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RESULTS OBTAINED REGARDING BENCH GRAFTING OF HAZELNUT CULTIVARS ON TWO ROOTSTOCKS AT UCV-SCDP VÂLCEA

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Abstract

Hazelnut propagation has been done over the centuries through suckers, layers and later by grafting. The development and modernization of hazelnut cultivation as a result of the need to increase nut production and quality directly involves the mechanization in the orchard, but also improving the propagation of cultivars. Present study had the aim to evaluate the bench grafting behavior of several Romanian cultivars alongside with Tonda Gentile dele Langhe, on two rootstocks (C. avellana and C. colurna) using different grafting methods. Grafting was performed in March and was followed by callus stimulation in a hot – callusing device, ensuring a temperature of 26 - 27°C at the grafting point. Grafting on C. avellana rootstock using the whip and tongue method proved to be superior (82.34% symbionts with callus formation; 75.3% grafting success rate and 70.2% survival rate of grafted plants after one year), to other grafting methods (cleft and lateral grafting). On C. colurna rootstock, 56.6% of the symbionts had callus formation; the grafting success rate was 52.0% while and the survival rate of grafted plants after one year was 45.1%. The grafting success rates using whip and tongue method on C. avellana of Romanian cultivars ranged between 66.5 and 82.25%, while for TGDL was 78.4% and on C. colurna varied between 42.85 and 64.0%, compared with 46.7% for TGDL. The average growth of the hazelnut scions in the first year of vegetation after grafting was 35.2 cm on the C. avellana rootstock and 18.1 cm on C. colurna.

Keywords: propagation, *Corylus avellana* L., *Corylus colurna* L., filbert

1. INTRODUCTION

Hazelnut, through its cultivars belonging mainly to *Corylus avellana* L. (European or common hazel) and *Corylus maxima* Mill. (filbert), is an advantageous nut crop due to its nutritional and economic values.

Global in-shell hazelnut production exceeded 1.13 million tons in 2023. The main hazelnut producing countries were: Turkey (650,000 t), Italy (102,740 t), USA (85,460 t), Azerbaijan (75,409 t), Chile (65,464 t), Georgia (36,900 t), China (24,750 t), France (17,160 t), Iran (13,601 t), Poland (10,700 t), Greece (6,950 t), Spain (6,790 t), etc. [1].

In the last 20-30 years Romania has substantially increased its cultivated area and production (over 1540 ha of hazelnut orchards and production of 2160 t in 2023) [1].

Hazelnut cultivars have been clonally propagated over time relatively easily by suckers and layers.

In the last decades, the mechanization of hazelnut harvesting became frequent in main production countries, manual harvesting being more and more expensive and this changed the type of planting material, hazelnut training and cultivation technology.

Due to the annual emission of suckers, which is present in all hazelnut cultivars and problematic either in single trunk trained trees and multi-stemmed bush, grafting of cultivars on non-suckering rootstocks was taken more and more into account. Sucker removal is laborious and very costly. Single trunk training allows easier mechanized harvesting of hazelnuts comparatively with multi-stemmed bush training.

Use of grafted material on rootstocks of *Corylus colurna* and *Corylus avellana* var. *rubra* and single stem orchards are more common in the USA and partially in some European countries such as France and Italy [2,3,4]. Research conducted in various countries, by budding and grafting rootstocks in the field has proven to be difficult, and grafting success rates are low, better results are obtained with bench grafting.

Radu et al. [5] obtained, when grafting in August - September with dormant buds, graft success rates between 35.4 - 47.0% next spring and that happened after minimum temperatures dropped to - 15° C during winter. The study carried out at the University of Craiova (SCDP Vâlcea) aimed to improve the grafting percentages of hazelnuts using different bench grafting methods with callus stimulation using heating at the grafting point.

2. MATERIALS AND METHODS

The research was conducted at UCv-SCDP Vâlcea, in the subCarpathian area of Oltenia, Romania. The area is characterized by a relatively mild temperate climate with average multi-annual temperature of 10.2° C, and 720 mm rainfall. The biological material used consisted in several Romanian hazelnut cultivars: 'Cozia', 'Romavel', 'Uriașe de Vâlcea' and 'Vâlcea 22' and the control was the Italian cultivar 'Tonda Gentile delle Langhe' ('TGDL'). The cultivars were grafted on two rootstocks: clonally propagated red leaf *Corylus avellana* ('Purple Filbert' cv.) and *Corylus colurna* (seedling rootstock). The grafting methods used were:

- whip and tongue grafting;
- cleft grafting;
- side grafting.

A three-factor experiment was set up (A – cultivar, B – rootstock and C – grafting method). The bench grafting was performed in the second half of March, using scionwood harvested in December and stored in the refrigerator at 2-4° C. Paraffin wax was used for covering the scion, the grafting point and a small part of the rootstock below grafting point after binding scion and rootstock with budding strips. The grafted plants were transferred to a special room equipped with a "hot callusing" device, which provides temperatures of 26 – 28° C at the grafting point, according to the "hot callusing" method described by Lagerstedt [6] and used to stimulate the callus formation, without removing the scion and the rootstock from vegetative dormancy. The successful grafted plants were transferred to the field in May, 30-35 days after grafting. The callus formation at the grafting point was observed along with the percentages of scions in growth, grafting success rate at the end of the 1st year, as well as measurements regarding the growth of scions and rootstocks.

3. RESULTS AND DISCUSSION

The grafted hazelnut plants were observed and counted at the end of the transition period (28 – 30 days) through localized heating at the grafting point, in order to determine the callus formation (Table 1). In the case of whip and tongue grafting on *C. avellana* rootstock, ratios of callused symbionts ranged between 75.0% ('Romavel') and 98.0% ('Cozia'), while the average percentage was 82.34%. When grafted onto *C. colurna*, successful callus formation ranged between 48.6% ('Cozia') and 70.2% ('Vâlcea 22'), with an average of 56.6%. The difference between the two rootstocks was of 25.74%. When cleft grafting method used along with *C. avellana* as rootstock, the percentage of successful callus formation varied between 52.0% ('Cozia') and 71.0% ('Romavel'), with an average of 65.6%. In the case of the *C. colurna* rootstock, callus formation ranged between 36.0% ('Cozia') and 71.0% ('Vâlcea 22'), with an average of 51.5%. For side grafting on the *C. avellana*, callus formation varied between 40.0% ('Romavel') and 95% ('Vâlcea 22'), with an average of 74.5%. Callus formation percentages on the *C. colurna* rootstock varied from 30.0% ('Vâlcea 22') to 50.0% ('TGDL'), with an average of 37.8%. After transferring the grafted plants in the nursery, it was found that not all grafts start vegetation. For whip and tongue grafting, the percentages of grafts started in vegetation ranged between 82.25% ('Cozia') and 66.5% ('Romavel'). For side grafting, even lower percentages were recorded (31.9% in 'Romavel' to 76.9% in 'Vâlcea 22'). Thus, when *C. avellana* was used as rootstock, whip and tongue grafting produced the highest level of grafts in vegetation (75.3%), followed by side grafting (55.7%) and cleft grafting (54.69%). When *C. colurna* rootstock was used along with whip and tongue grafting, between 42.85% ('Cozia') and 64.0% ('Vâlcea 22') of grafts started vegetation, with an average of 51.6%. On same rootstock, the average percentages of grafts starting in vegetation were 41.77% for cleft grafting (26.0%, 'Uriașe de Vâlcea' to 60.15% for 'Vâlcea 22'), and for side grafting an average of 30.7% was recorded (29.4% for 'Romavel' and a maximum of 39% for 'TGDL'). Regardless of the bench grafting methods, the *C. avellana* rootstock proved superior (61.9%), compared to the *C. colurna*, which achieved an overall average for these methods of 41.6%, with 20.74% for grafts started in vegetation. At the end of the vegetation period in the first year after grafting, the percentages of remaining grafts fluctuated greatly depending on the environmental factors. For whip and tongue grafting, the highest percentages of grafts were achieved (60.8% for 'Romavel' and 74.5% for 'Cozia') on the *C. avellana* rootstock (70.2% on average), while on the *C. colurna* rootstock the percentages of grafts oscillated between 34.85% ('Cozia') and 60.0% ('Vâlcea 22'), with an average of 45.1%. For cleft grafting on *C. avellana*, the percentages ranged from 42.3% ('Cozia') to 57.5% ('Romavel'), with an average of 51.12%. In the case of *C. colurna*, the percentages ranged between 21.6% (Uriașe de Vâlcea) and 58.35% ('Vâlcea 22'), with an average of 37.3%. When side grafting was applied on *C. avellana*, the percentages ranged between 22.9% ('Romavel') and 43.1% ('TGDL') and between 20.7% ('Uriașe de Vâlcea') and 34.2% ('TGDL') on *C. colurna*. The average percentages of grafts obtained with the three grafting methods was 53.84% for *C. avellana* and 36.76% for *C. colurna* rootstock. For both rootstocks, the whip and tongue grafting percentages was 75.3%, respectively 51.0% for grafts started in vegetation and 70.2%, respectively 45.1%, for grafts remaining after one year of vegetation. This situation is also relevant when calculating the "Grafting Success Index" (GSI), where GSI = (callused plants + graft shoots in vegetation + successful unions)/100. We

propose the following levers for GSI: 0.5 – 1.0 (low), 1.0 – 1.5 (medium), 1.5 – 2.0 (good), >2.0 (very good).
GSI had an average value of 2.278 on *C. avellana* and 1.903 on *C. colurna* rootstock. This index is lower for cleft and side grafting methods (Table 1).
At the end of the first vegetation period of the grafts, the sectional areas of the stock, of grafting point and of grafted twigs at the end of first year of vegetation were determined.
Subsequently, the ratio of cultivar/rootstock/grafting point was calculated according to Mladin et al. [7].
Table 2 presents the mean values obtained for each grafting method and for both rootstocks used. These ratios fall into the very good compatibility group. By comparing this ratio of grafting partner areas, with the grafting success index and with the percentages of grafts obtained after one year of vegetation, we find that these values are superior when grafting hazelnut varieties onto *C. avellana*, compared to *C. colurna*, especially when using whip and tongue grafting (Table 3). In Table 4, the graft lengths and cross-sectional areas were determined and a ratio was calculated to determine which cultivar, rootstock and grafting method are favorable.
The greatest differences were recorded between cultivars grafted on *C. avellana*, compared to *C. colurna*. For cultivars grafted on *C. avellana*, an average ratio of 0.016 was recorded, with differences between cvs. of 0.013 ('Uriașe de Vâlcea') to 0.018 ('TGDL'). In contrast, for cultivars grafted on *C. colurna*, the average ratio is 0.030, with differences between cultivars from 0.025 ('Cozia') to 0.57 ('Vâlcea 22').
Cultivars grafted onto *C. avellana* achieved, on average, a scion length of 35.2 cm and a shoot cross-sectional area of 0.56 cm^2. Differences in growth in length of a maximum of 10.1 cm were achieved. In the case of hazelnut cultivars grafted on *C. colurna*, the length of the scions was on average only 18.1 cm, with differences between cultivars of maximum 7.6 cm. The shoot scion cross-section area was similar for the cultivars grafted on the two rootstocks, respectively 0.56 and 0.52 cm^2. The *C. colurna* rootstock is much more vigorous than *C. avellana*, in the first year after grafting the scions developed better on *C. avellana*.

4. CONCLUSIONS

In the ecological conditions of Oltenia - Romania, the propagation of Romanian hazelnut cultivars through different grafting methods proved to be similar to that of introduced ones ('TGDL'). Bench grafting done inside with "hot callusing" stimulation and especially whip and tongue grafting method gave superior results to previous grafting/budding carried out in the field in August to September. Through the whip and tongue grafting method on the *C. avellana* rootstock, the callus formation percentages (82.34%), the starting in vegetation of grafts (75.3%) and the successful union rate after one year of vegetation (70.2%) are superior to cleft and side grafting methods. Cultivars grafted onto the *C. colurna* rootstock achieved the best percentages through the whip and tongue method in callus formation percentage (56.6%), starting in vegetation of grafts (52.0%) and the successful union rate after one year of vegetation (45.1%). Graft growth in the first year is superior to cultivars grafted on *C. avellana* (35.2 cm) compared to *C. colurna* (18.1 cm). In the first year, no significant differences were found in the ratio between the areas of the scion/rootstock/grafting point sections (0.392 – 0.480) nor in the grafting achievement index (1.910 – 1.310).

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Table 1. Evaluation of the grafting success index to be achieved when hazelnut cultivars were propagated by different bench grafting methods

No. crt.	Rootstock	Cultivar	Whip and tongue grafting				Cleft grafting				Side grafting				Mean	
			Callused plants (%)	Grafted shoots in vegetation (%)	Successful unions (%)	Grafting success index (GSI)	Callused plants (%)	Grafted shoots in vegetation (%)	Successful unions (%)	Grafting success index (GSI)	Callused plants (%)	Grafted shoots in vegetation (%)	Successful unions (%)	Grafting success index (GSI)	Successful unions (%)	Grafting success index (GSI)
1	*C. avellana*	'Cozia'	98.0	82.25	74.5	2.547	52.0	46.6	42.3	1.409	-	-	-	-	58.4	1,978
		'Romavel'	75.0	66.5	60.8	2.023	71.0	60.5	57.5	1.890	40.0	31.9	22.9	0.948	47.07	1,620
		'Uriașe de Vâlcea'	80.0	73.1	73.1	2.262	68.0	51.3	51.3	1.706	80.0	42.4	38.2	1.606	54.2	1,858
		'Vâlcea 22'	80.3	76.25	70.7	2.272	70.0	59.3	54.4	1.837	95.0	76.9	38.16	2.101	54.42	2,070
		'TGDL'	78.4	78.4	72.0	2.288	67.0	55.75	50.1	1.729	83.0	71.8	43.1	1.979	55.07	2,000
		Mean	**82.34**	**75.3**	**70.2**	**2.278**	**65.6**	**54.69**	**51.12**	**1.714**	**74.5**	**55.7**	**37.34**	**1.659**	**53.84**	**1,910**
2	*C. colurna*	'Cozia'	48.6	42.85	34.85	1.263	36.0	31.5	27.5	0.950	-	-	-	-	31.18	1,110
		'Romavel'	50.2	45.4	39.4	1.350	70.0	59.4	52.7	1.821	40.0	29.4	23.5	0.929	38.54	1,370
		'Uriașe de Vâlcea'	62.0	56.0	52.0	1.700	38.0	26.0	21.6	0.856	31.0	26.8	20.7	0.785	31.44	1,120
		'Vâlcea 22'	70.2	64.0	60.0	1.942	71.0	60.15	58.35	1.895	30.0	27.6	27.6	0.852	48.65	1,570
		'TGDL'	52.0	46.7	39.2	1.379	42.6	31.8	28.5	1.029	50.0	39.0	34.2	1.232	33.97	1,220
		Mean	**56.6**	**51.0**	**45.10**	**1.527**	**51.5**	**41.77**	**37.3**	**1.310**	**37.8**	**30.7**	**26.5**	**0.950**	**36.76**	**1,280**
Overall mean			***69.47***	***63.15***	***57.7***	***1.903***	***58.55***	***48.23***	***44.21***	***1.512***	***56.15***	***43.1***	***31.92***	***1.305***	***45.30***	***1.600***

Table 2. Growth pattern of hazelnut cultivars and rootstocks in the first year of vegetation after bench grafting and stimulation with hot-callusing device

No. crt.	Rootstock	Cultivar	Whip and tongue grafting				Cleft grafting				Side grafting			
			Sectional area (cm^2)			Cultivar/rootstock/ grafting point ratio	Sectional area (cm^2)			Cultivar/rootstock/ grafting point ratio	Sectional area (cm^2)			Cultivar/rootstock/ grafting point ratio
			Stock	Grafting point	One-year twig		Stock	Grafting point	One-year twig		Stock	Grafting point	One-year twig	
1	*C. avellana*	'Cozia'	1.322	1.391	0.674	0.366	0.746	0.975	0.419	0.576	-	-	-	-
		'Romavel'	1.215	1.556	0.588	0.311	1.017	1.576	0.641	0.400	1.132	1.695	0.672	0.350
		'Uriașe de Vâlcea'	0.748	1.157	0.375	0.433	0.783	0.809	0.315	0.497	0.905	1.780	0.417	0.259
		'Vâlcea 22'	1.152	1.260	0.602	0.415	1.072	1.653	0.435	0.245	1.278	2.495	0.629	0.197
		'TGDL'	0.874	1.298	0.595	0.524	1.256	1.345	0.703	0.416	1.065	1.610	0.680	0.396
		Mean	**1.051**	**1.324**	**0.562**	**0.410**	**0.975**	**1.272**	**0.503**	**0.427**	**1.091**	**1.871**	**0.594**	**0.300**
2	*C. colurna*	'Cozia'	1.323	1.320	0.570	0.326	-	-	-	-	-	-	-	-
		'Romavel'	0870	1.267	0.514	0.466	0.559	0.946	0.505	0.955	0.695	0.965	0.417	0.622
		'Uriașe de Vâlcea'	0.849	1.149	0.509	0.522	0.568	1.170	0.478	0.719	0.882	1.585	0.541	0.387
		'Vâlcea 22'	0.872	1.869	0.509	0.312	1.144	1.448	0.669	0.403	0.872	1.764	0.509	0.334
		'TGDL'	0.946	0.967	0.376	0.411	0.990	1.437	0.669	0.491	0.772	1.086	0.381	0.454
		Mean	**0.942**	**1.314**	**0.494**	**0.407**	**0.815**	**1.250**	**0.588**	**0.642**	**0.792**	**1.327**	**0.452**	**0.449**
Overall mean			***0.997***	***1.319***	***0.528***	***0.408***	***0.895***	***1.261***	***0.542***	***0.535***	***0.940***	***1.587***	***0.525***	***0.375***

Table 3. Results obtained after the first year of vegetation of hazelnut cultivars bench grafted and stimulated with hot callusing device

No. crt.	Rootstock	Cultivar	Whip and tongue grafting			Cleft grafting			Side grafting			Mean		
			Cultivar/rootstock/ grafting point ratio	Grafting success index (GSI)	One-year twigs (%)	Cultivar/rootstock/ grafting point ratio	Grafting success index (GSI)	One-year twigs (%)	Cultivar/rootstock/ grafting point ratio	Grafting success index (GSI)	One-year twigs (%)	Cultivar/rootstock/ grafting point ratio	Grafting success index (GSI)	One-year twigs (%)
1	*C. avellana*	'Cozia'	0.366	2.547	74.5	0.576	1.409	42.3	-	-	-	0.471	1,978	58.4
		'Romavel'	0.311	2.023	60.8	0.400	1.890	57.5	0.350	0.948	22.9	0.354	1,620	47.04
		'Uriașe de Vâlcea'	0.435	2.262	73.1	0.497	1.706	51.3	0.259	1.606	38.2	0.397	1,858	54.20
		'Vâlcea 22'	0.415	2.272	70.7	0.245	1.837	54.4	0.197	2.101	38.16	0.296	2,070	54.42
		'TGDL'	0.524	2.288	70.2	0.416	1.729	50.1	0.396	1.979	43.1	0.455	2,000	55.07
		Mean	**0.410**	**2.278**	**34.85**	**0.427**	**1.714**	**51.12**	**0.300**	**1.658**	**37.34**	**0.392**	**1,910**	**53.84**
2	*C. colurna*	'Cozia'	0.326	1.263	39.4	-	-	-	-	-	-	0.326	1,263	34.85
		'Romavel'	0.466	1.350	52.0	0.955	1.821	52.75	0.622	0.929	23.5	0.681	1,370	38.50
		'Uriașe de Vâlcea'	0.522	1.700	60.0	0.719	0.856	21.6	0.387	0.785	20.7	0.542	1,114	31.46
		'Vâlcea 22'	0.312	1.942	39.2	0.403	1.895	58.4	0.334	0.892	27.6	0.350	1,576	48.65
		'TGDL'	0.411	1.379	45.1	0.491	1.029	28.5	0.454	1.232	34.2	0.452	1,213	33.97
		Mean	**0.407**	**1.527**	**57.7**	**0.642**	**1.310**	**37.3**	**0.449**	**0.950**	**26.5**	**0.480**	**1,310**	**36.76**
Overall mean			***0.408***	***1.903***	***46.28***	***0.535***	***1.512***	***44.21***	***0.375***	***1.304***	***31.92***	***0.436***	***1.610***	**45.30**

Table 4. Growth characteristics of hazelnut cultivars bench grafted on different rootstocks and stimulated with hot callusing device, depending on grafting methods

No. crt.	Rootstock	Cultivar	Whip and tongue grafting		Cleft grafting		Side grafting		Mean		
			Shoot scion length (cm)	Shoot scion cross-sectional area (cm^2)	Shoot scion length (cm)	Shoot scion cross-sectional area (cm^2)	Shoot scion length (cm)	Shoot scion cross-sectional area (cm^2)	Shoot scion length (cm)	Shoot scion cross-sectional area (cm^2)	Shoot scion sectional area (cm^2) / Shoot scion length (cm)
1	*C. avellana*	'Cozia'	52.0	0.674	26.5	0.419	-	-	39.2	0.55	0.014
		'Romavel'	34.7	0.588	37.7	0.641	35.0	0.672	35.8	0.64	0.018
		'Uriașe de Vâlcea'	26.8	0.375	27.6	0.315	30.6	0.417	28.3	0.37	0.013
		'Vâlcea 22'	37.3	0.602	27.2	0.435	42.1	0.629	35.5	0.56	0.016
		'TGDL'	35.3	0.562	38.6	0.703	39.0	0.680	37.6	066	0.018
		Mean	**37.2**	**0.570**	**31.5**	**0.503**	**36.7**	**0.594**	**35.2**	**0.56**	**0.016**
2	*C. colurna*	'Cozia'	23.3	0.514	-	-	-	-	23.3	0.57	0.025
		'Romavel'	17.3	0.509	15.3	0.505	14.6	0.417	15.7	0.48	0.031
		'Uriașe de Vâlcea'	20.4	0.509	18.7	0.478	12.0	0.541	17.0	0.51	0.030
		'Vâlcea 22'	16.4	0.376	18.3	0.669	16.4	0.509	17.0	0.57	0.034
		'TGDL'	19.0	0.494	14.8	0.669	14.5	0.381	16.1	0.49	0.031
		Mean	**19.3**	**0.528**	**16.8**	**0.588**	**14.4**	**0.459**	**18.1**	**0.52**	**0.030**
Overall mean			***28.3***	***0.549***	***24.2***	***0.542***	***25.5***	***0.525***	***26.7***	***0.54***	***0.230***