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Post-harvest longevity of ornamental grasses conditioned in gibberellic acid and 8-hydroxyquinoline sulphate

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ABSTRACT

Florists' greens are becoming increasingly important in contemporary floristry. Numerous studies conducted on cut flowers have led to the development of technologies for their post-harvest handling; however, in the case of florists' greens they are still insufficient. Moreover, the extensive range of florists' greens lacks leaves and the leafy culms of grasses. The aim of this study was to determine the post-harvest longevity of the leaves and leafy culms of ornamental grasses conditioned in water solutions of gibberellic acid and 8-hydroxyquinoline sulphate. The post-harvest longevity of leaves was examined in cultivars of the following species: *Glyceria maxima* Hartm. 'Variegata', *Miscanthus sinensis* Thunb. 'Zebrinus' and *Spartina pectinata* Link. 'Aureomarginata'. The post-harvest longevity of leafy culms was investigated in *Alopecurus pratensis* L. 'Aureovariegatus', *Chasmanthium latifolium* Michx., *Miscanthus sinensis* Thunb. 'Silberspinne', *Pennisetum alopecuroides* L. and *Phalaris arundinacea* L. 'Picta'. Conditioning in gibberellic acid had a positive effect on the post-harvest longevity and fresh weight loss and the index of leaf greenness of leaves in the case of *Miscanthus sinensis* 'Zebrinus', while conditioning in 8-hydroxyquinoline sulphate improved fresh weight loss and the index of leaf greenness of the leafy culms of *Miscanthus sinensis* 'Zebrinus', *Pennisetum alopecuroides* and the leaves of *Glyceria maxima* 'Variegata'.

Key words: florists' greens, cut foliage, fresh weight, growth regulators, index of leaf greenness, vase life

INTRODUCTION

Florists' greens are becoming increasingly important in contemporary floristry. The green parts of plants with a very interesting shape and colour are used to obtain florists' greens. For this purpose, the leaves or leafy shoots of species commonly used for cut flowers, pot plants as well as herbaceous perennials are typically used. In a temperate climate, members of the latter group are particularly important, since their cultivation is much cheaper due to their lesser thermal requirements.

The extensive range of florists' greens lacks leaves and the leafy culms of grasses. Dutch whole flower markets offer only three grass species within the genera *Panicum*, *Setaria* and *Pennisetum*. However, they are grown for their decorative inflorescences (Meggelen-Logland 2010). Grasses are most often planted in home gardens and urban green areas (Henschke 2013, Henschke 2014). Their use as bouquet additions is not very common,

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as the post-harvest physiology of grown species is little known. Grasses and sedges, thanks to their long, narrow leaves, are perfect options for florists' greens. Numerous species have varieties with white or yellow variegated leaves. Moreover, some of them have dark green leaves. An additional advantage of many species coming from the temperate zone is the fact that they may be grown in unheated plastic tunnels.

Numerous studies conducted on cut flowers have made it possible to develop technologies of post-harvest handling for most species grown for cut flowers. In the case of florists' greens, research conducted to date has been insufficient. This results from the great variety of species and differences in the process of leaf senescence in comparison to flowers (Janowska and Stanecka 2011). Growth regulators and 8-hydroxyquinoline sulphate are most commonly used to extend the vase life of leafy flowering shoots (Pacifici et al. 2007, Elgimabi and Ahmed 2009). Studies indicated that in the case of florists' greens, growth regulators from the class of gibberellins and cytokinins are effective in this respect. Their advantageous effect was shown e.g. in the leaves of *Zantedeschia aethiopica* and *Hosta* 'Undulata Erromena' (Skutnik and Rabiza-Świder 2005), *Heuchera* (Krzymińska and Czuchaj 2006), *Paeonia lactiflora* (Michałek et al. 2006), *Arum italicum* (Janowska and Schroeter-Zakrzewska 2008), *Cordyline* (Koziara and Suda 2008), *Limonium latifolium* (Janowska et al. 2013) and the phylloclades of *Asparagus falcatus* (Skutnik and Rabiza–Świder 2008). The longevity of the cut leaves or leaf shoots of ornamental grasses has not yet been investigated in Poland.

The aim of this study was to determine the post-harvest longevity of the leaves and leafy culms of ornamental grasses and the possibility of its extension with the influence of conditioning in water solutions of gibberellic acid and 8-hydroxyquinoline sulphate.

MATERIAL AND METHODS

This study assessed the effect of gibberellic acid (GA_3) and 8-hydroxyquinoline sulphate (8HQS) on the post-harvest longevity of leaves or leafy culms of perennial ornamental grasses. The post-harvest longevity of leaves was investigated in the following species: *Glyceria maxima* Hartm. 'Variegata', *Miscanthus sinensis* Thunb. 'Zebrinus' and *Spartina pectinata* Link. 'Aureomarginata'. The post-harvest longevity of leafy culms was analysed in *Alopecurus pratensis* L. 'Aureovariegatus', *Chasmanthium latifolium* Michx., *Miscanthus sinensis* Thunb. 'Silberspinne', *Pennisetum alopecuroides* L. and *Phalaris arundinacea* L. 'Picta'. Leaves and leafy culms were collected from four- and five-year-old plants grown on beds in the collection of ornamental plants of the Department of Ornamental Plants, Poznan University of Life Sciences. The leaves and leafy culms were cut on 25 June in the morning, selecting mature, fully developed and healthy specimens. The length and fresh weight of leafy culms and leaves of the investigated taxa are presented in Table 1. The length of the leaves was measured from the cut site to the top, the length of the blades from the cut site to the end of the outstretched leaves and the fresh weight of the leafy culms and leaves was determined after cutting.

The leaves and leafy culms were conditioned for 4 h at 21°C in water solutions of gibberellic acid at a concentration of 100 mg L^{-1} and 8-hydroxyquinoline sulphate applied at 200 mg L^{-1}. These solutions were chosen due to a positive effect on the extension of the post-harvest longevity of leaves in other plants (Janowska and Stanecka

Table 1. Mean length and fresh weight of leaves and leaf blades before conditioning

Species and cultivar	Length (cm)	Fresh weight (g)
Leaves		
Glyceria maxima 'Variegata'	39.7	0.93
Miscanthus sinensis 'Zebrinus'	56.1	1.35
Spartina pectinata 'Aureomarginata'	79.1	1.06
Blades		
Alopecurus pratensis 'Aureovariegatus'	40.2	0.89
Chasmanthium latifolium	37.5	4.61
Miscanthus sinensis 'Silberspinne'	38.0	8.20
Pennisetum alopecuroides	77.5	5.43
Phalaris arundinacea 'Picta'	30.7	2.95

2011, Ulczycka-Walorska and Krzymińska 2015). After conditioning, the leaves and leafy culms were placed in distilled water. Control leaves and leafy culms were placed in distilled water immediately after cutting. The post-harvest longevity of the florists' greens was tested in a room at 20-22°C, relative humidity 65-70% and quantum irradiance of 30 µmol m^{-2} s^{-1}. Water was replaced daily.

The post-harvest longevity was determined in days. The loss of decorative value was defined by the moment when 30% of the leaf area was yellowed or wilted. The leaves and leafy culms were weighed before conditioning and after the loss of decorative value in order to determine changes in fresh weight (fresh weight loss or increase). Five days after the beginning of the experiment, the index of leaf greenness (SPAD), measured using a SPAD-502 chlorophyll meter and correlated with chlorophyll content, was determined (Gregorczyk and Raczyńska 1997, Gregorczyk et al. 1998).

The differentiating factor of the results was the kind of solution used for the conditioning of the leafy culms and leaves of grasses. Each variant comprised 21 leaves or leafy culms, i.e. three in seven replications. The experiments were conducted on 30 June 2013, and they were repeated in 2014, with means for the two years being analysed. A one-way analysis of variance was used, applying Tukey's test at the significance level p = 0.05.

RESULTS AND DISCUSSION

A positive effect of gibberellic acid conditioning on the post-harvest longevity of leaves was found in *Miscanthus sinensis* 'Zebrinus' (Tab. 2). The application of this growth regulator in 4-h conditioning extended post-harvest longevity by two days. We also found that gibberellic acid conditioning has a positive effect by limiting fresh weight loss in these grasses by as much as 95%. The reduction of fresh weight loss, probably due to decreased leaf transpiration, could have contributed to the extension of post-harvest longevity. The senescence of cut flowers or florists' greens is connected with the stress induced by stopping the supply of water, nutrients as well as hormones (Halevy and Mayak 1979). A longer post-harvest longevity of leaves following gibberellic acid conditioning was also reported by Janowska and Jerzy (2003) in *Zantedeschia elliottiana*, by Rabiza–Świder and Skutnik (2006) in *Hippeastrum* × *chmielii*, by Skutnik et al. (2006) in phylloclades of *Asparagus densiflorus* and by Janowska et al. (2013) in *Limonium latifolium.* This is an effect frequently observed in experiments, since leaves as organs separated from the rest of the plant are not capable of synthesising gibberellins (Marciniak et al. 2012). Their exogenous supply may have a positive effect on the extension of post-harvest longevity. The results of certain experiments indicate that post-harvest longevity is correlated with chlorophyll content in leaves, which was also demonstrated in our own experience, e.g. by *Spartina pectinata* 'Aureomarginata', which had the longest post-harvest longevity and the highest index of leaf greenness value. If gibberellic acid conditioning results in an extension of post-harvest

Table 2. Post-harvest longevity, fresh weight loss and leaf greenness of grass leaves depending on the type of conditioning solution

Species and cultivar	H_2O	Conditioning	
		GA_3	8HQS
Post-harvest longevity (days)			
Glyceria maxima 'Variegata'	7.6 a*	6.5 a	7.3 a
Miscanthus sinensis 'Zebrinus'	5.4 a	7.4 b	5.4 a
Spartina pectinata 'Aureomarginata'	10.1 a	11.3 a	10.9 a
Fresh weight loss (g)			
Glyceria maxima 'Variegata''	0.11 a	0.13 a	0.12 a
Miscanthus sinensis 'Zebrinus'	0.55 b	0.03 a	0.01 a
Spartina pectinata 'Aureomarginata'	0.09 a	0.09 a	0.11 a
Leaf greenness SPAD			
Glyceria maxima 'Variegata'	15.1 a	13.6 a	22.2 b
Miscanthus sinensis 'Zebrinus'	33.9 b	34.7 b	30.8 a
Spartina pectinata 'Aureomarginata'	40.4 a	40.6 a	39.2 a

*Averages marked with the same letters are not significantly different at p = 0.05

longevity, it also has an advantageous effect on the chlorophyll content in leaves (Janowska et al. 2013). A positive effect of *Zantedeschia* 'Sunglow' leaf conditioning in gibberellic acid solution on chlorophyll losses was observed by Janowska and Stanecka (2011).

A positive effect was also found for the conditioning of leaves in 8-hydroxyquinoline sulphate. It had no effect on the post-harvest longevity of grass leaves, but it reduced fresh weight losses in the leaves of *Miscanthus sinensis* 'Zebrinus', similarly as was observed for gibberellic acid conditioning. 8-Hydroxyquinoline sulphate can have a positive effect on the extension of post-harvest longevity, since it exhibits bactericidal and fungicidal activity, while also reducing water acidity, but also causes a blockage of conductive vessels in the stalk or stem (Nowak and Grzesik 1997). Janowska and Jerzy (2003) observed a negative effect on the post-harvest leaf longevity of *Zantedeschia elliottiana*. Quinoline compounds also have an advantageous effect by inhibiting the production of ethylene by the plant and by closing the stomata. A positive effect of 8-hydroxyquinoline sulphate conditioning on the extension of post-harvest longevity leafy inflorescence shoots of *Antirrhinum majus* was obtained by Asrar (2012), while a similar effect was reported by Janowska and Śmigielska for *Hypericum inodorum* (2010). In this experiment, we also found that this conditioning solution effectively reduced the index of leaf greenness in *Glyceria maxima* 'Variegata'. An advantageous effect of 8-hydroxyquinoline sulphate on the content of chlorophyll in leaves was also observed by Asrar (2012) in *Antirrhinum majus*. Similarly as in the experiment by Ulczycka-Walorska and Krzymińska (2014), the leaves of *Waldsteinia geoides* contained more chlorophyll if they were kept in a solution of 8-hydroxyquinoline sulphate. In contrast, in this experiment it also had a negative effect on the index of leaf greenness in *Miscanthus sinensis* 'Zebrinus'. The reaction of chlorophyll degradation progressed faster under the influence of 8-hydroxyquinoline sulphate conditioning in the leaves of this grass.

No positive effect was found for gibberellic acid conditioning on the post-harvest longevity of the leafy culms of ornamental grasses (Tab. 3). The lack of effect of gibberellic acid conditioning on the extension of post-harvest longevity may be the result of the leaf blade's capacity to synthesise these growth regulators in nodes and young leaves.

Table 3. Post-harvest longevity, fresh weight loss and leaf greenness of grass leafy culms depending on the type of conditioning

Species and cultivar	H_2O	Conditioning	
		GA_3	8HQS
Post-harvest longevity (days)			
Alopecurus pratensis 'Aureovariegatus'	6.7 a*	5.5 a	6.8 a
Chasmanthium latifolium	27.9 b	23.1 a	27.5 b
Miscanthus sinensis 'Silberspinne'	6.1 a	7.7 a	6.7 a
Pennisetum alopecuroides	5.4 a	5.6 a	5.8 a
Phalaris arundinacea 'Picta'	5.7 a	6.9 a	5.6 a
Fresh weight loss (g)			
Alopecurus pratensis 'Aureovariegatus'	0.06 a	0.05 a	0.06 a
Chasmanthium latifolium	0.27 b↑**	0.52 a↑	0.14 c↑
Miscanthus sinensis 'Silberspinne'	2.42 a	2.77 c	2.55 b
Pennisetum alopecuroides	0.57 b	0.63 b	0.36 a
Phalaris arundinacea 'Picta'	0.25 a	0.26 a	0.23 a
Leaf greenness (SPAD)			
Alopecurus pratensis 'Aureovariegatus'	20.9 c	14.5 a	18.1 b
Chasmanthium latifolium	29.1 a	27.2 a	26.9 a
Miscanthus sinensis 'Silberspinne'	31.2 ab	34.1 b	29.5 a
Pennisetum alopecuroides	40.2 a	40.6 a	39.4 a
Phalaris arundinacea 'Picta'	31.6 a	29.0 a	28.1 a

*Explanation: see Table 2
** ↑ Fresh weight increase

In this study, the application of this growth regulator in a 4-h conditioning treatment only reduced the post-harvest longevity of *Chasmanthium latifolium*. All blades during the study showed an increase in elongation, but gibberellic acid further stimulated them to grow and as a result can cause premature aging. A similar elongation effect in the peduncles of *Zantedeschia elliottiana* 'Black Magic' following storage in gibberellic acid was observed by Janowska and Jerzy (2004). It needs to be stressed that gibberellins frequently stimulate elongation growth by enhancing the plasticity of cell walls. The negative effect of gibberellic acid conditioning in this experiment was also observed when analysing fresh weight loss in *Miscanthus sinensis* 'Silberspinne'. Leafy culms conditioned using this growth regulator exhibited the greatest loss of fresh weight. Moreover, it was found that under the influence of gibberellic acid conditioning in the leaves of *Alopecurus pratensis* 'Aureovariegatus', the value of the index of leaf greenness was the lowest. Hicklenton (1991) also noted a lower index of leaf greenness following the conditioning of leafy peduncles of *Alstroemeria* using this growth regulator, irrespective of the applied concentrations, while only a mixture of GA_3 and benzyladenine had an advantageous effect on the investigated trait.

Conditioning in 8-hydroxyquinoline sulphate had no effect on the post-harvest longevity of the leafy culms of ornamental grasses. Ferrante et al. (2004) also reported a lack of any effect of conditioning using this solution on the post-harvest longevity of leafy culms of *Matthiola incana*. In contrast, in this experiment it had a positive effect on the limitation of fresh weight losses of the leafy culms of *Pennisetum alopecuroides* in comparison to those of the control and those conditioned in gibberellic acid. Moreover, a negative effect of 8-hydroxyquinoline sulphate conditioning was also recorded. In comparison to the control, the leafy culms of *Miscanthus sinensis* 'Silberspinne' had greater fresh weight losses, whereas in the leaves of *Alopecurus pratensis* 'Aureovariegatus' the index of leaf greenness was lower. Fresh weight loss in the leaves of *Arum italicum* under the influence of conditioning was also investigated in the experiment by Janowska and Schroeter-Zakrzewska (2008). They observed a much greater fresh weight loss in leaves after their conditioning in 8-hydroxyquinoline sulphate than after storage in water.

CONCLUSIONS

1. Conditioning in gibberellic acid applied at 100 mg dm^{-3} had a positive effect on the post-harvest longevity and fresh weight loss during storage for leaves of *Miscanthus sinensis* 'Zebrinus'.
2. The application of 8-hydroxyquinoline sulphate at 200 mg dm^{-3} conditioning had no effect on the extension of post-harvest longevity of ornamental grasses, although it reduced the fresh weight loss of *Miscanthus sinensis* 'Zebrinus' and *Pennisetum alopecuroides* and the value of the index of leaf greenness in *Glyceria maxima* 'Variegata'.

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AUTHOR CONTRIBUTIONS

The following declarations about the authors' contributions to the research have been made: concept of the study: M.H.; field research: M.H., K.P., S.O.; data analyses: M.H.; writing of the manuscript: M.H.; comments on the manuscript: M.H.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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