THE ASIAN JOURNAL OF HORTICULTURE
Volume **8** | Issue 2 | December, 2013 | 561-564

Research Paper

***Article history*:**
Received : 15.07.2013
Revised : 22.09.2013
Accepted : 06.10.2013

Optimizing harvesting stage of gladiolus spikes for wet refrigerated storage

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ABSTRACT : Spikes of gladiolus cv. White Prosperity were harvested at four stages of floret development *viz.*, S_1- tight bud stage (when 1-2 basal florets showed color); S_2-when 5-7 florets showed color; S_3- when basal floret was half open; and S_4- when one basal floret was fully open. The spikes were subjected to wet refrigerated storage at 4±0.5^{0}C for 3, 6, 9, 12, 15 and 18 days. Increase in storage duration hastened opening of the basal floret, increased vase life and per cent opening of florets on the spike. The spikes harvested at S_1 exhibited the minimum vase life and floret opening. The spikes harvested at S_2, S_3 and S_4 exhibited long post-storage vase life and opening of florets and were hence, found suitable for storage. In case of S_2 spikes, the florets did not exhibit complete opening till 9 days of storage. The spikes harvested at S_3 and S_4, however, exhibited an early opening of the basal floret *i.e.* after 3 to 6 days of storage and hence, could only be used for local marketing because open florets on the spike are highly prone to damage during transport. The spikes harvested at S1 exhibited maximum starch content. These spikes also showed low levels of total as well as reducing sugar content in the tepols which exhibited increase in the spikes harvested at S_2, S_3 and S_4.

KEY WORDS : Gladiolus, Storage, Stages of harvest

HOW TO CITE THIS ARTICLE : Singh, Kushal and Singh, Ranjit (2013). Optimizing harvesting stage of gladiolus spikes for wet refrigerated storage. *Asian J. Hort.*, **8**(2) : 561-564.

Gladiolus is an important flower which is being grown in the Indian subcontinent under open field conditions. *Gladiolus* spikes are in considerable demand in the domestic market which repeatedly experiences periods of lean demand leading to considerable fall in prices. Therefore, to regulate the supply of flowers in the market and to stabilize prices, the flowers are required to be stored under refrigerated conditions. In storage, the flowers can be either stored under dry or wet conditions. In dry storage, the flowers are stored in polymeric film sleeves where as in wet storage the stems are placed in water or a suitable chemical solution (Nowak and Rudnicki, 1990). Wet storage is used for short duration storage and is the most frequently used method for storage of cut flowers (Nowak and Rudnicki, 1990; Singh *et al.*, 2012). The flowers are reported to show decline in vase life with increase in the storage duration (Zencirkiran and Mengüc, 2003; Grover *et al.*, 2006, Geng *et al.*, 2009). Since gladiolus spike possesses many florets, it requires considerable amount of endogenous substrates for the expansion of florets. In gladiolus florets, the content of starch decreases whereas that of total soluble and reducing sugars increases with advancement in the stage of development on the spike (Grover and Singh, 2010). The upper florets on the spikes harvested too tight fail to expand after storage where as those on the spikes harvested at advanced stages of floret development continue to expand during storage which leads to loss of vase life. The present studies were conducted to work out an optimum stage of harvest for refrigerated storage of gladiolus spikes.

RESEARCH METHODS

Spikes of gladiolus cv. White Prosperity (≈ 90 cm long) were harvested at four stages of floret development *i.e.* S_1- tight bud stage (when basal 1-2 florets showed colour); S_2- when 5-7 basal florets showed colour; S_3- when basal floret was half open; and S_4- when one basal floret was fully open. The spikes were held vertically in buckets containing water and stored under refrigerated conditions in a cold room

(4 ± 0.5^0 C temperature; 85-90 % R.H.) for 3, 6, 9, 12, 15 and 18 days. Freshly-harvested spikes served as control. Before storage, basal two cm portions of the spikes were re-cut under water to remove surface blockages. Keeping quality of the spikes was evaluated in an air-conditioned laboratory at 23 ± 2^0 C temperature, 60-70 per cent R.H. and 16 h illumination of 1000 lux intensity provided by 40 W white fluorescent tubes. Observations were recorded for days to opening of basal floret, vase life, floret size (second floret from the base), per cent opening of florets and stage of floret growth in the storage. Vase life was measured from the day when one basal was open till there were five open florets on the spikes. The spikes on which less than five florets showed opening, wilting of the basal floret indicated termination of the vase life. Starch, total soluble and reducing sugar contents in the tepols were also analyzed in the freshly-harvested spikes and after 6, 12 and 18 days of storage, according to the methods of McCredy *et al.* (1950); Dubois *et al.* (1956) and Nelson (1944), respectively. The data presented are a mean of three replications each of three spikes.

RESEARCH FINDINGS AND DISCUSSION

The results obtained from the present investigation are summarized below :

Days to opening of basal floret and vase life:

Days taken for the opening of basal floret continued to decrease with increase in the duration of storage in case of spikes harvested at S_1 and S_2. Basal floret on the spikes harvested at S_3 and stored for 3 days opened almost the next day (1.11 days). After 6 to 18 days of storage, however, the basal floret in S_3 and S_4 spikes had already opened in storage (Table 1). Vase life of the spikes continued to decrease with increase in storage duration and was minimum after 18 days of storage. The decrease in vase life of flowers with increase in storage duration has already been reported in flowers (Grover *et al.*, 2006; Geng *et al.*, 2009). Vase life was minimum in case of spikes harvested at S_1 but showed substantial increase at stages 2 to 4. Spikes harvested at S_2 showed vase life of 5.18 days while it was 5.60 days and 6.01 days in case of S_3 and S_4 spikes, respectively. Vase life of the spikes harvested at S_2, S_3 and S_4 was also nearly 5 days after 12 days of storage. It indicates that spikes harvested at S_2, S_3, or S_4 could be stored for up to 9 to 12 days with acceptable vase life (Table 1).

Per cent opening of florets and floret size:

Per cent opening of florets on the spikes continued to decrease with progress of storage duration (Table 2). The opening of florets was minimum in S_1 spikes and continued

Table 1: Effect of stages of harvest on days to opening of basal floret and vase life in gladiolus spikes cv. WHITE PROSPERITY

Storage duration (days)	Days to opening of basal floret					Vase life				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
3	5.44	4.22	1.11	0.00	2.69	3.78	6.67	7.22	6.89	6.14
6	4.56	3.11	0.00	0.00	1.92	3.33	6.11	7.33	6.56	5.83
9	4.11	2.11	0.00	0.00	1.56	3.55	5.78	5.67	6.44	5.36
12	3.67	2.44	0.00	0.00	1.53	3.00	4.78	5.11	5.22	4.53
15	3.56	2.22	0.00	0.00	1.45	2.78	3.00	4.00	4.11	3.47
18	2.56	1.44	0.00	0.00	1.00	2.33	2.78	2.44	3.55	2.78
Control (0 days)	5.11	4.22	1.00	0.00	2.58	4.44	7.11	7.44	9.33	7.08
Mean	4.15	2.82	0.30	0.00		3.32	5.18	5.60	6.01	
LSD (P=0.05)	Stages (A)= 0.31; Storage duration (B)= 0.41; A x B= 0.81					Stages (A)= 0.27; Storage duration (B)= 0.35; A x B= 0.71				

Table 2 : Effect of stages of harvest on percent opening of florets , size of florets and in gladiolus cv. WHITE PROSPERITY

Storage duration (days)	Percent opening of florets					Size of the floret				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
3	44.25 (41.65)	69.63 (56.56)	79.44 (63.09)	80.48 (68.25)	68.45 (57.39)	9.43	9.67	11.50	11.40	10.50
6	43.85 (41.45)	70.37 57.12)	70.65 (57.25)	77.46 (60.40)	65.58 (54.05)	7.57	9.93	9.90	11.13	9.63
9	34.26 (35.67)	62.24 (52.06)	65.66 (54.11)	75.64 (63.86)	59.45 (51.42)	8.77	9.50	9.97	10.73	9.74
12	37.53 (37.71)	53.03 (46.72)	58.82 (50.08)	66.67 (54.71)	54.01 (47.30)	8.87	9.20	9.73	10.80	9.65
15	21.77 (27.79)	35.05 (36.16)	54.81 (47.74)	56.67 (48.81)	42.08 (40.13)	9.20	9.17	10.30	9.77	9.61
18	17.68 (24.36)	31.31 (33.99)	50.41 (39.21)	48.96 (44.36)	37.09 (35.48)	9.00	8.80	9.80	10.07	9.42
Control (0 days)	49.32 (44.59)	72.27 (61.56)	81.13 (65.50)	85.51 (61.84)	72.06 (58.37)	9.73	9.67	11.27	11.83	10.63
Mean	35.25 (36.17)	56.27 (49.17)	65.85 (56.08)	70.20 (57.46)		8.94	9.42	10.35	10.82	
LSD (P=0.05)	Stages (A)= 3.31; Storage duration (B)= 2.51; A x B= 6.66					Stages (A)= NS; Storage duration (B)= 0.59; A x B= 1.17				

Figure in parentheses are arc sine transformed values to increase with advancement in the stage of development of florets on the spike *i.e.* in case of S_2 to S_4 spikes. Per cent floret opening was more than 50 per cent after 12 days of storage in S_2, S_3 and S_4 stages, *viz.*, 53.03, 58.82 and 66.67 per cent, respectively. The spikes exhibited fifty per cent opening of florets are considered suitable for commercial use. Therefore, the spikes harvested at S_2, S_3 and S_4 can be stored for up to 12 days.

Floret size was minimum (8.9 cm) in S_1 spikes and showed increase with the advancement in the stage of harvest of the spike and was maximum (10.82 cm) in case of S_4 spikes.

Stage of floret growth in storage:

The florets also continued to expand during storage (Table 3). The florets on S_1 spikes did not show opening during storage where as basal floret on S_2 spikes exhibited opening after 12 days in storage. On the other hand, basal floret on S_3 and S_4 spikes showed opening after 3 days of storage. In case of these spikes, 1-2 florets exhibited opening after storage of 6 and 9 days where as 2-3 florets showed opening after storage of 12 and 15 days. The number of florets that opened during storage increased to 3-4 when S_3 and S_4 spikes were held in storage for 18 days. Opening of the florets during storage is not desired as spikes with open florets are prone to damage during post storage transport. Therefore, in case the spikes have to be transported to distant markets, these should be harvested at S_2. Such spikes can be stored for 9 days. For local market, however, the spikes can be stored for longer duration and at more advanced stage of floret development as such spikes do not require transportation.

Starch, total soluble sugar and reducing sugar contents in tepals:

Starch content of the tepals was maximum in S_1 spikes but showed decrease in case of S_2, S_3 and S_4 spikes. The content in S_2, S_3 and S_4 spikes was, however, at par. Starch content decreased with increase in the storage duration (Table 4). The decrease in starch content at S_3 and S_4 stages indicates that with the development of the floret, starch gets hydrolyzed to provide energy to the expanding florets. The content also continued to decrease with progress of storage duration and reached minimum level after 18 days of storage which indicates that hydrolysis of starch also continues during storage of the spikes. Total soluble sugar content showed increase at S_2 but showed moderate decline at S_3 and S_4 spikes. Reducing sugar content also continued to increase with advancement in the stage of harvest from S_1 to S_4. The content increased till 12 days in storage but showed decline thereafter. Yamane *et al.* (1991) demonstrated that predominant sugars in the gladiolus perianth were fructose and glucose. Starch in florets was primary source of soluble carbohydrates which contributed to early stages of flower expansion. They further demonstrated that high activity of acid invertase in the opening florets indicated that osmotic

Table 3 : Effect of stages of harvest on floret development in gladiolus cv. WHITE PROSPERITY

Storage duration (days)	Stage of harvest			
	S_1	S_2	S_3	S_4
3	4-6 florets show colour	2 basal florets half open	one basal floret open	one basal floret open
6	5-7 florets show colour	2 basal florets half open	1-2 florets open	1-2 florets open
9	5-7 florets show colour	2 basal florets half open	1-2 florets open	1-2 florets open
12	Basal floret half open	One basal floret fully open	2-3 florets open	2-3 florets open
15	1-2 basal florets half open	1-2 florets fully open	2-3 florets open	2-3 florets open
18	1-2 basal florets half open	1-2 florets fully open	3-4 florets open	3-4 florets open

Table 4 : Changes in starch, total soluble sugar and reducing sugar content (mg/g/dry weight) in tepals of gladiolus florets at varying stages of development after different durations of wet storage

Storage duration (days)	Starch content (mg/g/dry weight)					Total soluble sugar content (mg/g/dry weight)					Reducing sugar content (mg/g/dry weight)				
	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
6	23.66	15.80	14.12	17.01	17.65	173.50	178.66	167.65	190.86	177.67	58.26	66.62	71.76	88.47	71.28
12	19.59	12.68	11.88	14.10	14.56	175.58	211.30	179.06	228.06	198.50	67.71	74.02	87.04	95.19	80.99
18	17.27	10.44	12.38	11.52	12.90	184.61	266.35	234.91	172.41	214.57	53.52	51.57	50.79	45.28	50.29
Control (0 day)	24.60	19.93	9.46	19.54	20.88	155.05	163.29	162.19	187.29	166.96	54.63	62.80	68.29	79.77	66.37
Mean	21.28	14.71	14.46	15.54		172.19	204.90	185.96	194.66		58.53	63.76	69.47	77.17	
LSD (P=0.05)	Storage duration(A)=1.12; Stage(B)=1.12; AxB=NS					Storage duration(A)=15.37; Stage(B)=15.37; AxB=30.74					Storage duration(A)=7.00; Stage(B)=7.00; AxB=14.00				

changes required to drive cell expansion might be achieved by the hydrolysis of sucrose in the buds or sucrose translocated to the developing buds. Post-harvest pulsing with sucrose is also reported to improve opening and shelf life of flower buds (Bhattacharya and De, 2006; Bala *et al.*, 2008).

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