Agric Res J **60** (2) : 238-245, *April* 2023
DOI No. 10.5958/2395-146X.2023.00037.6

EVALUATION OF CORM TREATMENTS WITH BENZYLADENINE AND GIBBERELLIC ACID ON GROWTH AND FLOWERING ATTRIBUTES OF GLADIOLUS

Shalini Jhanji[1*] , Kompal Gaur[2] and K K Dhatt[1]

[1]Department of Floriculture and Landscaping, [2]Department of Botany
Punjab Agricultural University, Ludhiana-141004, Punjab

ABSTRACT

The efficacy of benzyladenine (BA) and gibberellic acid(GA_3) corm treatments on morpho-physiological, biochemical, post-harvest and yield parameters of *Gladiolus grandiflorus* cv. Novalux was evaluated. The corms were immersed for 24 hours in freshly prepared solutions of different concentrations (50 mg L^{-1}, 75 mg L^{-1}, 100 mg L^{-1} and 125 mg L^{-1}) of Benzyladenine (BA) and Gibberellic acid (GA_3). The corm treatment with GA_3 had positive effect on plant height, shoot weight, leaf area and leaf weight whereas, BA had adverse effect as compared to control. The biochemical parameters viz. total chlorophyll content, relative water content, membrane stability index, total soluble sugars and total protein content in leaves and florets were affected in response to both GA_3 and BA. Among the post-harvest and yield parameters, GA_3 @ 125 mg l^{-1} recorded maximum enhancement in vase life (15.33 days), floret size, number of florets open at one time, per cent opening of florets, pH reduction and water uptake by spikes. However, BA @ 125 mg L^{-1} recorded maximum enhancement in production of corms (3.66), cormels (16.33) and spikes per plant (3.00). Thus, vegetative and post-harvest parameters were improved more profoundly with GA_3 whereas, BA corm treatments were more efficient in promoting production of underground structures i.e. corms and cormels.

Keywords: Benzyladenine, Gibberellic acid, *Gladiolus,* Post-harvest life, Pre-sowing treatments

Gladiolus is a flower of perfection and glamour. It belongs to family *Iridaceae*and is commonly referred as sword lily on account of its sword like leaves. It has gained prominence in floriculture industry due to its availability in versatile colours, varied size of spikes, eye catching arrangements of florets on spikes and excellent vase life. It occupies fourth place in the international cut flower trade and is a popular choice of floriculturists because of its majestic spikes and various decorative utilities (Nag and Kumar, 2021).

Cut flowers are highly perishable and are thus subjected to post harvest losses. Commercially, many synthetic chemicals are being applied and tested for their potential to enhance vase life of these flowers. However, due to non-eco-friendly nature of synthetic chemicals, the focus is being shifted towards the use of more eco-friendly counterparts. Plant growth regulators are chemical compounds which are organic in nature and modify physiology of plant when applied in small concentrations. Among these, gibberellins and cytokinins are widely studied for their multifaceted physiological effects that could improve the quality of flowering crop at various stages (Emongor, 2004, Padmalatha *et al.,* 2013). The pronounced role of cytokinins in delaying senescence via reducing lipid peroxidation, maintaining membrane integrity and high levels of chlorophyll content could be contributing towards enhancement of post-harvest life (Zhang and Guo, 1998). Likewise, enhancement in vase life is also been demonstrated by gibberellic acid in many studies on account of its possible role in delaying fading of flower colour, suppression of proteolysis and postponing flower wilting (Eason*et al.* 2002).

Improvement in shelf life of several flowers e.g. petunia and rose by overexpression of *isopentenyltranseferase*(*IPT)* thus causing cytokinin overproduction has been demonstrated by molecular approaches (Faveroet *al. 2020*). The pre-harvest spray treatments of GA_3 and BA have reported to enhance vase life and improved quality of flowers of Rose and Lilium(Kaviya*et al.* 2021).

In majority of studies, growth regulators are applied as either foliar sprays or dip treatments of corms and their effects are recorded at various growth and developmental stages (Sajid*et al.*2015). Keeping in view, the various beneficial roles of BA and GA_3 and importance of gladiolus as cut flower, the present study was taken up as an attempt to understand the efficacy of BA and GA_3 corm treatments on various morphological, physiological, post-harvest and yield attributes of gladiolus.

*Corresponding author : shainijhanji@pau.edu
Date of receipt: 01.09.2022, Date of acceptance: 30.04.2023

MATERIALS AND METHODS

The uniform sized corms (3.5-4.0 cm dia) of gladiolus cv. Novalux were given dipping treatments in water and various concentrations (50 mg L^{-1}, 75 mg L^{-1}, 100 mg L^{-1} and 125 mg L^{-1}) of BA and GA_3 for 24 hours. The corms without any dipping served as control. The corms were raised in the Research Farms of Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana following recommended cultural practices to obtain spikes. The spikes were harvestedat tight bud stage (when basal 1-2 florets showed colour). After harvesting, the spikes were grouped in bundles of 3 each and each bundle was placed in vertical position in vase containing distilled water such that basal 5-7 cm portions of the spikes were dipped in water. Plant height and weight, leaf area and weight were recorded at tight bud stage from 9 plants per treatment. Leaf area was recorded using graphical method. The outlines of leaves were drawn on the graph paper and then number of square centimeters were calculated. Relative water content (RWC) (Weatherly 1950), membrane stability index (MSI) (Premchandra*et al.* 1990), total chlorophyll content (Anderson and Boardman 1964), total soluble sugars (Dubois *et al.* 1956) and total soluble protein content (Lowry *et al.* 1951) were recorded from leaves and floret at tight bud stage. The observations recorded for post-harvest quality parameters were vase life, per cent opening of florets, floret size, days to opening of basal floret, maximum florets open at one time, change in pH of vase solution, physiological loss in weight and total water absorbed by spike. Vase life was recorded in terms of days between the opening of basal floret till the day 50 % of opened florets showed wilting.The experiment was conducted in a randomized block design(RBD).All the treatments were replicated thrice with three spikes per replication. Data was subjected to statistical analysis of variance (ANOVA) using SAS software (version 9.2, SAS Institute Inc., Cary, NC, USA). Mean comparisons to calculate significant differences were performed using Least Significant Differences (LSD) test at 0.05 level of probability.

RESULTS AND DISCUSSION

Plant height

Both BA and GA_3hadpromoting effect on plant height as compared to control (Table 1). There was increase in plant height with increased concentration of GA_3 and maximum was in treatment with 125 mg L^{-1} GA_3 (97.53 cm) and minimum in control (79.50 cm). However, there was reduction in plant height with increased concentration of BA. Among BA treatments, plant height was maximum in BA @ 50 mg L^{-1} (87.43 cm) and minimum in BA @ 125 mg L^{-1} (84.36 cm).

The enhancement in plant height with GA_3 treatment could be attributed to the physiological role of GA_3 in cell elongation and division (Taiz *et al*. 2014). Singh *et al.* (2020) also recordedincrease in plant height with GA_3 corm treatments in gladiolus. Torres-Pio *et al*. (2021) recorded similar response of BA on plant height after bulb treatment in lilium cv. Arcachon.

Shoot weight

The shoot weight was maximum with GA_3 @ 125 mg L^{-1}(108.21 g $plant^{-1}$) which was significantly higher than control (98.26 g $plant^{-1}$) and BA corm treatments (Table 1). Shoot weight increased with increasing concentration of GA_3anddecreased with increasing

Table 1. Effect of BA and GA_3 corm treatments on plant height, weight, leaf area and leaf weight of gladiolus cv. Novalux.

	Plant height (cm)	Shoot weight (g $plant^{-1}$)	Leaf Area (m^2 $plant^{-1}$)	Leaf weight (g $plant^{-1}$)
T_1	87.43^{D}	98.46^{D}	0.55^{E}	29.94^{E}
T_2	86.03^{E}	98.55^{D}	0.53^{FG}	26.65^{F}
T_3	85.90^{E}	96.60^{E}	0.52^{GH}	23.87^{G}
T_4	84.36^{F}	95.34^{F}	0.51^{H}	21.20^{H}
T_5	88.10^{D}	100.59^{C}	0.57^{D}	33.17^{D}
T_6	90.40^{C}	100.63^{C}	0.60^{C}	37.51^{C}
T_7	92.93^{B}	102.55^{B}	0.62^{B}	40.15^{B}
T_8	97.53^{A}	108.21^{A}	0.67^{A}	43.98^{A}
T_9	82.73^{G}	98.71^{F}	0.55^{E}	30.02^{E}
T_{10}	79.50^{H}	98.26^{F}	0.54^{EF}	29.11^{E}
LSD (p=0.05)	1.25	1.25	0.10	2.03

T_1- 50 mg L^{-1} BA, T_2- 75 mg L^{-1} BA, T_3- 100 mg L^{-1}BA,T_4-125 mg L^{-1} BA. T_5-50 mg L^{-1} GA_3, T_6-75 mg L^{-1} GA_3, T_7-100 mg L^{-1} GA_3, T_8-125 mg L^{-1} GA_3, T_9-Water, T_{10}- Control

concentration of BA. The corm treatment with BA @ 125 mg L^{-1}recorded minimum shoot weightof 95.34 gplant^{-1} whichwas statistically at par with water treatment (98.71 g plant^{-1}) and control (98.26 g plant^{-1}).Gibberellic acid's beneficial effects on weight and size could be linked to its involvement in encouraging cell proliferation, organ elongation and expansion (Li *et al*., 2011).

Leaf area

The leaf area (Table1) increased with increasing concentration of GA_3 and was highest with GA_3@ 125 mg L^{-1}(0.67 m^2plant^{-1}). It declined with increasing concentration of BA as corm treatment with 125 mg L^{-1}BA recorded lowest leaf area(0.51 m^2 plant^{-1}). The increase in leaf area with GA_3 might be due to increase in cell division and elongation.The reduction in leaf area with BA could be attributed to its simultaneous role at two sinks (inflorescence and development of underground structures) during leaf development (Padmalatha *et al.,* 2013).

Leaf weight

GA_3@ 125 mg L^{-1} recorded highest leaf weight of 43.98 g plant^{-1} andBA@125 mg L^{-1}recorded lowest leaf weight of 21.20 g plant^{-1}(Table 1)which was statistically lower than control (29.11 g plant^{-1}). Leaf area increased with increasing concentration of GA_3 and decreased with increasing concentration of BA. This might be due to increase in length and width of leaves by adding more cells via division that improved photosynthetic capacity and accumulation of photo assimilates leading to increase in leaf weight (Sajid *et al.,* 2015).

Biochemical analysis from leaves

Total chlorophyll content of leaves

BA @ 125 mg L^{-1} recorded maximum chlorophyll content (0.29 mg g^{-1} FW), followed by GA_3 @ 125 mg L^{-1} (0.25 mg g^{-1} FW, Table 2) which was statistically at par with BA @ 100 mg L^{-1} (0.24 mg g^{-1} FW). Significantly lower chlorophyll content was recorded in water treatment and control (0.16 mg g^{-1} FW and 0.15 mg g^{-1} FW respectively) as compared to all other treatments. The data revealed that BA and GA_3 had positive influence on chlorophyll content as it increased with increasing concentration of both BA and GA_3. The results can be explained on the ability of BA and GA_3 to slow down chloroplast and chlorophyll degradation and thus maintenance of photosynthetic capacity of plant (Faraji *et al.,* 2011, Desai *et al.,* 2020).

Relative water content (RWC)

Highest RWC in leaves (Table 2) was recorded with BA @ 125 mg L^{-1} (80.09), followed by BA @ 100 mg L^{-1} (77.98) and GA_3 @ 125 mg L^{-1} (76.78). Relative water content increased with increasing concentration of BA and GA_3 and among all concentrations of these growth regulators, BA @ 125 mg L^{-1}(80.09) and GA_3 @ 125 mg L^{-1}(76.78) recorded highest value of RWC.

Membrane Stability Index (MSI)

Membrane Stability Index of leaves increased with increasing concentration of BA and GA_3 (Table 2). Corm treatment with 125 mg L^{-1} BA recorded maximum MSI (89.87) which was statistically at par with 100 mg L^{-1} BA (88.73) and125 mg L^{-1} GA_3 (88.24). Corm treatments

Table 2. Effect of BA and GA_3 corm treatments on total chlorophyll content, relative water content, membrane stability index, total soluble sugars and total soluble protein content in leaves.

	Total Chorophyllcontent (mg g^{-1} FW)	Relative water content	Membrane Stability Index	Total soluble sugars (mg g^{-1} FW)	Total soluble protein (mg g^{-1} FW)
T_1	0.19^{E}	72.99^{CD}	82.76^{C}	371.28^{F}	176.77^{DE}
T_2	0.19^{E}	75.13^{BC}	83.35^{C}	382.57^{D}	181.76^{CD}
T_3	0.24^{B}	77.98^{AB}	88.73^{A}	388.75^{C}	193.45^{AB}
T_4	0.29^{A}	80.09^{A}	89.87^{A}	431.22^{A}	195.63^{A}
T_5	0.19^{E}	71.17^{DE}	79.62^{D}	378.90^{E}	174.78^{E}
T_6	0.21^{D}	72.34^{CD}	81.98^{C}	381.18^{DE}	180.37^{CD}
T_7	0.22^{C}	72.99^{CD}	87.83^{B}	388.73^{C}	184.51^{C}
T_8	0.25^{B}	76.78^{AB}	89.24^{A}	421.60^{B}	189.61^{B}
T_9	0.16^{F}	66.55^{F}	76.91^{E}	366.77^{G}	162.66^{F}
T_{10}	0.15^{F}	68.74^{EF}	72.22^{F}	356.70^{H}	162.39^{F}
LSD (p=0.05)	0.10	4.59	1.89	4.12	4.92

T_1- 50 mg L^{-1} BA, T_2- 75 mg L^{-1} BA, T_3- 100 mg L^{-1} BA,T_4-125 mg L^{-1} BA, T_5-50 mg L^{-1} GA_3, T_6-75 mg L^{-1} GA_3, T_7-100 mg L^{-1} GA_3, T_8-125 mg L^{-1} GA_3, T_9-Water, T_{10}- Control

with BA had more pronounced effect on MSI than GA_3. All treatments recorded significantly higher MSI values than control. Singh and Tiwari (2021) proposed that cytokinins might maintain the membrane integrity of cells by scavenging free radicals that otherwise can contribute to flower senescence. Elanchezhian and Srivastava (2001) reported reduced lipid peroxidation due to GA_3 and BA and hence an increase in MSI.

Total soluble sugars

The corm treatment with BA and GA_3 significantly increased the total soluble sugar content in leaves (Table 2). Among all treatments, BA @ 125 mg L^{-1} recorded maximum total soluble sugar content (431.22 mg g^{-1} FW), followed by GA_3 @ 125 mg L^{-1} (421.60 mg g^{-1} FW). The control recorded minimum value of total soluble sugar content (356.70 mg g^{-1} FW). All concentrations of BA and GA_3 recorded significantly higher total soluble sugar content than control. The high TSS content could possibly be due to the inhibition of enzymes accountable for the hydrolysis of starch (Singh *et al*. 2006).

Total soluble protein content

Corm treatment with BA @ 125 mg L^{-1} recorded maximum total soluble protein content (195.63 mg g^{-1} FW). It was statistically at par with BA @ 100 mg L^{-1} (193.45 mg g^{-1} FW) and 125 mg L^{-1} (189.61 mg g^{-1} FW). Total soluble protein content increased with increasing concentration of BA and GA_3. Control recorded minimum total soluble protein content (162.39 mg g^{-1} FW). It was statistically at par with water treatment (162.66 mg g^{-1} FW). The high protein content in leaves and florets of GA_3 and BA-treated plants might be due to better supplementation of photo assimilates due to better efficiency of CO_2 assimilation exhibited by these plants (Salachna *et al*., 2020).

Biochemical analysis from florets

Relative water content (RWC)

Corms treated with BA @ 125 mg L^{-1} recorded maximum relative water content in floret (71.41, Table 3) and it was statistically at par with 125 mg L^{-1} GA_3 (68.34). Relative water content increased with increasing concentrations of BA and GA_3.

The maintenance of relative water content of leaves and florets might be attributed to GA_3 induced breakdown of complex carbohydrates like starch into sugars, leading to increased solute potential and water uptake (Emongor, 2004).

Membrane Stability Index (MSI)

Corm treatment with BA @ 125 mg L^{-1} recorded maximum MSI value in floret (Table 3). Membrane Stability index recorded with 100 mg L^{-1} (85.90) was statistically at par with 125 mg L^{-1} GA_3 (85.47). Among all treatments, BA @ 125 mg L^{-1} (87.62) recorded maximum MSI and it was 1.17 times the control (74.44). Membrane stability index is bound to decline with the onset of senescence due to lipid peroxidation and other irreversible phases of senescence (Jaleel*et al.* 2007). Studies have reported roles of GA_3 and BA in ameliorating lipid peroxidation and maintaining MSI in order to delay senescence Elanchezhian and Srivastava (2001).

Table 3. Effect of BA and GA_3 corm treatments on relative water content, membrane stability index, total soluble sugars and total soluble protein content in florets.

	Relative water content	Membrane Stability Index	Total soluble sugars (mg g^{-1} FW)	Total soluble protein (mg g^{-1} FW)
T_1	62.82^{DE}	82.96^{D}	190.82^{G}	250.55^{D}
T_2	65.77^{BC}	84.19^{C}	217.40^{F}	256.12^{C}
T_3	68.37^{B}	85.90^{B}	220.14^{E}	260.17^{B}
T_4	71.41^{A}	87.62^{A}	222.19^{E}	265.91^{A}
T_5	62.41^{E}	81.16^{E}	251.29^{D}	243.56^{E}
T_6	64.46^{CDE}	82.10^{D}	288.68^{C}	249.88^{D}
T_7	65.46^{CD}	84.02^{C}	314.81^{B}	256.00^{C}
T_8	68.34^{B}	85.47^{B}	332.87^{A}	259.98^{B}
T_9	62.10^{E}	76.15^{F}	184.81^{H}	213.61^{F}
T_{10}	58.32^{F}	74.44^{G}	184.74^{H}	200.52^{G}
LSD (p=0.05)	2.89	0.55	2.24	2.39

T_1- 50 mg L^{-1} BA, T_2- 75 mg L^{-1} BA, T_3- 100 mg L^{-1} BA,T_4-125 mg L^{-1} BA, T_5-50 mg L^{-1} GA_3, T_6-75 mg L^{-1} GA_3, T_7-100 mg L^{-1} GA_3, T_8-125 mg L^{-1} GA_3, T_9-Water, T_{10}- Control

Total soluble sugars

Corm treatment with GA_3 @ 125 mg L^{-1} recorded maximum value of total soluble sugar content (332.87 mg g^{-1} FW) (Table 3). It was 1.80 times that of control (184.74 mg g^{-1} FW). Among BA treatments, corm treatment with 125 mg L^{-1} BA recorded maximum total soluble sugar content (222.19 mg g^{-1} FW). Total soluble sugar content increased with increasing concentration of BA and GA_3. This could be accounted to the role of GA_3 in preventing the formation of enzymes responsible for starch hydrolysis (Ichimura *et al.,* 2002). High sugar content due to BA treatment could be due to increased activity of invertase and amylase with BA (Faraji *et al*., 2011).

Total soluble protein content

Maximum protein content was recorded with BA @ 125 mg L^{-1} (265.91 mg g^{-1} FW) which was 1.32 times higher than control, followed by BA @ 100 mg L^{-1} (260.17 mg g^{-1} FW) which was statistically at par with GA_3 @ 125 mg L^{-1} (259.98 mg g^{-1} FW, Table 3). Among all the treatments, 125 mg L^{-1} BA recorded maximum protein content at both stages (265.91 mg g^{-1} FW and 195.63 mg g^{-1} FW).Proteolytic enzymes lead to degradation of proteins by breaking internal peptide bonds (Mansee *et al*., 2013). Elevation recorded in protein content might be due to reduction in activity of protease enzyme under the influence of BA and GA_3 (Elanchezhian and Srivastava, 2001).

Post-harvest quality parameters

Vase life

All the corm treatments significantly increased vase life of gladiolus spikes as compared to control (8.16 days, Table 4). Maximum vase life was recorded in corm treatment with 125 mg L^{-1} GA_3 (15.33 days), followed by 100 mg L^{-1} GA_3 (14.33 days) as compared to the control (8.33 days). Vase life (15.33 days) recorded in GA_3 @ 125 mg L^{-1}, was 1.84 times than the control. Vase life increased with increase in concentration of BA and GA_3. Among all GA_3 concentrations, 125 mg L^{-1} recorded maximum vase life (15.33 days) and 50 mg L^{-1} GA_3 recorded minimum vase life (12.33 days). Likewise, among all BA treatments, maximum vase life of 13.66 days was recorded with 125 mg L^{-1} BA treatment and least vase life was recorded with 50 mg L^{-1} BA (10.33 days). Franco and Han (1997) have reported positive effect of gibberellins and cytokinins on post-harvest life of cut flowers by reducing rate of respiration and thus delaying senescence. Our results are in concordance with Emami *et al*. (2011) who also reported enhancement of vase life by treatment with GA_3 and BA via delaying lipid peroxidation and ion leakage.

Days to the opening of basal floret

The spikes obtained from the corms treated with 125 mg L^{-1} BA took maximum days (3.66) for the opening of basal floret. Whereas, spikes resulting from the corms treated with 125 mg L^{-1} GA_3 took minimum time (1.33) for the opening of basal floret (Table 4). The number of days for the basal floret opening increased with increasing concentration of BA whereas, number of days to the opening of basal floret decreased with increasing concentration of GA_3. The number of days taken by basal floret to open with 125 mg L^{-1} BA was 3.66 times than that of control (1.00). The possible explanation behind delayed opening of basal floret in response to BA treatments could be the promotion of

Table 4. Effect of BA and GA_3 corm treatments on post harvest and yield parameters of gladiolus cv. Novalux

	Vase Life (Days)	Days to Opening	Floret Size (cm)	Change in pH	Per cent Loss in Weight	Per cent Flowering	Water Uptake (ml)	Number of Corms	Number of Cormels	Number of Spikes Per Plant
T_1	10.33^{DE}	2.33^{BC}	8.13^{CD}	0.52^{DE}	9.67^{C}	54.95^{BC}	45.33^{F}	2.00^{C}	12.33^{D}	1.00^{C}
T_2	11.66^{CD}	2.66^{B}	7.80^{CD}	0.57^{CD}	9.03^{CD}	53.70^{BC}	44.30^{G}	2.33^{BC}	13.66^{C}	1.33^{BC}
T_3	12.33^{BC}	3.33^{A}	7.33^{DE}	0.72^{B}	8.60^{CD}	53.36^{BC}	55.76^{D}	2.66^{BC}	14.66^{B}	1.66^{B}
T_4	13.66^{AB}	3.66^{A}	6.30^{E}	0.89^{A}	5.95^{EF}	50.46^{BC}	60.46^{C}	3.66^{A}	16.33^{A}	3.00^{A}
T_5	12.33^{BC}	2.66^{B}	7.56^{CD}	0.42^{EF}	7.99^{DE}	56.66^{BC}	47.80^{F}	1.66^{CD}	11.00^{E}	1.00^{C}
T_6	13.66^{AB}	2.00^{C}	8.66^{C}	0.52^{DE}	6.89^{EF}	58.13^{BC}	54.43^{E}	2.00^{C}	12.00^{D}	1.33^{BC}
T_7	14.33^{A}	1.66^{C}	9.96^{B}	0.64^{BC}	6.62^{EF}	68.18^{B}	62.26^{B}	2.33^{BC}	12.66^{D}	1.66^{B}
T_8	15.33^{A}	1.33^{D}	12.33^{A}	0.96^{A}	5.05^{G}	87.96^{A}	72.36^{A}	2.66^{B}	13.66^{C}	1.66^{B}
T_9	9.66^{EF}	1.33^{D}	7.26^{DE}	0.40^{F}	26.51^{B}	42.12^{C}	35.10^{H}	1.66^{CD}	8.16^{F}	1.00^{C}
T_{10}	8.33^{F}	1.00^{D}	7.20^{DE}	0.33^{F}	28.57^{A}	40.90^{C}	30.63^{I}	1.33^{D}	7.33^{G}	1.00^{C}
LSD (p=0.05)	2.89	0.31	1.10	0.16	2.03	4.12	0.52	0.87	0.76	0.42

T_1- 50 mg L^{-1} BA, T_2- 75 mg L^{-1} BA, T_3- 100 mg L^{-1}BA,T_4-125 mg L^{-1} BA. T_5-50 mg L^{-1} GA_3, T_6-75 mg L^{-1} GA_3, T_7-100 mg L^{-1} GA_3, T_8-125 mg L^{-1} GA_3, T_9-Water, T_{10}- Control

sink activity of growing underground structures at the expense of developing flower spike (Baskaran *et al.,* 2014).

Size of fully expanded floret

Among all treatments, GA_3 @ 125 mg L^{-1} recorded maximum floret size (12.33 cm). It was followed by 100 mg L^{-1} GA_3 (9.96 cm, Table 4). Floret size increased with increasing concentration of GA_3. On the contrary, BA treatments had negative effect on floret size. Among BA treatments, maximum floret size was recorded with 50 mg L^{-1} (8.13 cm), which was statistically at par with 75 mg L^{-1} BA (7.80 cm). The lowest floret size was recorded with BA @ 125 mg L^{-1} (6.30 cm) and it was statistically at par with 100 mg L^{-1} BA(7.33 cm). Similar results were reported by Singh *et al.* (2020) where GA_3 treatments significantly increased floret size but BA had a negative effect on the same. Increase in floret size could be attributed to enhanced leaf number and leaf area in response to GA_3 treatments which might have enhanced its photosynthetic and reproductive attributes (Sajjad *et al.,* 2015).

Change in pH

Decrease in pH of vase solution was maximum in corm treatments with GA_3 @ 125 mg L^{-1} (0.96), which was statistically at par with BA @ 125 mg L^{-1} (0.89, Table 4). Among all concentration of GA_3 and BA, GA_3 @ 125mg L^{-1} recorded maximum pH reduction (0.96), which was 2.90 times than that of control (0.33). The value of change in pH increased with increasing concentration of BA and GA_3. Low pH in the vase solution promotes healthy post harvest life of spikes as it inhibits growth of several pathogen infections and vascular blockages (Marouski, 1971).

Loss in physiological weight (%)

Corms treated with 125 mg L^{-1} GA_3 recorded minimum per cent loss in physiological weight (5.05). The per cent loss in physiological weight in control was 5.67 times more than GA_3 @ 125 mg L^{-1} (Table 4). It was followed by 125 mg L^{-1} BA (5.95). The increasing concentration of BA and GA_3 recorded a fall in per cent physiological weight. The per cent loss in physiological weight of corms treated with BA and GA_3 was significantly lower than water treatment (26.51) and control (28.57). Lower physiological weight of spikes could be the result of lowered water uptake ability and simultaneously increased water loss. Post-harvest deterioration of spikes is also hastened by excessive loss in physiological weight of spikes. Corm treatments with BA and GA_3 contributed towards lowering loss in physiological loss in weight of spikes. Similar results were recorded by Mithilaa *et al.*(2021) in Dracenea.

Per cent opening of florets

Corm treatment with GA_3 had a positive effect on per cent opening of florets in gladiolus spikes (Table 4). Among all the treatments, 125 mg L^{-1} GA_3 recorded maximum per cent opening of florets (87.96) that was 2.15 times more than control (40.90), followed by GA_3 @ 100 mg L^{-1} (68.18).The data also revealed that maximum concentration of GA_3 recorded maximum opening of florets (87.96 % with 125 mg L^{-1} GA_3) whereas minimum concentration recorded least opening (56.66 % with 50 mg L^{-1} GA_3). However, opposite trend was observed in BA corm treatments where per cent opening of florets decreased with increasing concentration of BA. Increased cell division and number of florets might have become a contributory factor towards increased per cent opening of florets in response to GA_3 treatment (Gayakvad *et al*., 2014). Similar results were recorded with BA and GA_3 by Sajjad *et al.* (2015) in gladiolus.

Total water absorbed per spike (ml)

Water absorbed per spike was maximum with GA_3 @ 125 mg L^{-1} (72.36 ml), which was 2.36 times the control (30.63 ml, Table 4). It was followed by GA_3 @ 100 mg L^{-1} (62.26 ml). Among BA corm treatments, 125 mg L^{-1} BA recorded maximum water absorbed per spike (60.46 ml) and it increased with increasing concentration of both BA and GA_3. Water treatment and control recorded lowest values of total water absorbed per spike (35.10 ml and 30.63 ml respectively). High water uptake capacity of spikes is essential to maintain turgidity and freshness. Benzyladenine and GA_3 tend to make cell membrane more permeable to glucose and lowers down water potential of cell, leading to water uptake (Emongor, 2004). Lowering of cell water potential in response to BA might be due to increase in α-amylase and invertase activity. Similar results were recorded by Mangave *et al.* (2013) in Heliconia.

Number of corms and cormels per plant

The maximum production of corms and cormels was recorded with BA @ 125 mg L^{-1} (3.66 corms and 16.33cormels, Table 4). Among GA_3 corm treatments, 125 mg L^{-1} GA_3 recorded maximum corm and cormel production (2.66 corms and 13.66cormels). The production of corms and cormels increased with increasing concentration of BA and GA_3 indicating that BA and GA_3 had positive effect on production of underground structures. Increase in production of corms and cormels in response to BA and GA_3 treatments have been reported by Tirumalesh and Fatmi (2020). This increase could be attributed to property of BA to cause splitting and forming underground structuresoenhancement effect of sink activity of developing corms and cormels at the expense of spike

(Baskaran, 2009). Enhanced production of corms and cormels with GA_3 corm treatments might be due to its ability to increase chlorophyll content of leaves and thus making enough metabolites to developing corms and cormels (Jadhav *et al.,* 2015).

125 mg L^{-1} BA recorded highest number of spikes per plant (3.00), which was significantly higher than water treatment (1.00) and control (1.00). Among GA_3treatments, 125 mg L^{-1} recorded maximum number of spikes per corm (1.66). Further, the number of spike produced per corm increased with increasing concentration of BA and GA_3 and were statistically higher than water and control. The possible explanation for increased number of spikes per corm could be due to its role in causing cell division and lateral bud development, leading to multiple shooting (Murti and Upreti, 1995).

In conclusion, corm treatments with BA and GA_3 enhanced the vase life, yield and overall post harvest keeping quality of gladiolus cv. Novalux spikes. The growth regulators also had promotory effect on RWC, MSI, TSS, TSP content of leaf and floret. The RWC, MSI, TSS and TSP increased with increasing concentration of BA and GA_3. GA_3 further enhanced plant height, shoot weight, leaf area and leaf weight. However, these declined with BA corm treatments. Thus, GA_3 corm treatments could be instrumental while aiming for enhanced vase life, post-harvest keeping quality as well as vegetative attributes. While BA corm treatments could enhance vase life and yield via increased corms, cormels and spike production.

Authors' contribution

Conceptualization of research work and designing of experiments (SJ, KK); Execution of field/lab experiments and data collection (KG, SJ, KK); Analysis of data and interpretation (KG, SJ); Preparation of manuscript (KG, SJ,KK).

LITERATURE CITED

Anderson J H and Boardman N K 1964.Studies on greening of dark brown green plant. VI. Development of phytochemical activity. *Aust J BiolSci* 17: 93-101.

Baskaran V, Abirami K and Dam Roy S 2014. Effect of plant growth regulators on yield and quality in gladiolus and under Bay Island conditions. *J HorticSci* **9(2)**: 213-16.

Baskaran V, Misra R L and Abirami K 2009. Effect of plant growth regulators on corm production in gladiolus. *J HorticSci* **4:**78-80.

Desai S A, Patel B B, Aklade S A and Desai C S 2020. Performance of Tuberose cv. Prajwal as influenced by different plant growth enhancers. *Indian J Pure App Biosci* **8:**472-77.

Dubois M, Gilles K, Hamilton J, Rebers P and Smith F 1956. Colorimetric method for determination of sugars and related substances. *Anal Chem* **28:** 350-65.

Eason J R, Ryan D J, Pinkney T T and O"Donoghue E M 2002. Programmed cell death during flower senescence: isolation and characterization of cysteine proteases from *Sandersonia aurantiaca*. *Funct Plant Biol* **29:** 1055-64.

Elanchezhian R and Srivastava G C 2001. Physiological response of chrysanthemum petals during senescence. *Biol Plant* **44:** 411-15.

Emami H, Saeidnia M, Hatamzadeh A, Bakhshi D and Ghorbani E 2011. The effect of gibberellic acid and benzyladenine growth and flowering of lily (*Liliumlongiflorum*). *Adv Environ Biol* **5:** 1606-11.

Emongor V E 2004. Effect of gibberellic acid on post-harvest quality and vase life of gerbera cut flowers. *J Agron* **3:** 191-95.

Faraji S, Naderi R, Ibadli O V, Basaki T, Gasimov S N and Hosseinova S 2011. Effects of post harvesting on biochemical changes in Gladiolus cut flowers cultivars (White prosperity). *Middle-East J Sci Res* **9:** 572-77.

Favero B T, Lutken H, Dole J M and Lima G P P 2020. *Anthuriumandraeanum* senescence in response to 6-benzylaminopurine: Vase life and biochemical aspects. *Postharvest Biol. Technol,* **161**:1-7.

Franco R E and Han S S 1997. Respiratory changes associated with growth regulatordelayed leaf yellowing in Easter lily. *J Am Soc Hortic Sci* **122:** 117-21.

Gayakvad P, Jadeja D B and Bhalawe S 2014. Effect of foliar application of GA3, ethrel and copper sulphate on flowering behaviour and sex ratio of *Jatropha curcas* L. *J Appl Natural Sci* **6:** 286-89.

Ichimura K, Shimizu H and Hiraya T 2002. Effect of 1–methylecyclopropene (1–MCP) on the vase life of cut carnation, delphinium and sweet pea flowers. *Bull Natl Inst Flor Sci***2:** 1-8.

Jadhav P B, Mangave B D, A, Dekhane S S and Patel D J 2015. Effect of plant growth regulators and natural growth substances on growth and flowering on Gladiolus cv. American beauty. *Int J Curt Res* **7:** 17674-76.

Jaleel C A, Gopi R and Panneerselvam R 2007. Alterations in lipid peroxidation, electrolyte leakage and proline metabolism in *Catharanthusroseus* under treatment with triadimefon, a systematic fungicide. *C R Biol* **330:** 905-12.

Kaviya S S, Lourdusamy K, Ganga M and Vincenr S 2021. Influence of pre-harvest sprays on flower quality and vase life of *Alstromeria*. *J Pharmacogn Phytochem* **10**: 429-33.

Li YH, Wu YH, Wu B, Zou MH, Zhang Z and Sun GM 2011. Exogenous gibberellic acid increases the fruit weight of 'Comte de Paris' pineapple by enlarging flesh cells without negative effects on fruit quality. *Acta Physiol Plant* **33:**1715-22.

Lowry O H, Rosebrough N J, Farr A L and Randall R J 1951. Protein measurement with the folin phenol reagent. *J Biol*

Chem **193:** 265-75.

Mangave B D, Singh A and Mahatma M K 2013. Effects of different plant growth regulators and chemical spray on post harvest physiology and vase life of heliconia inflorescence cv. Golden Torch. *Plant Growth Regul* **69:** 259-64.

Mansee K, Mukherjee D and Seema 2013. Regulation of lipoxygenase and superoxide dismutase activities and longevity of chrysanthemum cut flowers by ethanol and methanol. *Indian J Hortic* **70:** 76-81.

Marousky F J 1971. *Handling and opening bud cut chrysanthemum flowers with 8- hydroxyquinoline citrate and sucrose*. US Department of Agricultural Marketing Research Report, 905.

Mithilaa B A, Kavitha M, Sankari A and Djanauguiraman M 2021.Effect of pre harvest spray and vase solutions under different growing environment on the vase life of cut foliage *Dracaena* (*D. reflexa*). *J Pharmacogn Phytochem* 10(1): 2261-65.

Murti G S R and Upreti K K 1995. Use of growth regulators in ornamental plants. *Advances in Horticulture, ornamental plants* **12:** 863-83.

Nag K and Kumar J 2021. Influence of GA_3 and spacing on spike per plant of gladiolus (*Gladiolus grandiflora*s L.). *The Pharma Innovation Journal* **10(1):** 660-61.

Padmalatha T, Reddy G S, Chandrasekhar R, Sivashankar A and Chaturvedi A 2013. Effect of pre-planting soaking of corms with chemicals and plant growth regulators on dormancy breaking and corm and cormel production in gladiolus. *Int J Plant Environ Sci* **3(1):** 28-33.

Premchandra G S, Saneoka H and Ogata S 1990. Cell membrane stability, an indicator of drought tolerance as affected by applied nitrogen in soybean. *J Agric Sci Camb* **115:** 63-66.

Sajid M, Anjum M A and Hussain S 2015. Affects growth, flowering, vase life and corm production of *Gladiolus grandiflorus* L. under calcareous soil. *Bulg J Agric Sci.* **21:** 982–89.

Sajjad Y, Jaskani M, Mehmood A and Ahmad N 2015. Pre-plant soaking of corms in growth regulators influences the multiple sprouting, floral and corm associated traits in *Gladiolus grandiflorus* L. *J Agril Sci* **7:** 9-13.

Salachna P, Zawadzińska A 2017. Effect of daminozide and flurprimidol on growth, flowering and bulb yield of *Eucomis autumnalis* (Mill.).*Chitt. Folia Hortic* **29:**33–38.

Singh A R, Kumar Sand Singh S B W. 2020. Analysis of effect of GA_3, NAA and BA on growth, flowering and corm production in gladiolus cv. white prosperity. *J Pharmacogn Phytochem* **9(4):** 234-40.

Singh M and Tiwari N 2021.Thidiazuron outpaces 6-benzylamino purine and kinetin in delaying flower senescence in *Gladiolus grandiflora* by alleviating physiological and biochemical responses. *J App Biol Biotechnol* **29:**56-62.

Singh A, Kumar J and Kumar P 2006. Petal senescence and flower quality of gladiolus spikes as influenced by plant growth regulators and sucrose. *J Ornam Horticul* **9:**188-91.

Taiz L, Zeiger E, Moller I M and Murphy A 2014. *Plant physiology and development*. Sixth Edition, Sinauer Associates, Sunderland, MA, 580p.

Tirumalesh B and Fatmi U 2020. A comparative study on growth, flowering and corm production as influenced by cut corms and growth regulators in gladiolus (*Gladiolus grandiflorus* L.) *J Phytocogn Phytochem* **9**(6): 2128-30.

Torres -Pio K, De la Cruz-Guzman GH, Aguilar-Rodriguez S, Grego-Valencia D, Arriga-Frias A and Mandujano-Pina M 2021. Morphological and anatomical changes in *Lilium* CV. Arcachon in response to plant growth regulators. *Hortic Environ Biotechnol* **62:** 325-35.

Weatherly P E 1950.Studies on the water relations of the cotton plant. I. The field measurement of water deficits in the leaves. *New Phytol* 49: 81-97.

Zhang Z H and Guo W M 1998. Regulation of 6-BA on membrane permeability of cut chrysanthemum in vase periods. *Adv Hort Sci* **2**: 697-701.