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Humic acid and cultivar effects on growth, yield, vase life, and corm characteristics of gladiolus

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Gladiolus (*Gladiolus grandiflorus* L.), a popular and economically profitable bulbous cut flower, has high demand in both Pakistan domestic and international markets on account of its attractive spikes, florets of huge forms, dazzling colors, varying sizes, and long vase life. However, its quality production is badly affected by non-uniform sprouting, poor crop stand, and old cultivars. To overcome these problems, an experiment was conducted to elucidate the effect of humic acid (HA) applied along with NPK (17:17:17) and five exotic cultivars of gladiolus, 'Eminence', 'Cantate', 'Essential', 'Corveira' and 'Fado', on uniform crop stand, growth, flowering, and quality of cut gladiolus. Among HA treatments, three applications of HA and NPK, applied at planting, 3-leaf, and 6-leaf stages of plant development, followed by two applications of HA and NPK, applied at planting and 3-leaf stage, proved best for early and uniform sprouting, more foliage growth per plant, greater leaf area, and total leaf chlorophyll contents, earlier spike emergence, greater number of florets per spike, longer stems and spikes, and greater diameter of a spike, higher flower quality, longer vase life, higher number of cormels per clump, and greater cormel diameter and weight. Plants grown without HA and NPK application (control) or application of NPK alone, applied at planting, had poor growth, reduced yield, and inferior quality. Among cultivars, 'Fado' performed best for commercial cultivation, considering the applications of HA.

Key words: Cormel production, cut flowers, *Gladiolus grandiflorus*, humic substances, nutrition.

INTRODUCTION

Gladiolus (*Gladiolus grandiflorus* L.), a member of the family Iridaceae, is one of the top ranking cut flower crops. Available in different shapes and hues with excellent vase life, gladiolus is considered a superior bulbous cut flower. It has a high demand in global cut flowers trade; which requires development of new, promising, high yielding cultivars and their evaluation for their suitability for commercial production (Ahmad et al., 2008). Moreover, quality is limited due to soil conditions that are not favorable in many arid and semi-arid parts of the world where gladiolus is grown in field (Kuznetsov and Shevyakova, 1997). High pH values of soils which hinder the absorption of nutrients, also pose a problem for quality flower production. Foliar application is one of the methods to overcome this problem by providing nutrients necessary for optimal growth. Soil health is a crucial factor for obtaining higher yields of horticultural crops. Poor soil health and structure, and reduced microbial activities may result in poor crop stand, reduced plant growth and development (Baldotto and Baldotto, 2013). Chemical fertilizers play vital role in growth, yield, quality of flowers, and corm & cormel production of gladiolus. Intensive cut flower production demands high levels of fertilization. Improper fertilization in combination with excessive irrigation may contribute soil, water and environmental pollution (Zafar, 2007). With the rapid increase in population and limited area of cultivation, there is need to improve crop productivity with less effect on the environment. This is only possible with the integration of conventional and non-conventional approaches.

Humic acid (HA), a naturally occurring polymeric organic compound, is a potential natural resource that can be utilized to increase growth, nutrient availability and yield (Sharif et al., 2002). Humic acid is a commercial product which is produced by decaying organic compounds. It contains elements that improve soil fertility, reduces soil nutrient deficiency and increases water and nutrient availability by forming chelates of various nutrients (Bohme and Thi Lua, 1997; Sanchez-Sanchez et al., 2002). HA produced visibly better and healthier plant growth and increased flower yield and quality of gerbera at 500 mg L^{-1} (Nikbakht et al., 2008), and economized

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water use in pomegranate (*Punica granatum* L.) (Khattab et al., 2012), thereby reducing high operational costs and fertilizer application (Russo and Berlyn, 1990; Piccolo et al., 1991; Nikbakht et al., 2008). Moreover, it helps in protection of natural resources and facilitates environment-friendly re-vegetation of degraded soils. Humic substances (humic and fulvic acids) constitute 65-70% of organic matter in soils and are the subject of study in various fields of agriculture because of the multiple roles played by these materials, that can greatly benefit plant growth (Friedel and Scheller, 2002; Pin et al., 2011).

Application of HA improves soil aggregation, structure, fertility, and moisture holding capacity, and increases microbial activity (Chen and Aviad, 1990; Sharif et al., 2002), microbial population, and cation exchange capacity (Marinari et al., 2000). Studies have shown beneficial effects of HA such as increasing cell membrane permeability, oxygen uptake, respiration and photosynthesis, phosphate uptake, and root elongation. In particular, the photosynthetic efficiency and chlorophyll contents of *Lolium perenne* (rye-grass) were significantly increased by HA application (Russo and Berlyn, 1990). Humic acid also has direct cytokinin (Zhang and Ervin, 2004) and auxin or gibberellin-like stimulatory effects (Pizzeghello et al., 2001), along with indirect effect on plant metabolism (Piccolo et al., 1991). Humic acid, extracted from cattle, food and paper-waste vermicomposts, increased root growth of marigolds (*Tagetes patula* L. 'Antigua Gold') and peppers (*Capsicum annuum grossum* L. 'King Arthur') (Arancon et al., 2003). Its substrate drenching or foliar application were equally effective in maintaining higher root fresh and dry weights in cucumber (*Cucumis sativus* L.), marigold, pansy (*Viola tricolor* L.), geranium (*Pelargonium × hortorum* L. H. Bailey), and impatiens (*Impatiens walleriana* Hook. f.) seedlings (Li and Evens, 2000), and root growth and nutrient uptake in gerbera (*Gerbera jamesonii* Bolus ex Hooker f.) (Nikbakht et al., 2008). It increased the number of fruits and/or flowers, leaf area and plant height in *Triticum aestivum* L. (Malik and Azam, 1985; Chen et al., 2004a; 2004b). Humic acid improved plant resistance to environmental stresses (Ferrara et al., 2006). Incidence of plant diseases can also be limited with the application of HA (Nakamura, 1996). Humic acid application was also beneficial for nutrient uptake, particularly uptake of N, P, K, Mg, Ca, Zn, Fe, and Cu by plants (Fagbenro and Agboola, 1993; Nikbakht et al., 2008).

Considering the significance of nutrients in plant structure and physiological processes, they are treated as the limiting elements for good spike, corm and cormel production in gladiolus (Halder et al., 2007). Studies have shown that HA enhanced nutrient absorption (Nikbakht et al., 2008; Haghighi et al., 2012), photosynthetic activity (Haghighi et al., 2012), and root growth (Li and Evens, 2000), and alleviated salt stress (Aydin et al., 2012), which increased yield and quality of many ornamental crops (Nikbakht et al., 2008; Pin et al., 2011). In this study, a field experiment was conducted to investigate the potential effects of HA application on growth, yield, quality, vase life, and cormel production of gladiolus. Another objective of the study was to compare five new, promising exotic cultivars for their suitability for commercial cultivation.

MATERIALS AND METHODS

The study was conducted at the Floriculture Research Area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad (31º30' N, 73º10' E; 213 m a.s.l.), Pakistan, to elucidate the effect of HA on growth, quality, yield, vase life, and cormel production of five exotic cultivars of *Gladiolus grandiflorus* L., 'Eminence', 'Cantate', 'Essential', 'Corveira', and 'Fado'. There were six HA treatments, no NPK or HA (control), NPK alone (applied at planting), HA alone (applied at planting), NPK and HA (applied at planting), NPK and HA (applied at planting and 3-leaf stage), or NPK and HA (applied at planting, 3-leaf, and 6-leaf stage). The planting material (corms) was purchased from Stoop Flower Bulb Company, The Netherlands, while humic acid (registered as "Gold Cross') was obtained from Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan. HA (extracted from a rock material 'Leonardite' with 5.5-6.0 pH) was applied at 7000 mL ha^{-1} (2 mL L^{-1} water) and sprayed uniformly on the planting beds for first application at planting and next two applications were applied to foliage of respective treatments, while NPK fertilizer (17-17-17; Engro Fertilizers, Ghotki, Pakistan) was applied at 250 kg ha^{-1}. Soil was thoroughly ploughed 3-4 times, pulverized with rotavator, and leveled before blocks were laid out in a randomized complete block design (RCBD) with factorial arrangements. The soil used in the study had loamy texture, 8.1 pH, 0.31 dS m^{-1} EC, 0.85% organic matter, 0.05% N, 8 mg L^{-1} available P, and 110 mg L^{-1} exchangeable K.

On arrival, corms were kept in laboratory at 25 ± 2 °C for 1 wk to acclimatize before planting. Corms were planted 10 cm deep during the first week of November, with 10 cm corm to corm distance on 60 cm spaced ridges. Twenty corms were planted in each treatment and each treatment was replicated three times. The experiment was repeated in the following year for confirmation of the results. Humic acid and NPK fertilizer were applied at planting, 3-leaf, and 6-leaf stage according to the treatments. Other cultural practices, irrigation, weed control, plant protection measures, and earthing up, were same for all treatments during entire study period. Data were recorded on time to 50% sprouting (d), number of leaves per plant, leaf area (cm^2) of individual leaves, total leaf chlorophyll contents (mg g^{-1}), time to spike (flower) emergence (d), number of florets per spike, stem length (cm), spike length (cm), diameter of spike (cm), flower quality (on a rating scale of 1-9, where 9 was best quality, uniform, sturdy, upright stem, 5 for average, medium quality stem, and 1 was poor quality, lanky, weak stem), vase life (d), number of cormels per clump, diameter of a cormel (mm) and weight of a cormel (g). For vase life evaluation, stems were harvested in the morning before 10:00 h, leaves were trimmed, and stems were taken to the postharvest evaluation performed in a laboratory within 1 h of harvest. On arrival, stems were sorted on the basis of stem diameter and number of open florets into groups of 10 stems, recut from bases to a uniform length of 45 cm, labeled, and placed individually in vases containing 300 mL distilled water. Stems were arranged on benches at 25 ± 2 °C and 60 ± 10% relative humidity (RH) with 12:12 h photoperiod provided by cool-white fluorescent lamps. Stems were examined daily for their visual appeal and were considered dead, when more than half of florets were wilted, faded, or dried (Ahmad et al., 2011).

Data were analyzed statistically according to Fisher's ANOVA technique and treatment means were compared according to Tukey's test at $P \leq 0.05$ (Steel et al., 1997).

RESULTS

Among HA applications, treatments containing HA and/or NPK application sprouted earlier than control (Table 1). Plants supplied with three applications of HA and NPK resulted in earliest 50% sprouting (8.4 d), while plants grown without HA or NPK application had delayed sprouting and took more number of days to emerge from soil (15.1 d). Among gladiolus cultivars, significant differences were recorded for time to 50% sprouting (Table 2). Earliest sprouting (10.0 d) was recorded in 'Fado', while 12.9 and 12.6 d were taken by 'Eminence' and 'Cantate', respectively, which were statistically similar. 'Essential' and 'Corveira' were also statistically at par. Plants receiving three applications of HA and NPK produced the greatest number of leaves per plant (5.7), while those without NPK or HA application produced 3.3 leaves per plant (Table 1). Although the differences in number of leaves were not great, 'Essential' had significantly more leaves than 'Eminence' 'Cantate', or 'Corveira'. Similar findings have also been reported by Saleem et al. (2013) for 'Essential' gladiolus.

Among HA treatments, plants supplied with three applications of HA and NPK had greater leaf area than those without HA or NPK application, or HA or NPK application alone (Table 1). Among gladiolus cultivars, 'Fado', 'Essential', and 'Corveira' had significantly greater leaf area than 'Cantate' and 'Essential' (Table 2). Plants provided with three applications of HA and NPK had the highest total leaf chlorophyll contents while those without HA or NPK application had the least (Table 1). 'Fado' and 'Corveira' had statistically similar total leaf chlorophyll contents, significantly higher than in 'Essential'. While in 'Fado' this was also higher than in 'Eminence' and 'Cantate' (Table 2). Humic acid also affected crop duration as three applications of HA and NPK, or one application of HA or NPK, resulted in earlier spike emergence than no NPK or HA application (Table 1). 'Cantate', plants initiated spikes earlier than 'Corveira', 'Fado', and 'Essential', but these three did not differ significantly from 'Eminence' (Table 2).

Humic acid positively affected the reproductive characteristics of gladiolus. There was no significant effect of treatment (Table 3) or cultivar (Table 4) on number of florets per spike. Two or three applications of HA and NPK produced longer stems than the untreated control (Table 3). 'Fado' had significantly longer stems than

Table 2. Varietals comparison of time to 50% sprouting, number of leaves per plant, leaf area (of individual leaves), total leaf chlorophyll contents and time to spike emergence of *Gladiolus grandiflorus* 'Eminence', 'Cantate', 'Essential', 'Corveira', and 'Fado'.

Cultivars	Time to 50% sprouting	Number of leaves per plant	Leaf area	Total leaf chlorophyll contents	Time to spike emergence
	d		cm^2	mg g^{-1}	d
Eminence	12.9a	4.3bc	97.2a	64.51bc	69.8ab
Cantate	12.6a	4.3bc	84.9b	64.51bc	69.1b
Essential	11.4b	4.7a	80.4b	63.33c	71.7a
Corveira	11.2b	4.2c	93.9a	65.00ab	71.9a
Fado	10.0c	4.5ab	98.0a	66.47a	71.9a

Mean values within a column followed by different letters indicate significant differences according to Tukey's test ($P \leq 0.05$).

Table 1. Effect of humic acid (HA) applications on time to 50% sprouting, number of leaves per plant, leaf area (of individual leaves), total leaf chlorophyll contents and time to spike emergence of *Gladiolus grandiflorus*.

Treatments[1]	Time to 50% sprouting	Number of leaves per plant	Leaf area	Total leaf chlorophyll contents	Time to spike emergence
	d		cm^2	mg g^{-1}	d
No HA and NPK	15.1a	3.3d	66.6d	53.90f	73.8a
NPK alone (1)	13.3b	4.0c	71.3d	56.91e	70.1bc
HA alone (1)	12.0c	4.3c	72.3d	64.50d	70.3bc
HA and NPK (1)	11.1c	4.2c	94.3c	67.57c	71.7ab
HA and NPK (2)	9.9d	4.9b	109.7b	70.66b	71.2ab
HA and NPK (3)	8.4e	5.7a	131.2a	75.04a	68.1c

Mean values within a column followed by different letters indicate significant differences according to Tukey's test ($P \leq 0.05$).
[1]Number of applications in parentheses.

Table 3. Effect of humic acid (HA) application on number of florets per spike, stem length, spike length, diameter of spike, flower quality and vase life of *Gladiolus grandiflorus*.

Treatments[1]	Number of florets per spike	Stem length	Spike length	Diameter of spike	Flower quality	Vase life
		cm	cm	cm		d
No HA and NPK	10.7a	84.7c	45.1d	6.0d	2.8f	9.7b
NPK alone (1)	12.2ab	88.1bc	49.1bcd	6.2cd	3.9e	9.8b
HA alone (1)	11.9ab	93.9bc	47.8cd	6.4bc	4.4d	10.5ab
HA and NPK (1)	12.6a	96.4b	51.4bc	6.0d	5.1c	10.7ab
HA and NPK (2)	12.5a	106.2a	54.1b	6.7b	5.6b	10.2ab
HA and NPK (3)	12.5a	105.8a	64.1a	7.3a	8.1a	12.0a

Mean values within a column followed by different letters indicate significant differences according to Tukey's test ($P \leq 0.05$).
[1]Number of applications in parentheses.

‘Cantate’ but did not differ from the other three cultivars (Table 4). Plants supplied with three applications of HA and NPK had the longest spikes, while shortest spikes were recorded in plants without HA or NPK application, which were of a statistically similar length to those with a single HA or NPK application (Table 3). ‘Fado’ stems also had longer spikes and ‘Eminence’ stems had shorter spikes than all other cultivars (Table 4).

When plants were supplied with three applications of HA and NPK, thicker spikes than with other treatments were recorded (Table 3). ‘Corveira’ stems had thicker spikes than ‘Eminence’ or ‘Essential’ (Table 4). Regarding flower quality, among HA treatments, highest flower quality stems were recorded in plants supplied with three applications of HA and NPK, while those without HA or NPK application had the lowest quality stems (Table 3). ‘Fado’ stems had higher quality spikes than all other cultivars, which were statistically at par (Table 4). Plants supplied with three applications of HA and NPK had longer vase life than the control but the vase life of plants treated with one or two applications of HA and/or NPK did not differ significantly from the control (Table 3). ‘Essential’ stems had longer vase life than ‘Cantate’, ‘Corveira’, and ‘Eminence’ (Table 4).

Humic acid application greatly influenced the corm characteristics of gladiolus. Higher number of cormels per clump was produced by plants supplied with three applications of HA and NPK than untreated control (Table 5). ‘Fado’ produced greater number of cormels per clump while ‘Eminence’ had least cormels in a clump (Table 6). Humic acid and NPK application at planting, at 3 and at 6-leaf stages produced cormels with greater diameter (Table 5). ‘Fado’ had larger diameter of a cormel, whereas, ‘Eminence’ had smallest cormel diameter (Table 6). Plants supplied with three applications of HA and NPK had highest weight of a cormel (Table 5). ‘Fado’ resulted in highest weight cormels than other cultivars, while ‘Eminence’ had least weight of a cormel (Table 6).

Table 4. Varietal comparison of number of florets per spike, stem length, spike length, diameter of spike, flower quality and vase life of *Gladiolus grandiflorus* ‘Eminence’, ‘Cantate’, ‘Essential’, ‘Corveira’, and ‘Fado’.

Cultivars	Number of florets per spike	Stem length	Spike length	Diameter of spike	Flower quality	Vase life
		cm	cm	cm		d
Eminence	11.9ab	94.7ab	41.9c	6.3b	4.9b	10.0b
Cantate	11.2b	91.7b	52.5b	6.4ab	4.9b	9.8b
Essential	11.9ab	95.8ab	50.5b	6.2b	5.1b	12.4a
Corveira	12.9a	95.6ab	51.6b	6.7a	5.0b	9.8b
Fado	12.2ab	101.4a	63.4a	6.5ab	5.7a	10.3ab

Mean values within a column followed by different letters indicate significant differences according to Tukey’s test ($P \leq 0.05$).

Table 5. Effect of humic acid (HA) application on number of cormels per clump, diameter of a cormel and weight of a cormel of *Gladiolus grandiflorus*.

Treatments[1]	Number of cormels per clump	Diameter of a cormel	Weight of a cormel
		mm	g
No HA and NPK	9.0f	4.0f	0.6e
NPK alone (1)	10.0e	4.9e	1.0d
HA alone (1)	12.5d	6.1d	1.7c
HA and NPK (1)	14.9c	7.3c	1.8c
HA and NPK (2)	18.0b	10.4b	4.9b
HA and NPK (3)	20.6a	13.4a	6.3a

Mean values within a column followed by different letters indicate significant differences according to Tukey’s test ($P \leq 0.05$).
[1]Number of applications in parentheses.

Table 6. Varietal comparison of number of cormels per clump, diameter of a cormel and weight of a cormel of *Gladiolus grandiflorus* ‘Eminence’, ‘Cantate’, ‘Essential’, ‘Corveira’, and ‘Fado’.

Cultivars	Number of cormels per clump	Diameter of a cormel	Weight of a cormel
		mm	g
Eminence	12.6c	6.8d	2.3c
Cantate	13.4bc	7.1cd	2.5c
Essential	13.3bc	8.1b	2.8b
Corveira	13.8b	7.5c	2.9ab
Fado	17.7a	8.9a	3.1a

Mean values within a column followed by different letters indicate significant differences according to Tukey’s test ($P \leq 0.05$).

DISCUSSION

Humic acid is a potential compound that can be used for increasing nutrient availability and crop production. It plays a vital role in the transport and availability of micronutrients, which are otherwise fixed in soils with higher pH. Many beneficial effects of HA have been documented by the researchers on different crops. Generally, it is absorbed through plant roots, and translocated to shoots and other plant parts, and enhances plant growth responses (Lulakis and Petsas, 1995). Among gladiolus cultivars, ‘Fado’ had earliest sprouting and plants supplied with three applications of HA and NPK at planting, 3 and 6-leaf stages had earliest sprouting. These results are in line with findings of Malik and Azam (1985), Lulakis and Petsas (1995), and Li and Evens (2000), who reported better seedling growth with HA application. Among cultivars, earlier sprouting in ‘Fado’ might be due to differential genetic make-up of the cultivars or HA interaction with the environmental conditions and/or different cultivars that helped plants supplied with HA sprout earlier compared to untreated plants. Similar findings have been reported by Saleem et al. (2013) for the early sprouting in “Fado’ gladiolus. Brownell et al. (1987) reported that foliar application of HA promoted growth and increased yield by 10.5% in processing tomatoes over untreated controls. They have also reported that leonardite extracts containing higher concentration of humic acid should be applied as soil application, while those with lower HA concentration should be used as post emergence foliar spray. Humic acid application greatly improved biometric characteristics of gladiolus on account of its effect on photosynthetic activity, N metabolism and protein synthesis (Baldotto and Baldotto, 2013). Results have shown that number of leaves per plant was significantly affected by HA. These results are in accordance with the findings of Baldotto and Baldotto (2013), who reported greater number of leaves 'White Friendship' gladiolus, which might be due to improvement of micro and macro nutrient uptake and reduction in water evaporation from soils. 'Fado' and three applications of HA and NPK had greater leaf area. Availability of HA for longer periods might be responsible for increasing photosynthetic activity, which in turn increased leaf area. Valdrighi et al. (1996) reported that enhancement in the growth of tomato (*Solanum lycopersicum* L.) and cucumber leaves may be possible because of incorporation of HAs into the soilless container medium which increases nutrient uptake by the plants.

The increased total leaf chlorophyll contents might be due the acceleration of N and NO_3 uptake, enhancing N metabolism and production of protein by HA that ultimately increase chlorophyll contents (Haghighi et al., 2012) or due to other functions of HA such as increasing cell membrane permeability, oxygen uptake, respiration and photosynthesis, phosphate uptake, and root elongation (Russo and Berlyn, 1990). Earliest spike emergence was recorded in 'Cantate', while comparing treatments three applications of HA and NPK produced early crop, which might be due to the higher nutrient availability extended by HA. Similar results have been reported by Ricardo et al. (1993), who observed that the application of HA produced earlier flowering and higher yield in marigold. Shortening crop cycle by early production not only lowers production cost and increase per unit return and profitability, but also lowers the risk of crop damage by different biotic and abiotic stresses.

Humic acid not only promoted the vegetative growth but also floral growth was improved as higher number of florets per spike were produced by plants provided with three application of HA and NPK. These results are in line with the findings of Kaya et al. (2005); Nikbakht et al. (2008); and Baldotto and Baldotto (2013), who reported that HA increased flowering and yield of common bean, gerbera, and gladiolus, when applied at higher concentrations, and Haghighi et al. (2012) who reported improved lettuce yield by stimulating N metabolism and photosynthetic activity, which ultimately increased yield. For stem length of gladiolus, two or three applications of HA and NPK produced longer stems. Similar results have been reported by Arancon et al. (2003) that different levels of HA significantly increased stem length of marigold. Among cultivars, 'Fado' had longer stems as well as spikes. Among HA treatments, plants supplied with three applications of HA and NPK had longer and thicker spikes. These results revealed that HA application increased spike length which confirmed the role of HA in improving nutrient uptake and in turn increased spike length and overall flower quality. Similar findings of improvement in nutrient uptake especially of N, P, and S by the activity of HA have also been reported by Atiyeh et al. (2002) and Arancon et al. (2003).

'Fado' stems supplied with three applications of HA and NPK produced best quality spikes. These results are in line with the findings of Baldotto and Baldotto (2013), who reported best flower quality, longer spikes, and increased nutrient uptake by the plants supplied with HA compared to untreated controls. 'Essential' had longer vase life than other cultivars, while among HA treatments, three application of HA and NPK produced longer vase life. Baldotto and Baldotto (2013) reported that HA, which has auxin-like activity, enhanced nutrient uptake which may be responsible for the longer vase life of cut stems. Similar findings have also been reported by Nikbakht et al. (2008), who reported vase life extension in gerbera when grown with 1000 mg HA L^{-1}.

Plants provided with three applications of HA and NPK produced larger diameter of a cormel and higher number of cormels per clump, which may be due to healthy soil conditions caused by HA application. Our results are in line with the findings of Baldotto and Baldotto (2013), who reported that the increased number of cormels per plant might be due the effects of HA to make more mineral nutrients available to plants. 'Fado' stems also had greater number of cormels $clump^{-1}$ and diameter of a cormel which were similar to the findings of Saleem et al. (2013). Plants supplied with three applications of HA and NPK also had greater weight of a cormel, while among cultivars, 'Fado' had higher weight of a cormel, which was contrary to the findings of Saleem et al. (2013) who reported less weight of a cormel for 'Fado' gladiolus compared to other cultivars. In this study, the increased weight of cormels $plant^{-1}$ could be due to the greater effect of HA for uptake of mineral nutrients by the 'Fado' plants (Baldotto and Baldotto, 2013), or increased microbial populations and biologically active metabolites such as plant growth regulators (Doube et al., 1997). Overall, the growth and yield comparison of the tested cultivars was similar to that of reported by Saleem et al. (2013) with minor variations might be due to the effect of HA.

CONCLUSION

Among HA applications, three applications of HA along with NPK surpassed all other treatments for most of growth, and physiological indices of the gladiolus production and proved to be effective for enhancing yield and quality of cut gladiolus stems. Among the tested exotic cultivars, 'Fado' responded well to HA treatments as compared with others. Based on the findings, cv. 'Fado' and three applications of HA and NPK (at planting, 3 and 6-leaf stage) are suggested for commercial cultivation of gladiolus in Punjab, Pakistan.

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