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THE EFFECTS OF CHEMICAL SUBSTANCES ON SENESCENCE OF *Weigela florida* (Bunge) A. DC. 'VARIEGATA NANA' CUT STEMS

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Abstract. In addition to flowers, cut foliage and leafy stems are very valuable florist material. However, florist greens frequently first loses its ornamental value in a flower arrangement, since it quickly wilts, fades, or browns. That is why it is important to develop agents for conditioning cut the florist greens that would extend its vase life effectively and inhibit senescence. Here we report on the effect of growth regulators and commercially available conditioning products on the post-harvest longevity of cut stems of *Weigela florida* 'Variegata Nana' and certain processes associated with their senescence. Senescence of *W. florida* cut stems resulted in reduced post-harvest quality, decrease in relative water content (RWC) and an increase in electrolyte leakage (E_L) in the leaf tissues. Chrysal Clear 2, applied in the form of a 24-hour pre-treatment, was the most effective in extending the longevity of cut stems of *W. florida*. The same conditioning product also had a beneficial effect on leaf tissue water content and the values of the chlorophyll fluorescence parameters, including maximum quantum yield and actual photochemical activity. Conditioning of *W. florida* stems in a solution of gibberellic acid at a concentration of 0.25 mg · dm^{-3} had the most beneficial effect on the cytoplasmatic membranes. However, the highest contentes of photosynthetic pigments (chlorophyll "a" and "b"), were found after the 24-hour pre-treatment of *W. florida* stems in a solution of 0.1 mmol · dm^{-3} benzyladenine and Chrysal Clear 2.

Key words: E_L, fluorescence, photosynthetic pigments, growth regulators, RWC, senescence, *Weigela*.

INTRODUCTION

In addition to flowers, cut foliage and leafy stems are very valuable florist materials. Pliable leafy or leafless stems are frequently used to form the shape that is filled with

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colourful floral elements. In flower arrangements, all elements should be characterized by more or less the same vase life. However, the florist greens frequently first loses its ornamental value in a flower arrangement, since it quickly wilts, fades, or browns. That is why it is important to develop agents for conditioning cut florist greens that would extend its vase life effectively and inhibit senescence.

Senescence of a plant part cut off from its parent organism is an unavoidable, quickly progressing process that can be seen in particular at the final stage of ontogenesis, during which irreversible changes are initiated leading to gradual cell destruction and death of the organism. This process leads to the modification and degradation of the cell components, both at the morphological and metabolic level [Nooden et al. 1997]. Changes in chlorophyll content occur often appear before visible yellowing of the leaf blade. According to Rubinstein [2000], the most important physiological processes are disturbed, in particular photosynthesis and transpiration, which causes irreversible changes in cell metabolism. At the final stage of senescence, the outer cell membranes lose their integrity [Wojtaszek 2001], and this is manifested by increased values of cell electrolyte leakage [Kacperska 1996]. Moreover, cutting off an organ from growing plant is accompanied by water stress, while during trading frequently secondary oxidative stress appears causing accelerated leaf and stem senescence [Skutnik 2009].

Standard flower solutions (8-hydroxyquinoline sulphate) used to prolong the vase life of cut flowers most frequently shorten the longevity of the florist greens or haven't any effect on it [Janowska and Schroeter-Zakrzewska 2008, Rabiza-Świder and Skutnik 2008]. Leaf and flower senescence is controlled by plant hormones. The most important groups that affect post-harvest quality include cytokinins, among them benzyladenine (BA) and gibberellins – including gibberellic acid (GA_3) [Skutnik et al. 2006, Janowska and Schroeter Zakrzewska 2008, Skutnik and Rabiza-Świder 2008]. Polyamines are also an interesting alternative; their synthesis pathways merge with ethylene synthesis, hence they may inhibit the production of this gas, which is recognised to be one of the main stimulators of plant senescence [Bouchereau et al. 1999]. The increased production of free oxygen radicals, or reactive oxygen species (ROS), also significantly accelerates the loss of decorative features of the florist greens. To help the plant in its fight against ROS, leafy stems can be conditioned in hydrophilic antioxidants that include, among others, ascorbate and flavonoids [Łata 1998]. Commercial conditioning products that are available on the Polish market, manufactured by the Dutch company CHRYSAL, are also used for pre-treatment of cut foliage [Skutnik et al. 2006, Skutnik and Rabiza-Świder 2008]. These conditioners are intended for use at every stage of trading. They maintain the water balance equilibrium, keep up the hormonal balance and control the processes of oxidation and the release of certain substances by the shoots into the water, bacteria development and air embolism in xylem. They can also contribute to carbohydrate supply of flower solution; saccharose present in their composition plays a great role in it [Łukaszewska 2009].

Present experiment aimed to determine the influence of growth regulators and commercially marketed conditioning products on cut stems of *Weigela florida* 'Variegata Nana' senescence processes, which was expressed as hydration changes, the leakage of electrolytes, photosynthetic pigment contents, and selected chlorophyll fluorescence parameters.

MATERIALS AND METHODS

All experiments were done on cut stems of *Weigela florida* (Bunge) A. DC. 'Variegata Nana', grown under field conditions and obtained from the Institute of Ornamental Plants and Landscape Architecture of the University of Life Sciences in Lublin. The stems were harvested in August and September 2011, in the morning. The experiment was conducted in a phytotron of the Department of Plant Physiology of the University of Life Sciences in Lublin, under controlled environment conditions: a temperature of 23°C during the day and 16°C at night, relative air humidity of 60%, quantum irradiance of 190 μmol m^{-2} s^{-1}, with a light/dark cycle of 14/8 hours. The experiment consisted of seven treatments, each of them comprising 15 foliate stems individually marked and treated as replicates. Directly after trimming the stems to a length of 25 cm, they were conditioned for 24 hours in aqueous solutions of the following: spermidine at a concentration of 1 mmol · dm^{-3}, gibberellic acid (GA_3) at 0.25 mmol · dm^{-3}, benzyladenine (BA) at 0.1 mmol · dm^{-3}, 1% Citrosept, and 0.5% Chrysal Clear 2. Then the stems were transferred to containers with distilled water, which was changed every day until the end of the experiment. Stems kept in distilled water throughout the experiment duration were the control.

Post-harvest vase life of the leafy stems of *W. florida* was determined by recording the number of days till the time when the symptoms of loss of decorative quality appeared (30% of leaves on a stem browned and dried up). The degree of damage in the cytoplasmatic membranes was assessed by determining electrolyte leakage (E_L) from the tissues following the method given by Kościelniak [1993] and using a CC-317 microcomputer conductivity meter (Elmetron). Relative water content (RWC) in leaf tissues was determined by the method of Barrs [1968]. The content of photosynthetic pigments (chlorophyll "a", chlorophyll "b", and carotenoids) of leaves was determined after extraction in 80% acetone. Absorbance was measured at three wavelengths (λ): 470 nm (carotenoids), 646 nm (chlorophyll "b"), and 663 nm (chlorophyll "a"), using a CE 9500 spectrophotometer (Cecil). Pigment content was calculated according to the method described by Lichtenthaler and Wellburn [1983]. Chlorophyll fluorescence was measured with a PAM-2000 fluorometer (Walz GmbH) using the saturation pulse method [Schreiber et al. 1992]. The measurements were always conducted on the fifth leaf counted from the bottom. Before measurement, portions of leaves were darkened for 20 minutes using special clips. A weak measuring light (< 1 μmol m^{-2} s^{-1}) was used to determine F_0, the minimum fluorescence obtained in the dark-adapted state. Maximum fluorescence (F_m) was determined for the dark adapted state by applying a saturating pulse of white light (4000 μmol m^{-2} s^{-1}, 600 ms duration) from a halogen lamp. Steady – state fluorescence (F_s) was achieved after exposure to actinic light for 10 min, as evidence by unchanging fluorescence levels. Maximum fluorescence under steady – state conditions (F'_m) was determined by applying pulses of the saturating white light every 60 s when the actinic light was on. Maximum quantum yield of PSII photochemistry was calculated as $F_v/F_m = (F_m - F_0)/F_m$. The actual quantum yield of PSII photochemistry (Y) was calculated as $Y = (F'_m - F_s)/F'_m$.

All assays and measurements were performed in quintuplicate. The analysis of photosynthetic pigment content as well as the measurements of tissue electrolyte leakage

and relative water content were performed after 1, 8 and 15 days of keeping the stems of *W. florida* in distilled water. The chlorophyll fluorescence measurements (F_0, F_m, F_v/F_m,Y), were carried out after 1 and 10 days. All results included in the tables were statistically analysed with the SAS software package, ver. 9.1.3, while the significance of differences was assessed using Duncan's confidence intervals at p = 0.05.

RESULTS AND DISCUSSION

The solution of GA_3 at a concentration of 0.25 mmol · dm^{-3} and Chrysal Clear 2 significantly affected the longevity of the leafy stems of *W. florida* (extension of their vase life by 5 and 7 days respectively relative to the control) (Tab. 1). The positive influence of a pre-treatment with gibberellic acid solution confirmed earlier studies made by Janowska and Schroeter-Zakrzewska [2008] on leaves of *Arum italicum*. Skutnik and Rabiza-Świder [2005] also found nearly a doubling of the extension of the vase life of leaves of *Zantedeschia aethiopica* after 24-hour conditioning in a solution of GA_3 at 0.25 mmol · dm^{-3}. The same substance also prolonged the longevity of shoots of *Asparagus densiflorus* 'Myriocladus', whereas the commercially marketed post-harvest treatment Chrysal SVB extended the vase life of *Asparagus densiflorus* 'Meyerii' [Skutnik et al. 2006]. Chrysal Clear 2, applied on a continuous basis, extended the post-harvest vase life of *Cordyline* 'Glauca' and *C. stricte*, which was found in the study conducted by Koziara and Suda [2008].

Table 1. Effect of conditioning of *Weigela florida* 'Variegata Nana' stems in the solutions of spermine, GA_3, BA, Chrysal Clear 2, and Citrosept on their post-harvest vase life

Tabela 1. Wpływ kondycjonowania pędów *Weigela florida* 'Variegata Nana' w roztworach sperminy, GA_3, BA, Chrysalu Clear 2 i Citroseptu na ich trwałość pozbiorczą

Conditioning substance Substancja kondycjonująca	Vase life (days) Trwałość (dni)
Control – Kontrola	7.50 a*
Spermine 1 mmol · dm^{-3}	7.50 a
GA_3 0.25 mmol · dm^{-3}	12.60 b
BA 0.1 mmol dm^{-3}	6.92 a
Chrysal Clear 2	14.64 c
Citrosept 1%	7.11 a

* Means followed by the same letter within a column do not differ significantly at $P_{0.05}$

* Średnie wartości w kolumnach oznaczone tymi samymi literami nie różnią się istotnie przy $P_{0,05}$

Relative water content (RWC) in the leaves of *W. florida* decreased significantly during advancing senescence (tab. 2). Changes in the value of RWC indicate of increasing water stress in the leafy stems, resulting from being cut off from the parent plant. Disturbances of water balance in the shoots, which accelerate the aging process, are

confirmed by research of Eason et al. [1997], Pogroszewska et al. [2009], and Lü et al. [2010]. After the first day of the experiment, the highest water content was found in the treatment with a 1% solution of Citrosept (RWC increased by 14.4%, compared to the control). The measurement taken after 8 days of experiment revealed a decrease in RWC value by 14.5%, when stems were treated with spermine and by 12.4%, at 0.25 mmol · dm^{-3} concentration of GA_3 as compared to stems treated only distilled water. Fifteen days after the treatment in the leaves of the stems pre-treated with Chrysal Clear 2 showed an increase in RWC of 18.1%, compared to the control. Chrysal Clear 2, manufactured by a Dutch company, maintain the water balance equilibrium in shoots cut off from the parent plant due to the presence of saccharose; they also contain bactericidal and fungicidal substances [Łukaszewska 2009]. This assumption find confirmation in earlier studies made by Koziara and Suda [2008]. Leaves of *Cordyline* 'Glauca' were conditioned in the solution of Chrysal Clear 2 resulted in the lowest loss in fresh weight and water content during the experiment.

Table 2. Effect of conditioning of *Weigela florida* 'Variegata Nana' stems in the solutions of spermine, GA_3, BA, Chrysal Clear 2, and Citrosept on the relative water content (RWC) and electrolyte leakage (E_L) in leaves

Tabela 2. Wpływ kondycjonowania pędów *Weigela florida* 'Variegata Nana' w roztworach sperminy, GA_3, BA, Chrysalu Clear 2 i Citroseptu, na wartość wskaźników względnej zawartości wody (RWC) i wypływu elektrolitów (E_L) w liściach

Date of analysis Termin analizy	Conditioning substance Substancja kondyconująca	Parameter (%) – Mierzony parameter (%)	
		RWC	E_L
After 1 day Po 1 dniu	Control – Kontrola	71.14 cd*	52.10 f
	Spermine 1 mmol · dm^{-3}	75.63 fgh	43.70 c
	GA_3 0.25 mmol · dm^{-3}	69.47 c	36.64 a
	BA 0.1 mmol dm^{-3}	75.96 gh	60.57 ij
	Chrysal Clear 2	78.44 hi	56.17 g
	Citrosept 1%	81.41 i	42.95 bc
After 8 days Po 8 dniach	Control – Kontrola	74.29 defg	56.89 gh
	Spermine 1 mmol · dm^{-3}	63.53 b	46.70 d
	GA_3 0.25 mmol · dm^{-3}	65.06 b	40.83 b
	BA 0.1 mmol dm^{-3}	72.01 cde	63.05 jk
	Chrysal Clear 2	77.02 gh	56.84 gh
	Citrosept 1%	71.80 cde	48.10 de
After 15 days Po 15 dniach	Control – Kontrola	63.63 b	65.29 k
	Spermine 1 mmol · dm^{-3}	54.73 a	59.05 hi
	GA_3 0.25 mmol · dm^{-3}	62.14 b	43.66 c
	BA 0.1 mmol dm^{-3}	70.65 c	56.99 gh
	Chrysal Clear 2	75.18 efgh	59.85 i
	Citrosept 1%	65.11 b	50.80 ef
Mean after 1 day Średnia po 1 dniu		75.34 c	48.69 a
Mean after 8 days Średnia po 8 dniach		70.62 b	52.07 b
Mean after 15 days Średnia po 15 dniach		65.24 a	55.94 c

* Means followed by the same letter within a column do not differ significantly at $P_{0.05}$

* Średnie wartości w kolumnach oznaczone tymi samymi literami nie różnią się istotnie przy $P_{0,05}$

Senescence leads to biochemical and biophysical changes in the cell membranes [Leurentz et al. 2002]. Later there occur changes in the permeability of the cell membranes, resulting in partial interaction between the components of the vacuole and the cytoplasm; the ratio of sterols to phospholipids also changes [Trippi and Paulin 1984]. Membrane degradation is reversible as long as proteins and lipids are able to maintain the structure of the membranes. If senescence is not inhibited, the tonoplast expands and ruptures, and this ultimately leads to the loss of cytoplasm integrity, leakage of the contents of the cells and their death [Nooden et al. 1997]. The results in table 2 indicate increased loss of membrane integrity, which was correlated with the duration of the experiment. In cell electrolyte leakage (E_L) in the leaves of *W. florida* increase from the first to the last day of the experiment. These results find confirmation in earlier studies conducted on *Paeonia lactiflora* leaves and flowers [Michałek et al. 2006, Pogroszewska et al. 2009]. When investigating the effect of conditioning on the leafy stems of the studied species in the solutions of the investigated chemical substances, the lowest values of electrolyte leakage were found for GA_3 at 0.25 mmol · dm^{-3}. The application of gibberellic acid caused a decrease in E_L by 29.7, 28.2, and 33.1%, respectively, compared to the control, during the successive measurements made after day 1, 8, and 15 of the experiment. The positive effect of this growth regulator on cytoplasmic membrane integrity was shown by earlier studies conducted by Agbaria et al. [2001] on rose petals and by Michałek et al. [2006] on leaves of *Paeonia lactiflora*.

One of effective methods to assess post-harvest quality of the cut florist greens is the analysis of photosynthetic pigment content. During leaf senescence, chlorophyll content decreases in favour of carotenoids whose synthesis increases during this period [Sood and Nagar 2003, Park et al. 2007]. The results in table 3 indicate decreased of chlorophyll "a" and "b" content, and increased of carotenoids content, which was correlated with the duration of the experiment. These results were also confirmed by earlier studies made by Skutnik et al. [2004, 2006], Skutnik and Rabiza-Świder [2004, 2005] as well as Pogroszewska et al. [2009]. The highest chlorophyll "a" content on day 15, were found in the treatments, in which the leafy stems were conditioned in 0.1 mmol · dm^{-3} solution of benzyloadenine and in Chrysal Clear 2. The measurement showed a 19.8% increase in the amount of chlorophyll "a" under the effect of BA and a 22.4% increase under the effect of Chrysal Clear 2, compared to the control. The last measurement showed the best effect of treated *W. florida* steams with GA_3, BA and Chrysal Clear 2 on chlorophyll "b" content. The amount of this pigment increase respectively by 25.3, 35.4 and 25.3%, compared to the control. During leaf senescence levels of endogenous cytokinins fall [Gan and Amasio 1997]. To compensate this shortage of endogenous hormone the exogenous cytokinins are delivered to cut leafy steams in order to delay leaf yellowing, what is crucial for the florist green. Benzyladenine preserves post-harvest quality by delaying several processes involved in senescence, including chlorophyll degradation in cut leaves of *Zantedeschia* [Skutnik and Rabiza-Świder 2005], cut *Asparagus* greens [Skutnik and al. 2006] and in *Cordyline* leaves [Koziara and Suda 2008]. Also Chrysal Clear 2 has the feature to delay chlorophyll degradation, which was confirmed by earlier studies made by Koziara and Suda [2008]. Cited authors reported positive influence of Chrysal Clear 2 on inhibition of chlorophyll "a" and "b" degradation in cut *Cordyline australis* 'Red Star' leaves.

Table 3. Effect of conditioning of *Weigela florida* 'Variegata Nana' stems in the solutions of spermine, GA_3, BA, Chrysal Clear 2, and Citrosept on leaf photosynthetic pigment content

Tabela 3. Wpływ kondycjonowania pędów *Weigela florida* 'Variegata Nana' w roztworach sperminy, GA_3, BA, Chrysalu Clear 2 i Citroseptu, na zawartość barwników asymilacyjnych w liściach

Date of analysis Termin analizy	Conditioning substance Substancja kondycjonująca	Leaf pigment content, mg g^{-1} DW Zawartość barwników w liściach, mg g^{-1} s. m.		
		Chl. a Chl. a	Chl. b Chl. b	carotenoids karotenoidy
After 1 day Po 1 dniu	Control – Kontrola	4.87 de	1.10 de	2.28 a
	Spermine 1 mmol · dm^{-3}	5.49 fg	1.11 de	2.42 a
	GA_3 0.25 mmol · dm^{-3}	6.59 h	1.32 f	2.84 b
	BA 0.1 mmol dm^{-3}	6.91 h	1.36 f	2.94 bc
	Chrysal Clear 2	5.80 g	1.15 e	3.00 bc
	Citrosept 1%	6.81 h	1.45 f	2.52 a
After 8 days Po 8 dniach	Control – Kontrola	4.79 d	0.94 abc	2.94 bc
	Spermine 1 mmol · dm^{-3}	4.88 de	1.15 e	2.94 bc
	GA_3 0.25 mmol · dm^{-3}	4.78 d	1.08 cde	3.01 bc
	BA 0.1 mmol dm^{-3}	5.16 ef	1.04 cde	3.22 c
	Chrysal Clear 2	4.92 de	1.16 e	3.06 bc
	Citrosept 1%	4.25 b	0.93 abc	2.78 b
After 15 days Po 15 dniach	Control – Kontrola	3.89 a	0.79 a	3.15 c
	Spermine 1 mmol · dm^{-3}	4.36 bc	0.88 ab	3.01 bc
	GA_3 0.25 mmol · dm^{-3}	4.40 bc	0.99 bcd	3,85 e
	BA 0.1 mmol dm^{-3}	4.66 cd	1.07 cde	3.95 e
	Chrysal Clear 2	4.76 d	0.99 bcd	3.55 d
	Citrosept 1%	3.85 a	0.83 a	3.86 e
Mean after 1 day Średnia po 1 dniu		6.08 c	1.25 c	2.67 a
Mean after 8 days Średnia po 8 dniach		4.79 b	1.05 b	2.99 b
Mean after 15 days Średnia po 15 dniach		4.32 a	0.92 a	3.56, c

* Means followed by the same letter within a column do not differ significantly at $P_{0.05}$

* Średnie wartości w kolumnach oznaczone tymi samymi literami nie różnią się istotnie przy $P_{0,05}$

The highest carotenoid content was found in the treatments of *W. florida* stems with gibberellic acid at 0.25 mmol · dm^{-3}, benzyladenine at 0.1 mmol · dm^{-3} and 1% solution of Citrosept (measurements after day 15 of the experiment) (tab. 3). On the third measurement a 22.2%, 25.4% and 22.5% increase in the amount of carotenoids was found under the effect of GA_3, BA and Citrosept respectively. The enhanced synthesis of carotenoids during the duration of the experiment is also associated with their ability to scavenge free oxygen radicals due to the presence of conjugated double bonds. Carotenoids are generated in increased amounts during oxidative stress accompanying plant senescence. They also react with singlet oxygen and organic radicals formed as a result of lipid peroxidation [Sroka et al. 2005].

It was found that the duration of the experiment and the applied conditioning substances significances affected chlorophyll fluorescence parameters (tab. 4). After

Table 4. Effect of conditioning of *Weigela florida* 'Variegata Nana' stems in the solutions of spermine, GA_3, BA, Chrysal Clear 2, and Citrosept on some chlorophyll fluorescence parameters (F_0, F_m, F_v/F_m,Y)

Tabela 4. Wpływ kondycjonowania pędów *Weigela florida* 'Variegata Nana' w roztworach sperminy, GA_3, BA, Chrysalu Clear 2 i Citroseptu, na wartość wybranych parametrów fluorescencji chlorofilu (F_0, F_m, F_v/F_m,Y)

Date of analysis Termin analizy	Conditioning substance Substancja kondycjonująca	Chlorophyll fluorescence parameters Parametry fluorescencji chlorofilu			
		F_0	F_m	F_v/F_m	Y
After 1 day Po 1 dniu	Control – Kontrola	0.28 bc*	0.88 ef	0.43 ab	0.31 a
	Spermine 1 mmol · dm^{-3}	0.29 c	0.80 de	0.39 a	0.29 a
	GA_3 0,25 mmol · dm^{-3}	0.29 c	0.63 abc	0.55 d	0.52 cd
	BA 0,1 mmol dm^{-3}	0.30 c	0.58 ab	0.50 bcd	0.52 cd
	Chrysal Clear 2	0.21 a	0.54 ab	0.45 abc	0.47 bc
	Citrosept 1%	0.24 ab	0.55 ab	0.48 bcd	0.51 cd
After 10 days Po 10 dniach	Control – Kontrola	0.30 c	0.84 def	0.52 cd	0.41 b
	Spermine 1 mmol · dm^{-3}	0.27 bc	0.72 cd	0.37 a	0.28 a
	GA_3 0,25 mmol · dm^{-3}	0.30 c	0.73 cd	0.72 e	0.57 d
	BA 0,1 mmol dm^{-3}	0.29 c	0.66 bc	0.70 e	0.53 cd
	Chrysal Clear 2	0.31 c	0.97 f	0.72 e	0.77 e
	Citrosept 1%	0.22 a	0.51 a	0.42 ab	0.44 b
Mean after 1 day Średnia po 1 dniu		0.27 a	0.66 a	0.46 a	0.44 a
Mean after 10 days Średnia po 10 dniach		0.28 a	0.74 b	0.57 b	0.50 b

* Means followed by the same letter within a column do not differ significantly at $P_{0.05}$

* Średnie wartości w kolumnach oznaczone tymi samymi literami nie różnią się istotnie przy $P_{0,05}$

10 days of the experiment maximum fluorescence (F_m), maximum quantum yield of PSII (F_v/F_m), and actual quantum yield of PSII (Y) rose insignificantly. During the first measurement, performed after one day of the experiment, the lowest value of minimum and maximum fluorescence was found in the treatment in which the stems of *W. florida* were pre-treated in the solution of Chrysal Clear 2 (a decrease in the values of these parameters by 25.0 and 38.6%, respectively, compared to the control). When analysing the results obtained during the second measurement, made after 10 days of the experiment, a decrease in the values of F_0 and F_m was found in the treatment in which the stems were pre-treated in a 1% solution of Citrosept (the values of these parameters were reduced respectively by 26.7 and 39.3%, compared to the control treatment). The lowest values of F_v/F_m and Y were recorded in the treatment in which spermine was used as the conditioning substance at a concentration of 1 mmol · dm^{-3}. This is confirmed by a 29.9 and 12.6% decrease in the values of these parameters compared to the treatment in which the stems were kept in distilled water from the beginning of the experiment. On the other hand, the highest increase in the value of F_v/F_m, compared to the control treatment, was found under the influence of conditioning of *W. florida* stems in the solutions of gibberellic acid, benzyladenine and Chrysal Clear 2. The application of above-mentioned substances caused an increase in the value of F_v/F_m respectively by 38.5, 34.6 and 38.5%, compared to the control. Moreover, pre-treatment of the leafy stems in the solution of Chrysal Clear 2 resulted in an increase in the value of Y by

87.8% and of F_m by 15.5% compared to the control, though in this latter case the significance of differences was not proven statistically.

One of the effective methods for assessing the quality of vegetables, fruits, and cut flowers at harvest and also during storage represents the measurement of chlorophyll fluorescence [Jolliffe and Lin 1997]. Investigating leaf senescence in *Paeonia lactiflora*, Michałek et al. [2006] found a decrease in maximum and actual quantum yield of chlorophyll as well as in the efficiency of open PSII reaction centres, which was correlated with the duration of the experiment. These authors noted a negative influence of the growth regulators (BA and GA_3) and of Chrysal Glory on F_v/F_m and Y when applied as conditioning products. Only benzyladenine, applied at a concentration of 100 mg · dm^{-3}, increased maximum quantum yield of chlorophyll. Similar results were also obtained by Hossain et al. [2008], who analysed changes in the values of some chlorophyll fluorescence parameters during senescence of bougainvillea shoots. Jordi et al. [1994], when studying the effect of gibberellic acid on the photosynthetic rates during senescence of cut stems of *Alstroemeria*, found that changes in photosynthetic pigment content were not correlated with the intensity of photosynthesis or gas exchange. These authors suggest that the values of the chlorophyll fluorescence parameters F_0, F_m and Y are affected by Rubisco concentration and activity, which is confirmed by the study of Grover [1993], and also by the intensity of transpiration.

CONCLUSIONS

1. Senescence of *Weigela florida* 'Variegata Nana' cut stems caused a decrease in RWC, chlorophyll "a" and "b" content and an increase in electrolyte leakage and carotenoid content in the leaf tissues.

2. Conditioning of stems in the aqueous solution of Chrysal Clear 2 retains water in leaf tissues and increases maximum quantum yield and actual photochemical activity, which is translated into the extension of post-harvest vase life of cut stems of *W. florida*.

3. Conditioning of *W. florida* stems in the solution of gibberellic acid at a concentration of 0.25 mmol · dm^{-3} had the most beneficial effect on the condition of the cytoplasmatic membranes.

4. The highest content of photosynthetic pigments (chlorophyll "a" and "b") was found under the effect of pre-treatment of *W. florida* stems in a 0.1 mmol · dm^{-3} solution of BA and in Chrysal Clear 2.

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WPŁYW SUBSTANCJI CHEMICZNYCH NA STARZENIE PĘDÓW *Weigela florida* (Bunge) A. DC. 'VARIEGATA NANA'

Streszczenie. Cięte liście oraz ulistnione pędy stanowią obok kwiatów bardzo cenny materiał bukieciarski. Często jednak zielone dodatki jako pierwsze w kompozycji tracą wartość ozdobną, szybko więdną, bledną czy brązowieją. Dlatego ważne jest opracowanie preparatów do kondycjonowania zieleni ciętej, które skutecznie przedłużyłyby jej trwałość i zahamowały postępujący proces starzenia. Celem podjętych badań było sprawdzenie, czy kondycjonowanie ulistnionych pędów *Weigela florida* 'Variegata Nana' w roztworach regulatorów wzrostu i preparatów komercyjnych może mieć wpływ na ich jakość

pozbiorczą. W przeprowadzonym eksperymencie analizowano trwałość pozbiorczą, stopień uwodnienia tkanek, integralność błon cytoplazmatycznych, zawartość barwników asymilacyjnych i wybrane parametry fluorescencji chlorofilu. Postępujący proces starzenia pędów *W. florida* spowodował obniżenie ich jakości pozbiorczej, o czym świadczy spadek wartości wskaźnika względnej zawartości wody (RWC) oraz wzrost wartości wskaźnika wypływu elektrolitów (E_L) w tkankach liści. Trwałość ciętych pędów *W. florida* najskuteczniej przedłużał preparat Chrysal Clear 2 zastosowany w formie 24-godzinnego kondycjonowania. Ten sam preparat wpłynął także korzystnie na stopień uwodnienia tkanek liści badanego gatunku oraz na wartość parametrów fluorescencji chlorofilu, w tym na maksymalną wydajność kwantową i rzeczywistą aktywność fotochemiczną. Na stan membran cytoplazmatycznych najkorzystniej wpłynęło kondycjonowanie pędów krzewuszki w roztworze kwasu giberelinowego w stężeniu 0,25 mmol · dm^{-3}, natomiast najwyższą zawartość barwników asymilacyjnych (chlorofilu „a" i „b") stwierdzono po zastosowaniu kondycjonowania pędów w 0.1 mmol · dm^{-3} roztworze BA i Chrysalu Clear 2.

Słowa kluczowe: barwniki asymilacyjne, E_L, fluorescencja, krzewuszka, regulatory wzrostu, RWC, starzenie

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