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THE SHORT-TERM COLD STORAGE EFFECT ON VASE LIFE OF CUT *Hosta* LEAVES

Mariusz Wachowicz, Julita Rabiza-Świder, Ewa Skutnik, Aleksandra Łukaszewska

Warsaw Agricultural University (SGGW)

Abstract. The longevity of cut leaves in flower arrangements is an important commercial consideration in horticultural practices. Here we report on the effect of short-term cold storage, in combination with a cytokinin treatment, on the post harvest longevity of cut leaves of *Hosta* 'Minima Glauca' and *Hosta* 'Golden Tiara'. Cut leaves were stored dry or wet in polyethylene bags for 2 or 4 days in darkness or in light at 6°C and then transferred to 20°C where their vase life was compared with those of freshly cut leaves. Storage length and method affected the vase life of detached leaves of both *Hosta* cultivars; however, reduced longevity of leaves in storage could not be attributed to a single parameter of the storage conditions. Pulse conditioning with a cytokinin benzyladenine was effective in prolonging vase life both in non stored and stored leaves, in the latter increasing it 2.5-fold as compared to untreated leaves. Practical implications are that cold storage can be successfully used for cut *Hosta* leaves but only in combination with a BA pretreatment.

Key words: florists' green, benzyladenine, low temperature, light, darkness, dry/wet storage

INTRODUCTION

Although leaf senescence is a genetically programmed process, it can also be triggered by many environmental factors such as temperature and shading [Gan and Amasino 1997]. As cut leaves are commonly used in flower arrangements as so called florists' green their postharvest storage characteristics, including tolerance to low storage temperatures, are important with respect to their market value. Cold storage permits some degree of control over the market supply in times of surplus production, 'holding--over' to achieve higher prices or accumulation of sufficient stock for commercial consignments when supplies are limited [Nowak and Rudnicki 1990]. However, low tem-

Corresponding author – Adres do korespondencji: Mariusz Wachowicz, Department of Ornamental Plants, Warsaw Agricultural University (SGGW), 159 Nowoursynowska Street, 02-787, Warsaw, Poland, e-mail: astilbe@op.pl

perature may trigger many disorders in plant tissues that include discoloration that reduces visual appeal and, thereby, shortens leaf vase life [Nowak and Rudnicki 1990; Vanstreels et al. 2002]. Storage at between 0 and 1°C is most effective for maintaining quality of most cut flowers [Reid 1992]. However, some species, especially those of subtropical and tropical origin suffer chilling injury at such low storage temperatures [Nowak and Rudnicki 1990].

Most studies on detached leaves have so far been conducted mainly in green vegetables such as spinach [Toledo et al. 2003], lettuce [Baur et al. 2005; Schofield et al. 2005], pak choy [Able et al. 2005], rocket and chicory [Ferrante et al. 2004] or herbs such as marjoram [Böttcher et al. 1999], basil [Meir et al. 1997] and parsley [Lomaniec et al. 2003]. In ornamental plants, the storage effects were mainly studied in cut flowers or potted plants [Joyce et al. 2000; Ranwala and Miller 2000] while the florists' greens were neglected. We feel that because of the growing market importance cut leaves merit more attention and understanding their response to storage conditions is necessary to ensure a good product quality. Genus *Hosta* is a diverse group of plants with numerous cultivars bred mainly for garden perennials. These plants are valued for their decorative foliage which has recently been appreciated by florists and so they are often used in cut flowers arrangements. Earlier we have studied the effect of growth regulators on senescence of cut leaves of a few green-leaved *Hosta* cultivars [Rabiza-Świder et al. 2006]. In this article we report the effect of different storage conditions and pre-storage pulse conditioning with BA on the leaf vase life in two colored-leaved hosta cultivars.

MATERIALS AND METHODS

Experiments were conducted in early summer of 2005 and 2006. Plants of Hosta 'Minima Glauca' and Hosta 'Golden Tiara' were grown outdoors, in the nursery of perennials at the Department of Ornamental Plants of the Warsaw Agricultural University, Warsaw, Poland. Hosta 'Golden Tiara' has small lime green, heart-shaped leaves with golden margins that hold color all season. It makes clumps to 40 cm in width. Hosta 'Minima Glauca' has medium sized heart-shaped glaucous waxy leaf coating that gives a blue appearance to the leaf. It makes a clump to 60 cm in width.

Mature, healthy, undamaged leaves were harvested in the morning, graded for uniformity and placed in vases with distilled water (non pulsed leaves) or benzyladenine (BA) 0.1 mmol·dm^{-3} solution (BA pulsed leaves) and placed for 24 hrs under controlled conditions: temperature 20°C, relative humidity 60%, 12 hrs photoperiod with light intensity of 35 μmol·m^{-2}·s^{-1} PAR. After pulsing, leaves were stored at 6°C. For storage, both pulsed and non pulsed with BA leaves were wrapped in a plastic perforated foil – either transparent or black (stored in light/in darkness) and kept either in water or dry (wet/dry storage). Leaves were stored 2 or 4 days. Non stored leaves served as controls. There were 30 leaves in each treatment. After storage, the ends of leaf petioles were recut and leaves placed in vases with distilled water at room temperature under light, and their vase life (in days) was determined. Leaves were discarded when 30% of their blade surfaces showed signs of discoloration and/or wilting.

As the results in both years showed this same exact pattern, including a drastic reduction in vase life by the BA treatment in 'Golden Tiara' stored wet/dark for 4 days, only results form 2006 are presented in this paper. Results were subjected to the two factorial analysis of variance (conditioning × storage method), separately for both storage lengths, using Statgraphics Plus 4.1 statistical Program and means were compared with the Duncan's test at the probability level P = 0.95.

RESULTS

Under standard conditions, detached leaves of both hosta cultivars 'Minima Glauca' and 'Golden Tiara' had a vase life of 22.2–23.2 days. Cold storage significantly reduced vase life, by an average 20–44% for *Hosta* 'Minima Glauca' (tab. 1–2) and 25–38% for *Hosta* 'Golden Tiara' (tab. 3–4). Post-storage mean longevity of leaves stored 2 or 4 days and then held in water was similar for both cultivars. It was 17.6 days for both storage periods of *Hosta* 'Minima Glauca' leaves and 16.8 and 16.2 days for *Hosta* 'Golden Tiara', respectively (tab. 1–4). In both cultivars a decrease in vase life of up to 56% relative to control was observed. However, storage condition causing such losses of longevity were completely different in each cultivar: 2 days under dry/light storage in the blue-leaved cultivar while 4 days under wet/dark storage in the yellow one.

A comparison of all tested experimental factors does not reveal any pattern that would indicate a single factor with the most harmful effect on leaf longevity. In 'Minima Glauca' dry storage significantly decreased vase life relative to wet storage: 13.0 days and 18.5 days respectively for leaves stored 2 days in light (tab. 1) and 14.3 days versus 17.7 days for leaves held 4 days in darkness (tab. 2). On the contrary, in 'Golden Tiara' it was the wet storage that negatively affected vase life of leaves stored 4 days in darkness: 12.3 and 16.2 days, for wet and dry stored leaves, respectively (tab. 4).

In the control leaves, pulse conditioning with benzyladenine (BA) considerably increased leaf longevity, by 50% and 79% in 'Minima Glauca' and 'Golden Tiara", respectively, relative to the non conditioned leaves (tab. 1–4). Effects of this pre storage treatment were even more spectacular in leaves subjected to different storage lengths and conditions. In 'Minima Glauca' the vase life of leaves stored 4 days increased, on average, over 2.5 fold following the cytokinin treatment and was even longer than that of the control non stored and BA-conditioned leaves placed into vases directly after harvest (tab. 2). In 'Golden Tiara', leaves stored for two days had their vase life more than doubled due to the pulse conditioning with BA, while in those stored wet/dark the increase was only 72%. The wet/dark conditions also were the worst for the longer storage period where the cytokinin treatment drastically decreased leaf vase life. Generally, for this storage length considerable variation was observed between the BA treatments and only in one case (dry/light conditions) the twofold increase in leaf vase life occurred.

Table 1. Effect of conditioning before the 2-day storage in various conditions on the post storage vase life (days) of cut leaves of Hosta 'Minima Glauca'

Tabela 1. Wpływ sposobu traktowania przed 2-dniowym przechowaniem w różnych warunkach ciętych liści Hosta 'Minima Glauca' na ich późniejszą trwałość, dni

Treatment – Traktowanie mmol·dm^{-3}	Storage conditions – Sposób przechowania					Mean for a treatment $LSD_{0.05}$ = 1.82 Średnia dla traktowania $NIR_{0.05}$ = 1,82
	non stored bez przechowania	wet/light mokro/jasno	wet/dark mokro/ciemno	dry/light sucho/jasno	dry/dark sucho/ciemno	
H_2O	23.2 c* *(100%)*	18.5 b *(80%)*	17.7 b *(76%)*	13.0 a *(56%)*	15.8 ab *(68%)*	17.6 a
0.1 mmol BA	34.7 de *(150%)*[2]	31.7 d (171%)[1] *(137%)*	33.2 d (188%) *(143%)*	24.0 c (185%) *(103%)*	37.3 e (236%) *(161%)*	32.2 b
Mean for storage conditions $LSD_{0.05}$ = 2.88 Średnia dla sposobu przechowania $NIR_{0.05}$ = 2,88	28.9 c	25.1 b	25.4 b	18.5 a	26.6 bc	

*Means followed by the same letter do not differ significantly at α = 0.05 (Duncan's test); to compare the means within the table: $LSD_{0.05}$ = 3.48 – Wartości oznaczone tą samą literą nie różnią się istotnie przy α = 0,05 (test Duncana); dla porównania wartości wewnątrz tabeli: $NIR_{0,05}$ = 3,48.

[1] % of the respective control, i.e. of vase life of the non conditioned leaves', stored under the same conditions – % trwałości liści niekondycjonowanych, przechowywanych w tych samych warunkach.

[2] % of vase life of the non conditioned and non stored leaves – % trwałości liści niekondycjonowanych i nieprzechowywanych.

Table 2. Effect of conditioning before the 4-day storage in various conditions on the post storage vase life (days) of cut leaves of Hosta 'Minima Glauca'

Tabela 2. Wpływ sposobu traktowania przed 4-dniowym przechowaniem w różnych warunkach ciętych liści Hosta 'Minima Glauca' na ich później–szą trwałość, dni

Treatment – Traktowanie mmol·dm^{-3}	Storage conditions – Sposób przechowania					Mean for a treatment $LSD_{0.05}$ = 2.09 Średnia dla traktowania $NIR_{0.05}$ = 2,09
	non stored bez przechowania	wet/light mokro/jasno	wet/dark mokro/ciemno	dry/light sucho/jasno	dry/dark sucho/ciemno	
H_2O	23.2 c *(100%)*	16.8 ab *(72%)*	17.7 b *(76%)*	16.0 ab *(69%)*	14.3 a *(62%)*	17.6 a
0.1 mmol BA	34.7 d *(150%)*[2]	43.5 f (259%)[1] *(188%)*	44.8 f (253%) *(193%)*	39.8 e (249%) *(172%)*	38.8 e (271%) *(167%)*	40.3 b
Mean for storage conditions $LSD_{0.05}$ = 3.30 Średnia dla sposobu przechowania $NIR_{0.05}$ = 3,30	28.9 abc	30.2 bc	31.3 c	27.9 ab	26.6 a	

*Means followed by the same letter do not differ significantly at α = 0.05 (Duncan's test); to compare the means within the table: $LSD_{0.05}$ = 3.20 – Wartości oznaczone tą samą literą nie różnią się istotnie przy α = 0,05 (test Duncana); dla porównania wartości wewnątrz tabeli: $NIR_{0.05}$ = 3,20.

[1] % of the respective control, i.e. of vase life of the non conditioned leaves', stored under the same conditions – % trwałości liści niekondycjonowanych, przechowywanych w tych samych warunkach.

[2] % of vase life of the non conditioned and non stored leaves – 2 % trwałości liści niekondycjonowanych i nieprzechowywanych.

Table 3. Effect of conditioning before the 2-day storage in various conditions on the post storage vase life (days) of cut leaves of Hosta 'Golden Tiara'

Tabela 3. Wpływ sposobu traktowania przed 2-dniowym przechowaniem w różnych warunkach ciętych liści Hosta 'Golden Tiara' na ich późniejszą trwałość, dni

Treatment – Traktowanie $mmol \cdot dm^{-3}$	Storage conditions – Sposób przechowania					Mean for a treatment $LSD_{0.05} = 2.15$ Średnia dla traktowania $NIR_{0.05} = 2,15$
	non stored bez przechowania	wet/light mokro/jasno	wet/dark mokro/ciemno	dry/light sucho/jasno	dry/dark sucho/ciemno	
H_2O	22.2 b *(100%)*	15.8 a *(71%)*	16.2 a *(73%)*	13.7 a *(62%)*	16.0 a *(72%)*	16.8 a
0.1 mmol BA	39.8 d *(179%)*[2]	40.2 d (254%)[1] *(181%)*	27.8 c (172%) *(125%)*	36.8 d (269%) *(166%)*	37.8 d (236%) *(170%)*	36.5 b
Mean for storage conditions $LSD_{0.05} = 3.40$ Średnia dla sposobu przechowania $NIR_{0.05} = 3,40$	31.0 c	28.0 bc	22.0 a	25.3 ab	26.9 b	

*Means followed by the same letter do not differ significantly at $\alpha = 0.05$ (Duncan's test); to compare the means within the table: $LSD_{0.05} = 4.06$ – Wartości oznaczone tą samą literą nie różnią się istotnie przy $\alpha = 0,05$ (test Duncana); dla porównania wartości wewnątrz tabeli: $NIR_{0.05} = 4,06$.

[1] % of the respective control, i.e. of vase life of the non conditioned leaves', stored under the same conditions – % trwałości liści niekondycjonowanych, przechowywa–nych w tych samych warunkach.

[2] % of vase life of the non conditioned and non stored leaves – % trwałości liści niekondycjonowanych i nieprzechowywanych.

Table 4. Effect of conditioning before the 4-day storage in various conditions on the post storage vase life (days) of cut leaves of Hosta 'Golden Tiara'

Tabela 4. Wpływ sposobu traktowania przed 4-dniowym przechowaniem w różnych warunkach ciętych liści Hosta 'Golden Tiara' na ich późniejszą trwałość, dni

Treatment – Traktowanie mmol·dm^{-3}	Storage conditions – Sposób przechowania					Mean for a treatment $LSD_{0.05}$ = 3.18 Średnia dla traktowania $NIR_{0.05}$ = 3,18
	non stored bez przechowania	wet/light mokro/jasno	wet/dark mokro/ciemno	dry/light sucho/jasno	dry/dark sucho/ciemno	
H_2O	22.2 e *(100%)*	13.7 bcd *(62%)*	12.3 b *(56%)*	16.7 d *(75%)*	16.2 cd *(73%)*	16.2 a
0.1 mmol BA	39.8 f *(179%)*[2]	21.0 e (153%)[1] *(95%)*	6.5 a (53%) *(29%)*	37.0 f (222%) *(167%)*	13.2 bc (81%) *(60%)*	23.5 b
Mean for storage conditions $LSD_{0.05}$ = 5.02 Średnia dla sposobu przechowania $NIR_{0.05}$ = 5,02	31.0 c	17.3 b	9.4 a	26.8 c	14.7 b	

*Means followed by the same letter do not differ significantly at α = 0.05 (Duncan's test); to compare the means within the table: $LSD_{0.05}$ = 3.14 – Wartości oznaczone tą samą literą nie różnią się istotnie przy α = 0,05 (test Duncana); dla porównania wartości wewnątrz tabeli: $NIR_{0.05}$ = 3,14.

[1] % of the respective control, i.e. of vase life of the non conditioned leaves', stored under the same conditions – % trwałości liści niekondycjonowanych, przechowywa–nych w tych samych warunkach.

[2] % of vase life of the non conditioned and non stored leaves – % trwałości liści niekondycjonowanych i nieprzechowywanych.

DISCUSSION

Ornamental plants have limited shelf life. Its length is a characteristic feature of each particular species or cultivar and is strongly dependent on handling after harvest. Temperature is the most important factor affecting post harvest quality of cut plant organs and their marketability. Higher temperatures accelerate senescence and lower temperatures slow down the respiration rate and utilization of carbohydrates and other storage materials in plant tissues [Paull 1999]. Lower temperatures also retard water loss and the development of microorganisms. Organs of plants from the temperate zones are best stored at temperatures slightly higher than the freezing points of their tissues. Plants of tropical origin are often sensitive to low temperature and must be stored at temperatures between 8–15°C [Nowak and Rudnicki 1990] though some may be stored at low temperature without any symptoms of chilling injury [Joyce et al. 2000]. Genus *Hosta* is native to Japan and China and individual accessions are generally frost-hardy [Szweykowska and Szweykowski 1993]. Therefore, their leaves do not need higher temperatures during storage and in the earlier trials carried out in our department, leaves of *Hosta* were stored at 6°C [Rabiza-Świder and Skutnik 2005]. In the preliminary trials on the colored-leaved hosta, the longevity of cut leaves was higher when they were stored at 6°C rather than at 10°C (data not shown).

Light does not significantly affect longevity of cut flowers but lack of light during long-distance transport or prolonged storage accelerates the yellowing of leaves in alstroemerias, chrysanthemums, lilies and other flowers [Nowak and Rudnicki 1990]. It was suggested that in cut spinach leaves, continuous illumination with light of 20–25 $\mu mol \cdot m^{-2} \cdot s^{-1}$ supports the photosynthetic capacity during post harvest storage [Toledo et al. 2003]. The negative effect of light deprivation during storage of leaves of *Zantedeschia*, but not *Hosta,* has been reported [Rabiza-Świder and Skutnik 2005].

In our earlier trial, non stored leaves of *Hosta*, treated with BA had a better longevity relative to those not BA-conditioned [Rabiza-Świder et al. 2006]. The results of this experiment indicate that the effect of conditioning leaves of *Hosta* with benzyladenine before storage on their longevity after shifting them to room temperature may depend on a cultivar as well as on storage length and conditions.

Cold storage allows plants to be marketed for a longer period but storage of the non BA-treated cut *Hosta* leaves significantly shortened their vase life. Pulse conditioning with BA alleviated the negative storage effect in both cultivars, more so in 'Minima Glauca' where leaves conditioned with BA and stored for 4 days had longevity even higher than those placed in vases immediately after harvest. It is known that water stress induces accumulation of cytokinins and their contents can increase after subsequent rehydration in some species, especially when plants were pre-treated with BA [Pospišilová et al. 2005]. Whether this is true in hosta leaves remains to be determined.

Water stress during storage has been shown to accelerate senescence of leaves as characterized by rapid chlorophyll degradation [Sankat and Maharaj 1996]. In cabbage seedlings, water stress reduced the leaf water potential at low temperature [Sato et al. 2004]. In cut leaves of both *Hosta* cultivars the post-storage longevity was not straightly affected by drought.

The above results show that cold storage can be successfully used for cut *Hosta* leaves but only in combination with a BA pre-treatment. A decrease in longevity of the cold-stored hosta leaves could not be attributed to a single parameter of storage conditions. Moreover, a response to a combination of the storage conditions can also be modified by a plant genetic background: here the yellow-leaved cultivar containing less chlorophyll (data to be published) was more affected by the storage and the treatments than the blue-leaved cultivar. Plenty additional work has to be done before practical recommendation can be issued for optimal methods of storage and transport of cut hosta leaves.

CONCLUSIONS

1. Storage length and method affected vase life of detached leaves of *Hosta* 'Minima Glauca' and *Hosta* 'Golden Tiara'.

2. A decrease in longevity of the stored hosta leaves could not be attributed to a single parameter of the storage conditions.

3. Pulse conditioning with benzyladenine was effective in prolonging vase life both in stored and non stored leaves relative to leaves not treated with BA.

4. Cold storage can be successfully used for cut *Hosta* leaves but only in combination with a BA pre-treatment.

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WPŁYW KRÓTKOTRWAŁEGO PRZECHOWANIA W NISKIEJ TEMPERATURZE NA TRWAŁOŚĆ CIĘTYCH LIŚCI FUNKII

Streszczenie. Analizowano wpływ krótkotrwałego przechowania w niskiej temperaturze ciętych liści dwóch odmian funkii, 'Minima Glauca' oraz 'Golden Tiara', na ich późniejszą trwałość. Liście przechowywano w 6ºC, na sucho lub z dostępem wody oraz w ciemności lub na świetle w polietylenowych workach. Przechowanie trwało 2 lub 4 dni, po czym liście przenoszono do pomieszczenia o temperaturze 20ºC, gdzie określano ich trwałość w porównaniu do kontroli, którą stanowiły liście nie przechowywane. Określono również wpływ kondycjonowania liści w roztworze benzyloadeniny (BA) na ich trwałość. Zarówno długość, jak i sposób przechowania wpłynęły na późniejszą trwałość ciętych liści obu odmian funkii, jednak jej zmniejszenie nie mogło zostać przypisane jednemu pa-

rametrowi przechowania. Kondycjonowanie w roztworze benzyloadeniny istotnie zwiększało trwałość liści zarówno nie przechowywanych, jak i przechowywanych: trwałość liści traktowanych BA była nawet 2,5-krotnie wyższa w porównaniu do tych nie poddanych kondycjonowaniu.

Słowa kluczowe: funkia, zieleń cięta, benzyloadenina, niska temperatura, światło, ciemność, przechowanie na sucho/mokro

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