Journal of Advances in Biology & Biotechnology

Volume 27, Issue 1, Page 211-224, 2024; Article no.JABB.113195
ISSN: 2394-1081

Improvement in Vase Life of Gladiolus Cut Flowers Using Different Holding Solutions of Sodium Nitroprusside and of Salicylic Acid

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JABB/2024/v27i1693

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/113195

Original Research Article

Received: 01/12/2023
Accepted: 06/02/2024
Published: 13/02/2024

ABSTRACT

Gladiolus (*Gladiolus hybridus* Hort.) is one of the most important commercial ornamentals cut flower used in the floriculture industry. Among cut flowers, gladiolus is popular for its glamour, perfection and attractive colorful spikes. The longevity of cut flowers is one of the main challenges of florists to gain consumers attention towards its marketing. In present investigation, we tried two chemicals *viz*.

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Sodium nitroprusside (SNP, a NO donor) and Salicylic Acid (SA, a signaling molecule) in different concentration combinations and observed their effect on gladiolus flowers vase life of two varieties *viz*. Pusa Shanti and Pusa Chandni. Spikes treated with T_7 (SA 150 mg/L), in Pusa Shanti and T_2 (SNP 100 mg/L), in Pusa Chandni was observed effective treatments than others and showed better performance of vase life, days after basal florets open**,** maximum size of florets, solution uptake, florets opening and maximum time taken for the vase deterioration and it helped to improve the postharvest quality of gladiolus spikes by influencing various morphological and physiological attributes of gladiolus vase. Through the present study we are able to know the role of Sodium nitroprusside and Salicylic acid to enhance the vase life of cut flower of Gladiolus.

Keywords: Cut flowers; gladiolus; senescence; salicylic acid; sodium nitroprusside; vase life.

1. INTRODUCTION

Gladiolus (*Gladiolus hybridus* Hort.) liked for its majestic spikes containing attractive, elegant and delicate florets. It is commonly, known as “Sword lily” owing to the shape of its leaves and “Queen of the bulbous plants” belongs to the family Iridaceae. “Cut flower of gladiolus is having great demand in domestic as well as international market” [43,49]. “The florets of spikes open in sequence over a longer duration and hence have a good keeping quality of cut flowers, spikes last for only 4-7 days, senescent florets remain at the bottom of the spikes after opening of the upper florets which is too less a post-harvest life for marketing of gladiolus for distant market” [29,28]. “Extension of life of detached flowers involves co-ordination of two seemingly conflicting processes, the promotion of growth during the first phase and retardation of senescent processes during the second phase” [50]. “In earlier time, silver nitrate was used and proved to be the best for improving the vase life of cut flowers, but concerns have been raised over its use and many countries had collectively eliminated its commercial use” [27]. “There is a great demand to replace it by other non-toxic chemicals. Now a day, Sodium nitroprusside (SNP) and Salicylic acid (SA) widely used to enhance the vase life of cut flowers as SNP produced nitric oxide (NO). NO has been shown to inhibit ethylene action and synthesis in plants, and it has been suggested that NO acts as a natural senescence delaying plant growth regulator and extending the post-harvest life of horticultural commodities” [1,38]. “Salicylic acid (SA) is an inexpensive and safe phenolic compound that has usually been applied to agricultural products, in order to increase their post-harvest longevity” [46]. “SA is naturally produced by plants as a defense mechanism against stress conditions and diseases and regulates several physiological phenomena such as flowering, cell membrane permeability, stomatal conductance, and defense against biotic and abiotic stresses” [49]. “Salicylic acid is useful in delaying flower senescence, leakage of ion in petals” [14]. “SA has also been shown to interfere with the biosynthesis and action of ethylene, abscisic acid and cytokinins in plants” [15]. “Exogenous SA and other different chemicals at appropriate concentrations has been applied previously in order to delay senescence in cut flower spikes of gladiolus as well as other cut flowers” [14,37,21].

“Senescence is the major cause for the loss of postharvest quality of cut flowers. Some of these processes may act independently to affect the senescence and vase life of cut flowers but most of them are inter-related” [12]. “Several factors at pre-harvest stage including genetic or inherent, climatic or environmental and management; harvest factors like stage, method, time of harvesting and post-harvest factors such as watering, re-hydration, pre-cooling, storage environment, packaging techniques and microorganisms influence the post-harvest quality and longevity of cut flowers” [26,37]. “It is induced by depletion of essential precursors like sugars or blockage of the vascular system”, [35,37]. “Petal senescence is the final stage of display life that follows the physiological maturity, reduced protein production and more protein degradation ultimately leading to the death of cells, organs or the whole plant” [27]. “The gladiolus is insensitive to exogenous ethylene and interesting to study the mechanism of senescence” [16]. Keeping in view of the above facts about both chemical, the present study was conducted to investigate the role of SNP and a SA in different concentration combinations in a pulsing solution to improve the post-harvest quality of two genotypes of gladiolus through its influence on morphological and physiological attributes. Therefore, the present work aimed to study the effects of SNP and SA on vase life of cut flowers of gladiolus varieties when used individually and used in different concentration and combinations.

2. MATERIALS AND METHODS

2.1 Plant Material

Two varieties of gladiolus *viz* ‘Pusa Shanti’ and ‘Pusa Chandni’ were selected for the present investigation. Field experiment was set up in the experimental field station at Sardar Vallabhbhai University of Agriculture and Technology Meerut. The spikes were harvested early in the morning between 8 to10 AM whenever required at stage of the first two basal florets emergence. Spikes were then harvested and placed in clean water and brought carefully to the laboratory without causing any damage. All spike stems were trimmed to have an average spike length 80-85cm in Pusa Shanti and 75-80cm in Pusa Chandni. Leaves were removed from the spikes and average about 12-14 flower buds/spike attained. The experiment was laid out in Completely Randomized Design (CRD), replicated thrice with three spikes per replication. Twelve treatments of each variety with control (C) were taken (Table 1). Vase life study was done in the months of February where temperature remained optimum. The flowers were pulsed for 20 h and after that the treated spikes were transferred to the 1000 ml borosilicate glass bottle containing 250ml distilled water. Spikes were kept in room temperature during the period of experiment and the distilled water was not changed. Flowers on distilled water were evaluated on basis of morphological and physiological parameters for post-harvest quality to the end of vase life of flower under ambient conditions. The observations on various parameter were recorded like Vase life (in days), Solution absorbed per treatments (ml), Physiological weight loss (%), Days after basal florets open, Maximum florets open at one time, Maximum size of florets in (cm) and Florets opening (%) etc.

2.2 Spike Characteristics

2.2.1 Vase life (in days)

Vase life is time duration starting on day zero (the day the flowers were placed in the vase) and wilting of florets. It is measured in number of days from the opening of one basal floret till the wilting of 50% of total number of opened florets occurred [7].

2.2.2 Solution absorbed per treatments (ml)

The difference in the total volume of solution taken in the vase before placing spikes and after removing them at the end of vase life was measured in ml and expressed as water absorbed per treatments [9].

2.2.3 Physiological weight loss (%)

The per cent loss in physiological weight was calculated based on consecutive difference between initial weight of spike after treatment and at the end of vase life [27].

$$\text{Percent loss in physiological weight} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

2.3 Flower Characteristics

2.3.1 Days after basal florets open

Days taken for complete opening of the basal floret were recorded from the days taken between the placing of the spikes at tight bud stage in distilled water till the opening of the basal florets in following treatment [27].

2.3.2 Maximum florets open at one time

The number of florets open on each spike were counted daily and the maximum number of florets opened at one time on the spike was recorded till the wilting of first floret started [7].

2.3.3 Maximum size of florets in (cm)

The maximum diameter of the 2nd fully opened floret from the base was measured in cm and expressed as the size of fully expanded floret [26].

Table 1. Sodium nitroprusside (SNP) and Salicylic acid (SA) and their combinations of concentration in mg/L used to assess the vase life of cut flowers of Pusa Shanti and Pusa Chandni

Treatments	C	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
SNP		80	100	120	140					100	100	100	100
SA						100	125	150	175	100	125	150	175

2.3.4 Florets opening (%)

The number of fully opened florets were counted daily throughout the duration of the experiment and expressed as per cent opening of florets on the spike [27].

$$\text{Percent opening of florets } = \frac{\text{No. of open florets}}{\text{Total no. fo florets}} \times 100$$

3. RESULTS AND DISCUSSION

Senescence is the age-dependent degenerative process that leads to death of plant cells. It is an integral part of the normal developmental cycle and can be viewed on a cell, tissue, and organ or organization level [1,40]. However, vase life is still difficult in ethylene-insensitive flowers because the process of cell death leading to petal senescence is incompletely understood [51]. The postharvest life of ornamental flowers is primarily dependent on the genetic constitution of the species and differs even among varieties of the same species [36]. In the present study, two chemical molecules SNP and SA to were used to see the effect of these chemicals on vase life of flowers of Gladiolus. Effects of these chemicals were observed on morphological and physiological traits of gladiolus spikes when they used in different concentration and combinations in a holding solution to enhance the post-harvest quality and vase life of cut spikes of gladiolus *viz*. Pusa Shanti and Pusa Chandni.

3.1 Spike Characteristics

3.1.1 Vase life (in days)

From the present investigation it was observed that different concentrations of SNP and SA substantially influenced the postharvest quality of cut flower spikes of both the varieties of gladiolus. Vase life that is a major concern of cut flowers was recorded highest in T_7 (13 days), followed by T_{10} (12.33days) and T_2 (12 days) and least vase life in T_{12} 5.67 days in compare to control (7.33 days) in Pusa Shanti variety (Table. 2). Whereas in Pusa Chandni variety T_2 showed highest vase life (12.67 days) followed by T_7 and T_{10} (11.67, 10.67 days), respectively and T_{12} least vase life (5.67 days) as compare to 7.33 days in control (Table. 3). Through the present investigation our results showed that given individual and combination of treatments showed variations in vase life of both varieties and 'Pusa Shanti' had better postharvest quality and longer vase life than Pusa Chandni. Among all vase solution treatments, concentration of SA (150 mg/L) is very much effective in spike of variety Pusa Shanti followed by other treatments in both variety for improving vase life of cut spikes of gladiolus (Fig. 1B). The reduction in vase life was comparatively less pronounced in treated flowers combination with high concentrations of SNP and SA than those placed in control and other solutions. Probably high concentrations of SNP and SA may have injured xylem vessels and collapsed the water flux up to the petals. Results of our study showed that adding SNP in vase solutions enhanced vase life of gladiolus cut flowers and leading to delay in stem defluxion for the cultivar used in the present study (Fig. 2A). The reason for extending the vase life may be that nitric oxide a signaling molecule that promotes antioxidant activities and also involved in biotic and abiotic stress tolerance [9], inhibits ethylene production [24] and inhibits respiratory metabolism [54]. The effects of NO could be evoked by (SNP) that improved vase life of gladiolus by affecting senescence related processes. Therefore, SNP has been increasingly used to extend the vase life of several cut flowers, such as carnation, chrysanthemum, rose and gladiolus has been extended with exogenous application of SNP [9,30,27]. SNP at low concentration suppresses ethylene production that improved vase life whereas at high concentration leads to toxicity to the flowers that enhanced senescence [30]. Similar finding was observed by Hatamzadeh et al. [14,37,29] where an increase in the vase life of gladiolus flowers with continuous treatment of flowers with SA (150 mg/L) given for 9,13,19 days respectively. SA treatment increased the vase life of of rose and tuberose cut flowers [53,2,20].

3.1.2 Solution absorbed per treatments (mL)

The results of the present study were observed that chemicals used in the present investigation helped to increase the amount of total solution (water) absorbed by the cut spikes of both gladiolus varieties up to 6th day and were found maximum at spikes held in T_7, T_2, and T_{10} (91.63ml, 87.41ml, 83.20ml) respectively and least water absorption by the treatments T_{12} (46.6) compare to control (58.29ml) in Pusa Shanti variety (Table 2). whereas in case of Pusa Chandni maximum water absorption observed by spikes kept in T_2, T_7 and T_{10} as per treatment (86.60ml, 82.50ml and 79.60ml) respectively and least quantity of solution was absorbed by when spikes held in treatments T_{12} (48.27ml) compare to control (54.80ml) (Table 3). From the present study we observed that the gladiolus spikes of both varieties absorbed more solution and performed better when kept in vase solution with SA and SNP than spikes kept in control. Salicylic acid SA (150mg/L)to the vase solution gave the maximum amount of water absorbed by the spikes, compared to the other treatments. These results may be due to the role of salicylic acid at a proper concentration in plants. Salicylic acid also helps to reduce water loss by controlling plant responses to various oxidative conditions and preventing cell wall breakdown. Salicylic acid protects chlorophyll [33], which enhances the relative water content of leaves [13] delays the senescence of the tepals of cut gladiolus spikes [14] protein degradation [45] and prolongs membrane stability. All these factors led to increase the efficiency of the cut gladiolus spikes to absorb a large amount of the vase solution. Similar trend of results was reported by [8] on Gladiolus, [39] on Narcissus and [34] on pot marigold, [29] Sucrose (5%) + Salicylic Acid (150 ppm) Salicylic acid (150ppm) + sucrose (2%) on Gladiolus [49]. Variation in solution uptake might be due to disturbance in transpiration pool, bacterial and fungal spp. gaining predominance in vase solution that results in water deficit followed by petal wilting [25]. Cut flower senescence is closely associated with water uptake stem and relative water content of petals, whereas, these characteristics are closely related to the contents of osmo-regulation substances such as soluble sugars and soluble proteins [17]. Besides improving water uptake, SNP also plays role in suppressing water loss as reported earlier in rose, chrysanthemum, gerbera and carnation [4]. Nitric oxide has a lead role in xylem differentiation which could be accounted for a higher amount of solution/water uptake by spikes with the application of SNP, NO donor, [11]. Asif et al. [3] also reported that that pH and EC of the vase solution increased while EC of the solution influenced the water uptake by cut spikes. Similar findings of our results reported by [27] maximum water absorb by when spikes held in sodium nitroprusside (100 mg/L).

3.1.3 Physiological weight loss

In the present study, significant variation was observed among the both gladiolus varieties with different treatments respect to change in percentage loss of physiological weight. The minimum loss of physiological weight (8.53%) were recorded under the treatment $T_{7,}$ followed by T_2 and T_{10} (11.07%, 12.45%) respectively and maximum loss was observed in T_{12} (29.23%) compared to control (27.73%) in Pusa Shanti variety (Table 2). Whereas in another variety Pusa Chandni, minimum loss of physiological weight (10.18%) was recorded under the treatment T_2 followed by T_7 and T_{10} (12.06%, 14.16%) respectively and maximum loss was observed in T_{12} (27.27%) as compared to control (24.53%) (Table 3). Percent loss in physiological weight after harvest is an important parameter of cut flowers that influences vase life [37,43,27]. In our results Pusa Shanti variety with SA (150 mg/L) alone showed minimum loss of fresh weight change compared to other treatments of both the varieties. Further it has been observed that Pusa Shanti has better performance in compare to Pusa Chandni. However, salicylic acid might be influencing CO_2 levels and thus rendering stomatal closure. These factors improved water status of the spikes and retained the fresh weight for a long period. Hatamzadeh et al. [14] also reported that SA have an important role in delayed the dehydration of gladiolus either by stomatal conductance, decreasing transpiration and evaporation of tissue as well as decreasing respiration which caused preventing water from loss of fresh weight in cut flower. Similar result reported by [37,29,48]. The spikes kept in SNP vase solution showed less reduction in weight in compare to control. This effect of SNP in reducing the weight loss could be attributed to increased water uptake that maintained turgidity [13]. The loss was comparatively more in higher concentrations of SNP and SA combination. This reduction in physiological weight could be accounted for reduced water uptake and increased respiration rate at a high concentration of SNP and SA [44]. Higher commercial value of flowers depends upon its postharvest life i.e., further regulated by maintaining physiological weight after harvest [23,42]. SNP has been demonstrated to have a significantly positive influence on relative fresh weight (RFW) in roses and carnations.

3.2 Flower Characteristics

3.2.1 Days after basal florets open

Our findings from the present investigation assessed that the opening of basal florets were significantly hasten with individual and different concentrations of SNP and SA in both varieties. The overall minimum number of days taken for opening of basal floret was recorded (2 days) in $T_{7,}$ followed by (2.33 days) in T_2 and T_{10} and maximum number of days was recorded in T_{12} (4.67 days) in compare to control (4.67 days) in Pusa Shanti variety (Table 2). Whereas in Pusa

Chandni took minimum number of days in T_2 (2.3 days) followed by T_7 and T_{10} (2.67, 3.0 days) respectively and T_{12} has maximum (5 days) when compared to control (4.67 days) (Table 3). Too much delay in the opening may lead to failure in the opening of buds and too early opening may shorten the vase life due to early senescence. Flower opening is vital for aesthetic value and appealing vase life of the cut flower. Floral opening is a complex process and illustrates the involvement of various biological mechanisms that is highly regulated physiological processes (19,31). In our results Pusa Shanti had better performance than Pusa Chandni. Vase containing SA (150 mg/L) in Pusa Shanti have overall minimum number of days to open of basal florets in all the treatments used for both the varieties. Similar finding was also reported by [48,37,18] 2017 in gladiolus, while basal floret opening took a higher number of days at higher concentrations of SNP and SA [43]. Mittal et al. [27] reported that spikes treated with SNP (100 mg/L) took 2.33 and 3 days to open the basal florets of gladiolus.

3.2.2 Maximum florets open at one time

The different vase treatments containing different concentration of SNP and SA significantly influenced the number of florets open at one time. There was an increase in a maximum number of florets opened at one time when spikes were held in T_7 (6 florets) followed by T_{10} and T_2 (5.33, 5.0 florets) respectively and minimum number of florets open at once in T_{12} (2.67 florets) treatment because containing high concentration of both chemical (SNP+SA) when compared to control (3.0 florets) in Pusa Shanti (Table 2). Whereas in Pusa Chandni variety showed maximum number of florets open when spike held in vase T_2 (6.33 florets) followed by T_7 and T_{10} (5.67, 5.33 florets) respectively and minimum number of florets open at a single time when spikes held in T_{12} treatment (2.33) compare to control (3.0) in Pusa Chandni (Table 3). The value was significantly different in the both varieties of gladiolus and was more in Pusa Chandni than Pusa Shanti. In our findings more number of florets open at one time adds to the ornamental value of spikes in Pusa Chandni cultivar. The maximum number of open florets per spike at one time induced by SNP (100 mg/L) could be associated with higher sugar and protein content in the florets of spikes held in SNP solution. SNP act as vase solution disinfectants and inhibited the pathogen growth, followed by increasing water uptake and TSS [22]. The present findings confirm the observations of earlier workers [6]. Similar findings were in accordance with results of Mittal et al*.* [27] where maximum 6.4 florets open at a single time. Sharma et al. [43] observed the similar findings where maximum six florets open at a time when spike treated with SNP (100 ppm).

3.2.3 Maximum size of florets

The size of floret is the genetic character but internal turgor pressure of petals affects the opening of florets. The overall maximum size of fully expanded floret was observed in florets of spikes held in T_7 resulted in significant increase in floret diameter (10.97cm) and followed by T_2 and T_{10} (10.12, 9.83cm), respectively and least size of floral diameter were observed in T_4 (7.07) comparison to control (7.93cm) in Pusa Shanti (Table 2). On the other hand, florets of spikes held in T_2 has 9.70cm followed by T_7 and T_{10} has 9.28 and 9.03cm, respectively and minimum floral diameter were observed when spikes held in T_{12} (7.07cm) in compare to control (7.75 cm) in Pusa Chandni (Table 3). The plant growth regulators are found helpful in improving the carbohydrate levels of cut spikes by increasing water uptake and cell turgidity might be the possible reason of increased diameter of basal flower in vase. Our results revealed that the size of fully expanded floret was significantly higher in ‘Pusa Shanti’ than ‘Pusa Chandni’ and spikes held in SA (150 mg/L) had maximum size. Similar findings are in accordance with results of Padamlatha et al*.* [32] found maximum diameter of flower in vase with SA (150ppm). Tamrakar et al. [48] Show that largest basal flower (10.67 cm) was found in 100 ppm of SA. Our study indicates that individual SNP and SA and its combination had a major impact on floret head diameter of cut flower of both varieties. Similar results of SNP treated spikes can be attributed to more protein and sugar content, and more solution uptake [41]. Mittal et al. [27], Sharma et al. [43] reported in their study where they observed greater floret diameter (10.13cm); (9.59cm) respectively. Changli and Chanyou [5] also reported higher flower diameter in lilium with SNP application. The effect of SNP on the size of floret is concentration dependent and might be due to the regulatory role of NO released from SNP on several metabolic processes [47]. Further, the increase in size could be attributed to the energy provided by SNP for all metabolic activities that helps in increasing flower diameter and maintaining turgidity for expansion.

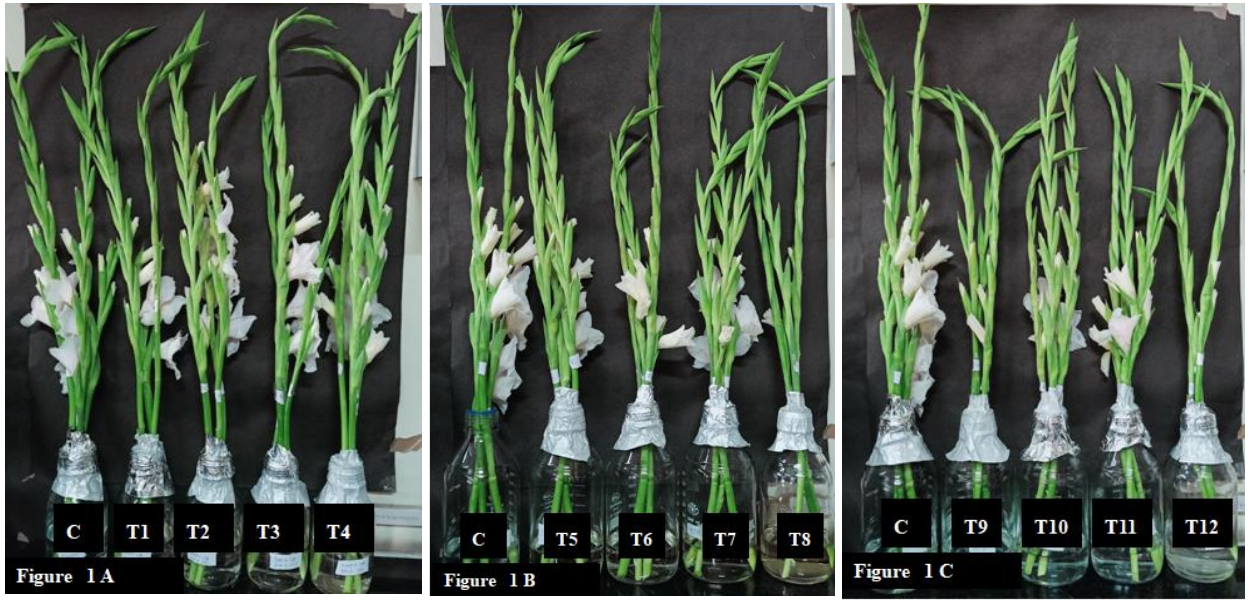

Fig. 1A. Gladiolus flowers variety Pusa Shanti with different treatments of Sodium nitroprusside
Fig. 1B. Gladiolus flowers with different treatments of salicylic acid
Fig. 1C. Gladiolus flowers treatments with combination of Sodium nitroprusside and Salicylic acid

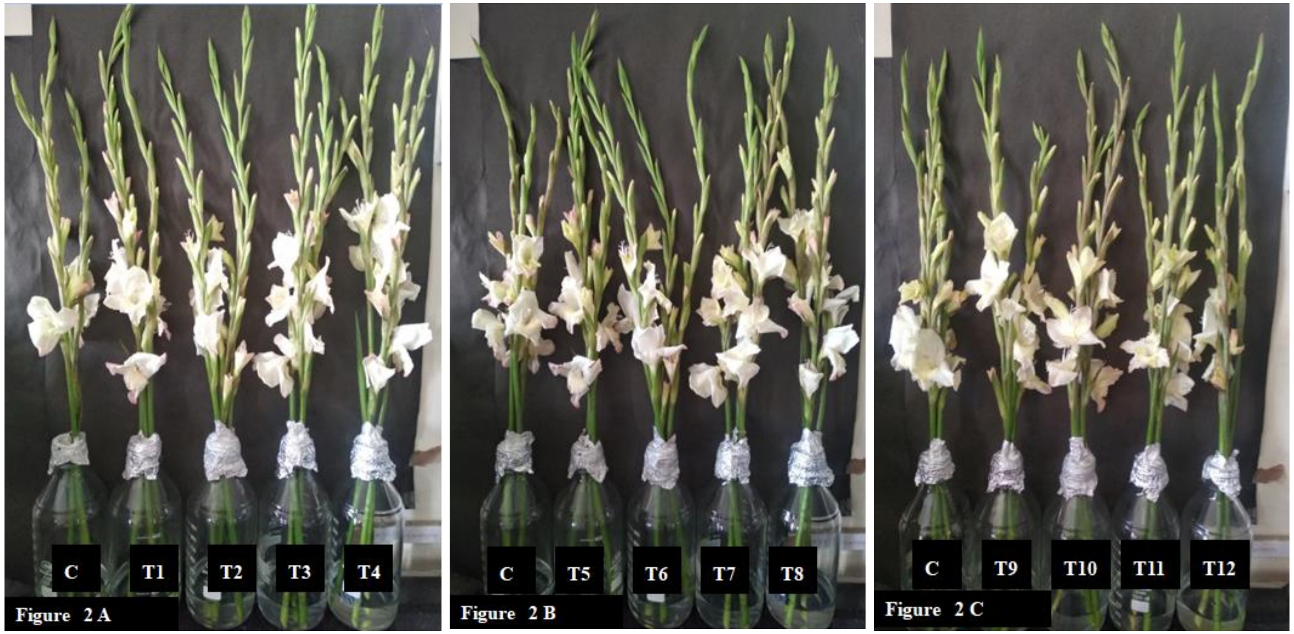

Fig. 2A. Gladiolus flowers variety Pusa Chandni with different treatments of Sodium nitroprusside
Fig. 2B. Gladiolus flowers with different treatment of salicylic acid
Fig. 2C. Gladiolus flowers treatment with combination of Sodium nitroprusside and Salicylic acid

Table. 2. Effect of different plant growth regulators (Sodium nitroprusside and Salicylic acid) on spike and floret characteristics of gladiolus variety Pusa Shanti

Treatments	Vase life (in days)	Solution absorbed per treatment (mL)	Physiological weight loss (%)	Days after basal florets open	Maximum florets open at one time	Maximum size of florets in (cm)	Florets opening (%)
T_1	11de	76.15d	14.63c	3cd	4.33cd	8.1bc	68.4de
T_2	12efg	87.41fg	11.07b	2.33ab	5ef	10.12e	78.13g
T_3	10d	78.22d	17.23ef	3.67ef	3.67b	7.97bc	66.33cd
T_4	8.33c	65.9c	18.27fg	4.33gh	3a	7.07a	61.43bcd
T_5	11.67ef	67.1c	14.14c	3.33de	4bc	8.23cd	60.43abcd
T_6	12efg	75.73d	16.15de	3cd	4.67de	8.9d	65.53bcd
T_7	13g	91.63g	8.53a	2a	6g	10.97f	82.2g
T_8	11de	82.74e	15.57cd	2.67bc	5.33f	9.87e	71ef
T_9	11de	68.32c	19.6g	3.33de	4.33cd	8.45cd	65.37bcd
T_{10}	12.33fg	83.2ef	12.45b	2.33ab	5.33f	9.83e	73.53f
T_{11}	6.67b	50.55a	24.44h	4fg	3.67b	8bc	41.13abc
T_{12}	5.67a	46.6a	29.23i	4.67h	2.67a	7.47ab	36.47ab
C	7.33b	58.29b	27.73h	4.67h	3a	7.93bc	57a
SE(m)	0.38	2.25	0.79	0.14	0.16	0.19	2.09
CD at 5%	0.972711	8.025301	1.51	0.378879	0.385778	0.640795	5.759468
CV	23.25	19.59	29.18	26.68	23.90	13.55	20.48

Table 3. Effect of different plant growth regulators (Sodium nitroprusside and Salicylic acid) on spike and floret characteristics of gladiolus variety Pusa Chandni

Treatments	Vase life (in days)	Solution absorbed per treatment (mL)	Physiological weight loss (%)	Days after basal florets open	Maximum florets open at one time	Maximum size of florets in (cm)	Florets opening (%)
T1	9.33d	74.23de	16.23d	3.67de	4.67fg	8.17cde	67.23de
T2	12.67g	86.6f	10.18a	2.33a	6.33j	9.7h	80.14g
T3	10.67e	77.63de	18.68fg	4e	5gh	7.97bcd	65.51de
T4	8.67cd	62.6bc	19.97g	4.67f	3.33bc	7.75bc	60.21bc
T5	8bc	70.63cd	16.47de	4e	4de	8.03bcd	64.34cde
T6	8.67cd	74.4de	18.05ef	3.33cd	4.33ef	8.47def	64.38cde
T7	11.67f	82.5ef	12.06b	2.67ab	5.67i	9.28gh	81.33g
T8	9.33d	77.67de	17.27def	3.67de	5gh	8.9fg	68.68ef
T9	9d	62.77bc	21.53h	3.33cd	4de	8.77efg	64.13cd
T10	10.67e	79.6ef	14.16c	3bc	5.33hi	9.03fg	71.56f
T11	6.33a	50.07a	23.14i	4.67f	3.67cd	7.44ab	59.37ab
T12	5.67a	48.27a	27.27j	5f	2.33a	7.07a	58.51ab
Control	7.33b	54.8ab	24.53i	4.67f	3b	7.75bc	55.35a
SE(m)	0.32	2.04	0.77	0.13	0.18	0.13	1.26
CD at 5%	0.68	7.75	1.52	0.42	0.40	0.61	4.03
CV	21.88	18.41	26.14	22.22	25.55	9.69	20.85

3.2.4 Florets opening

In the present study, significant variation was observed among the both gladiolus varieties with different treatments respect to change in percentage of florets opening in spikes. The maximum open florets (82.20%) were recorded under the T_7 treatment followed by the T_2 and T_{10} (78.13%, 73.53%), respectively and minimum floret (%) was observed in treatments T_{12} (36.47%) compare to control (57.0%) in Pusa Shanti (Table 2). In another cultivar Pusa Chandni, the percent opening of florets was maximum to be spike held in T_7 (81.33%) followed by T_2 and T_{10} (80.14%, 71.56%), respectively and minimum florets opening (55.35%) showed when spikes held in control (Table 3). In our studies, the gladiolus spikes of both varieties have maximum percentage of florets opening performed in vase solution with individual SA and SNP than spikes kept in control. These results may be probably due to the effect of adding SA and SNP at a suitable concentration to the holding solution on enhancing the level of photosynthetic pigments, photosynthetic rate and modification the actively of some of the important enzymes as well [52,37,27]. Similar trend of our results was reported by Ezilmathi et al. [10] on Gladiolus flowers. Saeed et al. [37] reported 100% florets opening on gladiolus and (29) Sucrose (5%) + Salicylic Acid 150 ppm. Similar result reported by Mittal et al. [27] and showed maximum to be 65.72% florets opening when spikes held in SNP (50 mgL^{-1}) solution followed by 53.66% in SNP (100 mgL^{-1}) which is relatively lower than our study. Asif et al. [3] in another study found highest percentage (83.0%) opened florets in the spikes treated with SNP [19,31].

4. CONCLUSION

It is concluded from the present investigation that Sodium nitroprusside and Salicylic acid and their various combinations of concentration in vase solutions proved effective to enhance the vase life of both varieties cut flowers. Our results showed that spikes treated with T_7 (SA 150 mg/L), in Pusa Shanti and T_2 (SNP 100 mg/L), in Pusa Chandni was also most effective treatments than others and significantly better performance like, vase life, days after basal florets open**,** maximum size of florets in (cm), solution uptake, florets opening (%) and maximum time taken for the deterioration. Therefore, SA and SNP were used as useful vase solution additives because they were naturally available, cost effective, safe to use and biodegradable compounds without persistent nature and were highly recommended for extending the postharvest longevity of the cut flowers species that are susceptible to vascular blockage caused by different bacterial strains and by ethylene hormone. The present study may be useful for the future researchers and floriculture industry to adopt Sodium nitroprusside and Salicylic acid with their combination of concentration to enhance the gladiolus cut flower vase life.

ACKNOWLEDGEMENTS

The authors are thankful to Director Research SVP University of Agriculture and Technology Meerut for providing necessary facilities for conducting the present research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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