Crops, Flowering, Gladiolus, Humic Acid, Vase Life.

1. INTRODUCTION

Gladiolus (*Gladiolus Grandiflorus* L.) is a popularly grown bulbous ornamental which is a member of the Iridaceae family. It is indigenous to South Africa, but now grows in many countries because of its exquisite beauty, long petal spikes, and their great variation in colors. About 260 species and nearly 1,000 cultivars have been identified with the genus with about 120 being cultivated as cut flowers [1]. The other cultivars are normally used in decoration of the garden, sales and display, and used in making seasonal flower displays. Gladiolus can also be called the "Queen of bulbous flowers" since it has a lovely look and excellent performance as a cut flower [2]. Its plant is popular due to its long shelf life after harvest and its beauty in decorative pots, in bouquet and flowers arrangements. The demand of gladiolus cultivation has increased tremendously in different states worldwide, the leading producers

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* Corresponding Authors: Hamza Ali and Masood Ahmad <hamzaali@nwafu.edu.cn; masoodhort@aup.edu.pk>
† These authors have contributed equally

of gladiolus are the United States, followed by Netherlands, Italy, and Brazil etc. [3]. It has got a large export value particularly in Europe in the winter seasons where people use it a lot in its indoor decoration and landscaping [4]. Gladiolus has the potential to generate handsome revenue in cut flowers trade [5].

In order to increase growth, quality and commercial value of gladiolus careful nutrient management is necessary. Humic acid is one of the numerous types of organic amendments that are becoming of great significance due to its capability to enhance soil health and plant performance. Humic acid is a polymeric organic compound in nature, which increases nutrient adsorption, raises the activity of microorganisms, and improved the soil properties [6]. It improves soil fertility due to the fact that it forms chelates with applicable nutrients making them more readily available to the plants [7]. Humic acid enhances the capacity to absorb water and aerate the soils as well as drain the soils and also makes plants withstand environmental stress [8]. It encourages early germination, strong vegetative development and effective flowering. Also, Humic acid minimizes the use of synthetic fertilizers thus enhancing sustainable farming. Soils contain large quantities of humic substances such as fulvic and humic acids that are very vital in the developmental stages of plants [9]. Application of Humic acid can induce relevant and significant physiological processes in plants that include a rise in respiration, enhanced photosynthesis, enhanced root growth, and more chlorophyll synthesis [10]. Such advances are especially valuable to ornamental crops such as gladiolus, where marketability depends on plant aesthetics, flower size and duration. The climate in Khyber Pakhtunkhwa, Pakistan, is favorable to the gladiolus production, but most of the available cultivars are poor in performance and do not meet the required characteristics in the global market [11]. A rising interest in comparing local and introduced cultivars is aimed at establishing cultivars that perform better. Moreover, the effect of organic amendments like humic acid on gladiolus in the agro-climatic conditions of Peshawar can help in enhancing the quality of flowers, its yield and its market value.

Current research was aimed to test the performances of the various gladiolus cultivars to evaluate the best levels of humic acid in enhancing various growth, yield and quality attributes of gladiolus under the agro-climatic environment of Peshawar. The objectives of the study were to determine the interaction between levels of humic acid and gladiolus cultivars on the general plant performance in order to be able to recommend the best cultivar-nutrient combination that can be used in commercial production of gladiolus flowers in the area.

2. MATERIALS AND METHODS

2.1. Experimental Design and Factors

This study was conducted at the Ornamental Horticulture Nursery, The University of Agriculture Peshawar. It was performed following the randomized complete block design with split plot arrangement. Main plots were consisted of four humic acid concentrations, i.e., 0, 2, 4, and 6 kg ha^{-1} whereas five cultivars, i.e., White Prosperity, Priscilla, Advance Red, Purple Flora, and Green Star were assigned to sub plots. There was a total of twenty treatments replicated three times.

2.2. Planting of Corms

The experimental site was thoroughly prepared before planting. Gladiolus corms were arranged from a reliable seed company in Islamabad. A basal dose of Nitrogen, Phosphorus, and Potassium at the rate of 100:75:75 kg ha^{-1} was applied before planting, with nitrogen supplied in two split doses, the first at the time of planting and the second at the three-leaf stage. Urea, di-ammonium phosphate (DAP), and sulphate of potash (SOP) were used as sources of nitrogen, phosphorus, and potassium, respectively. Humic acid was also applied in two split doses: the first at planting and the second at the three-leaf stage. Corms were planted with a spacing of 30 cm between plants and 60 cm between rows, at a depth of 6 cm. All cultural practices, including irrigation, weeding, and hoeing, were carried out uniformly across treatments. Additionally, soil-based application of humic acid was performed 15 days before corm planting.

2.3. Soil Analysis

Before the application of humic acid and planting of corms, soil samples were collected from the field at three depths (0-15 cm, 15-30 cm, and 30-45 cm). These samples were analyzed in the laboratory of the Department of Soil and Environmental Science, The University of Agriculture, Peshawar, to determine soil pH, electrical conductivity (EC), organic matter (OM), nitrogen, phosphorus, and potassium contents. These results are presented in Table 1, that gives the insights into the existing field conditions.

2.4. Cultural Practices

Weeds were removed from the field as needed throughout the cropping period. Irrigation was carried out on a weekly basis from January to August. Bamboo sticks were used for staking when necessary to support taller plants that could not stand upright on their own. For data collection, five plants were randomly selected and tagged from each subplot.

2.5. Attributes Studied

To evaluate the growth, flowering, and corm yield of gladiolus, various morphological and reproductive parameters were recorded during the experiment. Days to emergence of plants were calculated by noting the days from plantation of corms till the emergence of 50% plants in every treatment and replication and its mean was computed. The number of leaves per plant was determined by counting the total number of leaves on five randomly selected plants per treatment and calculating the mean. For leaf area (cm^2), mature leaves from five randomly selected plants were measured using a leaf area meter, and the mean was computed. Days to spike emergence were recorded by counting the number of days from planting to the appearance of flower spike in each treatment, with averages taken across replications.

The days to first floret opening were calculated by recording the time taken from planting until the first floret opened on three randomly selected plants, and the average was determined. The number of florets per spike was counted from five randomly selected plants per plot, and the average value was used for analysis. Spike length (cm) was measured using a meter rod from the internode just above the fourth leaf up to the tip of the spike on five randomly selected plants, and the results were averaged. Field flower persistency was assessed by noting the number of days from the opening of the first floret until the fading of the last floret on selected spikes, with the average calculated accordingly.

To evaluate postharvest performance, vase life (days) was measured by harvesting spikes at the color-showing stage, placing them in distilled water at room temperature, and recording the duration until it lost its decorative value. For corm yield assessment, corm weight (g) was recorded using a digital balance after harvesting, and mean values were calculated for each treatment. The size of the corms (cm) was measured using vernier caliper, and average dimensions were determined for each treatment. Lastly, the number of cormels per plant was obtained by counting all the cormels produced per plant in each plot and computing the mean [11].

2.6. Statistical Analysis

The analysis of variance (ANOVA) was analyzed for the collected data using Statistix 8.1 using a RCBD design with split plot arrangement, and treatment means were compared using the Least Significant Difference (LSD) test at a 5% level of significance [12]. The bar graphs were made using sigma plot 15.0, the PCA, correlation matrix and heatmap were built with R-studio.

Table 1. Soil analysis of the experimental area.

Property	Soil Depth		
	0-15 cm	**15-30 cm**	**30-45 cm**
pH	7.86	8.19	8.24
EC (ds m^{-1})	0.23	0.19	0.14
Soil Organic Matter (%)	0.78	0.61	0.42
AB–DTPA extractable N (mg kg^{-1})	0.15	0.12	0.09
AB–DTPA extractable P (mg kg^{-1})	5.34	5.10	4.32
AB–DTPA extractable K (mg kg^{-1})	73.2	68.4	66.1

3. RESULTS

The statistical analysis revealed that humic acid levels and gladiolus cultivars had significantly affected days to plant emergence, whereas their interaction was found to be non-significant (Figure 1(A)). Among the humic acid treatments, the earliest plant emergence (14.3 days) was recorded in plots treated with humic acid at 6 kg ha^{-1}, followed by 4 kg ha^{-1} (14.9 days) and 2 kg ha^{-1} (16.6 days). The maximum days to emergence (17.1) were recorded in the control (untreated) plots. Regarding cultivars, the minimum number of days to emergence was observed in Priscilla (13.5), followed by White Prosperity (13.9) and Advance Red (16.3), while the highest emergence duration (18.4 days) was noted in Green Star.

There was significant variation in number of leaves in response to humic acid and cultivars, but their interaction was found to be non-significant (Figure 1(B)). The max no. of leaves per plant (8.5) were recorded in plots supplied with 4 kg ha^{-1} humic acid, followed by 6 kg ha^{-1} (8.0) and 2 kg ha^{-1} (7.6), whereas the lowest (7.0) was noted in control plots. Among cultivars, White Prosperity produced highest no. of leaves per plant (8.5), followed by Priscilla (8.3) and Green Star (7.7), whereas Advance Red resulted in least no. of leaves (7.1).

The leaf area per plant was significantly affected by both humic acid levels and cultivars, though their interaction remained non-significant (Figure 1(C)). Maximum leaf area (290 cm^2) was observed when the gladiolus cultivars were

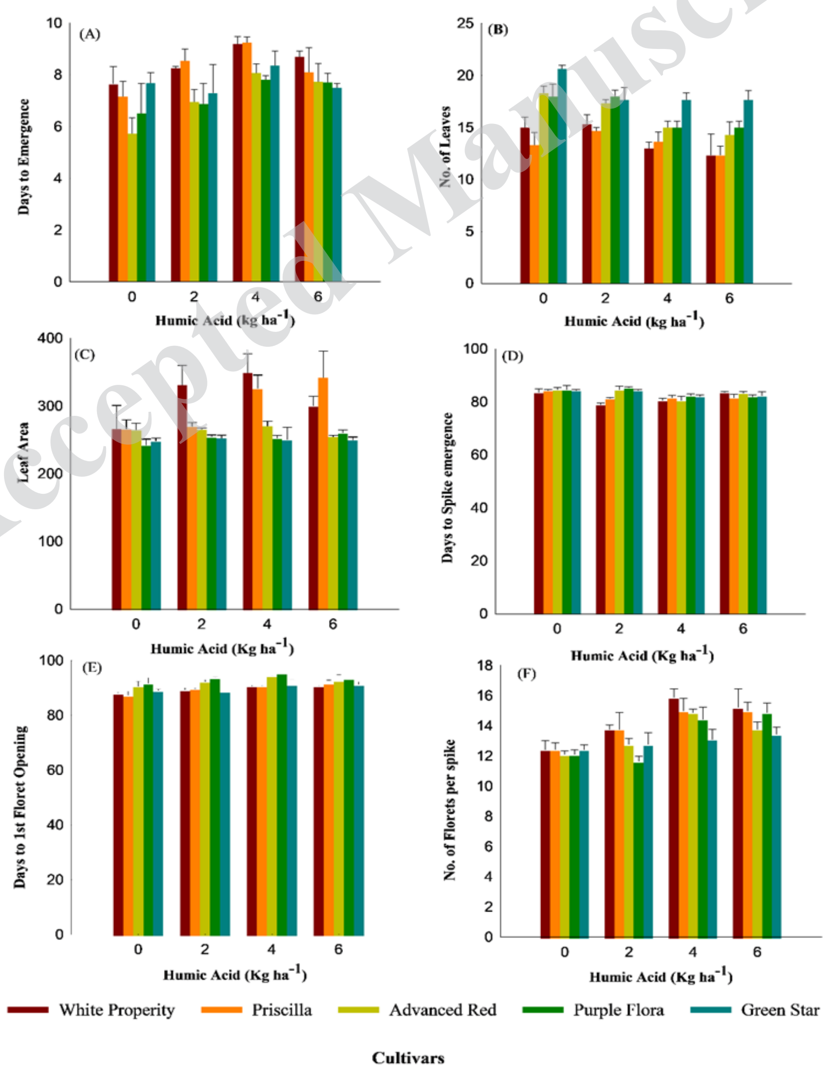

Fig. 1. Effect of humic acid on different gladiolus cultivars, (A) Days to Emergence, (B) No. of Leaves, (C) Leaf Area, (D) Days to spike emergence, (E) Days to floret opening, and (F) No. of florets per spike.

supplied with humic acid @ 4 kg ha^{-1} while the least was recorded in control. Among cultivars, the maximum leaf area was recorded in White Prosperity (312.1 cm^2), followed by Priscilla (301.2 cm^2) and Advance Red (264.2 cm^2), while Green Star produced the minimum leaf area (250.6 cm^2). The spike emergence was significantly influenced by humic acid levels, cultivars, and their interaction (Figure 1(D)). Plots treated with 4 kg ha^{-1} humic acid recorded the earliest spike emergence (70.7 days), followed by 6 kg ha^{-1} (73.5 days) and 2 kg ha^{-1} (74.7 days), while control plots took the longest (75.6 days). Among cultivars, White Prosperity produced the earliest spikes (69.9 days), followed by Priscilla (71.0 days) and Purple Flora (74.7 days), while the highest days to emergence (76.7) was noted in Green Star.

For days to first floret opening, significant effects were observed for humic acid and cultivar, but not for their interaction (Figure 1(E)). Plots treated with 4 kg ha^{-1} humic acid showed the earliest floret opening (76.0 days), followed by 6 kg ha^{-1} (78.7 days) and 2 kg ha^{-1} (79.5 days). The maximum days to floret opening (82.6) were recorded in the control. Among cultivars, White Prosperity opened first (76.9 days), followed by Advance Red (77.6 days), Purple Flora (79.9 days), and Priscilla (80.2 days), with Green Star that took maximum days (81.5) to first floret opening.

The number of florets per spike was greatly influenced by both humic acid levels and cultivars, while their interaction remained non-significant (Figure 1(F)). Maximum florets per spike (14.7) was observed at 4 kg ha^{-1}, followed by 6 kg ha^{-1} (14.5) and 2 kg ha^{-1} (13.0), with the control resulted in least no. of florets per spike (12.30). Among cultivars, White Prosperity produced the highest number of florets (14.3), followed by Priscilla (14.1), Advance Red (13.4), and Purple Flora (13.3), with Green Star recording the minimum (12.9).

Spike length was significantly affected by humic acid levels, cultivars, and their interaction (Figure 2(A)). The longest spike (66.3 cm) was produced with 4 kg ha^{-1} humic acid, followed by 6 kg ha^{-1} (66.2 cm) and 2 kg ha^{-1} (60.4 cm), while the control had the shortest spikes. Among cultivars, White Prosperity produced the longest spikes (67.0 cm), followed by Priscilla (63.2 cm) and Advance Red (62.5 cm), with Purple Flora producing the shortest (60.1 cm). Notably, the maximum spike length (71.5 cm) was recorded from the interaction in gladiolus cv. White Prosperity that received 4 kg ha^{-1} humic acid.

Vase life of gladiolus cultivars was significantly influenced by the different levels of humic acid and cultivars, whereas their interaction was non-significant (Figure 2(B)). The longest vase life (9.3 days) was recorded cut flowers of plants treated with 4 kg ha^{-1} humic acid, followed by 6 kg ha^{-1} (8.4 days) and 2 kg ha^{-1} (7.5 days), while the control showed the shortest (6.1 days). Among cultivars, Advance Red had the longest vase life (9.9 days), followed by White Prosperity (8.4), Priscilla (7.8), and Purple Flora (6.7), with Green Star exhibiting the shortest vase life (6.3 days).

The analysis also indicated that both humic acid and cultivars had a significant effect on field flower persistency, though their interaction was non-significant (Figure 2(C)). The longest field persistency (12.5 days) was observed in plants that received humic acid @ 4 kg ha^{-1}, followed by 6 kg ha^{-1} (11.6 days) and 2 kg ha^{-1} (10.4 days), while the control exhibited the shortest duration. Among cultivars, White Prosperity showed the highest persistency (12.3 days), followed by Priscilla (12.0 days) and Advance Red (10.2 days), while the lowest (8.8 days) was noted for Green Star.

In case of corm weight, there was significant variation in corm weight due to humic acid levels and cultivars, but their interaction was not significant (Figure 2(D)). The heaviest corms were obtained from plots supplied with 4 kg ha^{-1} humic acid (20.7 g), followed by 6 kg ha^{-1} (19.2 g) and 2 kg ha^{-1} (17.4 g), while the control plots that received no humic acid had the lowest weight (13.8 g). Priscilla had the heaviest corms (22.2 g) followed by White Prosperity (18.9 g) and Purple Flora (18.0 g) whereas Green Star produced the lightest corms (14.7 g).

The largest corms (4.3 cm) were obtained at 4 kg ha^{-1} humic acid, followed by 6 kg ha^{-1} (3.9 cm) and 2 kg ha^{-1} (3.7 cm), while the smallest corms were found in control plots (Figure 2(E)). Among cultivars, Priscilla produced the largest corms (4.3 cm), followed by White Prosperity (3.9 cm) and Purple Flora (3.7 cm), while Green Star recorded the smallest corms (3.0 cm).

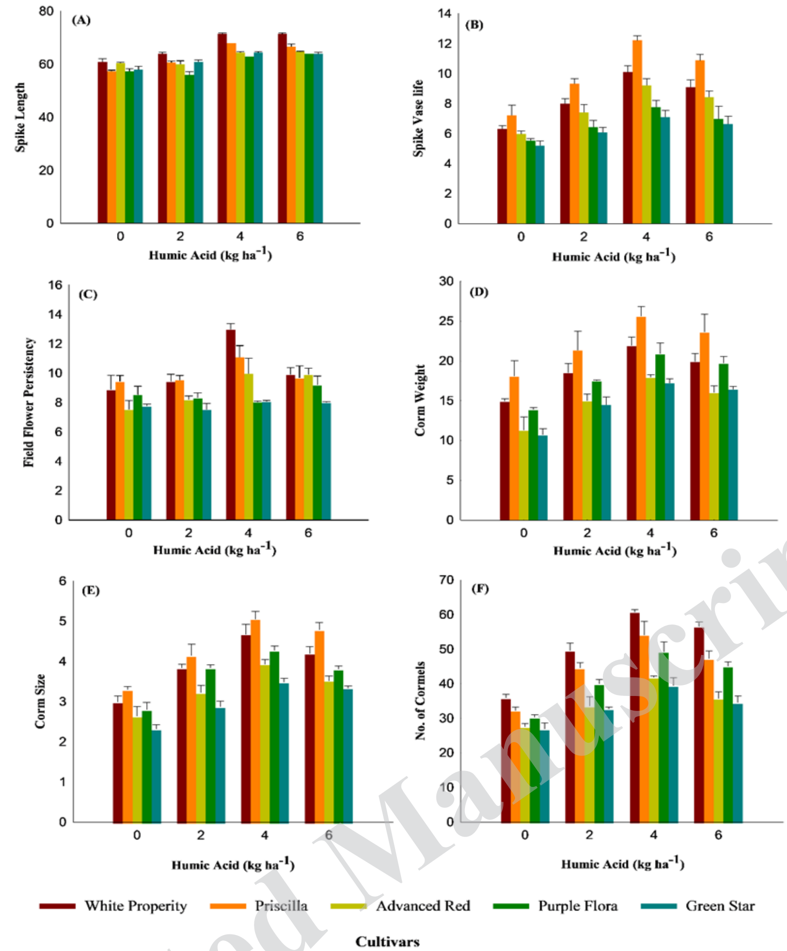

Fig. 2. Effect of humic acid on different gladiolus cultivars, (A) Spike Length, (B) Spike Vase life, (C) Field Flower Persistency, (D) Corm weight, (E) Corm Size, and (F) No. of Cormels.

Lastly, humic acid and cultivars had a significant effect on the number of cormels per plant but the interaction was not significant (Figure 2(F)). Plots treated with 4 kg ha^{-1} had the highest cormels (49.1) and were followed by 6 kg ha^{-1} (43.9), 2 kg ha^{-1} (40.1) and the lowest number (30.6) was recorded in the control. White Prosperity recorded the highest number of cormels (50.7), however least no. of cormels (33.5) were noted in Green Star.

3.1. Principal Component Analysis

The principal component analysis (PCA) was conducted to reduce dimensionality and identify the most influential traits contributing to overall variation among the genotypes (Figure 3(A)). The first principal component (PC1) accounted for 55.9% of the total variance, while the second principal component (PC2) explained an additional 9.6%, making the cumulative contribution of the first two components 65.5%.

The PCA biplot revealed that traits such as corm weight (CW), corm size (CS), number of cormels per plant (NOC), spike length (SL), and number of florets per spike (NOF) were strongly associated with PC1, indicating their dominant role in explaining variability. Conversely, days to first floret opening (DFO) contributed more significantly to PC2. The quality of representation (cos^2) indicated by the color gradient revealed that DFO, CW, and CS were well represented in the two-dimensional space. The accompanying scree plot illustrated a sharp decline in explained variance after the first component, supporting the selection of PC1 and PC2 for interpretation and trait analysis (Figure 3(B)).

The Pearson correlation analysis elucidated the strength and direction of relationships among vegetative, phenological, reproductive, and yield-related traits in gladiolus (Figure 4. Strong and highly significant positive correlations were

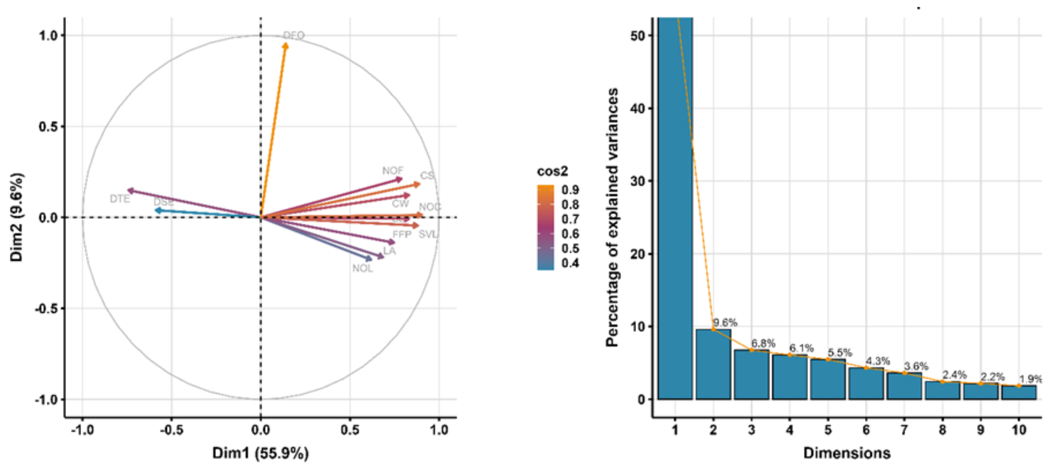

Fig. 3. Principal component analysis (A) and scree plot (B) of the studied attributes of gladiolus.

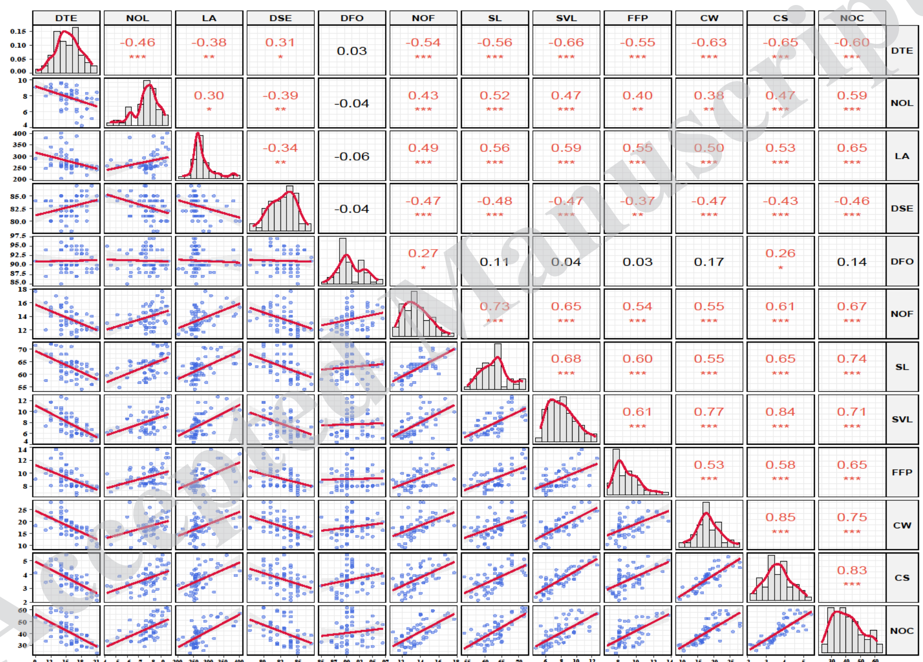

Fig. 4. Correlation matrix of the studied attributes of the gladiolus.

observed among floral and yield attributes, indicating their coordinated contribution to overall plant performance. In particular, corm weight (CW) was positively and significantly correlated with corm size (CS; r = 0.85), number of cormels (NOC; r = 0.75), and spike length (SL; r = 0.65), suggesting that plants producing larger and heavier corms also express superior floral traits.

Conversely, phenological traits such as days to plant emergence (DTE), days to spike emergence (DSE), and days to first floret opening (DFO) exhibited negative correlations with most reproductive and yield-related attributes, indicating that earlier developmental progression favors enhanced flowering and corm productivity. These negative associations, particularly between DTE and CW or SL, were visually represented by red shades in the heatmap, highlighting the inverse relationship between delayed phenology and reproductive performance. Moderate positive correlations were also observed among vegetative traits, including number of leaves per plant (NOL), leaf area (LA), field flower persistency (FFP), and spike vase life (SVL), reflecting their indirect yet meaningful contribution to floral longevity and yield.

The correlation heatmap (Figure 5) provided an intuitive visualization of these relationships by integrating correlation strength and significance through color intensity and symbol size. Strong positive associations among CW, CS, SL, number of florets (NOF), and NOC were depicted by large, dark blue circles, reinforcing patterns observed in the correlation matrix. In contrast, traits such as DFO exhibited several non-significant associations, marked by 'X' symbols, suggesting that their variation may be regulated by different or more independent factors. Overall, the heatmap effectively complements the correlation matrix and PCA results by visually confirming key trait interrelationships that are critical for targeted breeding and selection programs.

4. DISCUSSION

Humic acid is a well-known organic fertilizer that is very effective in the early emergence of gladiolus plants as it as soil conditioner and helps to improve soil structure, lower soil pH, and raise the availability of nutrients [13]. It enhances root development and metabolic activity, which increases the release of stored energy in corms, and hence increase the rate of emergence [14, 15]. Furthermore, soil consisting of humic acid is more porous, which makes sprouting more favorable [16]. The variability in days to emergence among different cultivars might be due to the differences in their genetic constitution, which influences their physiological responses in the prevailing soil and environmental conditions [17]. Our findings are in line with that of Rizwan *et al.* [18], they also reported significant differences in plant emergence in gladiolus cultivars grown in Peshawar condition. The positive effect of humic acid application on the number of leaves per plant is due to enhanced absorption of essential nutrients such as nitrogen, potassium, and trace elements [19]. They are essential nutrients having directly or indirectly a role in the biosynthesis of chlorophyll and cellular metabolism as well as continuous leaf formation [20]. The increase in nutrient availability causes a more vigorous shoot meristem encouraging growth in the leaves [21]. Our results are in agreement with that of Baldotto and Baldotto [22]; they also reported significant increase in no. of leaves in plants treated with humic acid. The variation in the number of leaves in the cultivars also depend on how efficiently they used the available nutrients and control their growth [19]. Likewise, Nasir *et al.* [11] also reported a significant variation in leaves no. among gladiolus cultivars grown under the agro-climatic conditions of Peshawar.

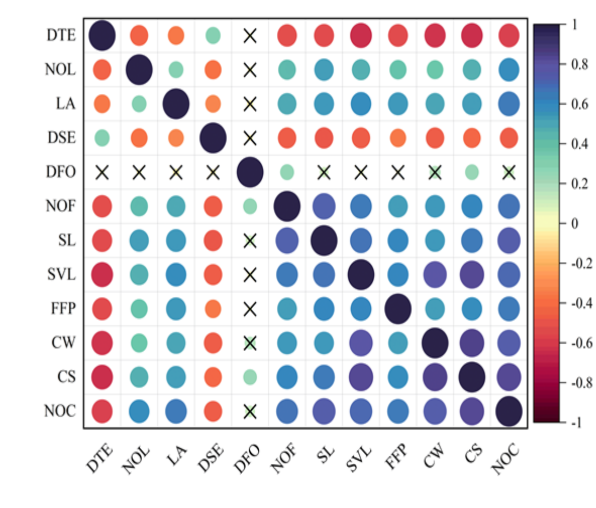

Fig. 5. Heat map of the studied attributes of gladiolus.

Being acidic in nature and a good soil conditioner, humic acid may cause better absorption of other essential plant nutrients such as nitrogen, potassium, and trace elements for improved vegetative growth [23]. The increased nutrient uptake causes an increase in the activity of the shoot meristem that stimulate the development of leaves [24]. Humic acid is also reported to improve shoot formation due to enhanced uptake of nutrients and development of chlorophyll and other pigmented compounds [25]. Humic acid improves the hormonal balance of the plants and increases cell division, and expansion, resulting in larger leaf area [10].

The earlier emergence of spike on treatment with humic acids suggests an accelerated shift in growth between vegetative and reproductive growth. Hormonal balance, and in particular gibberellins and cytokinins can regulate and stimulate flower bud initiation in plants raised on the soil with optimum level of humic substances [26]. Better root systems also facilitate the acquisition of nutrients which facilitates the development of reproductive organs [27]. This interaction between the level of humic acid and cultivars was significant and these findings indicated that there were some cultivars that are more sensitive to hormones or efficient in resource allocation in terms of being grown in enriched conditions. Early floret opening is usually observed due to better physiological condition and optimal water and nutrient supply [28]. Humic acid helps in enhanced root development, which makes it easy to absorb nutrients, leading to fast growth of flowers [29]. Optimum concentrations of the humic acid improve flowering due to reduced stress and more allocation of resources to the reproductive organs with improved source-sink relationship [30].

Enhanced florets per spike in response to humic acid might be due to the enhanced photosynthesis and production of energy. The increase in availability of nutrients, in particular phosphorus and potassium, by the presence of humic acid favors the development of the floral meristem and floret differentiation [31]. It also stimulates hormonal messages that control flowering [32]. Variability occurred because cultivars differed in the intrinsic genetic ability to transform nutrients into reproductive output in the form of floret production [33]. Humic acid enhanced spike elongation considerably, due to the enhanced nutrient and water base uptake and regulated auxins that initiate cell elongation [14]. With a better soil, the vascular system grows stronger and internode grows big [34]. The profound interaction between humic acid and cultivar indicates that some genotypes including the White Prosperity are more responsive to such favorable growth conditions and hence exhibited taller spikes. Our results are similar as those of Hassan *et al.* [14] they also reported significant increase in spike length of gladiolus cv. White prosperity.

The higher persistency of field flowers is associated with better retention of reducing and non-reducing sugars and also due to the osmotic balance [35], and provision of humic acid to the plants. Producing better nutrient retention and stress tolerance, humic acid delays senescence and preserves cell integrity of floral tissues [36]. Such genotypes as 'White Prosperity' are less liable to be discolored in the fields as they have better quality metabolic and structural stability. The prolonged vase life on the use of humic acid is probably through increased calcium and other building nutritious intake which makes the cell walls stronger and less prone to oxidative stress [37]. Humic acid also plays a role in hormonal balance to slow down the process of senescence and maintain color and shape of petals [38]. Similarly, humic acid has significant role in calcium uptake of the plants that enhances the membrane stability and increase vase life in cut flowers of tuberose [39]. Changes in the cell structure, rate of transpiration, and post-harvest metabolism can explain variation in the vase life among cultivars.

Higher photosynthetic efficiency and nutrient transport result in greater biomass distribution of plants to corm development [36]. Higher corm weight of the cultivars probably indicates an increased sink strength and shows capacity to allocate biomass with the best possible growing settings [40]. The increased size of the corm can be attributed to increase of nutrient accessibility and hormonal activity that causes division and expansion of cells under the humic acid treatment [14]. The presence of more essential nutrients such as phosphorus and potassium due to the presence of humic acid contributes towards the growth of the corms [40]. Humic acid improves the calcium use efficiency of the plants which ameliorate the weight of corms in gladiolus thereby results in significant increase in corm production per unit area [41, 42]. The variation between different cultivars can be attributed to genotypic differences where some cultivars are more vigorously growing [43]. Humic acid caused a significant improvement in vegetative attributes such as number of leaves and leaf area (Figure 1(B and C)), resulted in healthy plants with enhanced nutrient uptake [44] and hence resulted in better production of cormels in gladiolus.

5. CONCLUSIONS

Applying humic acid at a rate of 4 kg ha^{-1} enhanced the vegetative and reproductive traits of gladiolus. It significantly improved almost all the measured vegetative and reproductive parameters. Among cultivars, White Prosperity showed improvements in spike length, leaf area, number of florets, number of cormels, and field flower persistence, while Priscilla demonstrated better vase life, corm size, and corm weight. Therefore, humic acid at 4 kg ha^{-1} is recommended for better performance of gladiolus while cultivars White prosperity and Pricilla could be grown for better flowers and corm production under the agro-climatic conditions of Peshawar.

6. CONFLICT OF INTEREST

The authors have declared no conflict of interest.

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