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Improvement of grafting procedures for the ornamental species: II. *Abies concolor* [(Gord. & Glend.) Lindl]

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Abstract. The achieved results concerning the grafting silver-fir - *Abies concolor* [(Gord. & Glend.) Lindl] scions on white-fir (*Abies alba* Mill.) rootstocks are reporting in this article. The double-side-veneer grafting method and the plastic tape and the ecological Ceraltin® wax were applied in four experimental variants. The side-veneer-grafting method and the classic materials, such as raffia and the hot wax were used at the two controls involved in this experiment. The grafting success expressed in percents, were transformed in arcsin square root of percent values, and a two-way analysis of variance was performed. Highly significant ($p < 0.001$) statistical differences were found between grafting variants, including controls. The Duncan Multiple Range Test showed that the four experimental grafting variants were highly significantly ($p < 0.01$) better than the two controls. The grafting success of the best experimental variant has surpassed the two controls by 129 and 153%, respectively. Consequently, the double-side-veneer grafting method, the new developed plastic tape and the ecological Ceraltin® wax have contributed to this grafting success owing to which they are recommended to be used for grafting silver-fir ornamental trees.
Keywords *Abies concolor*, *A. alba*, side-veneer-grafting, double-side-veneer grafting, Ceraltin® grafting wax, plastic tape, ANOVA, Duncan Test.

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Introduction

The silver-fir is a very large tree, native to mountainous regions of the western United States occurring at altitudes of 900-3400 m (Hunt 1993). It is commonly planted because of attractive needles, hardiness, fast growth, and tolerance of drought and shade. Needles between 40 and 70 mm long, blunt or somewhat pointed; intensely whitish-bluish-green owing to dense lines of white dots on both sides; horizontally spreading in two distinct ranks on horizontal branches; side needles sickle-shaped and upwards; upper needles pointed forward; resin ducts near lower surface; odour of oranges when crushed (Farrar 1995). The name *concolor* refers to the fact that both upper and lower needle surfaces are the same colour (Little Jr. 1980). Owing to its esthetical characteristics, such as needle-colour-shape and regular-pyramidal-shape of crown, the white-fir has been highly appreciated as ornamental tree (Dumitriu-Tătăranu 1960); in addition, the species proved to be tolerant to the industrial smog which occurs in some cities, so that it is recommended to be planted in such environments (Stănescu et al. 1997). Taking into account the previously mentioned ornamental and smog tolerant characteristics, propagation by side-veneer-grafting of the silver-fir are highly recommended (Dumitriu-Tătăranu 1960).

A comprehensive survey of literature concerning side-veneer-grafting in both conifers and broadleaf trees was very recently done (Blada & Panea 2011) and for this reason, it is not repeated here. In addition, it should be stressed that by using side-veneer-grafting method, promising results were obtained in *Pinus cembra* propagation of selected parent trees (Blada & Popescu 2008).

This new experiment was focussed on silver-fir species with the following objectives: (i) to test the efficiency of the double-side-veneer-grafting method in comparison with the side-veneer-grafting one and (ii) to test the performance of both plastic tape and ecological Ceraltin® wax in comparison with the classic grafting materials, i. e. raffia and hot wax.

Materials and methods

Plant materials

The plant material has consisted in the white-fir rootstocks and the silver-fir scions. Full details about this item were published in a previous article (Blada & Panea 2011); consequently, those information will not be include here. It should be pointed out that two mature silver-fir trees, of unknown origin, with whitish-bluish-green coloured foliage were the source of the fresh scions. The scion dimensions were 8 to 10 cm length and 4-7 mm thickness. Scion collection took place five days prior to grafting, so that the period for their keeping in fridge was very short; presumably, the grafting success was not negatively influenced by that short storage in fridge.

Non plant materials

Two categories of non-plant materials were employed in this study. The first category consisted in the blue plastic tape and the ecological Ceraltin® wax applied for tying and waxing, respectively, the grafting partners of the four (V.1; V.2; V.3; V.4) experimental variants. The second category was represented by the classic materials, i.e. raffia and hot wax used for tying and waxing, respectively, the grafting partners of the two (V.5; V.6) controls. More information concerning the characteristics and utilization of the previously mentioned non plant materials can be found elsewhere (Blada & Panea 2011).

The grafting

The double-side-veneer-grafting method (Blada & Panea 2011) was applied to the four experimental variants while the side-veneer-grafting one (Hartmann et al. 2002, Smith 2007) was applied to the two control variants. A total of 960 rootstocks were grafted and it means six grafting variants, including controls x four replications x 40 seedling in each replication.

Usually, the grafting of *Abies* species carried out in the Oregon took place during December-January-February period (Meacham 1995) while, in the present experiment, the grafting operation was made just at the end of March. According to the acquired local experience, the grafting was accomplished on flushed rootstocks (Enescu 1967) because at this stage the bark or vascular cambium can be easily separate from the wood or xylem; if the bark has adherence to the wood, the percentage of bud will be severely limited (Hartmann et al. 2002, Smith 2007).

In order to keep the variant identity, all grafted seedlings were labelled as in the Figure 1. The environmental conditions inside the greenhouse during and following grafting (temperature, atmospheric moisture and plant water relations), aftercare of grafted seedlings (lopping and crippling the rootstocks, aftercare of scion, protection of grafted plants, grafted seedlings transfer to the nursery) were detailed in another article (Blada & Panea 2011) of this Annals of Forest Research, and consequently, they are not repeated here.

Statistical analysis

By early July 2010 year, when the graft union took place successfully, an inventory of grafted seedlings was done on variants and replications. The results calculated in percents were transformed in arcsine of the square root va-

Figure 1 Shown is a V.3 grafting variant where the two grafting partners were wrapped strip-space-strip then waxed with Ceraltin® (Original I. Blada)

lues. These data were statistically analyzed by using a two way analysis of variance (Ceapoiu 1968). Two variance analyses were performed: the first analysis has included all six variants (Table 1), i. e. four experimental and two controls, while the second analysis has included only the four experimental variants (Table 2). Then, the Fischer's & Yates (1963) test and Duncan Multiple Range test (Duncan 1955) were applied (Table 3). Finally, the superiority of the experimental variants (S), expressed in percents, compared to the two controls (Table 4) was calculated by the formula:

$$S = \frac{Px - Py}{Py} \cdot 100$$

where P_x is the value of the experimental variant; P_y is the control variant.

Results

The Fischer's & Yates test from the first variance analysis indicated highly significant ($p < 0.001$) differences between all six grafting variants, controls included (Table 2, row 2, column 5). Similarly, the second analysis which took into account only the four experimental variants clearly demonstrates the existence of highly significant ($p < 0.01$) differences between them (Table 2, row 5, column 5). These two variance analysis suggested that selection of some performing variants can be made not only within the former set of variants where

Table 1 Characterization of the six grafting variants

Variant	Variant characterization
	Experimental variants
V.1	Grafting partners tied strip-near-strip with blue colour plastic tape without Ceraltin® wax application
V.2	Grafting partners tied strip-near-strip with yellow colour plastic tape without Ceraltin® wax application
V.3	Grafting partners tied strip-space-strip with blue colour plastic tape with Ceraltin® wax application
V.4	Grafting partners tied strip-space-strip with yellow colour plastic tape with Ceraltin® wax application
	Control variants
V.5	Grafting partners tied strip-near-strip with classical natural raffia and hot wax application (Control 1)
V.6	Grafting partners tied strip-near-strip with classical natural raffia without wax application (Control 2)

Table 2 Analysis of variance for tre analiysed variants

Row	Source of variation	*SSD*	*D.f*	*MS*	*F*
ANOVA for experimental and control variants put together					
1	Replications	11.37	3	3.790	0.97
2	Variants	7109.23	5	1421.850	363.75***
3	Error	58.63	15	3.910	
ANOVA for experimental variants, only					
4	Replications	23.41	3	7.803	2.47
5	Variants	76.69	3	25.562	8.10**
6	Error	28.41	9	3.156	

Note: ** $p < 0.01$; *** $p < 0.001$; *SSD* - sum square deviations; *Df* - degrees of freedom; *MS* - mean squares; *F* - Fischer & Yates test controls were included, but within the second one, as well, where the controls were excluded. The presence of statistical significant differences between the experimental variants means that some treatments were more efficient than others.

The ranking of the grafting variants and the absolute differences between them according to the Duncan Multiple Range Test were presented in Table 3 from which the following details are given. The V.3 and V.4 variants have occupied the first and the second places in the rank with a grafting success of 96 and 94%, respectively (Table 3, rows 1-2, columns 1-2). With their grafting success of 93 and 91%, respectively, the V.1 and V.2 variants have occupied the third and the fourth places in the rank (Table 3, rows 3- 4, columns 1-2). As expected, the two controls (V.5 and V.6) have occupied the last two places in the rank; their grafting success was 42 and 38%, respectively (Table 3, rows 5-6, columns 1-2). No statistically significant difference was found between the best V.3 and V.4 variants, while between the V.3 variant on one hand, and the V.1, V.2, V.5 and V.6 variants, on the other hand, significant ($p < 0.05$) or highly significant ($p < 0.01$) differences were found; the magnitudes of these differences were as much as 3%, 5%, 54% and 58%, respectively (Table 3, row 1). No statistically significant difference was found between the V.4 and V.1 variants, while between the V.4 variant, on one hand, and the V.2, V.5 and V.6 variants, on the other hand, significant ($p < 0.05$) and highly significant ($p < 0.01$) differences were found and their magnitudes were of 3%, 52% and 56%, respectively (Table 3, row 2, columns 5 to 7). No statistically significant difference was found between the V.1and V.2 variants while between the V.1 variant, on one hand, and the V.5 and V.6 control variants, on the other hand, highly significant ($p < 0.01$) differences were found and their magnitudes were as much as 51 and 55%, respectively (Table 3, row 3, columns 6 and 7. All experimental variants, i. e. V.1, V.2, V.3 and V.4 were highly significantly ($p < 0.01$) different of the two controls (V.5 and V.6) (Table 3, rows 1 to 5, columns 6 and 7). Highly significant difference was found between the first (V.5) and second (V.6) control (Table 3, row 5, column 7).

Table 3 Differences in absolute values between grafting variants and their significance (Duncan Multiple Range Test)

Row	Var[1)]	Mean (%)	V.4 94	V.1 93	V.2 91	V.5 42	V.6 38
	1	2	3	4	5	6	7
1	V.3	96	2^{ns}	3*	5**	54**	58**
2	V.4	94		1^{ns}	3*	52**	56**
3	V.1	93			2^{ns}	51**	55**
4	V.2	91				49**	53**
5	V.5	42					4**
6	V.6	38					0

Note: * $p < 0.05$; ** $p < 0.01$; *ns* - non significant difference.

The grafting success superiority of the experimental variants was very high compared to the two controls one. Thus, the experimental variants have surpassed the V.5 control with values ranging from 117 to 129% while the V.6 control was surpassed by values ranging from 139 to 153% (Table 4, rows 1 to 4, columns 2 and 3). Such positive results have demonstrated the high efficiency of the double-side-veneer grafting and the two tested materials i. e. the Ceraltin® wax and the two plastic tapes in comparison with the side-veneer-grafting and the classic raffia and hot wax.

During this experiment there was tested also the capacity of silver-fir to support two grafted scions on the same rootstock. The Figure 2 demonstrates that this procedure can be successfully applied. Therefore, the double grafting in silver-fir could become a promising

Table 4 The superiority, in relative values, of the experimental variants compared to the two controls

Row	Var	Superiority (%) versus: V.5	Superiority (%) versus: V.6
1	V.3	129	153
2	V.4	124	147
3	V.1	121	145
4	V.2	117	139

Figure 2 A successful graft union following a double-side-veneer-grafting between the two scions grafted on the same rootstock. The upper scion was grafted (V.3) on one year old shoot wile the lower one was grafted (V.4) on the two years old shoot (Original I. Blada)

procedure for getting nicer and perhaps cheaper ornamental plants.

Discussion

The white-fir grafting was applied on large scale in the Romanian seed orchards establishment program which was developed between 1960-1988 years. Within that period, the grafting success has varied between 35 and 53% in greenhouse and between 20 and 41% in nursery (Blada unpublished data). Almost similar results (30 to 50%) in the same species were reported by Enescu (1967). The newly acquired results presented in this paper are much higher. According to the experimental grafting variant involved in this study, the grafting results in silver-fir have varied between 91 and 96%. The best grafting success of 94 and 96% was obtained at the two variants (V.3 and V.4) where the grafting partners were tied strip-space-strip with plastic tape then covered with Ceraltin® wax. Slightly lower results, i. e. 91 and 93%, respectively were obtained in the other two experimental variants (V.1 and V.2) where the grafting partners were tied strip-near-strip with plastic tape but without Ceraltin® wax application.

Substantial economical advantages may be made in comparison with the two controls involved into experiment. For example, the best in the rank experimental variant V.3 has reached a grafting success of 96% while the two controls V.5 and V.6 only 42 and 38%, respectively. The superiority of the previously mentioned best variant was of 129 and 153%, respectively, over the two controls (Table 4, row 1, columns 2 and 3). Comparing the best V.3 variant to the 50% best result reported by Enescu (1967) an advantage of nearly double, i.e. 92% could be obtained. Economically, such differences represent significant financial increase for the ornamental tree producer, especially when such grafted material is in high demand. This is the evidence according to which, the double-side-veneer grafting method and the modern plastic tape and the ecological Ceraltin® wax should be promoted in ornamental silver fir production and perhaps in many other species.

Conclusions

The double-side-veneer grafting proved to be very efficient method; it should be used on large scale for production of silver-fir ornamental trees.

The plastic tape and Ceraltin® wax were more efficient than the classic materials, i. e. raffia and hot classic wax; therefore it is recommendable to discard the latter materials and to promote the former ones.

In order to achieve better efficiency in silver-fir ornamental tree propagation, all basic grafting variants (V.1 to V.4) should be used; however, the priority should be given to the V.3 grafting variant by employing the double-side-veneer grafting method and the Ceraltin® wax applied on strip-space-strip tied blue tape.

Additional improvements of the grafting success rate may result from detailing green house microclimatic conditions, such as temperature control, frequency and amount of misting, and other factors.

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