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Effect of low temperature dry storage on vase life of cut carnation (*Dianthus caryophyllus* L.) flowers

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Abstract
Studies were conducted to find out the effect of dry storage durations on vase life of cut carnation (*Dianthus caryophyllus* L.) flowers. Dry storage significantly reduced flower diameter, flower appearance, consumption of holding solution, RWC, membrane stability and vase life as compared to un-stored conditions. Highest vase life was observed with four days dry storage duration. Vase life and other post-harvest characteristics were negatively affected as dry storage duration increased further. Serotonin proves to be promising holding solution for enhanced vase life of cut carnation flowers.

Keywords: Low temperature, holding solutions, dry storage

Introduction
Post-harvest handling of cut flowers is very crucial to maintain the colour and freshness for longer duration (Reid 2002) [2, 3, 5]. Improper storage conditions and duration can negatively effects the vase life of cut carnation flowers. At present dry and wet storage methods are being used to store the cut carnation flowers. Both methods have advantages and disadvantages for cut flower longevity. Cut flowers of carnation at 5 °C under wet conditions resulted in increased vase life of cut carnation (Pranuthi *et al.*, 2018) [4]. Wet storage at low temperature can reduce the respiration and transpiration. It improves cell elongation and turgidity which increased the vase life (Halevy and Mayak, 1981) [1]. However, wet storage can create pathogenic contamination which will lead to stem end plugging, reduced water uptake and faster wilting (Macnish *et al*., 2009, Nell and Reid, 2000) [2, 3]. It is evident from the literature that long term storage should be done under dry conditions (Reid, 2002, Sacalis, 1993) [5, 6]. During dry storage flowers can be sealed to reduce the water loss. Dry storage method for storing cut flowers is more laborious but can hold the flower for longer duration. However, it is crucial to find out the optimum duration of dry storage for carnation.

Materials and Methods
The studies were carried out at Hi-Tech centre of Department of Floriculture and Landscaping, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan during 2019-2020. Experiment was conducted using CRD design (factorial) with three replications. Harvested cut flower stems of carnation were reduced to a uniform length of 30 cm by giving a slanting cut at the basal portion. After completion of dry storage duration, basal 2-3 cm portions of the stems were re-cut again before keeping them in vases containing holding solutions.
For dry storage cut flower stems after harvesting at paint brush stage were wrapped in cellophane paper and stored for different duration's *viz*. 0, 4, 8 and 12 days at 4 °C in cold room at 85-90 % RH. After completion of dry storage period cut stems were placed in holding solutions namely; distilled water, sucrose (2%) + 8-HQC (150 ppm) + BA (5 ppm) and Serotonin (300 uM). The effects of low temperature dry storage durations on vase life and post-harvest parameters were studied in different holding solutions.

Results and Discussion
Days taken to flower opening
Time taken to flower opening was recorded highest (4.25 days) when these cut stems were not dry stored. Dry storage of different durations significantly decreases the time taken to flower opening. Among different dry storage durations at 4 ^{0}C, minimum time taken for flower opening (2.56 days) was recorded when the cut flower stems were stored for longest duration

of 12 days while, maximum time taken for flower opening was recorded when cut flowers were stored for 4 days (3.64 days). Such results can be explained by the fact that even in dry storage at low temperature cut flowers are physiologically active and when they are kept in storage, they are at the verge of opening. Due to this reason flowers takes less time to open as compared to un-stored flowers. Longer duration stored flowers produces higher ethylene which can delay the opening of dry stored flowers as compared to un-stored fresh flowers. Among different holding solutions, cut flowers placed in H_3 (Serotonin, 300 µM) solution recorded minimum time for flower opening (3.05days) and it was found at par with H_2.

Flower diameter (cm)

Flower diameter was recorded highest (7.24 cm) when these cut stems were not stored in dry storage. Among different dry storage durations, maximum flower diameter of 6.77 cm was recorded when stored for 4 days while, minimum flower diameter of 5.61 cm was obtained with 12 days storage. Such a decrease in flower diameter with increase in duration can be due to the fact that senescence process continues even during cold storage of cut flowers (Faragher *et al.*, 1986) [7]. Such process continues on stored food and longer duration storage flowers consume more amount of stored food as compared to short term stored flowers. Due to not depletion of food in un-stored flowers resulted in higher flower diameter. Among different holding solutions, cut flowers placed in H_3 (Serotonin, 300 µM) solution recorded maximum flower diameter (6.93 cm), which was found to be at par with H_2 [(Sucrose (2%) +8HQC (150ppm) +BA (5ppm)].

Appearance of cut bloom (Score out of 5.00)

Flower appearance was best (4.20) when these cut stems were not stored in dry storage. Dry storage significantly reduces the appearance of cut flowers. Among different dry storage durations, flowers appeared best when stored for 4 days with a score of 3.84. Minimum score of cut flowers (3.05) was recorded with the longest storage duration of 12 days which was found to be at par with 8 days storage duration. It was pointed out by Halevy and Mayak (1981) [1] that stored flowers looks better when taken out of storage but such flowers do not remain fresh for long time as compare to fresh flowers. In case of holding solutions, flowers appeared better with a score of 3.83 when placed in H_3 (Serotonin, 300 µM) after completion of the dry storage.

Holding solution consumed (ml/stem)

Results on consumption of holding solutions shows that effect of storage durations, holding solutions and their interaction were significant. Highest consumption of holding solution (30.91 ml/stem) was recorded when cut flowers were not dry stored. This can be due to that un-stored flowers survived longer as compared to stored flowers. Dry storage for different durations at 4°C significantly reduces the consumption of holding solution. Among different dry storage durations, cut flowers absorbed maximum quantity of holding solution (22.33 ml/stem) when stored for 4 days. In contrast, minimum amount of holding solution (10.46 ml/stem) was absorbed with longest storage duration of 12 days. Consumption of vase solution decreases as duration of dry storage was increased due to low survival duration. Cut flower stems when placed in different holding solutions after dry storage, showed significantly higher consumption of holding solution (23.32 ml/stem) in H_3 (Serotonin, 300 µM).

Relative water content (%)

RWC differed significantly among storage durations and holding solutions. The interaction between storage durations and holding solutions was found non-significant. Results showed significantly highest RWC (80.36 %) under un-stored treatment compared to different dry stored treatments. Among different storage durations, shortest storage duration of 4 days showed maximum (73.66 %) and longest storage duration of 12 days showed minimum (64.32 %) RWC of cut flowers petals. Among different holding solutions, cut flowers placed in H_3 (Serotonin, 300 µM) solution showed highest RWC (75.97%).

Membrane stability (%)

The results on membrane stability revealed that it differed significantly due to storage durations and holding solutions. The interaction between storage durations and holding solutions was found non-significant. It was observed that cut flower membrane stability was recorded highest (70.51%) in un-stored treatment and it was at par with 4 days storage duration treatment. Among different storage durations, shortest storage duration of 4 days showed maximum (68.26 %) and longest storage duration of 12 days showed minimum (50.48%) membrane stability. Cut flowers placed in Serotonin (300 µM) holding solution after dry storage recorded highest membrane stability (66.76 %).

Vase life (Days)

Un-stored cut flowers showed highest vase life of 15.62 days compared to dry storage of different durations. Dry storage reduces the vase life. Rudnicki *et al.* (1989) [8] also reported that storage of cut flowers reduces the vase life in comparison to un-stored flowers. Among different storage durations, highest vase life of 12.21 days was recorded when cut flowers were stored for 4 days in dry storage. Further, there was significant reduction in vase life with the increase in dry storage duration from 4 to 8 days. Minimum vase life (5.68 days) was observed when cut flowers were stored for 12 days duration and it was found to be at par with 8 days dry storage duration treatment. Such results are in conformity with the findings of Serrano *et al*. (1995) [9]. It was found that during cold storage of cut carnation flowers, content of ACC (precursor of ethylene synthesis) increases with increase in storage duration (Menguc and Usta, 1994) [10]. Due to this vase life of stored flowers decreases when storage duration is increased. The current result shows that four days dry storage at 4ºC can be used to store cut carnation flowers. Cut flower stems when placed in different holding solutions after dry storage, showed significantly higher vase life (12.19) in H_3 (Serotonin, 300 µM) as compared to other holding solutions. It can be concluded from the above results that serotonin (300 µM) can be used as holding solution for improving the longevity of cut carnations.

Table 1: Effect of dry (4 °C) storage durations and holding solutions on time to flower opening, flower diameter, appearance of cut bloom, vase life, holding solution consumed, relative water content and membrane stability (%) of cut carnation flowers cv. 'Bizet'

Wet storage durations (Days) (D)	Days to flower opening	Flower diameter (cm)	Appearance of cut bloom (Score out of 5.00)	Vase life (days)	Holding solution consumed (ml/stem)	Relative water content (%)	Membrane stability (%)
0	4.25	7.24	4.20	15.62	30.91	80.36	70.51
4	3.64	6.77	3.84	12.21	22.33	73.66	68.26
8	3.12	6.03	3.27	6.11	15.64	67.58	56.59
12	2.56	5.61	3.05	5.68	10.46	64.32	50.48
Holding Solution (S)							
H_1	3.96	5.47	3.28	6.63	15.75	67.52	56.47
H_2	3.17	6.85	3.66	10.89	20.45	70.97	61.15
H_3	3.05	6.93	3.83	12.19	23.32	75.97	66.76
H_1 = Control (Distilled water), H_2 = [(Sucrose (2%) +8HQC (150ppm) +BA (5ppm)], H_3 = Serotonin (300 µM)							
$CD_{0.05}$ for:							
D	0.39	0.26	0.25	0.84	1.78	2.81	2.78
S	0.34	0.23	0.22	0.73	1.54	2.44	2.41
D x S	NS	NS	NS	1.46	3.08	NS	NS

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