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STABY

Storage of Rose and Carnation Flowers

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Abstract. **Normal refrigeration (NR), low pressure (LP, 10 to 35 mm Hg), and low oxygen (0.5% to 8%) storage trials were conducted using cut flowers of carnation (*Dianthus caryophyllus* L.) and rose (*Rosa* sp.). Variables studied were storage time, gas partial pressures, vapor barriers, chemical pretreatments, grower source, cultivars, and stem recutting methods. Low oxygen storage was not beneficial regardless of variables tested. In general, carnations could be stored for 6 weeks under NR and 8 weeks under LP conditions if the flowers were pretreated with silver thiosulfate (STS) and vapor barriers were utilized during NR storage. Roses could be stored up to 2 weeks under NR and up to 4 weeks under LP conditions and still exhibit at least 61% of their nonstored, original vase-life if LP-induced leaf disorders were not considered. Rose vase-life after NR storage was enhanced by utilizing vapor barriers during storage, and visual appearance improved if stems were recut under water upon removal from storage. LP-stored roses did not benefit by these treatments. However, the same cultivars from different growers did not respond equally and great variability was noted among rose cultivars tested regardless of storage method. Of special concern were the LP-induced leaf disorders noted on 'Forever Yours', 'Royalty', 'Town Crier', and 'Spanish Sun' roses.**

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Stoddard and Hummel (27) were among the early investigators of LP storage techniques. However, it was mainly the research of Burg et al. (7, 8, 13) that stimulated over a decade of LP studies and the eventual commercialization of these technologies (16, 17). Although, the literature review below emphasizes carnation and rose flowers, a greatly expanded literature review of LP research can be obtained by writing the senior author.

Initial LP storage results with carnation flowers were generally favorable (7). Flowers stored up to 79 days retained 81% of their original vase-life (10). Carnation vase-life, in one study averaged over 4 experiments, (after 24 and 48 days of storage) was 39% and 0% for NR and 90% and 71% for LP, respectively, of the vase-life of freshly harvested flowers (2). Bud-harvested carnations stored better than flowers harvested fully open (9, 11–13) and 50 or 100 mm Hg gave equal results (13). NR produced the same results as LP when flowers were stored for 3 weeks, but after 6 weeks of storage LP flowers lasted approximately 9 days longer than NR-stored ones (13). Ethylene and CO_2 production rates were reduced and/or delayed after 5 weeks for flowers stored under LP compared to freshly harvested flowers (13). The longest LP storage test (20 weeks) determined that prestorage treatments with STS and sucrose were essential (15).

Contrary to these favorable results for carnations, our initial findings showed little, if any, advantage of LP over NR storage techniques (23). For example, after 6 weeks of storage, LP-stored carnation flowers had only 46% of their original vase-life compared to 57% for NR-stored ones (25).

Roses cannot be stored satisfactorily as long as carnations; however, early studies on cut roses showed that LP storage was more beneficial than NR (3, 4, 7, 22, 24). 'Belinda' roses, for example, could be stored for 3 weeks under LP and retain 72% of their original vase-life while those stored in NR retained only 49% (3). Other cultivars like 'Mercedes' and 'Sonia' also could be stored for similar time periods when judging only petal quality, but the leaves became unacceptable due to a mottled appearance (5). However, LP storage of 'Belinda' roses prevented the petal blueing so often seen in this cultivar after storage.

It was the purpose of our research to further investigate the effects of LP storage on carnation and rose flowers as influenced by prestorage, storage, and poststorage treatments.

Materials and Methods

Prototype LP units were constructed using 40-liter milk cans as described previously (14). Low oxygen levels were obtained by a flow board technique in which gases were premixed to the

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desired partial pressure O_2 (ppO_2) using O_2 and N_2. Flowers in all prototype LP, low oxygen, and NR treatments were held at similar temperatures (0.5° to 3°C), relative humidities (estimated to be over 90%), and air exchange rates (0.25 to 1 per hour) except where noted in the text. Pressures ranged from 10 to 40 mm Hg.

A larger LP prototype (a cylinder 4.4 m long and 1.8 m in diameter) and a commercial unit (12.2 m long by 2.4 m high by 2.4 m wide) were loaned to The Ohio State University for the duration of the tests by Grumman Dormavac, the commercial manufacturer of LP units until 1982. More precise temperature, humidity, air exchange rates, and pressures were obtained using these 2 larger units.

Rose and carnation flowers were obtained from 14 growers located in Ohio, California, Indiana, and Bogota, Colombia. Flowers were either shipped to our facilities using standard transportation modes or were placed into storage shortly after harvesting and transported to us under LP or NR conditions. All flowers were precooled to 3° or 4°C prior to placing into storage. When vapor barriers were utilized, a 4-mil polyethylene sheet served as a liner inside the flower box encasing the flowers.

The rose pretreatment solution consisted of a 2% sucrose-based commercial preservative in which the flowers were kept at 21°C for 2 hr prior to storage. Pretreated carnations were kept in a STS solution prepared by putting 80 mg silver nitrate in 500 ml deionized water and 467 mg sodium thiosulfate in an equal volume and then pouring the silver nitrate into the sodium thiosulfate. Carnation stems were recut and then placed into this solution for 1 hour at 26° prior to storage.

Pruning shears were used to recut the flower stems after storage, removing approximately 2 cm, either in air or with the stem ends held under water. Stems then were placed in a 2% sucrose-based preservative solution in which they remained for the duration of the vase-life tests.

Rose and carnation flowers, for vase-life evaluations, were considered senesced when at least 25% of the petals on an individual flower were dessicated, discolored, flaccid, and/or had abscised. Vase-life determinations were made at 27°C and 70% relative humidity with 18.2 μmol s^{-1} m^{-2} continuous light provided. Completely randomized or randomized complete block designs and a minimum of 3 replications with 5 flowers per replicate were used.

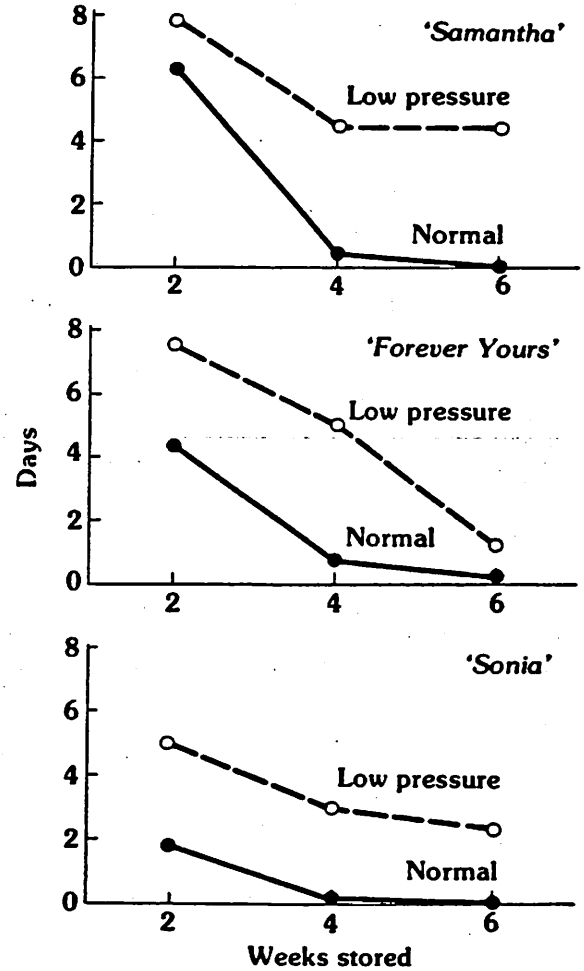

Fig. 1. Vase-life (days) of roses as influenced by cultivar, storage type, and storage time (HSD 5% = 3.0).

Results

Numerous experiments in which various ppO_2 were compared under LP and NR storage conditions demonstrated that none of the modified atmospheres were beneficial in extending rose or carnation vase-life after storage when compared to NR at ambient

Table 1. Vase-life and visual acceptability immediately upon removal of 'Forever Yours' roses and 'Improved White Sim' carnations after storage under normal refrigeration, low pressure, and low oxygen conditions at 2.9° ± 1.1°C.

	Storage time							
	4 wk				8 wk			
	Carnation		Rose		Carnation		Rose	
Treatment	Vase-life[z] (days)	Acceptable (%)	Vase-life[z] (days)	Acceptable[y] (%)	Vase-life[z] (days)	Acceptable (%)	Vase-life[z] (days)	Acceptable[y] (%)
No Storage	12.3	100	9.4	100	12.3	100	9.4	100
Normal	9.3	100	5.6	87	5.7	100	0	7
Low pressure[x]	7.6	100	6.4	100	6.6	100	1.0	100
0.5% O_2[w]	8.8	100	4.4	67	7.1	100	0.2	13
4% O_2[w]	9.6	100	4.4	80	6.9	100	0	7
8% O_2[w]	8.8	100	4.7	67	6.6	100	0	0

[z]Significance at 1% level only for storage time. "No storage" control not in analysis.
[y]Significance at 1% level only for interaction between storage time and treatment. "No storage" control not in analysis.
[x]Pressure mean = 31.6 ± 13.5 mm Hg.
[w]Percentage of oxygen for the 3 treatments were 1.97 ± 1.7, 4.34 ± 1.4, and 8.06 ± 1.6, respectively.

atmospheric gas levels (Table 1). While LP-stored roses were visually 100% acceptable upon removal after 8 weeks of storage, they deteriorated rapidly with a vase-life of only 1 day. Roses kept for 8 weeks under low ppO_2 at atmospheric pressure were moldy (primarily *Botrytis* sp.) and produced a fermentation-like odor.

Rose vase-life and occurrence of leaf disorders following LP storage (Table 2 and Fig. 1) varied by cultivar. Cultivars such as 'Samantha' and 'Visa' responded favorably, retaining 49% and 50%, respectively, of the original vase-life after 4 to 5 weeks of storage and having no leaf disorders. Other cultivars like 'Royalty' and 'Spanish Sun' had vase-lives of 51% and 99%, respectively, after 4 to 5 weeks of storage, but necrotic/chlorotic blotches formed on the leaves which would render them commercially unacceptable. In general, LP was better than NR for up to 4 weeks of storage, but only in a few experiments could roses be stored for over 4 or 5 weeks successfully under any conditions (Fig. 2). It seemed in these cases that preharvest cultural factors might be important since the same cultivars from different growers responded differently.

Vapor barriers in the cartons were beneficial under NR conditions for roses stored between 2 and 4 weeks, but were not needed for shorter NR storage times (2 weeks or less) or under any LP conditions (Fig. 3). The same benefits of vapor barriers were noted for carnations (data not presented).

Table 2. Vase-life of rose cultivars stored from 4 to 5 weeks under normal refrigeration and low pressure conditions.

Cultivar	Expt. (no.)	Vase-life (days) Treatment: No storage	Low pressure	Normal
Forever Yours[z]	11	10.7	5.4	2.3
Sonia	8	7.2	3.6	2.2
Samantha	8	11.9	5.8	3.2
Merinor	1	5.0	0.9	2.3
Royalty[z]	4	13.1	6.7	3.2
Cara Mia	2	10.4	1.5	0.6
Town Crier[z]	3	3.9	1.1	0.3
Carina	2	6.8	2.5	2.9
Garnette	1	9.7	8.3	3.7
Belinda	2	8.0	4.9	2.5
Jack Frost	2	8.3	5.5	7.0
Spanish Sun[z]	1	7.9	7.8	4.9
Visa	2	11.5	6.7	4.7
Faberge	1	7.8	6.0	3.9
Golden Wave	1	7.6	3.1	2.6
Carte Blanche	2	6.0	2.5	3.5

[z]Exhibited low pressure-induced leaf damage which was not considered in determining vase-life.

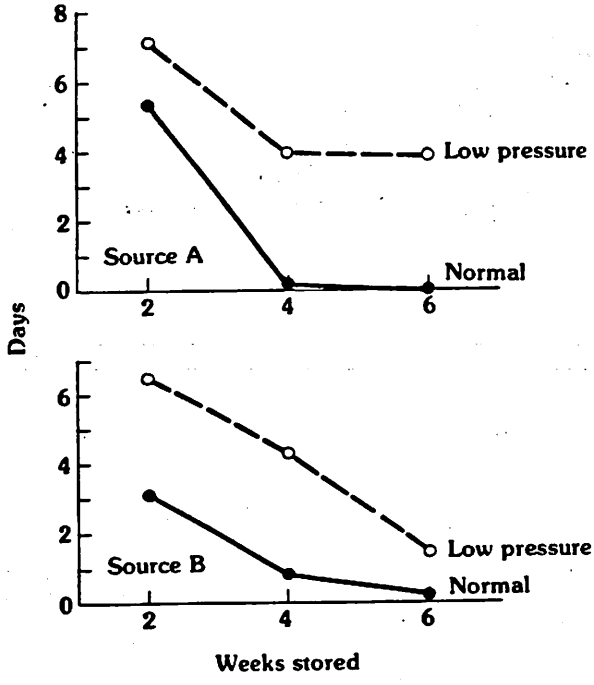

Fig. 2. Vase-life (days) of 'Samantha', 'Sonia', and 'Forever Yours' roses as influenced by storage type, grower source, and storage time (HSD 5% = 2.3).

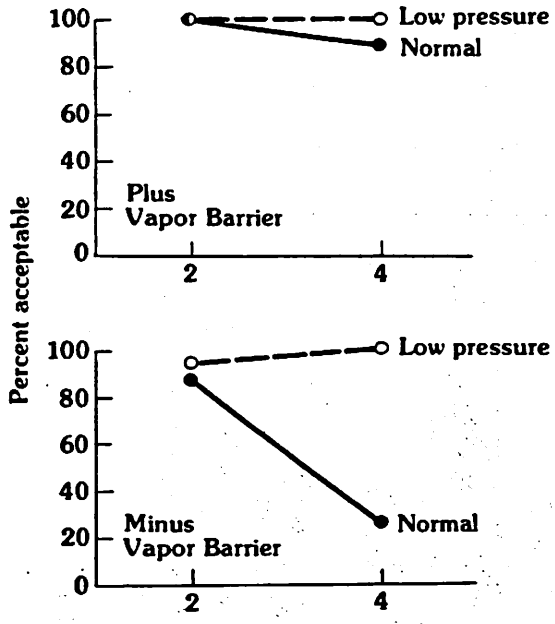

Fig. 3. Percentage of 'Samantha', 'Sonia', and 'Forever Yours' roses visually acceptable on removal from storage as influenced by storage type, storage time, and vapor barriers (HSD 5% = 22).

The appearance of rose flowers 1 hr after removal from storage under NR conditions was enhanced if they were recut under water. However, no such benefit was found for roses stored under LP (Fig. 4). Placing the flowers into a preservative solution rather than handling them dry prior to LP or NR storage as well as different recutting techniques after storage had little effect on vase-life (Table 3).

Carnation vase-life was enhanced when flowers were treated with STS prior to storage, regardless of storage method or storage time (Fig. 5). The advantage of STS was greater for LP- than for NR-stored flowers, with no advantage of LP over NR when flowers were not STS-treated. Averaged over both LP and NR treatments, STS effectiveness in enhancing vase-life of carnations decreased between the 6th and 8th week of storage (Fig. 6).

Discussion

A quantitative discussion of LP research is limited by the numerous qualitative measurements made on plant tissues including those used in our own study, such as vase-life and percentage acceptable. While all researchers attempt to be as quantitative as possible, the very nature of biological systems

Table 3. Vase-life of 'Forever Yours' roses as influenced by storage type, preservative solution treatment prior to storage, stem recutting method after storage, and storage time.

Storage type	Pretreatment[z]	Recutting	Vase-life (days) Storage time 0 wk	2 wk	4 wk	6 wk
Normal[y]	No	Air	10.2	6.8[x]	3.1	0
	No	Water	10.5	7.3	3.5	0
	Yes	Air	9.8	7.0	1.6	1.6
	Yes	Water	10.1	7.7	3.0	3.8
Low pressure[w]	No	Air	10.2	8.8	7.2	6.1
	No	Water	10.5	8.0	7.4	6.0
	Yes	Air	9.8	8.0	6.7	---[v]
	Yes	Water	10.1	7.2	6.9	4.9

[z]Kept in a 2% sucrose-based preservative solution for 2 hr prior to storage.
[y]Storage temp = 2.5° ± 0.8°C.
[x]Significance at 1% level only for interaction between storage time and storage type. "No storage" control not in analysis.
[w]Pressure mean = 11.1 ± 1.5 mm Hg and storage temperature = 0.7° ± 0.9°C.
[v]Data unavailable.

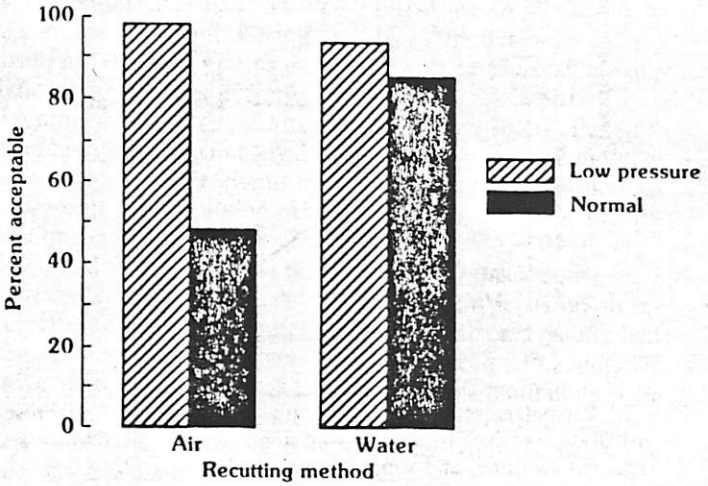

Fig. 4. Percentage of 'Forever Yours' rose flowers usually acceptable 1 hr after removal from storage, as influenced by stem recutting technique (HSD 5% = 30).

sometimes necessitates the use of qualitative judgments. For example, Bredmose (5) stated that 2 cultivars of roses could be stored for 1 month under LP "and still be satisfactory regarding the flowers (petals), however, their leaf quality was deteriorated." The actual percentage of reduction in flower life was about 42% which could be interpreted as being unsatisfactory. Bredmose (5) also stated that another rose cultivar maintained a "consumer-satisfying" vase-life of 1 week after 1 month of storage, even though this was a 25% reduction in vase-life of no-storage control flowers. We made similar qualitative decisions. However, we must judge both past and present research, regardless of the qualitative or quantitative nature of the data, to incorporate it into our working knowledge of LP storage.

Considering the above, the following summary represents our understanding of LP research results to date:

1. Numerous studies (2–5, 7–13, 15–17, 20, 21, 27), including our own (6, 14, 22–25), have shown that LP is beneficial on particular commodities. However, some of these same and other studies have shown limited benefits of LP (14, 18, 22,

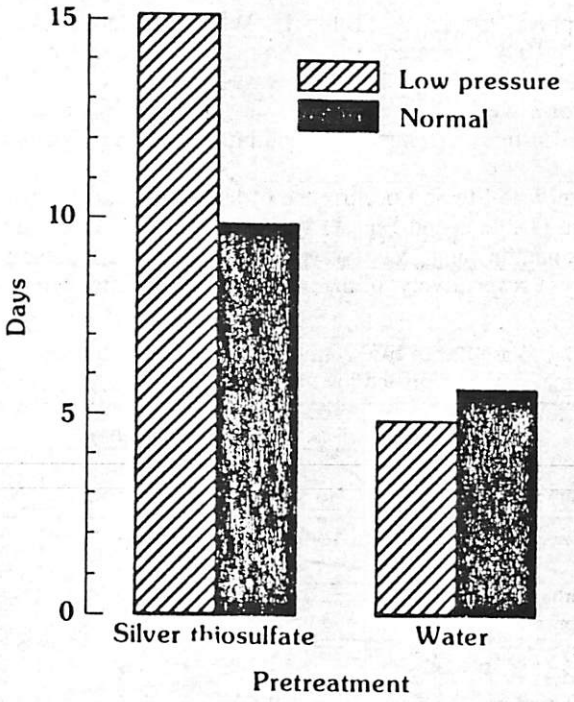

Fig. 5. Vase-life (days) of 'Improved White Sim', 'Pink Ice', and 'Scania 3C' carnations as influenced by water or silver thiosulfate pretreatment prior to storage and storage type (HSD 5% = 2.6).

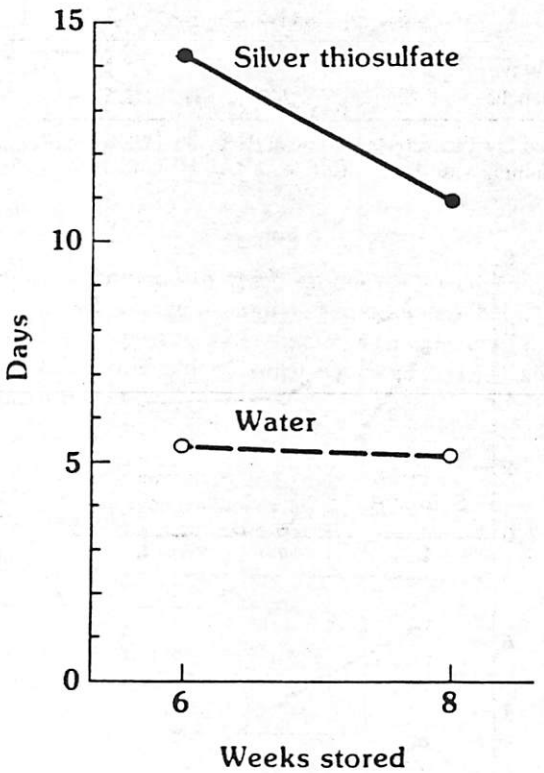

Fig. 6. Vase-life (days) of 'Improved White Sim', 'Pink Ice', and 'Scania 3C' carnations treated prior to storage with water or silver thiosulfate (HSD 5% = 2.6).

25, 26). There are many uncontrolled variables, such as preharvest conditions, differences in cultivar response, etc. which may account for the conflicting reports in the literature. Unfortunately, too much may have been expected of the LP system

from the start, and data not measuring up to the original expectations may have resulted in unduly negative reports.

2. As a total system, LP offers much more than the pressure component, including temperature, humidity, and air exchange capabilities. Our findings indicated that STS was more important than the LP system for carnations (Fig. 5) in that LP could not extend vase-life without the silver treatment, a finding supported in the literature (15). Hence, the LP system did not provide enough ethylene protection to these flowers. A series of other experiments showed that ppO_2 was the key factor, regardless of the total pressure (1, 6, 18, 19, 20, 21, 26).

3. Our findings (Tables 2 and 3, Fig. 1–6) clearly show that both pre- and poststorage treatments can greatly influence any storage technology, including LP. Therefore, a total-systems approach must be utilized to store successfully any given crop species or cultivar.

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