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RESPONSE OF MORPHOLOGICAL AND PHYSIOLOGICAL GROWTH ATTRIBUTES TO FOLIAR APPLICATION OF PLANT GROWTH REGULATORS IN GLADIOLUS 'WHITE PROSPERITY'

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Gladiolus is very popular among ornamental bulbous plants mainly used as cut flower and greatly demanded in the world floral market. Production of inferior quality spikes is one of the major hurdles for their export. The research was conducted under Faisalabad conditions to evaluate the use of plant growth regulators in order to improve the vegetative, floral and physiological attributes. Gladiolus plants were sprayed thrice with different concentrations (0.1, 0.4, 0.7 and 1mM) of gibberellic acid, benzylaminopurine and salicylic acid at three leaf stage, five leaf stage and slipping stage. Foliar application of 1mM gibberellic acid increased the plant height (122.14cm), spike length (58.41cm), florets spike^{-1} (13.49), corm diameter (4.43cm), corm weight (25.34g) and total cormel weight (20.45g) compared to benzylaminopurine and salicylic acid. Gibberellic acid at 1mM concentration also increased the total chlorophyll content to 7.72mg/g, total carotenoids (1.61mg/g), total soluble sugars (3.68mg/g) followed by application of benzylaminopurine. Salicylic acid application at 1mM concentration decreased the number of days to flower (64.93) compared to 76.12 days in non treated plants.
Keywords: Gladiolus, plant growth regulators, corms, flower spike, sugars, phenolics.

INTRODUCTION

Gladiolus is perennial bulbous flowering plant belongs to family Iridaceae. The genus gladiolus consists of about 260 species among which 10 species are native to Eurasia and 250 belongs to sub-Saharan Africa (Goldblatt and Manning, 1998; Manning and Goldblatt, 2008). There is high demand of gladiolus in the world as cut flower. In USA, 60 million gladiolus spikes were sold in the market having worth of 16 million dollars which is 4.5% of total produced cut flowers in 2011 (USDA, 2012). The floriculture sector of Pakistan is becoming profitable for small farmers. The cut flowers production in Pakistan is estimated about 10 to 12 thousand tons per annum and their demand has been increased in the market (Rehman, 2004). Floriculture market of Pakistan is dominated by roses due to their usage on various occasions and various places (Nadeem *et al.*, 2011) followed by gladiolus as cut flower. Gladiolus is profitable crop even for small farmers but they are facing different problems regarding its cultivation due to absence of standard crop production system. There is need to develop the modern production system compatible to our climatic conditions. The use of plant growth regulators is important component of this system being used in the world to improve the different characteristics of floriculture crops.

Foliar application of plant growth regulators is helpful to improve the quality parameters of fruits and cut flowers (Sajid *et al*., 2009; Khalid *et al*., 2012). Gibberellins are important among plant growth regulators possessing various functions in vegetative and reproductive phases of plant life cycle. These have important role in controlling processes of growth, development, seed germination, stem elongation, leaf expansion and flower development (Kawa and Saniewski, 1986). Gibberellins are among the strong growth promoters as they can increase internodal distance, induce flowering and can also modify sex expression in some plant species (Davies, 1995). The beneficial effects of gibberellic acid on growth has been reported in different plants such as croton (Shedeed *et al*., 1991), rose (Eraki, 1994), *Ocimum basillicum* (Bedour *et al*., 1994), lilly (Sajid *et al*., 2009), *Lavandula officinalis* (Talaat, 1998) and grapes (Ozer *et al*., 2012).

The cytokinins are important part of several commercial plant growth regulators (Padhye *et al*., 2008). The cytokinins have influence on process of cell division (Francis and Sorrel, 2001; Vreugdenhil, 2004), biosynthesis of chloroplast pigments (Bondok *et al*., 1995), nutrient uptake especially potassium (Guo *et al*., 1994) and increasing photosynthetic efficiency (Oosterhuis and Zhao, 1998). The beneficial use of cytokinins in ornamental plants has been reported numerous times but its useful concentration of

application varies among ornamental plants (Werbrouk *et al*., 1996). The positive effect of cytokinins has been reported in many plants including *Dendrobium orchid* (Sakai *et al*., 1998), Lilium (Ohkawa, 1978) and *Achimenes longiflora* (Vlahos, 1985).

Salicylic acid is well known for its growth promotive functions and induction of stress tolerance in plants. Its effects different physiological processes as stomatal closure, somatic embryogenesis, induction of flowering, root growth stimulation and thermogenesis (Quiroz *et al*., 2001; Gutierrez-Coronado *et al*., 1998), root and shoot growth stimulation (Ahmad *et al*., 2013). In flowering plants, the salient effect of salicylic acid is reported on different characteristics of flower, the enhancement in flowering of Lemna (Khurana and Cleland, 1962), induction of flowering in *Phaseolus* (Lagoa and Pereira, 1991) and African violet (Martin-Mex *et al*., 2005) and flower bud regeneration in Streptocarpus (Handro *et al*., 1997). Salicylic acid application not only enhance the process of flower initiation in angiosperms (Raskin, 1992) but also have positive effect on chlorophyll concentration, photosynthetic rate and uptake of mineral in plants grown under stress condition (Karlidag, 2009) thus enhance the growth and plant productivity.

Keeping in view the potential of gladiolus crop nationally and internationally, the present study was planned to evaluate the effect of different plant growth regulators on morphological and physiological growth parameters of gladiolus crop.

MATERIALS AND METHODS

The corms of variety, White Prosperity were planted on ridges in the field of Floriculture research area, Institute of Horticultural Sciences, University of Agriculture, Faisalabad at 15 cm plant to plant and 60 cm row to row distance in October 2011. All the cultural practices including fertilization, irrigation, weeding and earthing up were done according to recommendations. The gladiolus plants were sprayed thoroughly with different concentrations (0.1, 0.4, 0.7, 1.0 mM) of freshly prepared solution of gibberellic acid, 6-benzylaminopurine and salicylic acid in distilled water, separately, each plant received about 8ml of solution. The spray was done at three leaves stage, five leaves stage and slipping stage (emergence of flower spikes) as shown in Figure 1. Only distilled water was sprayed on control plants. The experiment was designed as randomized complete block design (RCBD) with three replicates in the field having 20 plants in each replication. The experimental field area was located at 31°- 26' N latitude, 73°- 06' E longitude and 184.4m altitude.

The data for morphological parameters including plant height (cm), spike length (cm), spike diameter (mm), corm diameter (cm), corm weight (g), number of cormels/plant, total cormel weight/plant (g) and days to flower was recorded accordingly. The chlorophyll content was measured from mature leaves of gladiolus plants according to the protocol of Lichtenthaler (1987). Determination of total soluble sugars, reducing sugars and non reducing sugars was done by using spectrophotometer according to protocol of Riazi *et al*. (1985). Total phenolic contents (mg/g) were estimated according to Ainsworth and Gillespie (2007). Nitrogen, phosphorus and potassium were determined according to method of Chapman and Parker (1961).The collected data was analyzed for analysis of variance by using CoStat software and treatment means were compared by applying Least Significant Difference (LSD) test at 5% level according to Steel *et al*. (1997).

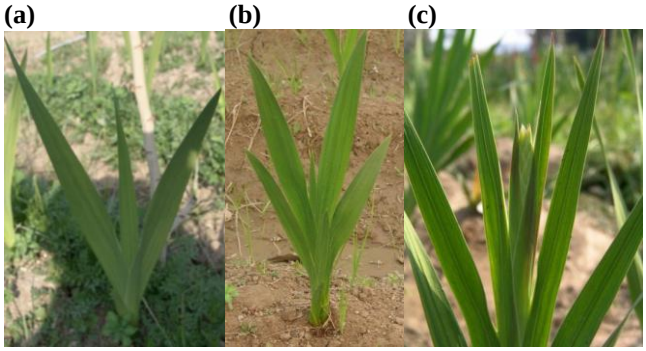

Figure 1. Description of different phases of gladiolus plant, a. three leaf stage, b. five leaf stage, c. slipping stage

RESULTS AND DISCUSSION

The plant morphological characteristics like plant height, spike length, spike diameter and number of florets spike^{-1}were significantly affected by foliar application of gibberellic acid, benzylaminopurine and salicylic acid as shown in Table 1. Gibberellic acid at 1mM concentration increased the maximum plant height (122.14cm), spike length (58.41cm) and also the number of floret spike^{-1} (13.49). At 1mM concentration, benzylaminopurine resulted in increased diameter of spike (7.23mm) and salicylic acid increased the spike length (48.63cm) compared to non treated plants (39.52cm). Similarly, Sajid *et al.* (2009) studied the effect of foliar application of nutrient solution containing gibberellic acid on flower characteristics and growth of lily plants. They found an increase in stem length, number of buds and flowers in response to foliar application of gibberellic acid. Gibberellic acid has numerous functions in plants as Davies (1995) reported that gibberellins are powerful growth promoters that can increase the internode spacing and promote flowering in many plants. Almost similar functions were reported by Sun and Gubler (2004) that gibberellic acid is involved in several physiological

Table 1. Effect of plant growth regulators on morphological growth parameters of gladiolus

Treatment (mM)		Plant height (cm)	Days to flower	Spike length (cm)	Spike diameter (mm)	Florets spike^{-1}	Corm diameter (cm)	Corm weight (g)	Cormels plant^{-1}	Total cormel weight (g)
Control		89.41 g	76.12 a	39.52 i	6.19 g	10.52 c	3.20 c	14.00 f	53.57 i	14.30 g
T1	0.1	97.22 e	75.23 ab	44.26 fg	6.35 f	11.53 bc	3.87 ab	16.46 e	60.64 f	16.83 def
	0.4	109.89 b	73.71 ab	51.15 c	6.75 d	12.41 ab	4.01 ab	21.13 c	65.15 e	17.37 cd
	0.7	120.15 a	73.04 ab	55.52 b	6.90 bc	13.04 ab	4.35 ab	24.70 a	75.33 a	19.43 ab
	1	122.14 a	71.81 abc	58.41 a	6.94 bc	13.49 a	4.43 a	25.34 a	75.64 a	20.45 a
T2	0.1	93.35 f	74.34 ab	42.45 gh	6.51 e	11.81 bc	3.82 abc	15.71 e	58.18 g	15.70 efg
	0.4	99.11 e	73.19 ab	45.28 ef	6.84 cd	12.46 ab	3.92 ab	19.76 d	65.56 e	17.07 de
	0.7	103.82 d	72.52 abc	50.41 c	6.98 b	12.59 ab	4.10 ab	22.72 b	70.44 c	18.59 bc
	1	106.28 c	72.19 abc	50.74 c	7.23 a	12.61 ab	4.21 ab	24.22 a	73.41 b	20.16 a
T3	0.1	91.08 g	72.07 abc	40.52 hi	6.31 fg	10.62 c	3.71 bc	15.16 ef	56.32 h	15.51 fg
	0.4	97.20 e	68.35 bcd	43.67 fg	6.62 e	11.66 bc	3.85 abc	18.47 d	66.14 de	16.59 def
	0.7	102.60 d	66.01 cd	47.67 de	6.80 cd	12.46 ab	3.98 ab	21.73 bc	67.48 d	17.48 cd
	1	103.92 d	64.93 d	48.63 cd	6.81 cd	12.46 ab	4.08 ab	22.66 b	70.61 c	19.78 ab
LSD at 5%		2.19	6.03	2.48	0.12	1.39	0.56	1.31	1.41	1.28

Means sharing similar letters are statistically non significant.

T1 = Gibberellic acid; T2 = Benzylaminopurine; T3 = Salicylic acid

processes including stem elongation. In the present study, benzylaminopurine also found effective in the improvement of flower characteristics of gladiolus plant. The results are compatible with the research work of Nambiar *et al*. (2012) that foliar application of benzylaminopurine on orchids results in increasing the inflorescence length, reduced day to flower and number of flowers per spike. Benzylaminopurine is an important cytokinin, and Bonhomme *et al*. (2000) stated that cytokinins have critical role in the triggering of flowering process in plants. The statement is further supported by the findings of Nguyen *et al*. (2006) that application of cytokinin is helpful in increasing the flowering percentage of rose plants. Bang and Xu (2011) reported that exogenous application of benzyladenine increased the number of flowers in *Jatropha curcas* plants. Application of salicylic acid was also helpful in the improvement of morphological characters including florets spike^{-1} (12.46) and reduction in number of days to flower (64.93) compared to 76.12 in control plants. The results confirms the findings of Ram *et al*. (2012) that foliar application of salicylic acid on gladiolus plants increased the spike length, number of florets spike^{-1} and decreased the number of days to flower. Similar findings regarding decrease in number of days to flower are reported by Jabbarzadeh *et al*. (2009) through foliar application of salicylic acid on African violet.

Gibberellic acid at 1mM concentration enhanced the diameter of corms (4.43cm), corm weight (25.34g), number of cormels (75.64) and total cormel weight (20.45g). Benzylaminopurine and salicylic acid application at 1mM strength also resulted in increased corm diameter (4.21cm) and 4.08cm, respectively. An increase in corm diameter, corm weight, number of cormels plant^{-1} and total cormels weight was found in response to PGRs treatment. The results are supported by Naveen and Chandrashekar (2008) who reported that foliar application of PGRs including gibberellic acid and benzyladenine on gladiolus plants increased the number of corms, corm size and its weight. Sudhakar and Kumar (2012) also reported that foliar application of PGRs including gibberellic acid on gladiolus plants resulted to increase the corm weight, number and weight of cormels.

Gibberellic acid at 1mM concentration was the most efficient treatment in increasing the chlorophyll a (5.55mg/g), chlorophyll b (2.17mg/g), total chlorophyll (7.72mg/g) and carotenoid contents (1.61mg/g) compared to benzylaminopurine and salicylic acid as they increased the total chlorophyll content (7.63mg/g) and 6.90mg/g, respectively (Table 2). This increase in chlorophyll content and carotenoids might have good impact on the growth and development of gladiolus plant. The results are in accordance with the findings of Janowska and Jerzy (2003) that gibberellic acid is able to prevent the degradation of photosynthetic pigment, i.e. the chlorophyll content in plants. With application of gibberellic acid the increase in carotenoids occurred in *Beaucarnea recurvate* (Abdel-Wahid and Sweify, 2009) and similarly in *Cucumis* and *Cucurbita* but with application of benzyladenine (Penner and Wiely, 2008). Mousa *et al*. (2001) reported that application of gibberellic acid increased the carotenoid content in leaves of *Nigella sativa* than application of cytokinin. In present investigations salicylic acid increased the chlorophyll content of leaves as compared to control plants, and the effectiveness of salicylic acid to increase the chlorophyll content is also reported by Bayat *et al*. (2012) in calendula plants.

Table 2. Effect of plant growth regulators on physiological parameters of gladiolus

Treatment (mM)		Chlorophyll a (mg/g dry wt)	Chlorophyll b (mg/g dry wt)	Total Chlorophyll (mg/g dry wt)	Carotenoids (mg/g dry wt)	Reducing sugars (mg/g dry wt)	Non reducing sugars (mg/g dry wt)	Total soluble sugars (mg/g dry wt)
Control		3.10 h	1.59 h	4.69 k	0.73 f	0.77 f	1.20 f	1.97 g
T1	0.1	4.59 f	1.75 efgh	6.35 hi	1.22 e	0.93 cd	1.96 cd	2.89 d
	0.4	5.14 bcd	1.87 de	7.01 d	1.46 bcd	0.99 bc	2.06 c	3.05 c
	0.7	5.43 ab	1.97 bcd	7.40 c	1.51 ab	1.08 ab	2.24 b	3.32 b
	1	5.55 a	2.17 a	7.72 a	1.61 a	1.10 a	2.58 a	3.68 a
T2	0.1	4.49 fg	1.68 fgh	6.17 i	1.20 e	0.90 cde	1.87 d	2.77 e
	0.4	4.83 def	1.90 cde	6.73 ef	1.37 cd	0.95 cd	1.96 cd	2.91 d
	0.7	5.39 abc	2.07 abc	7.46 bc	1.45 bcd	0.98 cd	2.05 c	3.03 c
	1	5.52 a	2.11 ab	7.63 ab	1.48 bc	0.99 bc	2.28 b	3.27 b
T3	0.1	4.18 g	1.65 gh	5.83 j	1.18 e	0.80 f	1.59 e	2.39 f
	0.4	4.72 ef	1.76 efgh	6.49 gh	1.24 e	0.83 ef	1.91 d	2.74 e
	0.7	4.85 def	1.81 defg	6.66 fg	1.35 d	0.89 de	1.95 cd	2.84 de
	1	5.05 cde	1.85 def	6.90 de	1.44 bcd	0.93 cd	2.30 b	3.23 b
LSD at 5%		0.35	0.16	0.19	0.1	0.09	0.11	0.11

Means sharing similar letters are statistically non significant.
T1 = Gibberellic acid; T2 = Benzylaminopurine; T3 = Salicylic acid

The sugar contents of leaves increased with the application of gibberellic acid, benzylaminopurine and salicylic acid. Total soluble sugars (3.68mg/g) was recorded in application of gibberellic acid followed by benzylaminopurine (3.27mg/g) at 1mM concentration (Table 2). Salicylic acid yielded higher total soluble sugars (3.23mg/g) compared to non treated plants (1.97mg/g). This increase in sugar content might be helpful in producing healthy flower spikes. Sugars provide energy required for the synthesis of new cell and for cell division and elongation, thus produce the positive effect on growth of plant. The results are in agreement with the findings of Eid and Leila (2006) that foliar application of gibberellic acid on ornamental plants increases carbohydrates of leaves.

Total phenolic contents of leaves increased to 0.62mg/g with 1mM salicylic acid and to 0.57mg/g with 1mM gibberellic acid application. The phenolic compounds helps in strengthening the defense system of plant against diseases and abiotic stresses. The foliar application of 1mM gibberellic acid increased the N (1.52%), P (0.28%) and K (0.64%) content of leaves. Salicylic acid application at 1mM concentration resulted to increase the 1.55% N compared to 0.96% in non treated plants (Table 3). The nutrients play an important role in the production of quality flowers in ornamental plants. Viradia and Singh (2004) reported the importance of N for ornamental plants as it is essential

Table 3. Effect of foliar application of plant growth regulators on total phenolic content and N, P, K contents of leaves

Treatments (mM)		Total Phenols (mg/g)	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Control		0.44 f	0.96 f	0.16 f	0.41 h
Gibberellic acid	0.1	0.49 ef	1.24 d	0.24 bcd	0.52 fg
	0.4	0.57 bc	1.39 bc	0.26 abc	0.59 bcd
	0.7	0.59 ab	1.47 ab	0.27 ab	0.63 ab
	1	0.57 bc	1.52 a	0.28 a	0.64 a
6-Benzylaminopurine	0.1	0.47 ef	1.13 e	0.22 de	0.48 g
	0.4	0.50 de	1.23 de	0.23 cd	0.54 ef
	0.7	0.57 bc	1.25 d	0.25 abcd	0.57 de
	1	0.60 ab	1.28 d	0.28 ab	0.58 cde
Salicylic acid	0.1	0.48 ef	1.23 de	0.19 ef	0.49 g
	0.4	0.54 cd	1.30 cd	0.22 de	0.52 fg
	0.7	0.61 ab	1.45 ab	0.24 bcd	0.57 de
	1	0.62 a	1.55 a	0.25 abcd	0.61 abc
LSD at 5% level		0.04	0.1	0.04	0.04

Means sharing similar letters are statistically non significant.

component of protein and nucleic acid, required for vegetative growth and production of quality flowers. Phosphorus is also important and involved in the most important metabolic processes and helpful in flowering characteristics in plants. Zhang *et al*. (2004) found that P is effective in increasing the number of flowers. Gibberellic acid effectively increased the P and K content of leaves in the present study. Similar results were obtained by Eid and Leila (2006) that gibberellic acid application on croton plants increased N, P and K content. The promotive effect of gibberellic acid in increasing the phosphorus and potassium concentration in plants may be due to its vital role in regulating plant growth via nucleic acid and enzyme synthesis (El-Azzouni, 2003).

***Conclusion*:** The foliar application of plant growth regulators improved the economically important characteristics of gladiolus flower spike as spike length and number of florets spike^{-1}. These traits have significant importance in gladiolus spikes exhibition and are also economically important for their marketing. The use of plant growth regulators also helped in improving the size of corms which is supportive in obtaining good size flower spike in the next generation. Thus the use of plant growth regulators in our production system can help the growers to improve the flower traits of gladiolus which will ultimately lead to fetch more price in the domestic and international market.

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