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EFFECT OF PRE-STORAGE PULSING TREATMENT ON STORAGE OF GLADIOLUS SPIKES UNDER MODIFIED ATMOSPHERE

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SUMMARY

Studies were conducted on the effect of pre-storage pulsing of gladiolus spikes with sucrose (20 percent)+$Al_2(SO_4)_3.16H_2O$ (400 ppm), on storage in polypropylene (PP) sleeves of 100 gauge (25 µ) thickness. PP packages maintained modified atmospheres with low levels of O_2 and high levels of CO_2 throughout the duration of the storage. Pre-storage pulsing treatment significantly improved post-storage vase life of the spikes, per cent opening of florets, floret size and number of florets opening at one time and also decreased per cent loss of weight of spikes in storage. The utility of dry refrigerated storage of spikes on long-term shipment has been discussed.

Key words: **Gladiolus, modified atmosphere storage, pulsing**

INTRODUCTION

Gladiolus is among the most important cut flower crops, well adapted to varying climatic conditions. Gladiolus spike, being a multifloret system, requires a considerable amount of respiratory substrate to ensure opening of immature florets (Singh *et al.* 2000). Hence, pulsing of spikes with sucrose or use of vase preservative containing sucrose have been found to increase vase life of spikes (Halevy and Mayak 1981, Nowak and Rudnicki 1990, Singh *et al.* 2000, 2001).

Due to lack of regular marketing system of cut flowers in our country, there are frequent gluts, which lead to crashing of prices of the flowers. Refrigerated storage of flowers is an important process to preserve them during the periods of decline in demand. Besides, storage is of considerable utility to hold the flowers for days of high demand and also offers the possibility of long term shipment (Goszczsnka and Rudnicki 1988). Modified atmosphere storage of flowers in moisture proof polymeric films holds considerable significance as flowers in these packages occupy less space in storage as well as in transit. It has earlier been reported that gladiolus spikes show considerable decline in the post-storage opening of florets and vase life (Arora *et al.* 2001)

Halevy and Mayak (1974) and Kofranek and Paul (1975) introduced the concept of short duration pulsing of carnation flowers with high concentrations of sucrose to provide respiratory substrate throughout their entire post harvest life. Arora *et al.* (2001) reported that pulsing solution containing 20 per cent sucrose significantly extended vase life and improved opening of florets in gladiolus. Since sucrose is reported to promote microbial growth in vase water (Singh *et al.* 2000), it was used in combination with $Al_2(SO_4)_3.16H_2O$ at 400 ppm concentration. $Al_2(SO_4)_3.16H_2O$ acts as an effective biocidal compound and at this concentration it significantly prevents microbial growth promoted by sucrose treatment, on the stem surface as well as in the vase water (Arora *et al*. 2001). Kofranek and Halevy (1976)

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reported that pre-storage loading of gladiolus stems with sucrose resulted in greater floret opening and floret size. Grover (2001) suggested that polymeric film packages differed in gaseous permeability properties and only the packages which tend to retain high levels of CO_2 and lower levels of O_2 are suitable for modified atmosphere storage of flowers. Present study was conducted on the effect of pre-storage pulsing treatment on storage of gladiolus spikes in polypropylene (PP) film packages of 100 gauge (25 µ) thickness.

MATERIALS AND METHODS

Spikes of gladiolus cv. White Prosperity (85-90 cm long) were harvested from the field-grown crop, at tight bud stage (when colour was visible in basal 1-2 florets). The spikes were immediately put in buckets containing water, pre-cooled in a cold room at 4±0.5^{O}C for 6 hours and cut to a uniform length of 75 cm. The spikes were divided into 2 lots. One lot was subjected to pulsing treatment with sucrose (20 per cent)+ $Al_2(SO_4)_3.16H_2O$ (400 ppm), by dipping the basal 5-7 cm stem portions in the solution, at 23±2^{O}C, under continuous illumination (1000 lux) for 24 hours whereas the second lot was similarly placed in distilled water. The spikes were then grouped into bundles of 3 each, loosely tied at the base with rubber band and inserted into PP film sleeves of 100 gauge (25 µ thickness). The sleeves were hermatically sealed from both the sides using electronic polythene sealing machine. The packages had an identical size of 80 cm x 10 cm with an effective area of 800 cm^2 on each side for gaseous diffusion and water vapour transmission. The void volume inside the packages was kept constant i.e. 2320±20 cc (an average of 10 packages). The packages were stored in vertical position in a cool chamber (4±0.5^{O}C temperature and 90-95% RH) for 9, 12, 15, 18 and 21 days. The spikes were weighed both before and after the storage for determining per cent decrease in weight during storage. The concentrations of CO_2 and O_2 inside the polymeric film packages were measured after 9, 12, 15, 18 and 21 days of storage using Nucon 7500 gas chromatograph equipped with thermal conductivity detector, according to the method of Singh (1999). Gas chromatograph (GC) columns packed with porapak–Q and molecular sieve–5A were employed for measuring CO_2 and O_2 concentrations, respectively. Gaseous mixture samples (300 µl) were withdrawn from the film packages using hypodermal gas tight syringe and were injected into GC column through injectors which were fitted with silicon rubber septums. Argon gas at constant pressure of 3 kg/cm^2 was used as a carrier gas. The retention time and area of each constituent gas was determined with the help of a computer equipped with software prepared in oracle and compared with the standard reference. Atmospheric levels of CO_2 and O_2 were also measured in the laboratory and found to be 0.03 and 20.99 per cent, respectively.

After the storage, bottom 2 cm portions of the spikes were recut under water to remove surface blockages. The spikes were put in cylindrical vases of glass containing distilled water and kept in an air-conditioned laboratory at 23±2^{O}C temperature, 60-70% RH and 16 h illumination (1000 lux) provided by 40 W white fluorescent tubes. Observations were recorded for vase life, per cent opening of florets, floret size (diameter of the second floret from the base) and maximum number of florets opening at one time. Vase life was measured from the day one basal floret was open till there were five open florets on the spike. The spikes on which less than five florets showed opening, wilting of the basal floret was considered as a sign of termination of vase life. Freshly-harvested spikes served as control. The data presented are a mean of 3 replications each representing 3 spikes. The data were analyzed by the least significant differences test (LSD) using complete randomized design.

RESULTS AND DISCUSSION

Vase life and per cent opening of florets

Vase life of the spikes decreased with increase in the duration of storage and was 6.11, 6.00, 5.28, 3.50 and 1.89 after 9, 12, 15, 18 and 21 days of storage, respectively (Table 1). The decrease in post storage vase life of flowers has also been reported in other flowers (Halevy and Mayak 1981, Nowak and Rudnicki 1990) and has been ascribed to loss of membrane phospholipids, increase in membrane microviscosity and loss of membrane integrity leading to sharp rise in ion leakage (Halevy and Mayak 1981, Paulin *et al.* 1985, Goszcznska and Rudnicki 1988). In *Iris germanica*, refrigeration

Table 1. Vase life and per cent opening of florets of gladiolus spikes stored in PP packages for different storage durations

Storage duration (days)	Vase life (days) Treatment		Mean	Florets opened (%) Treatment		Mean
	Pulsed	Un-pulsed		Pulsed	Un-pulsed	
9	7.11	5.11	6.11	60.85	51.74	56.30
12	7.33	4.67	6.00	57.76	47.38	52.57
15	6.22	4.33	5.28	54.52	45.21	49.87
18	4.44	2.56	3.50	41.25	29.29	35.27
21	2.55	1.22	1.89	30.28	19.84	25.06
Mean	5.53	3.58		48.93	38.69	
LSD (P=0.05)	Treatment(A)=0.21; Storage duration (B)= 0.35; AxB= NS			Treatment(A)=3.40; Storage duration (B)= 5.37; AxB= NS		
Control (unstored):	Pulsed:	9.11			80.26	
	Un-pulsed:	6.33			62.64	

caused decline in the content of soluble proteins and an increase in the ammonia and amino acid levels in the petals, both during cold storage and during the subsequent vase life (Paulin 1973, 1975). Paulin (1981) and Paulin *et al.* (1985) have also reported that accumulation of high levels of toxic metabolites during refrigeration of cut flowers provokes rapid wilting upon return to normal conditions.

Pulsing treatment improved vase life of the spikes. The pulsed spikes exhibited an average vase life of 5.53 days as compared to 3.58 days in un-pulsed ones. Not only this, the spikes subjected to pulsing treatment maintained higher vase life than their un-pulsed counterparts, throughout the storage duration. The vase life of these spikes decreased to 7.11, 7.33, 6.22, 4.44 and 2.55 days after 9, 12, 15, 18 and 21 days, respectively. On the other hand, the water treated spikes exhibited vase life of 5.11, 4.67, 4.33, 2.56, and 1.22 days after 9, 12, 15, 18 and 21 days in storage, respectively. Pulsing of spikes also significantly improved percentage of opened florets over the un-pulsed spikes. However, the tendency of the florets to open after storage continued to decrease with an increase in the storage duration.

It can thus be inferred that pre-storage pulsing improved the post-storage vase life and tendency of the florets to open. Sucrose pulsing has also been reported to increase vase life and improve opening of immature buds in many flowers (Halevy and Mayak 1981, Nowak and Rudnicki 1990, Singh *et al.* 2001). Kofranek and Halevy (1976) reported that pulsing of gladiolus stems with sucrose in combination with $AgNO_3$, prior to dry storage resulted in greater floret opening than those not pulsed. The spikes were wrapped after pulsing in the tissue paper and then in several layers of newspaper before placing them in a fibreboard carton for refrigerated storage for one week. In the present study, however, the spikes were stored in PP sleeves which tended to create modified atmospheres with low O_2 and high CO_2 levels inside the packages (as discussed in the subsequent section).

Floret size and maximum florets opened at one time

The florets showed decline in their size with progress in the duration of storage (Table 2). Pulsing of spikes significantly improved floret size. Average floret size (of the second floret from the base) in pulsed spikes was 9.46 cm as compared to 8.65 cm in un-pulsed spikes. Pulsing of spikes also maintained higher floret size throughout the storage duration. Increase in floret size due to pulsing treatment was apparently due to the sucrose loading which provided an additional respiratory substrate for their growth (Singh *et al.* 2000).

Table 2. Floret size and maximum number of florets opened at one time in gladiolus spikes stored in PP packages for different storage durations

Storage duration (days)	Floret size (cm) Treatment		Mean	Maximum florets open at one time Treatment		Mean
	Pulsed	Un-pulsed		Pulsed	Un-pulsed	
9	10.07	9.33	9.70	5.67	4.89	5.28
12	9.61	9.10	9.36	5.22	4.44	4.83
15	10.14	9.00	9.57	5.44	4.11	4.78
18	9.33	8.50	8.92	4.89	3.22	4.06
21	8.17	7.33	7.75	2.67	2.11	2.39
Mean	9.46	8.65		4.78	3.75	
LSD (P=0.05)	Treatment(A)= 0.24; Storage duration (B)= 0.37; AxB= NS			Treatment (A)= 0.22; Storage duration (B)= 0.35; AxB= 0.50		
Control (unstored):	Pulsed: 11.37			7.00		
	Un-pulsed: 10.27			5.45		

The maximum florets that opened at one time on the spike also showed decline with increase in the storage duration. Pulsing of spikes improved the number of florets that were open at one time to 4.78 as compared to 3.75 in un-pulsed ones.

Per cent decrease in weight of spikes

Table 3 shows that per cent decrease in weight of spikes remained very low during storage but was higher in un-pulsed spikes than the pulsed ones. The values of per cent loss in weight were 0.66, 0.77, 0.94, 1.01 and 1.29 in pulsed spikes as compared to 0.85, 0.90, 1.05, 1.43 and 1.41 in un-pulsed ones after 9, 12, 15, 18 and 21 days of storage, respectively. It indicates that sucrose pulsing reduced the physiological loss in weight which helped in maintaining the water balance and freshness of spikes thereby, increasing their longevity. It was also evident that though spikes did not lose considerable weight during storage, they showed significant decline in the opening of florets with increase in storage duration. Pulsing of spikes, however, tended to retain the ability of florets to open which was reflected in the increased percentage of florets that showed opening. It has also been earlier reported that sucrose not only improved longevity of cut flowers by supplementing endogenous carbohydrates but also helped to close stomata thereby reducing water loss from the cut stems (Halevy and Mayak 1979, Nowak and Rudincki 1990, Singh *et. al.* 2001).

Table 3. Per cent decrease in weight of pulsed and un-pulsed spikes stored in PP packages for different storage durations

Storage duration (days)	Decrease in weight (%) Treatment		Mean
	Pulsed	Un-pulsed	
9	0.66	0.85	0.76
12	0.77	0.90	0.84
15	0.94	1.05	1.00
18	1.01	1.43	1.22
21	1.29	1.41	1.35
Mean	0.93	1.13	
LSD (P=0.05)	Treatment (A)= 0.05; Storage duration (B)= 0.18; AxB= 0.20		

Oxygen and carbon dioxide concentrations in the packages

Table 4 presents changes in O_2 and CO_2 concentrations (%) in PP packages with pulsed and un-

Table 4. O_2 and CO_2 concentrations (%) in PP packages containing pulsed and un-pulsed gladiolus spikes after storage for different durations

Storage duration (days)	O_2 concentration (%) Treatment		Mean	CO_2 concentration (%) Treatment		Mean
	Pulsed	Un-pulsed		Pulsed	Un-pulsed	
9	0.47	0.76	0.62	9.01	7.32	8.17
12	0.38	0.72	0.55	8.52	7.35	7.94
15	0.42	0.51	0.47	8.76	8.54	8.65
18	1.49	0.47	0.98	6.81	8.55	7.68
21	0.95	0.42	0.69	7.06	8.85	7.96
Mean	0.74	0.58		8.03	8.12	
LSD (P=0.05)	Treatment (A)=NS; Storage duration (B)= NS; AxB= 0.38			Treatment (A)=NS; Storage duration (B)= NS; AxB= 0.92		

pulsed spikes, during storage for different durations. The O_2 concentrations observed were 0.47, 0.38, 0.42, 1.49 and 0.95 per cent in packages containing pulsed spikes and 0.76, 0.72, 0.51, 0.47 and 0.42 per cent in those with un-pulsed spikes, after storage of 9, 12, 15, 18 and 21 days, respectively. Low concentrations of O_2 as compared to the atmospheric level (20.99%) inside the PP packages were apparently due to the consumption of O_2 by the spikes during respiration and low influx of this gas from the outer atmosphere. PP packages also tended to accumulate considerably high percentage of CO_2 throughout the duration of the storage. There was, however, no effect of the treatment on CO_2 and O_2 concentrations inside the packages. Packages containing both the pulsed and un-pulsed spikes accumulated an average of nearly 8 percent CO_2. High CO_2 concentrations inside the packages were apparently due to its release during respiration and low efflux to the outer atmosphere. It may, however, be added that after 18 and 21 days of storage, the packages containing pulsed spikes exhibited an increase in O_2 and decline in CO_2 levels which indicated decline in respiratory activity of these spikes. It has earlier been reported that sucrose as well as aluminium sulphate induced stomatal closure in cut roses, thereby causing reduction of water loss (Halevy and Mayak 1979,1981). Stomatal closure might also affect the gaseous exchange through the stomates and hence, reduce the rate of respiration thereby, decreasing utilization of O_2. No such studies have, however, been made in gladiolus, so far. The modified atmospheres with high levels of CO_2 and low O_2 levels have been reported very useful for storage of flowers because such conditions lower the respiration rate, alleviate damaging effects of ethylene and prevent loss of water from the cut stems (Goszczynska and Rudnicki 1988, Nowak and Rudnicki 1990, Wills *et al*. 1995). Under such a modification of environment, the spikes pulsed with sucrose (20 per cent) + $Al_2(SO_4)_3$. $16H_2O$ (400 ppm) could be stored for 15 days with vase life of more than 6 days.

It may be mentioned that most flowers are preferably transported under refrigerated conditions to maintain their freshness during transit. Due to increase in the cost of air transport, alternate methods of transport especially, surface transport are being worked out for the commercial transportation of cut flowers. Being heavy in weight, air shipment of gladiolus spikes to the export markets is a very expensive proposition and hence, is a major impediment in their export. There is therefore, considerable scope for refrigerated transportation of gladiolus spikes in PP packages. These packages can be held in transit for 15 days with post-storage vase life of more than 6 days.

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