Corvinus University of Budapest

The production and postharvest treatments of Hungarian *Salix* taxa used as woody cuts

Thesis of PhD Dissertation

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1 INTRODUCTION AND AIMS OF THE STUDY

In the marketing of ornamental plants, the so called woody cuts are becoming more and more popular among traditional (greenhouse) cut flowers throughout Europe, and also in Hungary in the last decade. These woody cuts serve as fillers or even as main decorative elements in a bouquet. Their appearance, as well as their decorative value, is very desirable. Sometimes they even exceed that of traditional cut flowers. Cultivation costs are much lower due to open ground production. The cut stems and branches of willow species with catkins (appearing before the leaves) are a type of woody cuts. Their main demand period is before Easter, but they often start to show up in February in bouquets and in floral spring compositions.

There is a relatively big number of willow species in Hungary. There is also considerable cross pollination in nature resulting in many forms and transition forms. This variability in the 12 *Salix* species, their subspecies, varieties and hybrids should be discovered and exploited. Today, cut willow twigs with catkins mainly come to the Hungarian market from gathering. It would be good both from the aspect of horticultural production and the protection of nature as well to take them into formal production.

Our knowledge is incomplete about production, because the cultivation of willow species to produce woody cuts decorated with catkins is not yet practiced in Hungary. This is especially true for the production of the prostrate *S. rosmarinifolia*, which has a totally different habit than other *Salix* species. As it is commonly known, willows root easily. At the same time, the most decorative male clones root poorly. The relevant literature is also quite contradictory.

Easter is a so-called moving holiday: its date changes every year. Thus the catkins developing in the fields often are already in full bloom and unsaleable. The later forming catkins of *S. rosmarinifolia* are not yet developed enough by the time of the peak demand.

The aim of my work was to present the richness resulting from Hungarian willows' variability; to select decorative clones capable for woody cuts' production; to provide useful data and information for taking (them) into production (e.g. plant growth, yield, rooting, plant spacing); to discover pathogens and pests and their effects on woody cut production; and to work out the proper method of vegetative propagation (rooting), forcing and preservation of the cut twigs, and a new method of evaluating the results of the preservation experiments.

2 MATERIALS AND METHODS

Besides the clones detailed in Table 1, I examined the following species from the aspect of woody cuts' production, demand and supply, and I observed pests and pathogens on them as well: *S. caprea, S. purpurea, S. rosmarinifolia, S. cinerea, S. viminalis,* and *S*. x *smithiana*.

Table 1: Taxa involved in the experiments, the place and time of their procurement/purchasing and propagation, and the summary of observations, examinations and experiments done with them

Taxa involved in the experiments / examinations	of cut twigs' purchasing		of propagation		Experiments and examinations					
	Place	Time	Method	Time	Morphological and phenological examinations (2004-2013)	Rooting trial	Detailed rooting experiment (2009 - 2010)	Forcing (2006, 2007)	Preservation (2008)	Determination of water-content and Z-factor (2013)
Salix caprea CA1	Flora Hungaria, Szigetszentmiklós	2004. 03.22	in open ground (Soroksár) with hardwood cuttings	2004, 2006, 2007	●	●	●	●	●	●
Salix purpurea PU1	Flora Hungaria, Szigetszentmiklós	2004. 03.01	in open ground (Soroksár) with hardwood cuttings	2004, 2006, 2007	●	●		●		
Salix purpurea PU2	Flora Hungaria, Szigetszentmiklós	2004. 03.22	in open ground (Soroksár) with hardwood cuttings	2004, 2006, 2007	●	●		●	●	
Salix rosmarinifolia RO1	Flora Hungaria, Szigetszentmiklós	2004. 03.22	in open ground (Soroksár) with hardwood cuttings	2004. 04.02	●	●			●	
Salix rosmarinifolia RO2	Flora Hungaria, Szigetszentmiklós	2004. 03.22	in open ground (Soroksár) with hardwood cuttings	2004.04.02	●	●				
Salix rosmarinifolia RO3	Flora Hungaria, Szigetszentmiklós	2006. March	in open ground (Soroksár) with hardwood cuttings	2006. April	●	●	●			
Salix rosmarinifolia RO4	Szombathely	2008. 02.08	in non-heated greenhouse with hardwood cuttings (Soroksár)	2008. 02.21	●	●				●
Salix rosmarinifolia	Felsőmizse	2006. 02.11	-	-				●		

2.1 Examination of the morphological and phenological characteristics, yield, and rooting of *Salix* clones selected for woody cuts' production

Phenological and morphological observations and research of the yield and rooting were made on parent plants and stools propagated 2, 3, 4, and 6 years later listed in **Table 2** between 2003 and 2013.

2.2 Effect of bottom heat, rooting compounds and time of propagation on the cuttings' rooting

Experiments were made with *S. caprea* CA1 and *S. rosmarinifolia* RO3 clones which rooted in a very low percentage without any treatment in open ground hardwood cutting propagation previously. In a three-factor trial the following factors' effects were examined.

Applied treatments

- Rooting on heated bins (500 cuttings/clone/propagation time)
- Rooting without bottom heat (500 cuttings/clone/propagation time)

Applied rooting compounds

- α-naphthalene acetic acid (NAA) in 6‰ concentration in 50% ethanol solution
- α-naphthalene acetic acid (NAA) in 6‰ concentration in the form of talcum powder
- Kelpak® in 2‰ concentration, systemic treatment for 30 minutes
- Kelpak® in 2‰ concentration, systemic treatment for 8 hours
- Control

Time of propagation and cutting twigs for hardwood cutting propagation

- Propagation in November (third decade of November, 2009.)
- Propagation in December (third decade of December, 2009.)
- Propagation in January (third decade of January, 2010.)

An evaluation series were set up for each species to classify cuttings at the final evaluation. The size and amount of the developed roots gave the point of reference. The final evaluation took place on 22nd February, 19th March, and 22nd March, 2010 in case of cuttings propagated in November, December and January, respectively. The following six categories were determined:

- 0: did not root at all
- 1: developing roots shorter than 10 mm or callus on the cuttings
- 2: few (1-3) medium (10-30 mm long) intact, healthy roots on the cuttings
- 3: 3-6 roots longer than 20 mm – half of root ball full with roots
- 4: entire root ball full with roots
- x: rooted shoot originated and separated from the cutting

2.3 Observation and identification of pathogens, pests, and others causing quality defects of *Salix* woody cuts

First of all the effects (injuries) and symptoms of the pathogens and pests were observed on the plants. To identify the pathogens and pests examinations with microscope and experiments to raise adult forms were carried out.

2.4 Examinations of forcing *Salix rosmarinifolia* cut twigs with catkins

Two different forcing solutions were made, for control the twigs were placed in tap water. Each treatment were tested on 33 twigs in three different containers, where twigs cut from the same polycormon, one-year-old non-branching twigs, and branching ones with older stem parts

were placed. Development of the floral and open buds was registered daily until the stock became saleable (for three weeks). Forcing solutions:

1. forcing solution (1,5‰ GA_3):

- 8-hydrxyquinoline-sulphate (8HQS): 0,4 g/l
- Sucrose (beet sugar): 20 g/l
- Gibberellic-acid (GA_3): 1,5 g/l
- Citric acid: 0,73 g/l

2. forcing solution (6‰ GA_3):

- 8- hydrxyquinoline-sulphate (8HQS): 0,4 g/l
- Sucrose (beet sugar): 20 g/l
- Gibberellic-acid (GA_3): 6 g/l

2.5 Examination of the long-term preservation of *Salix* cut twigs

Preservation experiments were carried out between February-June, 2008 with three willow species' cut twigs (*S. rosmarinifolia*, *S. purpurea*, *S. caprea*). Quantitative (see chapter 2.5.4) and qualitative (see chapter 2.5.5) methods were applied for the evaluation.

2.5.1 Taxa involved in the preservation experiment

Twigs with catkins were cut in Soroksár, at the end of February, 2008 from the selected clones:

- *Salix caprea* CA1 clone 80 (20/treatments) 90 cm long twigs
- *Salix purpurea* PU2 clone 120 (30/treatments) 90 cm long twigs
- *Salix rosmarinifolia* RO3 clone 100 (20/treatments) 90 cm long twigs

2.5.2 Treatments trialed at the preservation experiment

In case of *S. caprea* and *S. purpurea* clones the following four (GU, CL, CLC, DC), in case of the *S. rosmarinifolia* clone the following five (GU1, GU2, CL, CLC, DC) treatments were applied:

1.) Dry Control (DC): Twigs were kept in the laboratory of the Department of Floriculture and Dendrology, Corvinus University of Budapest, at room temperature (23-24^{o}C), dry, in a 10 cm diameter and 25 cm high cylinder glass vase.

2.) Glycerin uptake (GU): A 1:2 ratio of glycerin-water mixture was applied in case of *S. caprea* twigs, and a 1:1 ratio of glycerin-water mixture was applied in case of *S. purpurea* twigs. The applied glycerin (1,2,3-trihidroxi-propane) was 99,5% (analytical) clear, it was mixed with distilled water. The treatment (uptake of the glycol solution) took one week for both species. *S. rosmarinifolia* twigs were treated with glycerin in two ways:

2/a.) Glycerin uptake for one week (GU1): Twigs were placed in a 1:1 ratio of glycerin-water mixture. Bottom 10 cm of the 90 cm long twigs was covered with the preservative solution. The stem parts (the entire bundle) above the container were wrapped with polyethylene foil.

2/b.) Glycerin uptake for two weeks (GU2): Twigs were placed in the above described solution without foil coverage.

3.) Cold storage after harvest for 8/10 days (CL): Twigs were taken into cold storage immediately after harvest and kept at 4°C for eight (*S. rosmarinifolia)* or ten (*S. caprea, S. purpurea)* days. Following the cold treatment twigs were kept in the Department's Laboratory to imitate a bundle's state getting out from the grower's cold storage and used by the florist/end user.

4.) Cold storage control (CLC): Twigs were kept in a cold store at 4°C continuously from harvest until final evaluation (for 16 weeks). Intermediate evaluations were made six times in an unheated greenhouse at a temperature close to that of the cold store.

2.5.3 Date of intermediate and final evaluations

Measurements were repeated six times (not included the initial measurements before the treatments) to exactly determine the elasticity between the end of February and June:

T1: first week of March

T2: second week of March

T3: third week of March (18th March, 2008)

T4: fourth week of March

T5: first week of April

T6: 18th and 19th of June, when long-term effects of the treatments could be examined.

2.5.4 A new method of determining *Salix* twigs' elastic modulus

To evaluate the results of the preservation experiment, no proper method existed. Therefore a new method of evaluating the results was worked out by determining the elastic modulus of the twigs under different treatments. Using several different formulas the effective *Young-modulus* of the twigs was calculated, thus the elasticity resulting from the different treatments became numerical. Young-modulus: $E = l^3F[12s\pi R^4]^{-1}$, where *l*: is the interval between the twig's two points of support (in case of *Salix caprea l* = 0,4 m; in case of *S. purpurea* and *S. rosmarinifolia l* = 0,25 m); *F*: the force needed to bend the twig 40 mm down in the middle of the above mentioned interval, measured with a manual dynamometer (each twig three times); *s*: the scale of stoop; *R*: the radius of the twigs' cross section calculated from the average diameter of the twigs measured at the two points of support with a digital caliper. A special stand was also designed and created to help with the measurements and the determination of the elastic modulus. Values of the elastic modulus were evaluated by statistical methods (ANOVA, Tukey-test, two-sample T-test) with IBM SPSS.

2.5.5 The method of evaluating morphological parameters

The following parameters and their changes were observed and measured: stem color, size of catkins (with Precision Gold digital caliper), state of catkins (e.g. undeveloped/elongated ra-

chis/blooming), ratio of the bud scale and visible catkins (part of the catkins not covered with the bud scale any more), falling off of bud scales and catkins (number or ratio of lasting and falling bud scales and catkins), tactile examination of twigs and catkins (e.g. soft/rigid, brittle, oily/dry, smooth/rough), angle of the catkins' rachis and the twig.

3 RESULTS

3.1 Morphological and phenological characteristics, yield, and rooting of *Salix* clones selected for woody cuts' production

A fancy looking *S. caprea* clone, two *S. purpurea* clones with different stem colors, and four *S. rosmarinifolia* clones were selected as a result of my work (Table 2).

Table 2: Botanical description of the selected *Salix* clones

Clone's code		CA1	PU1	PU2	RO1	RO2	RO3	RO4
Name		Big Black	Green Robust	Purple Lace	Straight Gold	Green Creeper	Straight Orange	Straight Scarlet
Stem color		greenish brown	yellowish green	bright red-dish purple	yellow	bright green	orange	scarlet red
Habit		hemisphere	hemisphere	flat-round, broad	initially growing broadwide, then straight upward	creeping shoots forming new roots	upward growing	upward growing
Final plant	height (cm)	230-280	270	300-320	100-150	40-60	160-180	100-140
	diameter (cm)	250	270	300-350	80-100	80-100	180	80-100
Leaf	shape	broadly elliptic	long oblanceolate, tapering ended	long oblanceolate, rounded ended	lanceolate	lanceolate, long ta-pering, slightly oblique	narrow lanceolate, long tapering	narrow lanceolate, parallel leaf-margins in the middle, taper-ing ended
	length (mm)	100	120	80	45-50	50-60	40-50	40-50
	width (mm)	20-30	15	15	8-10	10-12	4-5	10-12
	broadest part	mid-leaf/upper third	mid-leaf	upper third	middle / basal third	mid-leaf	mid-leaf / basal third	
	margin	sparsely dentate	finely dentate	finely dentate, basal third entire	finely dentate / crenate	entire	finely dentate	finely dentate

clone	CA1	PU1	PU2	RO1	RO2	RO3	RO4
upper side of the leaves	matt green, wrinkled	bald	bald	soft pubes-cent	bald	white soft pubescent, later gla-brous	soft pubes-cent
lower side of the leaves	densely pubescent, with ele-vated veins	glaucous which can be wiped off	glaucous which can be wiped off	glaucous, cannot be wiped off	glaucous which can be wiped off	silvery soft pubescent	silvery glaucous, cannot be wiped off
length of petiole (mm)	10	6	8	2-2,5	1-1,5	3	3-4
stipule	remain-ing	cadu-cous	cadu-cous	partially remain-ing	cadu-cous	partially remain-ing	cadu-cous

Older specimens of the *S. caprea* clone bloomed earlier and developed larger catkins than stools propagated one year later. The one-year-old stools yielded 86% 2nd class and 14% 3rd class cut twigs. Extra size (120-150 cm long) and branching twigs grow on at least two years old plants (**Table 3**). To produce pussy willow cut stems the proper planting distance is 1 m x 2,5 m.

Table 3: Sizes and percentile distribution of *S. caprea* CA1 clone's cut twigs

Stem length (cm)	Category	Category percentage in case of 2-5 years old stools (%)
120-150	Extra	18
90-120	1st class.	35
60-90	2nd class	34
60-90 and 90-120	Branching	13

PU2 clone of the two *S. purpurea* clones rooted more rapidly and intensively than the other clone, and both of them produced marketable cut twigs the first year after propagation (**Table 4**). In order to produce good quality twigs and to keep the plants at a reasonable size, it is necessary to cut them back every year. Plant height grew 20 cm in average as a result of twin row spacing according to stools planted in simple rows. Since too long stems developed catkins only on their tops due to shade caused by close planting, it is recommended to space in simple rows with 2,5 m distance.

Table 4: Sizes and percentile distribution of *S. purpurea* PU2 clone's cut twigs

Stem length (cm)	Category	Category percentage in case of 2-5 years old stools (%)
160-190	Extra	11
120-160	1st class.	18
90-120	2nd class	8
0-90	3rd class	58
180	Branching	5

Bud scales of the species *S. purpurea* do not fall off by splitting on the side towards the twigs like on other willow species. The base of the bud scale separates from the spike's basal part around. Then the entire bud scale, as a whole, like a small tube, slips off the growing spike lengthwise. Such type of bud scale separation does not allow the dry bud scales to remain at the base of the catkins, like they do on other *Salix* species used as woody cuts decorating with catkins. On this species all bud scales separate and fall off from the catkins much before the full bloom, at the same time as the rachis elongates. It is of great importance from the aspect of the decorative value.

S. rosmarinifolia clones reached their final size by the 3rd (RO1 and RO2) or 4th (RO3 and RO4) year after propagation. Woody cuts in sufficient amount and quality can be harvested from at least two (RO1 and RO2) or three (RO3 and RO4) years old plants (Table 5,Table 6Table 7Table 8). Proper planting space is 40 cm x 100 cm (RO1, RO2, RO4) or 40 cm x 150 cm (RO3). The largest amount of pussy willow catkins can be harvested from 4-8 years old stools. Older plants age and stunt so it is practical to site the plants on at least two different territories with four years difference and sustain the stools for eight to ten years.

Table 5: Yield, size categories and the percentage of categories of *S. rosmarinifolia* RO1 clone 2006-2013

Stem length (cm)	Category	Percentage of categories (%)					
		2006	2008	2010	2011	2012	2013
90-120	Extra	30	76	62	58	49	42
60-90	1st class	36	16	20	42	21	58
40-60	2nd class	18	5	18	0	26	0
20-40	3rd class	16	3	0	0	4	0
Average yield (twigs/stool)		24,5	56,7	117,6	66,7	100,1	92,5

Table 6: Yield, size categories and the percentage of categories of *S. rosmarinifolia* RO2 clone 2006-2012

Stem length (cm)	Category	Percentage of categories (%)				
		2006	2008	2010	2011	2012
40-60	1st class	26	30	11	46	20
25-40	2nd class	39	38	42	19,5	45
15-25	3rd class	35	32	47	34,5	35
Average yield (twigs/stool)		**40,5**	**37,8**	**31,4**	**18,9**	**28,3**

Table 7: Yield, size categories and the percentage of categories of *S. rosmarinifolia* RO3 clone 2008-2011

Stem length (cm)	Category	Percentage of categories (%)		
		2008	2010	2011
120-160	Extra	0	7	51
90-120	1st class	0	39	29
60-90	2nd class	24	54	12
40-60	3rd class	76	0	8
Average yield (twigs/stool)		**13,9**	**37,3**	**49,9**

Table 8: Percentage of categories of *S. rosmarinifolia* RO4 clone' cut twigs in 2013

Stem length (cm)	Category	Percentage of categories (%)
120-150	Extra	8
90-120	1st class	45
60-90	2nd class	47

3.2 Effect of bottom heat, rooting compounds and time of propagation on the cuttings' rooting

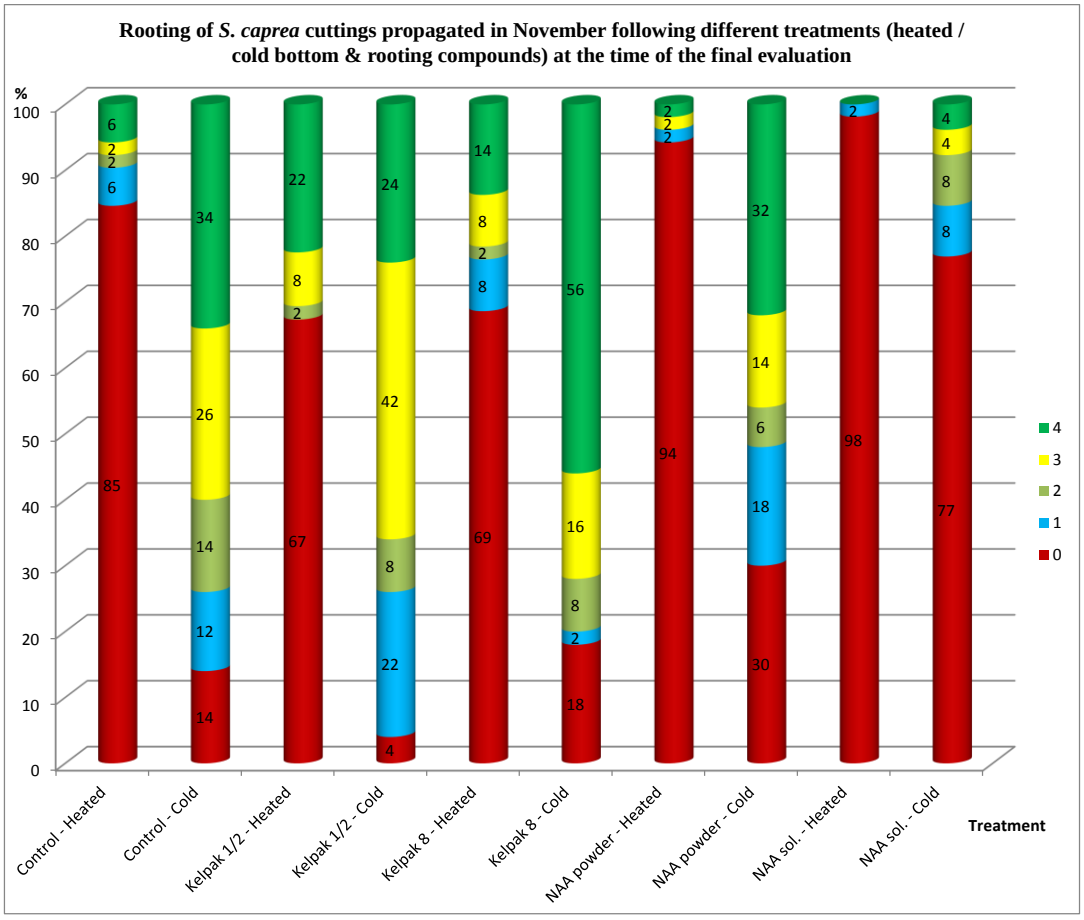

Figure 1: Rooting of *S. caprea* cuttings propagated in November at the time of the final evaluation

(For key to legend 0-4 see *Chapter 2.2* on *page 5*)

Formation of callus started on *S. caprea* cuttings without applying bioregulator or hormone treatment; sufficient root formation occurred on heated bins; and most intensive rooting was performed by cuttings propagated in January. Treatment with NAA (naphthil-acetic-acid) in 50% ethanol solution is not recommended to improve rooting, because following the initial extremely intensive callus formation – especially on heated bins – a significant proportion of the cuttings

died. Treatment with NAA in the form of talcum powder is recommended without bottom heat. As a result of this treatment, callus was formed on cuttings propagated in November after one week. It took eight weeks to develop at least five, 25 mm long roots per cuttings (Figure 1). The treatment resulted in intensive callus formation and initiation of adventitious roots on the cuttings propagated in January in two weeks. Of all rooting compounds involved in the experiment, the bioregulator called Kelpak® had the best effect on the rooting of *S. caprea* cuttings. Cuttings treated with Kelpak® for 30 minutes rooted better without bottom heat. 33-34% of the cuttings propagated in November and December perished on heated bins. The effect of the 8 hour long Kelpak® treatment was better expressed in combination with bottom heat. At least five, 5 mm long roots/cuttings formed on 54-56% of the cuttings propagated in December and January in three or two weeks, respectively (Figure 2).

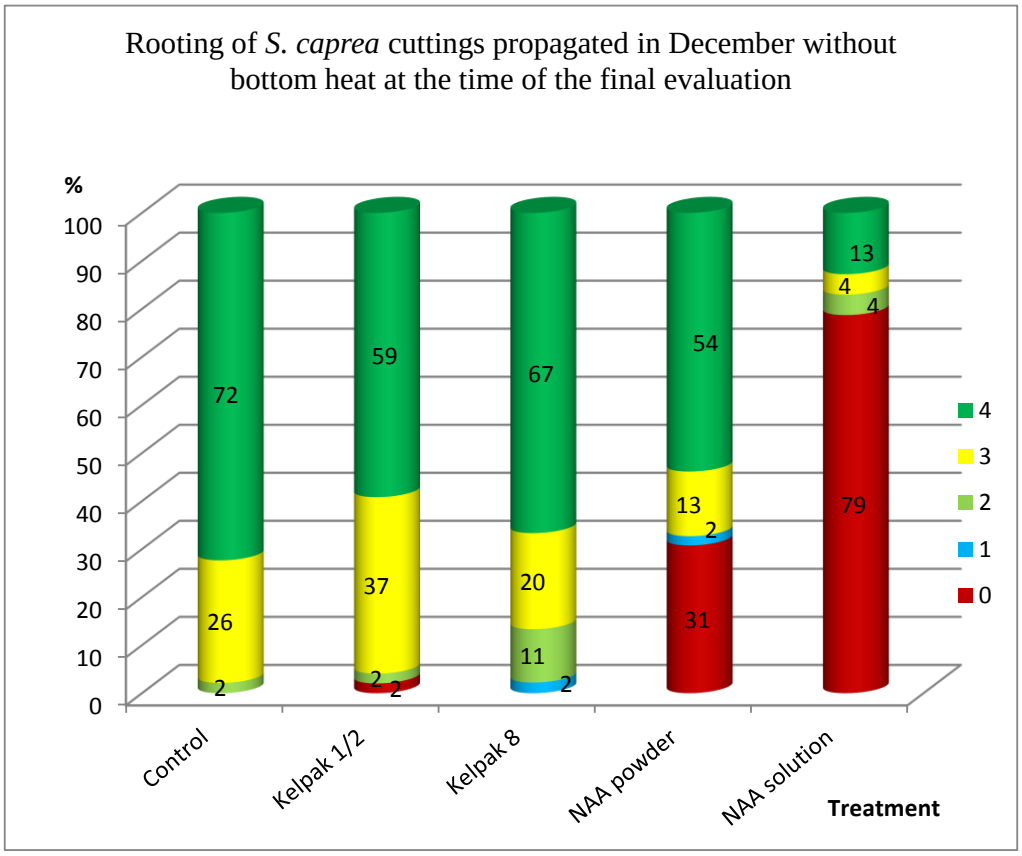

Figure 2: Rooting of *S. caprea* cuttings propagated in December at the time of the final evaluation

(For key to legend 0-4 see *Chapter 2.2* on *page 5*)

Using bottom heat is not recommended during the propagation of *S. rosmarinifolia* cuttings. It did not improve root formation. In most cases, cuttings died due to this treatment. Without bottom heat, root formation was best improved by 6‰ NAA powder treatment in case of cuttings propagated in November and December. It took eight weeks in November to form 10 mm long roots. Root formation took longer in case of propagating in December. Positive effect of the treatment showed up 13 weeks later when 27% of the cuttings rooted well in the rooting

medium (another 22% formed callus and roots shorter than 10 mm). Eight hour long treatment with the bioregulator Kelpak® had the second best effect on the rooting of *S. rosmarinifolia* cuttings propagated in November and December. Cuttings propagated in January showed best root formation following 30 minutes of Kelpak® treatment: 26% of the cuttings rooted well in the rooting medium, 14% formed callus and roots in 52 days (Figure 3).

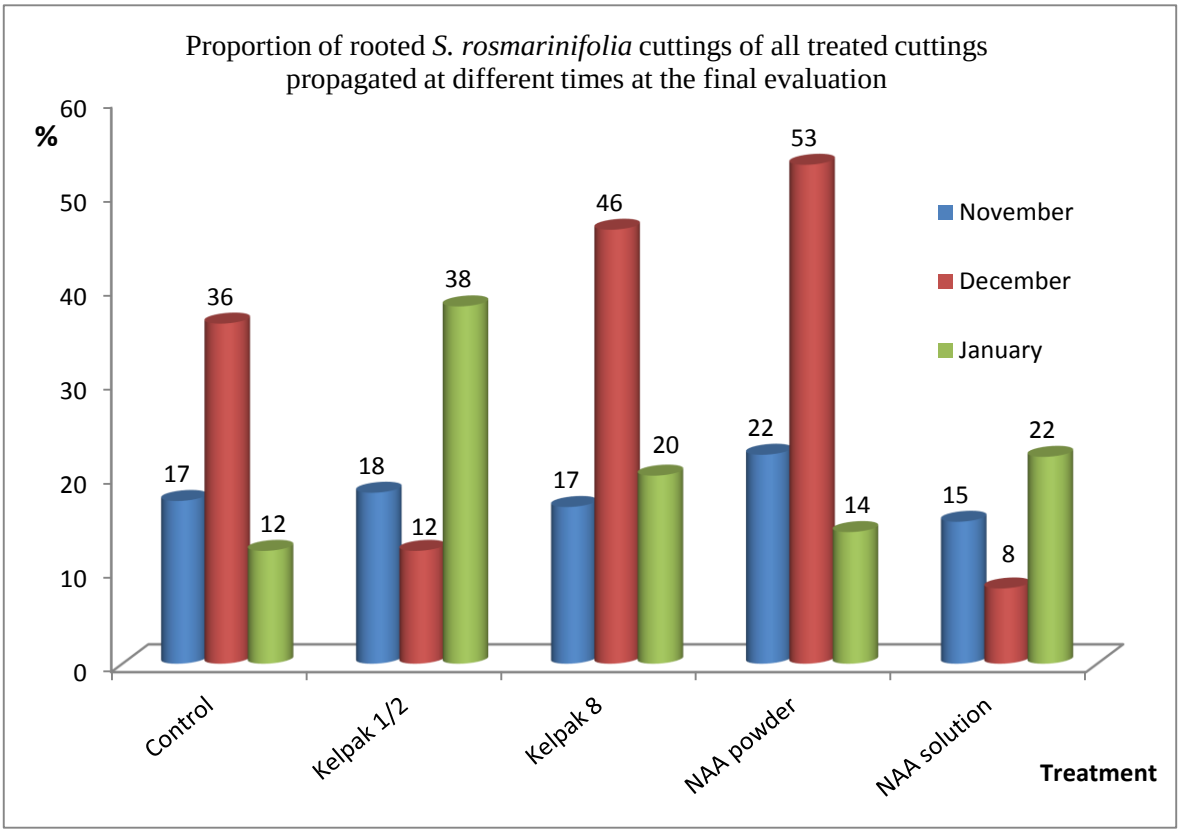

Figure 3: Rooting of *S. rosmarinifolia* cuttings propagated in November, December and January, following treatments

3.3 Pathogens, pests, and others causing quality defects of *Salix* woody cuts

On the clones selected for woody cuts' production and in their plantings and habitats, I observed and identified the following pathogens and pests. Pathogens: *Erysiphe adunca, Drepanopeziza sphaeroidea, Melampsora sp., Phellinus igniarius.* Pests*: Chaitophorus salijaponicus, Chaitophorus salicti, Pterocomma salicis, Arctornis l-nigrum, Pontania vesicator, Cossus cossus, Xanthia togata, Rodentia, Stylommatophora.* The existence of the diseases did not cause a problem. Plant protection is necessary only in case of severe infections; during times of extremely high amount of rainfall, for instance. Aphids and caterpillars of black v moths (*Arctornis l-nigrum*) harmed the leaves and shoots to such an extent that it had a negative effect on the growth and ripening of the shoots and twigs and therefore on the quality of the woody cuts produced for sale next spring. Caterpillars of goat moth (*Cossus cossus*) totally ruined some willow

stools in some plantings in Hungary. Caterpillars of pink-barred sallow (*Xanthia togata*) can cause serious damage during storage of the cut stems.

3.4 Forcing *Salix rosmarinifolia* cut stems

Dormancy of the buds of *S. rosmarinifolia* blooming at least four weeks later than other examined willow species could be broken successfully by applying GA_3 in the forcing solution, so that the desired state of catkins can be precisely timed. 30-50% bud break of the generative buds results in products ready to sell. Bud scales normally stay on the twigs by the catkins, but – in contrast with other willow twigs – it does not reduce the decorative value of the twigs called pearl-catkins in Hungary. Two weeks after starting the trials, 50% of the generative buds started to develop by using 1,5‰ concentration of the hormone. The four times higher, 6‰ hormone concentration had the same effect a week earlier. So the lower concentration proved to be sufficient for forcing *S. rosmarinifolia* twigs. Treatment should take place, however, in adequate time before the desired sales' period. Twigs cut with a stem older than a year old produced even 50% larger catkins in the forcing solution so it is recommended to cut the twigs with an older section of the stem for forcing. Table 9 summarizes the proportion of the buds broken in the forcing solutions.

Table 9: Proportion of buds broken on *S. rosmarinifolia* twigs

Treatments (forcing solutions)	Time elapsed after the experiment's setting:			
	4 days	7 days	14 days	21 days
Control	0%	14,986%	25,16%	25,167%
1,5 ppm GA_3	19,69%	29,72%	43,708%	43,708%
6 ppm GA_3	29,64%	44,842%	44,842%	44,842%

3.5 The effect of the preservative treatments on the elasticity and morphological parameters of *Salix* twigs

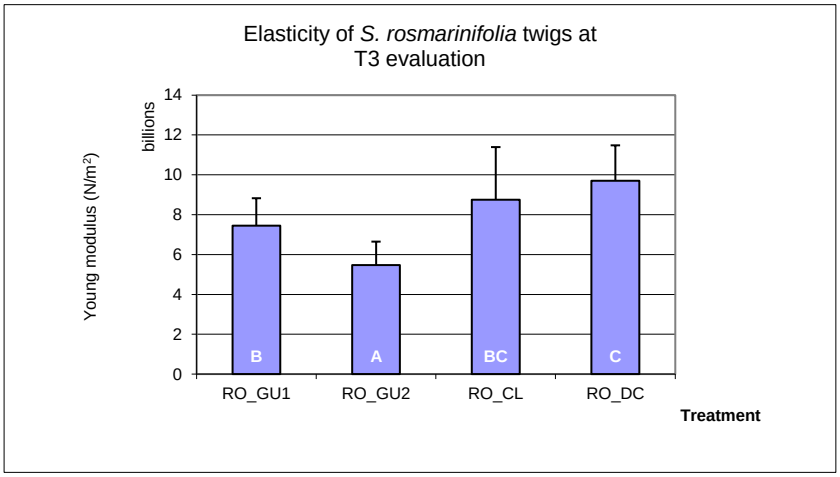

Figure 4: Elasticity of *S. rosmarinifolia* twigs at the third evaluation

Cold storage had similar effects to glycol (glycerin) preservation on the suppleness of *S. caprea* twigs in the short term (within two weeks). Therefore cold treatment can be sufficient only when there is a short time period between the time of harvest and the usage. Thinner twigs of *S. purpurea* and *S. rosmarinifolia* proved to be significantly suppler due to glycol preservation even in a short time period (Figure 4). Treatment with glycerin proved to be efficient in the preservation of all three species (Figure 5). Best results were achieved by using 33 percent by volume glycerin solution for one week in the case of *S. caprea*, 50 percent by volume glycerin solution for one week long treatment in case the of *S. purpurea*, and 50 percent by volume solution for two weeks long uptake in the case of *S. rosmarinifolia* twigs. Results showed that the twigs' elasticity was preserved even 16 weeks after the experiment set-up. Control twigs kept in room temperature dried out and the most catkins fell from the *S. purpurea* twigs. Control twigs of *S. rosmarinifolia* kept their decorative appearance and lost fewer catkins, but the stems dried out and become so brittle that they could not be used in any floral arrangements. Their color faded the least and the dry control twigs kept their greenish yellow stem color. *S. caprea* proved to be the least stable in point of stem color: the dry control twigs faded and the preserved twigs turned brown. Reddish *S. purpurea* twigs kept their original color best in the systemic preservation solution.

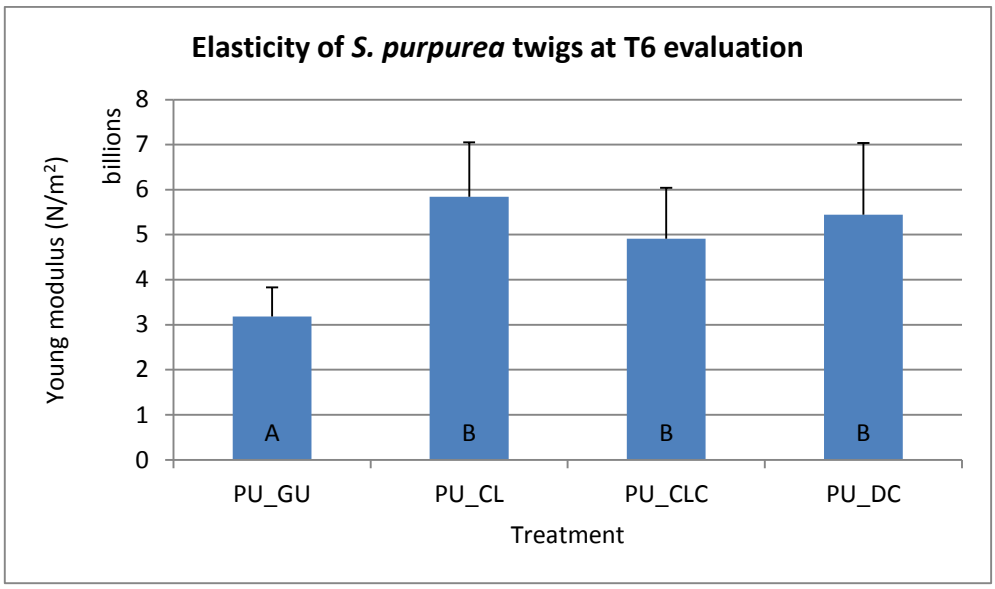

Figure 5: Elasticity of *S. purpurea* twigs at the final (6th) evaluation

3.6 Summary of new scientific results

1. Seven *Salix* taxa were selected from the Hungarian flora which can be used as woody cuts, decorative with their stem color / catkins. Description of six selected clones was published

in the manual-book of TÓTH (2012)[*]. Detailed botanical description of the selected clones and useful information on the plants' growth was given.

2. The special type of bud scale separation of the species *S. purpurea*, – which differs from the bud scale separation typical to the genus *Salix* – was first described and published.

3. Average yield of the selected clones was determined. Recommendation for the optimal length of keeping *S. rosmarinifolia* in culture was given. Optimal size categories of the selected clones were set up for marketing purposes.

4. Based on the rooting experiments it was determined, that rooting of the cuttings of *S. caprea* CA1 clone and *S. rosmarinifolia* RO3 clone (poorly rooting, but at the same time especially decorative woody cuts with catkins) can be improved with the applied treatments. Callus and root-formation can be induced by treatments.

5. Optimal rooting method was worked out for *S. caprea* CA1 clone and *S. rosmarinifolia* RO3 clone. The most effective rooting compound, date, duration, and temperature of the optimal treatments, and the suitable date to collect cuttings were determined.

6. The list of pests and pathogens most frequently occurring in Hungary on willow species grown for woody cuts' production was assembled. Effects of these pests and pathogens on the cut twigs' quality and quantity were also described.

7. Experiments intended to break *S. rosmarinifolia* generative buds' dormancy were first carried out. Required concentration of the hormone GA_3 and duration of the forcing time were determined.

8. A new method to quantify the twigs' elasticity was worked out.

9. The effectiveness of *Salix* twigs' glycol-preservation was proved by the method to quantify elasticity. This method is suitable to compare other specialty cut flowers' (woody cuts') preservation treatments and to evaluate the results of these experiments.

10. The proper methods to preserve three *Salix* species' cut twigs were worked out. Proper compounds of the preservative solutions and the duration of the preservative uptake were determined for each species.

4 DISCUSSION

4.1 *Salix* clones with decorative catkins and/or stem color selected for woody cuts' production

To produce woody cuts with decorative catkins the propagation of *S. caprea* CA1 clone should be carried out in a greenhouse with the aid of rooting compounds (6‰ NAA powder or at

[*] TÓTH I. (2012): Lomblevelű díszfák, díszcserjék kézikönyve. (*Manual of broad-leaved ornamental trees and shrubs*). Tarkavirág. Budapest. 789. pp.

least 30 minutes Kelpak® uptake) in early spring or in January at the time out for nursery works based on my rooting experiments. Applying bottom heat is not necessary. Rooted plants can be potted at spring or at the beginning of summer (other than the nursery works' peak time). They can be planted on the field (plant spacing: 1 x 2,5 m) at fall even until the end of November, depending on weather conditions. Plants should be cut back every year in order to produce twigs of proper quality. The time of harvesting the twigs with decorative catkins is usually in February or the first part of March, depending on the actual change of temperature. It requires special attention to harvest twigs with the proper state of the spike (catkin), because catkins can develop at such a rate due to a sudden warming at the end of winter or at early spring that saleable product cannot be harvested any more if not cut in time.

Both *S. purpurea* clones produce decorative woody cuts, especially the glossy purple twigs look good of clone PU2. Due to the extreme vigor of the plants at least as many shoots grow full with vegetative buds than shoots with generative buds. Therefore a remarkable amount of waste arouses at harvest and at selecting (cutting off second- or third-rate twigs). It is crucial to cut back stools every year, but this, and selecting the saleable twigs is quite labor-intensive. Thus it is suggested to plant these clones for woody cuts' production only on territories where cheap manual labor is available. Since too long twigs produced generative buds only on their upper parts due to shade, it is recommended to plant in simple rows at a 2,5 m spacing. The clones worth more experiments, for example grafting on other willow rootstocks, or to grow on high strain, in order to reduce vigor.

RO1 of the *S. rosmarinifolia* clones produced the highest yield of all considering both the number and size of the twigs. Yield of the purple stem colored clone RO4 was close to this, and habit and plant size was also similar to that of the yellow stem colored clone RO1. Clone RO2 is called 'Green Creeper' and it is a suitable plant for ground cover due to its creeping shoots which root easily, and the reticulated root system helps to set tilt grounds. This produces the shortest twigs of all *S. rosmarinifolia* clones, and the twigs are lightly curved due to the plant's habit (first growing sideway then upright). At the same time it is a really decorative woody cut thanks to the special, bright green stem color and short internodes full with tiny silver catkins, and can be used in small bouquets with shorter spring flowers (e.g. hyacinth, tulips). The largest *S. rosmarinifolia* clone is RO3, named 'Straight Orange', which reached its final size in the fourth year after propagation. Besides used as woody cut the clone is suitable to plant in home gardens, it makes a decorative color spot in every season. Bright orange-red twigs show at wintertime, decorative catkins appear on them before the leaves at spring, the leaves are decorative silvery at summer, and turn nice yellow at fall.

None of the clones produce real saleable cut twigs the first year after propagation, but it is necessary to cut them back anyways. Proper quality and quantity of cut twigs can be harvested from at least two years old, rather three years old stools. Instead of determining yield per stool it might work to give yield per area, since – especially the intensively rooting, creeping clone – stools spread over time.

It is strongly recommended to propagate *S. rosmarinifolia* clones in a greenhouse at the end of winter or at early spring. Hardwood cuttings can be cut even from the bottom, vegetative part of the twigs cut for sale. The thicker the cutting the better it roots. It is recommended to avoid the use of bottom heat. It is best to put the cuttings in cell-trays. Later the plants need to be potted, and after growing them in containers they can be planted in the field at fall. The low habit clones (e. g. RO2) it would be interesting to carry out ground-cover growing experiments, because some weeds (first of all members of *Poaceae* family) settle between the stools and overgrow the twigs. Harvest and selecting the twigs is more labor-intensive due to the dry weeds mixed with the twigs.

4.2 Effect of bottom heat, rooting compounds and time of propagation on the cuttings' rooting

The use of bottom heat proved to be unnecessary in case of both species, it proved to be even harmful for the cuttings of *S. rosmarinifolia* thus it is recommended to avoid its use.

In case of *S. caprea* propagation in November the best results seemed to be achieved by treating the cuttings with NAA powder in the first few weeks after propagation. The final evaluation however proved that the eight hours long treatment with Kelpak® improves best rooting without the use of bottom heat. In December cuttings root without the use of bottom heat or any rooting compound, but due to the extremely long rooting time at the December propagation, it is better to propagate in January (eight hours treatment with Kelpak®). Control cuttings rooted well, but it also took a long time in case of propagation in January (control cuttings formed only some callus three weeks after propagation, at the same time the treated cuttings formed 5-10, 10-20 mm long roots). Hence it is recommended to treat cuttings with Kelpak® so cuttings with enough roots can be potted still before the spring peak of nursery works.

Cuttings of *S. rosmarinifolia* RO3 clone rooted poorly even when treated with rooting compounds. The best result achieved was 53% rooting of all cuttings (6 ‰ NAA powder, in December). In November it was also the 6‰ NAA powder treatment to have the most (22%) rooted cuttings. Thus for propagation at late fall or early winter the 6‰ NAA treatment in the form of powder is recommended. In January this treatment proved to be less effective, propagating at this time is most effective with the 30 minutes long Kelpak® treatment.

4.3 Pathogens, pests, and others causing quality defects of *Salix* woody cuts

Pathogens and pests mentioned in literature did not mean such a problem on the clones I propagated or in plantings I visited. Thus treating plantings with fungicides is not reasonable unless an especially severe infection occurs due to extreme weather conditions. To prevent overwintering of rust (*Melampsora* spp.) and the willow anthracnose-causative organism (*Drepanopeziza sphaeroidea*) on the dead infected leaves in the litter it is recommended to take away, work in the soil or burn the litter at fall. In older plantations the appearance of trunk- and stool putrefacting fungi can be expected. In Soroksár a putrefacting fungus was found on the trunk of a four-year old *S. caprea* stool, but it did not affect yield so far.

Regarding pests it is the mass appearance of aphids and the caterpillars of black v moth (*Arctornis l-nigrum*) which can cause problems, prevention with pesticides is reasonable against them. Opposite to what is stated in literature the caterpillar of goat moth (*Cossus cossus*) does harm severely willow plantations throughout the country, entire stools died due to its damage. Most important way of prevention is the use of healthy propagation material not infected with caterpillars or eggs. Because of the hidden life-cycle of the larvae, there is no way of prevention in large. Possible prevention is uniquely kill the larvae by injecting gasoline, carbon-disulfide, or dichlorphos formulations into the tree-trunk where older caterpillars borrowed then sealing the holes with wax. To prevent re-infection swarming time can be detected with sex-pheromone traps and trunks can be sprayed. Larvae getting out of the eggs got killed by grazing the insecticide.

During storage of *Salix* woody cuts the appearance of pests should be prevented. Mice cannot get into a properly closed store, or can be trapped. Against pests (eggs, caterpillars) carried inside the storage with the bundles, an insecticide treatment can be applied spraying the plants before the floral buds' breaking.

4.4 Forcing *Salix rosmarinifolia* cut stems

The dormancy of buds on *S. rosmarinifolia* cut twigs can be broken and flower development can be speeded up by using gibberellic acid in the forcing solution based upon my experiments. It is unnecessary to use the hormone in a concentration of 6 ‰, a quarter of it (1,5‰ concentration) was enough to speed up bud opening. The floral buds' development started on stems cut at the beginning of February in water as well, but it took at least two weeks to even perceive the elongation of the rachis, and to descaling. During this time twigs could dry out easy. Bud development can be more precisely timed by adding gibberellic acid to the forcing solution. It is especially important to ensure high humidity during forcing since the tiny buds on the fine twigs

can dry up easily. Periderm injured during harvest can also cause drying up of the fine twigs, so proper, cautious harvesting is important. Breaking and opening of half or even only one third of the buds show such an image which makes the twigs already saleable. In a bouquet or bundle they look especially decorative, looking at them there is no feeling of any lack, they look like twigs full with catkins. It is recommended to harvest and place the twigs in the forcing solution with an older stem part. It always results in larger, more decorative catkins than on twigs cut from the older parts and place in the solution this way. *Salix rosmarinifolia* cut twigs are mostly demanded in stems cut one by one, florists prefer these cut stems instead of branching ones. Therefore forcing should happen in a branching state with older stem parts at the bottom, and the twigs should be cut off only after forcing one by one and put together in uniform bundles.

4.5 Preservation of *Salix* cut twigs

Literature includes mainly handbooks regarding glycol preservation which are not always based on scientific research, and sometimes controversial. I experienced this in case of VAUGHAN's book (1998) where it is said the end of treatments is shown by glycerin drops appearing on the surface of the plant. At the same time it is detailed in KOCH's (1995) handbook as a phenomenon to avoid, and the reasons of it are also explained. My own experiences support that the appearance of excess glycerin on the plant surface ("bleeding") threatens the salability of the product. Therefore it requires special attention to create suitable environmental conditions. Unwanted increase of humidity during the treatment can be prevented by proper ventilation and by placing the containers holding the preservative solution at a proper distance from each other.

Evaluation of the preservative treatments proved that in the long-term (over three months) glycerin preservation can keep the suppleness of the twigs, preservation of the product is sufficient. In the short-term (for two weeks) cool storage can be satisfying. In case of an early Easter or long-lasting, cold weather before the holiday freshly cut twigs might keep their suppleness in a cool storage until Palm Sunday or Easter. However in most cases it is reasonable to apply glycol-preservation. Statistical tests also proved that twigs preserved with glycerin kept their suppleness (elasticity) during the examined time period.

Glycerin preservation of the species *S. purpurea* and *S. rosmarinifolia* with finer twigs resulted in significantly more supple twigs even on the short-term than other methods of preservation. Control twigs kept dry at room temperature dried up, catkins of *S. purpurea* were falling off in the highest degree. Dry catkins of this species have larger angles from the twigs and break off readily during manipulation. Therefore in case of the species *S. purpurea* the proper timing of harvest is especially important. Twigs should be harvested when most of the bud scales had gone off, but the catkins have not elongated much yet, and still nuzzle with the stem. If harvest is not

properly timed, the elongated catkins can break and fall off easily. *S. rosmarinifolia* twigs gone under treatment GU1 breaking vegetative buds and elongation of the catkins proved that twigs lived and developed under the foil-cover longer, which is unwanted from the aspect of preservation. Elongated catkins saturated with glycerin fell off easily and proved that the glycerin uptake combined with foil cover is not capable for preservation. Since humidity has increased under the foil, the glycerin contained in the twigs absorbed water from the air causing a decrease in viscosity of the glycerin-water solution to such a level that the solution became capable to flow through internal cracks and crevices until some of it made its way to the plant's surface. Therefore it requires special attention to have proper ventilation and airflow during the treatment or during storage of glycerin preserved material.

Regarding stem color the species *S. caprea* proved to be the least stable: the color of its twigs kept dry faded, those preserved with glycerin turned brown. Keeping them dry, twigs of *S. rosmarinifolia* kept their original stem color (greenish-yellow for the clone involved in the experiment) best, and fewer catkins fell off them. At the same time the dried up twigs which still looked quite decorative became very brittle, thus unable to use in florists' work. The yellow twigs soon turned brown in the glycerin solution. The reddish twigs of *S. purpurea* kept their original stem color in the glycerin preservation solution best. Therefore in case of *S. rosmarinifolia* it is recommended to apply glycerin preservation in case of reddish stem colored clones (e.g. RO3 and RO4).

5 PUBLICATIONS OF THE AUTHOR IN THE TOPIC OF THE DISSERTATION

Articles in Scientific Journals

Articles in Non-IF journals

1. **Treer-Windisch M.** (2006): Examination of the diversity of Hungarian willow species as woody cuts. *Kertgazdaság* 38 (2): 49-60.
2. **Treer-Windisch M.**, Erdélyi É., Tilly-Mándy A., Vozáry E. (2013): Determination of the water-replacement factor and the elastic modulus in case of *Salix caprea* L. and *S. rosmarinifolia* L. catkins' glycol preservation. *Kertgazdaság* 46 (1): in press

Publications in conference issues

Hungarian conferences (full papers)

1. **Treer-Windisch M.** (2010): Woody cuts as local new crops (poster in English, full paper in Hungarian). "*Agriculture and Countryside in the Squeeze of Climate Change and Recession*" *IX. Wellmann Oszkár International Scientific Conference*. Hódmezővásárhely. 22nd April. Book of Abstracts. Conference Proceedings.

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1. **Treer-Windisch M**. (2005): Vágott barkának alkalmas hazai *Salix* fajok szelekciós lehetőségei. *XI. Növénynemesítési Tudományos Napok (Plant Breeders' Conference)*, 3-4th, March. Summaries. p.133.
2. **Treer-Windisch M.** (2005): Vágott barkának alkalmas hazai füzek változatosságának és eltarthatóságának vizsgálata. *XXVII. Országos Tudományos Diákköri Konferencia, Agrártudományi Szekció*, Szarvas, 31st March – 2nd April. Summaries of presentations. p. 178.
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6. **Treer-Windisch M**. (2006): A virágzás idejének előrehozása és megnyújtása barkás *Salix* vesszők esetében. *Hungarian Biology Association, Section of Botany, 1418th Scientific Session*, 24th April. *Botanical Bulletins* 93 (1-2): p. 121.

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1. **Treer-Windisch M.** (2010): The opportunities and cultivation of ornamental woody cuts in Hungary (poster and full paper in English). 7th International Conference of PhD Students. Miskolc, 8-12th August. Conference Proceedings (ISBN 978-963-661-935-0, 978-963-661-936-7) Agriculture. p. 63-68.
2. **Treer-Windisch M. (**2010): The potentialities of *Salix rosmarinifolia* cultivation (presentation and full paper in English). 2nd International Conference on Horticulture post-graduate study 2010. Faculty of Horticulture in Lednice, Mendel University Brno, Czech Republic.

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1. **Treer-Windisch M.** (2008): Diversity of *Salix* species in Hungary and their use as woody cuts. *International Life Sciences Students' Conference*. Warsaw, Poland. 10-14th September. Book of Abstracts. p. 56.