ACTA SCIENTIARUM POLONORUM
Acta Sci. Pol. Hortorum Cultus, 16(1) 2017, 51–60
www.acta.media.pl ISSN 1644-0692

ORIGINAL PAPER

Accepted: 8.08.2016

EXTENDING THE VASE LIFE OF CUT CLEMATIS FLOWERS

Julita Rabiza-Świder✉, Ewa Skutnik, Agata Jędrzejuk, Aleksandra Łukaszewska

Department of Ornamental Plants, Warsaw University of Life Sciences – SGGW

ABSTRACT

Clematis is a popular vine with showy flowers therefore there is an increasing interest in growing it for cut flowers. The results of trials – carried out for over a decade – on vase life of 54 clematis taxa are presented. Only 3 cultivars lasted as short as 3 days when kept in water ('Krakowiak', 'Olgae' and 'Pink Flamingo'), 7 cultivars had the vase life of 11–12 days ('Arabella', 'Blue Light', 'Nina', 'Proteus', 'Rooguchi', 'Silver Moon' and 'Solina') while for most of taxa it ranged between 6 and 8 days. The efficiency of postharvest treatments depended on a taxon and a preservative. Generally, none of the solutions tested significantly prolonged flower vase life, though the standard preservative composed of 8-HQC and sucrose markedly improved flower longevity in 10 cultivars. Clematis flowers should be harvested when fully open and the shoot length does not affect flower longevity. Though the flowers of 'Julka' did not produce ethylene in detectable amounts they were sensitive to exogenous C_2H_4 and 24 h conditioning with the inhibitors of ethylene action, STS or 1-MCP, significantly prolonged their longevity. However, this treatment was not completely effective against ethylene as flowers pulsed in ethephon solutions had their vase life decreased relative to flowers untreated with ethylene.

Key words: biocide, ethylene, preservatives, sucrose

List of abbreviations: 8-HQC – 8-hydroxyquinoline citrate, $Al_2(SO_4)_3$ – aluminium sulphate, $Ca(OCl)_2$ – calcium hypochlorite, NaOCl – sodium hypochlorite, S – sucrose, SP – standard preservative

INTRODUCTION

Clematis is a versatile cut stem, since its flowers, foliage and seed heads can all be used in floral arrangements. Numerous species and cultivars provide a long flowering period but Greer and Dole [2009] claim that plants are difficult to establish. Vase life of cut clematis is usually short [Skutnik and Rabiza-Świder 2005, 2006, Greer and Dole 2009]. While in US clematis is grown for cut flowers, in Europe it is mainly planted outside and only large flowered hybrids of cv. Blue Piroutte started to be produced for cut flowers. They were first presented as such on the international horticultural fair in Essen (Internationale Pflanzenmesse IPM Essen) in 2012.

In cooperation with the Polish clematis breeder, Dr. Szczepan Marczyński, the Dept. of Ornamental Plants of the Warsaw University of Life Sciences has been carrying out studies on clematis in order to select species and cultivars suitable for cut flower production and to develop postharvest treatments improving their keeping qualities.

Considering the short shelf life of the cut flowers and their economical values, it seems necessary to choose the best treatment to delay the rate of deterio-

✉julita_rabiza_swider@sggw.pl

ration and increase their postharvest life. Such a treatment should improve quality and maintain the natural appearance of cut flowers to attract wholesalers, retailers, and finally consumers. Increasing shelf life of the cut flowers depends on different factors including anti-ethylene and anti-microbe treatments after-harvest as well as preservative solutions used by consumers [Amini et al. 2013]. The latter extend flower longevity by providing three essential ingredients, namely biocide, sugar and acidifier.

One of the most important causes of shortening of vase life is blockage of vascular system, which inhibits water supply to the flowers [De Stigter 1980] and leading to water stress. Antimicrobial compounds can reduce these occlusions and increase vase life of flowers [Aarts 1957, Marousky 1969, Halevy and Mayak 1981], but the response of many cut flowers to germicides can vary among species and cultivars [Jones and Hill 1993].

It has been shown that shortage of soluble carbohydrates in petals is one of the most important causes for shortening cut flowers vase life and applying sucrose in vase solutions increases flower longevity [Marousky 1969, Halevy and Mayak 1979, Ichimura et al. 1999, 2003, 2006, Liao et al. 2000]. Petals of cut flowers accumulate sugars taken from the vase solutions [Halevy and Mayak 1981]. According to Ichimura et al. [2002] the content of soluble carbohydrates in cut flowers is related to the length of their vase life.

Sucrose is used as a nutrition source in preservation solution and it serves as a respiration substrate which prevents damages to proteins. Due to closing stomata it improves the water balance in cut flowers. Preservative solutions composed of sucrose and a biocide were invented for cut flowers nearly 60 years ago [Aarts 1957]. The most frequently used – because of its simplicity and efficiency – is a solution composed of 8-HQC (or 8-HQS) and sucrose [Halevy and Mayak 1981], which is an important commercial preservative for several flowers. It is called "the standard preservative" and often used as a reference to compare effectiveness of other postharvest treatments.

In the study we present the results of trials carried out for over a decade on postharvest longevity of 54 different taxa of clematis in order to find cultivars suitable to be grown for cut flowers. We also developed and tested the effectiveness of different solutions composed of germicides and sucrose on vase life of clematis.

MATERIALS AND METHODS

Flowering stems of 54 cultivars of clematis (*Clematis* L.) were used as an experimental material. Plants were kindly provided by Clematis Sz. Marczyński and W. Piotrowski Nursery in Duchnice near Warsaw. Flowers were harvested at the same stage of development, i.e. open flowers with no visible symptoms of disease or insect pests or mechanical defects. Shoots were trimmed to the same length (appr. 20 cm) with one pair of leaves and placed in: distilled water (control), in 200 $mg \cdot dm^{-3}$ 8-hydroxyquinoline citrate (8-HQC), in the preservative solution containing 200 $mg \cdot dm^{-3}$ 8-HQC and sucrose (S) – 2, 4 or 8%, in the commercial preservative recommended by Chrysal International B.V. (Holland) for cut flowers during their turnover i.e., Chrysal Professional 2 [Molenaar 2009].

Apart from 8-HQC the following biocides were included in the trials: calcium hypochlorite – $Ca(OCl)_2$ (10, 100 $mg \cdot dm^{-3}$), sodium hypochlorite – NaOCl (0.01, 0.10 $ml \cdot dm^{-3}$), citric acid (10, 100 $mg \cdot dm^{-3}$), and aluminium sulphate – $Al_2(SO_4)_3$ (50, 500 $mg \cdot dm^{-3}$), used with or without 2% sucrose.

The cultivar Julka was chosen to compare the effect of maturity stage at harvest on flower longevity. Flowers cut in bud stage (mature, fully pigmented) or fully open were placed in water or in the above mentioned solutions. In two cultivars the effect of stem length on flower longevity was compared: in 'Kardynał Wyszyński' (17 and 28 cm) and in 'The Vagabond' (20 and 40 cm).

The experiments were carried out in the Dept. of Ornamental Plants Warsaw University of Life Sciences in the years 2004–2014. Flowers were placed in a room with controlled conditions: temperature 20°C, relative humidity 60%, 12 h photoperiod with light intensity of 35 $\mu mol \cdot m^{-2} \cdot s^{-1}$ PAR.

Vase life was recorded in days and regarded as terminated when petals showed wilting, drying or dropping. Each treatment contained 10 stems, individually

tagged and treated as single replicates. Each experiment was repeated 3–4-times during three or four years of trials. Results in tables are the average of 3–4 years.

Cut flowers of cv. Julka were subjected to ethylene by placing them into water solutions of Ethrel (the preparation releasing ethylene, containing 48% ethephon) for 24 h and then transferred to water. Before placing flowers into Ethrel solution they were conditioned with STS (50 mg $AgNO_3$ + 500 mg $Na_2S_3O_3$ in dm^3 water – 24 h) or gazed with 1-MCP in concentration 625 ppb. The measurements of ethylene emission were carried out in the Ethylene Laboratory of the Pomology Department at WULS using gas chromatograph HP5890. Flowers were placed in the tightly closed 2.50 dm^3 glass jars. Ethylene production was determined in flowers from 3 phases: just after harvest, in full bloom and at the moment of fading. The measurements were made 2, 4, 8, 12 and 24 hours after placing the flowers in the jars.

Results were statistically evaluated with one-way ANOVA and the means were compared using Duncan's test probability level P = 95%.

RESULTS

Vase life of 54 clematis taxa was evaluated for cut flower held in water (tab. 1, 2). From 13 botanical varieties the longest vase life was observed in 'Arabella' and 'Rooguchi' (about 11 days), while it was 8–9 days for 'Alionushka', 'Blue Boy', *C.* × *durandii*, 'Gravetye Beauty' and 'Princess Diana'. The shortest longevity was in 'Krakowiak', 'Olgae' and 'Pink Flamingo' (about 3 days) (tab. 1). Among 41 large flowering cultivars the following lasted the longest (11–12 days): 'Blue Light', 'Nina', 'Proteus', 'Silver Moon' and 'Solina' (tab. 2). Postharvest longevity of most cultivars ranged between 6 and 8 days. The shortest vase life (4–5 days) was noted for: 'Andromeda', 'Ascotinensis', 'Doctor Ruppel', 'Kardynał Wyszyński, 'Lasurstern', 'Lech Wałęsa', 'Minister', 'Rhapsody' (tab. 2).

The standard solution (8-HQC + 2% S) prolonged vase life of 10 from 45 cultivars: in 'Andromeda' the vase life was doubled relative to water control, while in 'Fujimusume' it was prolonged by 56%, in 'Jackmanii' by 36%, in 'Kiri Te Kanawa' by 49%, in 'Lech Wałęsa' by 74%, in 'Maria Skłodowska-Cürie' by 57%, in 'Mazury' by 40%, in 'The Vagabond' by 22%, in 'Ville de Lyon' by 51% (tab. 3) and in 'Viva Polonia' by 42% (tab. 4). The higher sucrose concentration (4%) in the preservative prolonged the vase life only in 'Fujimusume' – by 35%, while the highest (8%) – tested on 7 cultivars – either did not affect vase life or shortened it in 3 cultivars as compared to the relative controls. The biocid (8-HQC) used alone gave results comparable to the preservative (8-HQC + 2%S) in cv. Generał Sikorski, Jackmanii, Lech Wałęsa and Ville de Lyon (tab. 3). In 'Viva Polonia' application of 8-HQC prolonged vase life less than standard preservative (SP), i.e. by 21% but in 'Vyvan Pennell' the biocid used alone was more effective than when applied together with sucrose and prolonged vase life by 25% (tab. 4).

Application of Chrysal Professional 2 only in 3 cases prolonged vase life relative to the respective control: in 'Blue Boy' by 20%, in 'Generał Sikorski' by 31% and in 'Lech Wałęsa' – nearly 100% (tab. 3). Only in 'Blue Boy' this commercial preparation was more effective than the standard preservative.

Table 1. The vase life of botanical and perennial cultivars of cut clematis flowers held in water

Cultivar	Vase life (days)
Alionushka	8.2 bcd[1]
Arabella	11.0 f
Bill Mac Kenzie	6.5 b
Blue Boy	9.0 de
C. × *durandii*	8.9 de
Gravetye Beauty	8.8 de
Krakowiak	2.7 a
Odoriba	7.9 bcd
Olgae	2.9 a
Pink Flamingo	3.0 a
Princess Diana	8.6 cd
Rooguchi	10.8 ef
Sweet Sumer Love	6.7 bc

[1] Means followed by the same letter do not differ at α = 0.05

Table 2. The vase life of large-flowered cultivars of cut clematis flowers held in water

Cultivar	Vase life (days)
Andromeda	4.7 ab[1]
Ascotinensis	4.7 ab
Barbara	6.2 bcde
Beautifull Bride	5.8 bcd
Blue Light	11.0 ij
Comtesse de Bouchand	9.8 ghi
Diamond Ball	5.2 abc
Doctor Ruppel	3.7 a
Fujimusume	7.9 efg
Generał Sikorski	5.9 bcde
Hagley Hybrid	7.2 cdef
Hania	7.6 ef
Isago	9.2 ghi
Jackmanii	6.9 cdef
Julka	10.0 ghi
Kacper	9.8 ghi
Kardynał Wyszyński	4.5 ab
Kiri Te Kanawa	7.3 def
Kryspina	6.4 bcde
Lasurstern	4.7 ab
Lech Wałęsa	4.3 ab
Maria Skłodowska-Cürie	7.0 cdef
Mazury	8.0 efg
Minister	5.1 abc
Multi Blue	7.3 def
Nina	11.2 ij
Piilu	7.2 cdef
Popiełuszko	8.6 fgh
Proteus	10.6 hij
Rhapsody	5.5 abcd
Silver Moon	12.0 j
Solidarność	8.9 fgh
Solina	10.8 hij
The First Lady	7.1 cdef
The Vagabond	6.3 bcde
Ville de Lyon	6.1 bcde
Viva Polonia	7.1 cdef
Viola	8.0 efg
Vyvan Pennell	8.9 fgh
Warszawska Nike	6.3 bcde
Westerplatte	7.3 def

[1] Explanations as in table 1

No effect of stem length on flower longevity was observed in two cultivars: Kardynał Wyszyński and The Vagabond (tab. 3).

Placing cut stems of 'Julka' into the preservatives increased vase life of flowers harvested in both phases: bud stage and fully open flowers. There was no difference in longevity of flowers cut when fully open and placed either into the preservative solution or Chrysal Professional 2. Both preservatives increased as well vase life of flowers cut in bud stage and opened in vase. Flowers cut in bud stage and placed in water or preservative solutions needed 5–6 days to open and their longevity was only half of this in flowers cut when fully open (tab. 5) and their diameter was by 1/3 smaller than that in flowers cut when fully open (data not presented).

Application of citric acid on flowers of the 'First Lady' and $Al_2(SO_4)_3$ on flowers of 'Vyvyan Pennell' did not increase their longevity or even shortened it (tab. 4). The solution containing calcium hypochlorite in concentration 10 $mg \cdot dm^{-3}$ plus 2% sucrose prolonged by 20% vase life of flowers in cv. Jackmanii, similarly as did SP and 8-HQC (tab. 4). In 'Viva Polonia' sodium hypochlorite 0.10 $ml \cdot dm^{-3}$ used together with 2% sucrose prolonged vase life by 31%, comparably to SP (tab. 4).

Measurements of endogenous ethylene produced by flowers of 'Julka' placed in closed jars during 24 h did not reveal gas presence. However, in a successive experiment sensitivity of flowers to exogenous ethylene was proved. Flowers placed for 24 h in Ethrel solution (5 $mg \cdot dm^{-3}$ ethephon), and then transferred to water had their vase life reduced relative to the untreated control (tab. 6). Conditioning flowers during 24 h in STS or gassing them with 1-MCP significantly prolonged their vase life, by 46 and 31%, respectively, as compared to unconditioned flowers. These treatments were, however, not completely effective in protecting against ethylene as the flowers placed in the ethephon solutions had their vase life reduced as compared to flowers not treated with C_2H_4. In this case 1-MCP was more effective: the flowers treated with the gas lost only 7% of their vase life while those treated with STS – 29% (tab. 6).

Table 3. Effect of preservatives on vase life (days) of cut clematis flowers

Cultivar		H_2O	8-HQC	8-HQC + 2%S	8-HQC + 4%S	8-HQC + 8%S	Chrysal professional
Alionushka		8.2 a[1]	–[2]	8.2 a	–	–	8.7 a
Andromeda		4.7 a	6.7 a	9.0 b	–	–	6.8 a
Arabella		11.0 c	11.2 c	8.9 b	5.5 a	5.4 a	10.5 bc
Ascotinensis		4.7 a	–	3.3 a	–	–	4.7 a
Beautifull Bride		5.8 b	–	6.4 b	–	–	3.5 a
Blue Boy		9.0 b	8.8 ab	8.3 ab	7.3 a	–	10.8 c
Blue Light		11.0 b	9.0 a	10.8 b	–	–	8.6 a
Comtesse de Bouchand		9.8 c	5.0 a	7.3 b	–	–	4.7 a
Diamond Ball		5.2 ab		7.0 b	–	–	4.1 a
Doctor Ruppel		3.7 b	3.2 b	2.2 a	–	–	3.2 b
C. × *durandii*		8.9 a	9.7 a	9.0 a	–	–	9.9 a
Fujimusume		7.9 a	9.4 ab	12.3 c	10.7 b	–	8.9 a
Generał Sikorski		5.9 a	7.7 b	7.7 b	–	–	7.7 b
Gravetye Beauty		8.8 a	9.0 a	10.1 a	–	10.0 a	10.3 a
Hagley Hybrid		7.2 bc	7.4 c	–	6.4 abc	–	6.1 ab
Hania		7.6 a	7.7 a	8.0 a	8.1 a	7.1 a	7.2 a
Isago		9.2 ab	11.3 b	8.0 a	7.5 a	7.2 a	8.8 a
Jackmanii		6.9 ab	9.3 c	9.4 c	5.5 a	–	7.3 bc
Julka		10.0 b	9.2 b	9.9 b	10.1 b	6.4 a	9.2 b
Kacper		9.8 a	10.1 a	10.6 a	9.1 a	–	10.1 a
Kardynał Wyszyński	17 cm	4.7 bc	5.6 bc	5.8 c	2.7 a	–	4.0 ab
	28 cm	4.2 ab	5.2 b	3.2 a	3.1 a	–	4.3 ab
Kiri Te Kanawa		7.3 b	4.8 a	10.9 c	–	–	4.7 a
Krakowiak		2.7 a		2.4 a	2.0 a	–	2.7 a
Kryspina		6.4 a		5.1 a	–	–	5.0 a
Lech Wałęsa		4.3 a	8.0 b	7.5 b	–	–	8.5 b
Maria Skłodowska-Cürie		7.0 b	5.2 a	11.0 c	–	–	5.2 a
Mazury		6.7 a	6.0 a	9.4 b	–	–	6.0 a
Minister		5.1 a	3.9 a	5.6 a	–	–	5.1 a
Multi Blue		7.3 b	7.6 b	5.3 a	4.3 a	–	7.1 b
Nina		11.2 bc	11.8 c	9.9 ab	11.6 c	–	8.4 a
Olgae		2.9 ab	3.3 b	3.7 bcd	1.8 a	–	3.5 bc
Piilu		7.2 a	7.0 a	8.1 a	6.7 a	–	7.0 a
Princess Diana		8.6 a	10.3 a	10.2 a	9.1 a	–	–
Rhapsody		5.5 b	7.2 b	6.2 b	5.9 b	2.5 a	5.4 b
Rooguchi		10.8 a	6.6 a	10.8 a	8.0 a	–	8.3 a
Solidarność		8.9 a	8.4 a	9.3 a	8.1 a	–	8.9 a
Solina		10.8 b	–	8.4 a	–	–	8.1 a
Sweet Summer Love		6.7 ab	–	7.3 b	–	–	6.1 a
The Vagabond	20 cm	5.8 a	6.0 a	–	–	–	5.9 a
	40 cm	6.7 a	6.7 a	8.2 b	–	–	7.0 a
Ville de Lyon		6.1 a	8.5 b	9.2 b	5.3 a	4.3 a	4.4 a
Warszawska Nike		6.3 a	4.6 a	6.5 a	–	–	6.2 a
Westerplatte		7.3 a	5.6 a	6.8 a	–	–	5.3 a

[1] Means in each verse followed by the same letter do not differ significantly at $\alpha = 0.05$
[2] Treatment not included

Table 4. Effect of biocides on vase life of cut clematis flowers

Jackmanii		The First Lady	
Treatment	Vase life (days)	Treatment	Vase life (days)
H_2O	9.0 ab[1]	H_2O	7.1 b
8-HQC (200 mg·dm^{-3})	11.1 d	8-HQC (200 mg·dm^{-3})	7.3 b
8-HQC (200 mg·dm^{-3}) + 2%S	10.6 cd	8-HQC (200 mg·dm^{-3}) + 2%S	4.4 a
$Ca(OCl)_2$ (10 mg·dm^{-3})	7.8 a	citric acid (10 mg·dm^{-3})	7.0 b
$Ca(OCl)_2$ (10 mg·dm^{-3}) + 2%S	10.8 cd	citric acid (10 mg·dm^{-3}) + 2%S	5.0 a
$Ca(OCl)_2$ (100 mg·dm^{-3})	9.3 bc	citric acid (100 mg·dm^{-3})	4.3 a
$Ca(OCl)_2$ (100 mg·dm^{-3}) + 2%S	8.3 ab	citric acid (100 mg·dm^{-3}) + 2%S	7.5 b
Viva Polonia		Vyvyan Pennell	
H_2O	7.1 ab	H_2O	8.9 c
8-HQC (200 mg·dm^{-3})	8.6 c	8-HQC (0.200 g·dm^{-3})	11.1 d
8-HQC (200 mg·dm^{-3}) + 2%S	10.1 d	8-HQC (200 mg·dm^{-3}) + 2%S	8.0 bc
NaOCl (0.01 ml·dm^{-3})	6.6 a	$Al_2(SO_4)_3$ (50 mg·dm^{-3})	9.0 c
NaOCl (0.01 ml·dm^{-3}) + 2%S	7.1 ab	$Al_2(SO_4)_3$ (50 mg·dm^{-3}) + 2%S	7.1 ab
NaOCl (0.10 ml·dm^{-3})	8.4 bc	$Al_2(SO_4)_3$ (500 mg·dm^{-3})	6.7 ab
NaOCl (0.10 ml·dm^{-3}) + 2%S	9.3 cd	$Al_2(SO_4)_3$ (500 mg·dm^{-3}) + 2%S	6.0 a

[1] Means in each column followed by the same letter do not differ significantly at α = 0.05

Table 5. The vase life (days) of cut clematis 'Julka' flowers cut in bud stage and when fully open

Treatment	H_2O		8-HQC+2%S		Chrysal Professional	
	open flower	flower bud	open flower	flower bud	open flower	flower bud
Vase life	8.6 c[1]	4.0 a	10.3 d	5.5 b	9.6 d	4.6 b

[1]– explanations as in table 1

Table 6. Effect of STS and 1-MCP on vase life (days) of cut clematis 'Julka' flowers

Treatment	H_2O	Et hephon 5 mg·dm^{-3}/H_2O	24 h STS		24 h 1-MCP	
			H_2O	et hephon 5 mg·dm^{-3}	H_2O	et hephon 5 mg·dm^{-3}
Vase life	8.6 b[1]	7.0 a	12.6 e	9.0 b	11.3 d	10.6 c

[1] Explanations as in table 1

DISSCUSION

The length of vase life is one of the most important factors for quality of cut flowers [Ichimura et al. 2002]. Vase life can vary not only from one species of plant to another but also from one cultivar to another within the same species [Onozaki et al. 2001, Ichimura et al. 2002, Timmerman and Kroon 2009]. In the present study, we found that the vase life of cut clematis flowers markedly varied among 54 cultivars. The vase life was the shortest (3 days) in 3 botanical cultivars: Krakowiak, Olgae and Pink Flamingo. The shortest vase life of large-flowered cultivars was longer by 1–2 days. The longest vase life (11–12 days) was noticed in 2 botanical cultivars: Arabella and Rooguchi and in 5 large-flowered cultivars: Blue Light, Nina, Proteus, Silver Moon and Solina. According to Greer and Dole [2009] the clematis vase life ranged from 3 to 10 days, although 7 days was typical. Double flowers often have longer vase life than single ones [Greer and Dole 2009]. Among seven tested cultivars with the longest vase life only two had double flowers: 'Blue Light' and 'Proteus'.

Parke [1993] claims that the flowers should be harvested when sepals begin to open. If flowers are cut when more than three-quarters of bud is open, vase life is shortened [Greer and Dole 2009]. In clematis 'Julka' the situation was reverse: harvesting stems in a bud stage shortened flower longevity by half as compared to those cut when fully open. We also observed that prematurely cut flowers had diameters considerably reduced relative to those cut in full bloom.

Longevity of cut flowers is not only genetically determined but according to Teixeira da Silva [2003] and Tekalign et al. [2011], it can be affected by the postharvest treatments of biocides or preservative solutions during the entire period of turnover. Many germicides such as HQS, $AgNO_3$, $Al_2(SO_4)_3$ have been shown to inhibit bacterial growth in cut stems [van Doorn and Perik 1990, van Doorn 1997, Ichimura et al. 2003] and reduce stem plugging [Ichimura et al. 1999, Kwon and Kim 2000], thus maintaining clarity in the solution and preventing blockage of xylem elements by microorganisms [Knee 2000]. Therefore, extension of cut flower vase life with solutions that contained $Ca(OCl)_2$, NaOCl, 8HQS and 8-HQC could be due to their antibacterial effects [Tekalign et al. 2011].

The response of many cut flowers to germicides is highly variable among species and cultivars, what was found in freesia, gerbera, rose, carnation and chrysanthemum [Jones and Hill 1993]. This is in agreement with this study. 8-HQS is known to extend the vase life of rose cut flowers, by preventing the accumulation of microorganisms in xylem vessels [Kwon and Kim 2000]. Thus, 8-HQS may act as an antimicrobial agent and hence, reduce stem plugging and wilting. This explains the short vase life of untreated rose control and long vase life when 8-HQS was applied [Ichimura et al. 1999, Elgimabi and Ahmed 2009]. Addition of germicide 8-HQC was crucial to increase the vase life of linaria [Dole et al. 2009] and rose [van Doorn and Perik 1990]. Certain cut flower species are known to be sensitive to specific germicides [Jones and Hill 1993]. According to Knee [2000] 8-HQC is the most effective and safest (not phytotoxic) biocide. After adding of 8-HQC to vase solution, fresh weight was improved in carnation and alstroemeria [Knee 2000]. In clematis 8-HQC increased flower vase life but only in several cultivars: Generał Sikorski, Jackmanii, Lech Wałęsa, Ville de Lyon, Viva Polonia and Vyvan Pennell. These results agree with previous findings [Ichimura et al. 1999, 2006], where HQS was not suitable for cut rose flowers although no visible symptom of chemical injury was observed [Ichimura et al. 1999] or the vase life of some rose cultivars was shortened because of toxicity to some flowers [Ichimura et al. 2006].

HQC is known to inhibit the production of ethylene in cut flowers [Parups and Peterson 1972, van Doorn et al. 1989]. Bartoli et al. [1997] reported that the vase life of chrysanthemum cut flowers was increased when they were treated with 8-HQS + sucrose and this was attributed to the inhibition of ethylene. Although we showed that clematis flowers do not produce ethylene in detectable amounts they are sensitive to exogenous C_2H_4. Conditioning flowers with inhibitors of ethylene action – STS and 1-MCP – significantly increased longevity of clematis flowers. 1-MCP and STS were similarly effective in ex-

tending cut flower vase life of lupine and trachelium [Dole et al. 2009], but in clematis 1-MCP was more effective. However, neither of two inhibitors was not completely effective in protection against exogenous ethylene and flowers placed in ethephone solutions had their vase life shortened as compared to flowers untreated with C_2H_4. Silver from STS complex competes with ethylene for the same site of action and therefore reduces the negative effect of ethylene. Applying STS as an antimicrobial and anti-ethylene compound was more useful in roses and flowers treated by STS had higher water uptake, fresh weight, flower diameter and longevity [Rezvanypour and Osfoori 2011].

Aluminium sulphate has been used as a microbial inhibitor in commercial preservatives [Halevy and Mayak 1981], although van Doorn et al. [1990] reported that this compound had a weak antimicrobial activity and the positive effect in extending the vase life could be associated with inhibition of transpiration from leaves. Aluminium sulphate, which is a common biocide used by cut flower growers, was not able to extend the vase life of cut rose flowers over the control (water) [Tekalign et al. 2011], similarly as we observed in clematis flowers. Use of aluminium sulphate in a higher concentration (500 $mg \cdot dm^{-3}$) even shortened flower longevity. The toxic effect of a high concentration of aluminium sulphate was observed on cut roses [Renvanypour and Osfoori 2011, Tekalign et al. 2011], where fading of the petals color was intensive [Tekalign et al. 2011], however the reaction depended on a cultivar [Ichimura et al. 2006]. Application of other biocides such as NaOCl and $Ca(OCl)_2$ or citric acid as acidifier proved ineffective for cut clematis flowers. It confirms the earlier observations that the response of many cut flowers to germicides is highly variable among species and cultivars [Jones and Hill 1993, Tekalign et al. 2011].

Recently, Knee [2000] reported that Isocil, a commercially prepared germinicide was suitable for extending vase life of cut roses, carnations and alstroemeria flowers. In clematis the use of the commercial preparation Chrysal Professional 2 was effective only in 3 cultivars: Blue Boy, Generał Sikorski and Lech Wałęsa, prolonging their vase life relative to respective controls.

One of the most important causes of shortening cut flowers' vase life is a shortage of soluble carbohydrates in petals [Liao et al. 2000, Ichimura et al. 2002, 2003, 2006]. Sugars act as a source of nutrition for tissues approaching carbohydrate starvation and as an osmotically active molecules, thereby leading to the promotion of water uptake [Ichimura and Hismatsu 1999]. Dissolved sugars in cells of petals are osmotically active substances that are drawn into the corolla-cells making the cells turgid while the hydrolyzed sugars are ready for respiration [Ichimura and Hismatsu 1999]. Treatment with sugars in combination with some germicides was shown to extend vase life of many cut flowers [Aarts 1957, Ichimura et al. 2006, Dole et al. 2009]. Delaying protein degradation, regulating water balance due to limiting transpiration, inhibition of ethylene producing and decreasing flower sensitivity to ethylene are the advantages of sugars [Ichimura et al. 1999, 2006, Elgimabi and Ahmed 2009].

In clematis supplementation a biocid with sucrose improved its efficiency, however, flower response depended on sugar concentration and a cultivar. Relative to vase water, the solution containing 8-HQC and 2% sucrose prolonged vase life of 10 cultivars: Andromeda, Fujimusume, Jackmanii, Kiri Te Kanawa, Lech Wałęsa, Maria Skłodowska-Cürie, Mazury, The Vagabond, Ville de Lyon and Viva Polonia. The higher sucrose concentration (4%) increased vase life only in one cultivar Fujimusume while the highest (8%) either did not affect vase life or even decreased it. Similarly, sucrose supplementation of 2% was sufficient to improve vase life in linaria, trachelium and zinnia [Dole et al. 2009]. A high sucrose concentration (10–20%) but only for pulsing, caused a positive response in cut lisianthus [Cho et al. 2001], zinnia and linaria [Dole et al. 2009]. In contrast, a high (10–20%) sucrose pulse decreased vase life of trachelium and rudbeckia [Dole et al. 2009].

The above results show that clematis can be grown for cut flowers providing that suitable cultivars are chosen and proper postharvest treatments are individually developed for them.

CONCLUSIONS

Clematis can be grown for cut flower production providing that suitable taxa are chosen.

Clematis flowers should be harvested when fully open.

Efficiency of postharvest treatments depends on a taxon and chemicals used. The solution composed of 8-HQC with 2% sucrose can be recommended as a flower preservative for cut clematis.

Clematis flowers do not produce ethylene in detectable amounts, they are, however, sensitive to exogenous C_2H_4 and the respond positively to the inhibitors of ethylene action.

REFERENCES

Aarts, J.F.T. (1957). Over de houdbarheid van snijbloemen. Mededelingen van de landbouwhoge school te Wageningen/Nederland, 57, 1–62.

Amini, S., Jafarpour, M., Golparvar, A. (2013). Effect of pulsing treatments (calcium chloride + sucrose and distilled water) with fixed hormonal treatments on postharvest quality of cut Gerbera flowers. Tech. J. Engin. App. Sci., 3(13), 1120–1123.

Bartoli, C.G., Juan, G., Edgrdo, M. (1997). Ethylene production and responses to exogenous ethylene in senescing petals of *Chrysanthemum morifolium* RAM cv. Unsei. Plant Sci., 124, 15–21.

Cho, M.C., Celikel, F., Dodge, L. (2001). Sucrose enhances the postharvest quality of cut flowers of *Eustoma grandiflorum* (Raf.) Shinn. Acta Hortic., 543, 305–315.

De Stigter, H.C.M. (1980). Water balance of cut and intact Sonia rose plants. Z. Pflanzenphysiol., 99, 131–140.

Dole, J.M., Viloria, Z., Fanelli, F.L., Fonteno, W. (2009). Postharvest evaluation of cut dahlia, linaria, lupine, poppy, rudbeckia, trachelium and zinnia. Hort Technol., 19(3), 593–600.

Elgimabi, M.N., Ahmed, O.K. (2009). Effects of bactericides and sucrose-pulsing ion vase life of rose cut flowers (*Rosa hybrida*). Bot. Res. Int., 2(3), 164–168.

Greer, L., Dole, J.M. (2009). Woody cut stems for growers and florists. Timber Press. Portland, London.

Halevy, A.H., Mayak, S. (1979). Senescence and postharvest physiology of cut flowers, part 1. Hort. Rev., 1, 204–236.

Halevy, A.H., Mayak, S. (1981). Senescence and postharvest physiology of cut flowers, part 2. Hort. Rev., 3, 59–143.

Ichimura, K., Hismatsu, T. (1999). Effect of continuous treatment with sucrose on the vase life, soluble carbohydrate concentrations and ethylene production of cut snapdragon flowers. J. Japan Soc. Hort. Sci., 68, 61–66.

Ichimura, K., Kojima, K., Goto, R. (1999). Effects of temperature, 8-HQS and sucrose on vase life of cut rose flowers. Hortic. Sci., 15, 33–40.

Ichimura, K., Kawabata, Y., Kishimoto, M., Goto, R., Yamada, K. (2002). Variation with the cultivar in the vase life of cut rose flowers. Bull. Natl. Inst. Flor. Sci., 2, 9–20.

Ichimura, K., Kawabata, Y., Kishimoto, M., Goto, R., Yamada, K. (2003). Shortage of soluble carbohydrates is largely responsible for short vase life of 'Sonia' rose flowers. J. Jap. Soc. Hortic. Sci., 72, 292–298.

Ichimura, K., Taguchi, M., Norikoshi, R. (2006). Extension of vase life in cut roses by treatment with glucose, isothiazolinonic germicide, citric acid and aluminium sulphate solution. Jap. Agri. Res. Quart., 40, 263–269.

Jones, R.B., Hill, M. (1993). The effect of germicides on the longevity of cut flowers. J. Amer. Soc. Hort. Sci., 118, 350–354.

Knee, M. (2000). Selection of biocides for use in floral preservatives. Postharv. Biol. Technol., 18, 227–234.

Kwon, H., Kim, K. (2000). Inhibition of lipoxygenase activity and microorganism growth in cut freesia by pulsing treatment. J. Korean Soc. Hortic. Sci., 41(2), 135–138.

Liao, L., Lin, Y., Huang, K., Chen, W., Cheng,Y. (2000). Postharvest life of cut rose flowers as affected by silver thiosulfate and sucrose. Bot. Bull. Acad. Sin., 41, 299–303.

Marousky, F.J. (1969). Vascular blockage, water absorption, stomatal opening, and respiration of cut 'Better Times' roses treated with 8-hydroxyquinoline citrate and sucrose. J. Am. Soc. Hort. Sci., 94, 223–226.

Molenaar, P. (2009). Walka ze stratami, czyli produkty firmy Chrysal a posprzętna jakość kwiatów ciętych. In: Niech żyją kwiaty w wazonie. Praca zbiorowa, Łukaszewska, A.J. (red.). Drukrol, Warszawa, 185–190.

Onozaki, T., Ikeda, H., Yamaguchi, T. (2001). Genetic improvement of vase life of carnation flowers by crossing and selection. Sci. Hortic., 87, 107–120.

Parke, M. (1993). A garden for cutting: Gardening for flower arrangments. Stewart, Tabori & Chang, New York.

Parups, E.V., Peterson, E.A. (1972). Inhibition of ethylene production in plant tissues by 8-hydroxyquinoline. Can. J. Plant. Sci., 53, 351–353.

Rezvanypour, S., Osfoori, M. (2011). Effect of chemical treatments and sucrose on vase life of three cut rose cultivars. J. Res. Agri. Sci., 7(2), 133–139.

Skutnik, E., Rabiza-Świder, J. (2005). Przydatność kwiatów ciętych wybranych odmian powojników (*Clematis* L.) do wykorzystania we florystyce. Zesz. Probl. Post. Nauk Roln., 504, 507–513.

Skutnik, E., Rabiza-Świder, J. (2006). Wpływ chłodzenia na pozbiorczą trwałość wybranych odmian powojnika (*Clematis* L.). Zesz. Probl. Post. Nauk Roln., 510, 587–592.

Teixeira da Silva, J.A. (2003). The cut flower: Postharvest considerations. J. Biol. Sci., 3(4), 406–442.

Tekalign, T., Tilahun, S., Humphries, G. (2011). Influence of pulsing biocides and preservative solution treatment on the vase life of cut rose (*Rosa hybrida* L.) varieties. Ethiop. J. Appl. Sci. Technol., 2(2), 1–18.

Timmerman, R., Kroon, M. (2009). Rosa documentation by Chrysal International BV, 7–8.

van Doorn, W.G. (1997). Water relations of cut flowers. Hort. Rev., 18, 1–85.

van Doorn, W.G., Perik, R.R.J. (1990). Hydroquinoline citrate and low pH prevent vascular blockage in stems of cut rose flowers by reducing the number of bacteria. J. Amer. Soc. Hort. Sci., 115, 979–981.

van Doorn, W.G., Schurer, K., de Witte, Y. (1989). Role of endogenous bacteria in vascular blockage of cut rose flowers. J. Plant Physiol., 134, 375–381.

van Doorn, W.G., de Witte, Y., Perik, R.R.J. (1990). Effect of antimicrobial compounds on the number of bacteria in stems of cut rose flowers. J. Appl. Bacteriol., 68, 117–122.