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Effect of Different Concentrations of Sodium Nitroprusside (SNP) and Salicylic Acid (SA) on Vase Life of Tuberose (*Polianthes tuberosa* L.) cv Prajwal

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ABSTRACT

The tuberose (*Polianthes tuberosa* L.) is a bulbous flower bearing plant which is used for cut flower production both in India and around the world. Due to overproduction of ethylene in tuberose cut flowers causes florets to wilt and burn, flower spike tips to bend, and responsible to reduce vase life. Tuberose flower is also used for aroma and essential oil. Though, many preservative have been used to prolong the vase life and freshness of tuberose cut flowers. In the present study, we assessed the effect of two chemical compounds viz., Salicylic acid (SA), Sodium nitroprusside (SNP) along with their chemical combinations were used to enhance vase life of tuberose which a floriculture crop. The experiment was performed in CRD (Completely Randomized Design) with 15 treatments and is replicated thrice. Among the selected treatments, the treatment of 10 mg/l sodium nitroprusside (SNP) with 80 mg/l salicylic acid showed floret opening and increase in spike length with longer vase life in compare to control. The present study indicated that sodium nitroprusside in combination of salicylic acid played an important role to enhance the vase life of cut flower of tuberose.

Keywords Tuberose, Cut flowers, Vase life, Salicylic acid, Sodium nitroprusside.

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INTRODUCTION

Widespread cultivation of tuberose (*Polianthes tuberosa* L.) is done to get cut flowers which are having pleasing and potent aroma (Kumar *et al*. 2021). Mexico is considered the native place of tuberose. The basic chromosome number of single-stemmed tuberose is 2n = 60, whereas double-flowered species have chromosome numbers ranging from 2n = 50 to 2n = 54 and 60 and 120 (Karihaloo 2019). These Amaryllidaceae species are grown commercially in

the tropics and subtropics, mostly for cut flowers, due to their pleasant flowery aroma (Dogra *et al*. 2020). The tuberose (*Polianthes tuberosa* L.), a perennial herbaceous flowering plant is one of the most significant bulbous flowering plants known to be a favorite cut flower both in India and around the world (Singh and Shankar, 2011). Tuberose is susceptible to the synthesis of ethylene, which causes florets to wilt and burn, flower spike tips to bend, and shortened vase life (Pérez-Arias *et al*. 2019). The aroma comes from the Tuberose's extremely fragrant flower terminal spike (Jadhav *et al*. 2020). Additionally, the manufacturing of pricey perfumes and cosmetics places a strong demand on flower wax and tuberose essential oils (Bharathi and Kirthiahree 2019). Tuberose loose flowers have a concrete content of 0.080-0.135 % and are used to extract essential oils for the high-end perfume industry (Singh *et al*. 2010). It is unnecessary to point out how much loose flowers, cut flowers, concrete, absolute, and essential oils are used domestically, but export has a huge amount of potential (Naik *et al*. 2018). Flowers are processed to separate the rich natural aromatic oil that is essential to the expensive perfume business (Qureshi *et al*. 2018). Numerous preservation treatments are applied in the floral business to prolong the vase life and freshness of these cut flowers. Among these solutions, sucrose is widely applied because it provides a food supply or respiratory substrate, slows down protein deterioration, and keeps increasing flower petals' turgidity (Rabiza-swider *et al*. 2020). The tuberose flower has a beautiful aroma when it blooms at night. The fragrance of tuberoses is made up of a variety of volatile compounds that have antibacterial and antifungal properties as well as some therapeutic benefits for rheumatism, sleeplessness, and influenza (Rani and Singh 2013, Babarabie *et al*. 2017). The florist industry in general continues to be challenged by the shorter vase life of many cut flowers. In a vase, the spikes usually survive 7–12 days, depending on the ambient temperature. Individual florets are used to create bouquets, garlands, button holes, and crowns; the latter is worn at weddings and other religious occasions.

It is estimated that 20 % of tuberose cut flowers is lost during the transport because of its perishable nature. Therefore, it is crucial to handle flowers properly and tuberose requires specific handling. Many studies showed that PGR's also played an important role for better growth of tuberose plants which ultimately produce good quality of cut flowers (Ram *et al*. 2012, Pal *et al*. 2015, Tiwari *et al*. 2018a, 2018b, Ashutosh *et al*. 2019, Mujadidi *et al*. 2019, Kumar *et al*. 2021). Plant growth regulators (PGRs) are also reported to use in the floral industry to prolong the vase life of cut flowers and keep them fresh for longer time (Mansouri 2012, Raj *et al*. 2013, Kumar 2015). Among the plant growth regulators, salicylic acid (SA) is a naturally occurring, less costly, extremely safe, and biodegradable substance that may be used to prolong of vase life of gladiolus cut flowers (Abdolmaleki *et al*. 2015). This natural or artificial chemical is well known as a signalling molecule due to its useful regulation of plant growth and development along with providing maximum resistance against endemic diseases many pathogens and environmental changes. Furthermore, SA inhibits the manufacture of ethylene, abscisic acid, and cytokinin's in plants, which can occasionally improve their effects (Hayat *et al*. 2010). Salicylic acid treatments for longer vase life are linked to ethylene production suppression. Instead of salicylic acid (SA), sodium nitroprusside (SNP) has also been found to enhance the vase life of a variety of cut flowers and its favourble effect to extend the vase life and has been documented in several reports. Keeping in view the above facts, the present study was carried out to assess the roles of different plant growth regulators to enhance the vase life of tuberose cut flowers.

MATERIALS AND METHODS

The present study was conducted at the post-harvest laboratory, College of Horticulture, Sardar Vallabhbhai Patel University of Agriculture and Technology, Modipuram, Meerut, Uttar Pradesh, during the year 2021-2022. Longer spikes with a greater number of fresh flowers of the Prajwal genotype of tuberose were choosen for the study. The spikes (cult flowers) of tuberose were harvested at 8.00 AM. from Horticulture Research Centr (HRC) and were bring to lab which were then kept overnight with stem ends in water and placed in chemical solutions the next morning at 8.00 AM. The experiment was laid out in a Completely Randomized Design (CRD) with three replications. The required concentrations of salicylic

Table 1. Salicylic acid (SA) and sodiumnitroprusside (SNP) concentrations and combinations of treatment in mg/l used for tuberose cut flowers.

Treatment	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}	T_{13}	T_{14}	T_{15}
SA	-	-	-	-	-	-	40	60	80	100	120	40	60	80	100	120
SNP	-	4	6	8	10	12	-	-	-	-	-	10	10	10	10	10

acid and sodium nitroprusside (SNP) were prepared by dissolving the calculated amount of these chemicals in double distilled water as mentioned in Table 1 with various treatments including control.

Characteristics of the spike and floret

Spike characteristics

Vase life (in days)
Stems were checked on a regular basis for visual appeal and calculated according to the methods of Joyce *et al.* (2000) and Ahmad *et al.* (2011).

Water intake (in mL)
The water intake was calculated according to the method of Kazemi and Ameri (2012).

The relative fresh weight (RFW)
The relative fresh weight was calculated according to protocol of He *et al*. (2006) and Ahmad *et al*. (2011).

Days to open 50% florets (days)
The number of days was calculated from day 0 to the day when 50% of the total florets on the spike were completely open.

Floret characteristics

Floret head diameter (in cm)
The head diameter of the fully opened two highest florets from each spike in each replication was measured with a digital calliper on the last day of vase life, and the average was calculated.

Floret length (in cm)
The average lengths of two fully opened top most florets from each spike in each replication were measured using a measuring scale on the last day of vase life.

Open florets (in percent)
Total number of florets (opened and closed) tallied on the last day of vase life and the number of opened florets is computed as follows:

(florets opened/ total florets) x 100

The proportion of open florets was calculated by averaging three spikes per treatment.

Spike/flower quality

Flower quality was assessed by three separate judges (students) by using the method of Dest and Guillard (1987) and an average was calculated. Flower quality was graded on a scale of 1 to 9, with 1 denoting poor quality, 5 denoting medium quality, and 9 denoting excellent quality. Spike quality is determined when 50% of florets on spikes have opened.

RESULTS AND DISCUSSION

Spike characteristics

Vase life (days)

Data presented in Table 2 clearly indicates that the vase life of spikes was influenced by different chemical solutions and their combinations used in the present investigation. The maximum vase life was recorded in the treatment T_{13} (9.6 days) which was at par with the treatments T_3 (9.3 days), T_8, T_9 and T_{12} (8.67 days), while minimum vase life was recorded when spikes were kept in control (6.3 days). Our results showed that a moderate concentration of SA can increase the vase life of tuberose flowers. The reduction in vase life was comparatively less pronounced in treated flowers with low SA and SNP concentrations than those placed in control and other solutions. Results of our study showed that adding sodium nitroprusside (SNP) in vase solutions enhanced

Table 2. Effect of different plant growth regulators (sodium nitroprusside and salicylic acid) on spike and floret characteristics of tuberose cv Prajwal.

Treatment	Vase life days	Water uptake in ml	Spike quality	Days to open 50% florets	RFW= (FW5/FW0) X100	Floret length in cm	Open floret (%)	Floret diameter in cm
Con.	6.33f	81d	3.67f	4d	96.92h	4.63f	69.29e	3.6e
T_1	7.33def	88.33bc	5.33de	5abc	111.68efg	5.3de	78.62cd	4.73ab
T_2	7.33def	92.67b	6.83a	4.33cd	116.78cde	5.7bcd	82.68bc	3.8de
T_3	9.33ab	102.33a	6bcd	5.67a	123.29ab	6.07bc	86.18ab	3.9de
T_4	8.33bcd	101.33a	6.67ab	5abc	114.75cde	5.63cd	79.93cd	4.63ab
T_5	7.33def	91.33b	6bcd	5.33ab	112.74defg	4.9ef	84.08bc	3.73e
T_6	6.67ef	82.33cd	5.67cde	5.33ab	111.71efg	5.77bcd	80.17cd	4.83a
T_7	8.33bcd	99.67a	6.33abc	5.33ab	119.74bc	5.77bcd	80.4cd	3.9de
T_8	8.67abc	98.33a	6.67ab	4.67bcd	112.78defg	6.3ab	80.64cd	3.93de
T_9	8.67abc	91.33b	6.67ab	5.33ab	107.94g	5.67cd	83.74bc	3.83de
T_{10}	7.67cde	86.67bcd	5e	4.33cd	111.85efg	5.53cd	86.83ab	3.83de
T_{11}	7ef	87.67bc	6bcd	4.67bcd	128.42a	5.87bcd	78.69cd	3.87de
T_{12}	8.67abc	101.33a	5.83cd	4.33cd	113.95def	5.77bcd	82.2bcd	4.17cd
T_{13}	9.67a	102.67a	7a	4.33cd	118.5bcd	6.7a	89.29a	4.83a
T_{14}	7.67cde	91.67b	6.33abc	5.33ab	108.1fg	5.8bcd	79.71cd	4.43bc
T_{15}	7.33def	88.33bc	5.33de	4.33cd	108.5fg	5.53cd	76.75d	3.8de
SE(m)	0.37	1.92	0.24	0.26	1.78	0.18	1.65	0.11
CD	1.06	5.58	0.69	0.76	5.16	0.52	4.78	0.33

vase life of tuberose cut flowers and leading to delay in stem bending for the cultivar used in the present study. The reason for extending the vase life may be that the SNP is a nitric oxide donor known to be a signal molecule involved in biotic and abiotic stress tolerance. Therefore SNP has been increasingly used to extend the vase life of cut flowers, such as rose, gladiolus, and carnation (Zeng *et al*. 2011, Liao *et al*. 2013, Dwivedi *et al*. 2016). Kazemi *et al*. (2011) also showed an increase in the vase life of carnation flowers with continuous treatment of flowers with1.5 mM SA (10 days). Treatment of cut rose flowers by SA increased the vase life of flowers (Zamani *et al*. 2011, Alaey *et al*. 2011). Similar findings have been observed in other cut flowers (phlox, rose, gladiolus, and carnation), in which SNP at lower concentrations was less effective to promote vase life, while high concentrations shortened vase life compared to the control treatment (Zeng *et al*. 2011, Liao *et al*. 2013, Dwivedi *et al*. 2016, Naing *et al*. 2017).

Water uptake (mL)

Comparing the results of different water-hold revealed the statistically significant differences such that the highest water absorption among all treatments was recorded in treatment T_{13} (102.67ml) and was at par with the treatments T_3 (102.33ml), T_4 (101.33ml), T_{12} (101.33ml), T_7 (99.67ml) and T_8 (98.33ml) (Table 2). Whereas, the lowest water uptake was observed in the control (81.0ml). Our results showed that moderate levels of SNP, SA and SNP+SA solutions were responsible for higher water uptake in compare to control, while lower and higher levels of SNP, SA and SNP+SA solutions did not showed enhanced level of vase life of tuberose cut flower vase life (Figs. 1 A - C). According to Seyf *et al*. (2012), the significant impact was owing to SNP's participation in stomata closure, reduced transpiration and water loss. Salicylic acid also helps to reduce water loss by controlling plant responses to various oxidative conditions and preventing cell wall breakdown. Cut flower senescence is closely associated with water uptake stem and RWC of petals, whereas, these characteristics are closely related to the contents of osmoregulation substances such as soluble sugars and soluble proteins (Hou *et al*. 2018). Similar findings were reported by Asif *et al*. (2016), where they used water sources having different pH and EC (electrical conductivity) and thereby affected spike and floret characteristics. They also observed that pH and EC of the vase solution increased while EC of the solution

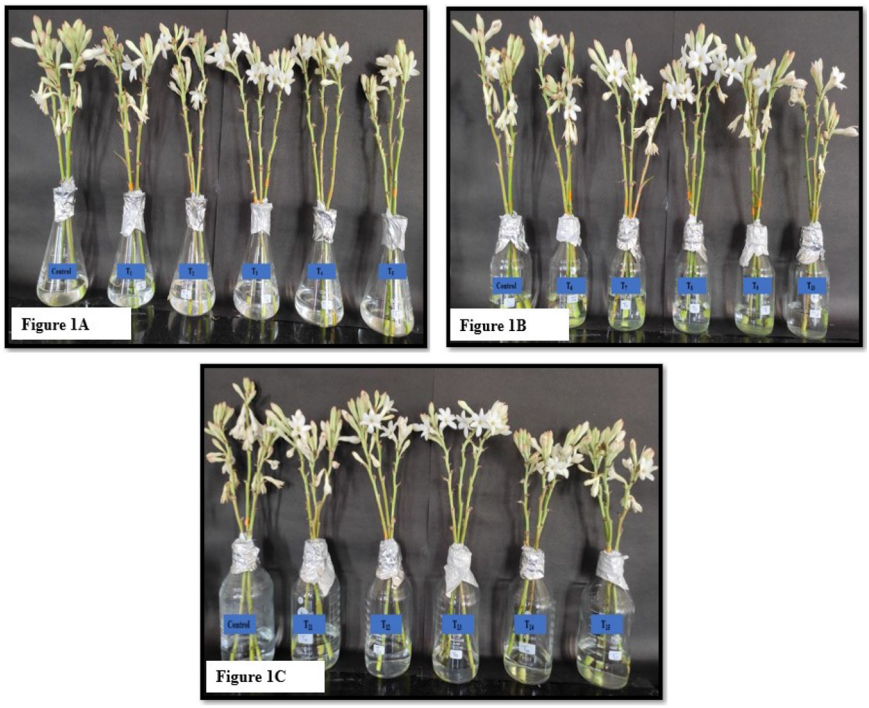

Fig. 1A.- Tuberose flowers treatment with Sodium nitroprusside.
Fig 1B.- Tuberose flowers treatment with Salicylic acid.
Fig 1C.- Tuberose flowers treatment with combination of sodium nitroprusside and Salicylic acid.

influenced the water uptake by cut spikes.

Spike quality

Data of the present investigation showed that there were significant variations in spike quality among several treatments (Table 2). The best quality of the spike was recorded under the treatment T_{13} (7.0) which was significantly at par with the treatments T_2 (6.83), T_4 (6.67), T_7 (6.33), T_8 (6.67), T_9 (6.67), T_{14} (6.33). The minimum spike quality was found in the control (3.67) (Fig. 1 A-C). Findings in the current investigation suggest that salicylic acid alone or in combination with other chemicals such as sucrose, enhances numerous spikes in characteristics of cut tuberose. In response to environmental challenges, salicylic acid was recognized for its vital function in the maintenance of plant's growth (Hayat *et al*. 2010).

Days to open 50 % of florets (days)

The data shown in table 2 clearly indicate that days to open 50 % of florets were influenced by different chemical factor and their combination used in the experiment. Florets take the maximum (T_3- 5.67) days to open 50 percent of the floret's spikes, which is significantly at par with treatment T_5 (5.33), T_6 (5.33), T_7 (5.33), T_9 (5.33) and T_{14} (5.33). The minimum (4.0) days to open 50% of florets were recorded under the control. Similar findings are reported by Asif *et al*. (2016), who found that spikes pulsed with 10% sucrose plus 50 mg/l salicylic acids took long time to open its 50 % florets (5.0 days) and showed increase in the time period to open 50 % florets on spikes by 1.6 days in comparison to the control. They also observed that spikes without pulsing i.e. any treatment (distilled water) took a minimum number of (3.4) days to open 50 % of florets.

Relative fresh weight (percent of initial FW)

The relative fresh weight of spikes recorded on day five of vase life was observed between various

treatments (Table 2). All the treatments significantly influenced compared to the control. The highest relative fresh weight (128.4%) was recorded under the treatment T_{11}, was significantly at par with T_3 (123.2 %), and significantly superior to the rest of the treatments used in the experiment. The minimum relative fresh weight (96.9%) was recorded in the control. SNP has been demonstrated to have a significantly positive influence on RFW in roses and carnations (Seyf *et al*. 2012, Zeng *et al*. 2011). Seyf *et al*. (2012) observed a detrimental effect of SNP at greater doses on RFW, which might be attributed to harm to membranes and nucleic acids, similar to our results (Yamasaki 2000). As a result, salicylic acid is used because it is a natural, safe, inexpensive, and acts as a biodegradable compound for increasing the postharvest longevity of tuberose cut flower species that were susceptible to the bacterial and ethylene vascular blockages (Tehranifar *et al*. 2013).

Floret characteristics

Floret length (cm)

Floret length was significantly affected by the various combinations of SNP and SA used in the experiment (Table 2). The longest floret length (6.7 cm) was recorded under treatment T_{13}, which was significantly at par with T_8 (6.3cm) and significantly superior over the rest of the treatments used in the experiment. Minimum floret length (4.6 cm) was observed in the control. Similar results were also reported by Asif *et al*. (2016) in their study where they observed the longest floret (7.0 cm) in the florets of the spikes of the cut tuberose pulsed with 10 % sucrose and 50 mg/l salicylic acid for 24 hrs period. Asif *et al*. (2016) in another study found lower maximum floret length (5.4 cm) than us in carbonated plus distilled water at (1:1), which is lower than our observations.

Open florets (%)

The percent of open florets significantly shown in Table 2 among different treatments were used in the present study. The maximum open florets (89.2%) were recorded under the treatment T_{13}, followed by the T_{10} (86.8%), T_3 (86.1%) and the minimum open floret (69.2%) was found in control. Asif *et al*. (2016) reported that the highest percentage of opened florets (90.0%) was observed in the florets of the spikes of the cut tuberose when pulsed with 10% sucrose along with 50 mg/l salicylic acid for 24 hours period which is in accordance with our study. Mittal *et al*. (2021) stated that the percent opening of florets was maximum (65.72%) in SNP @50 mg/l solution, which is relatively lower than this study. Asif *et al*. (2016) in another study found highest percentage (83.0%) of opened florets in the spikes kept in carbonated plus distilled water (1:1). Our results proved the role of sodium nitroprusside to enhance the florets opening for a longer duration in compare to control treatment.

Floret head diameter (cm)

The floret diameter was shown significantly different treatments in Table 2. The highest floret diameter (4.8cm) was recorded with the treatments T_6, and T_{13} among all treatments used in the present investigation, followed by the treatments T_1 (4.7cm) and T_4 (4.6cm). The minimum floret diameter (3.6cm) was found under the control. Asif *et al*. (2016) reported in their study where they observed greater floret diameter (4.2 cm), in the florets of the spikes of the cut tuberose pulsed with 10% sucrose and 50 mg/L salicylic acid for 24 hours period. This was lower than the results obtained in this study. Our study indicates that SA alone and in combination with SNP had a major impact on floret head diameter of cut flower of tuberose cv Prajwal. The present study clearly indicated that the effect of salicylic acid alone and in combination of sodium nitroprusside had a major impact to enhance the vase life of cut flower of tuberose by altering the flower characteristics.

CONCLUSION

To conclude, it was determined from the present investigation that treatments for the cut tuberose spikes which were imposed with sodium nitroprusside and salicylic acid alone and their various concentration combinations in vase solutions proved effective to enhance the vase life of tuberose cut flowers. Further, spikes with sodium nitroprusside (08 mg/l) alone was also effective and acts as useful evidence for increasing vase life along with improved cut tuberose spike

postharvest performance in cv Prajwal. 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. Our study may be useful for the future researchers and floriculture industry to adopt sodium nitroprusside alone or in combination with salicylic acid to enhance the tuberose cut flower vase life.

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