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EVALUATION OF DIFFERENTIATION BETWEEN ROMANIAN WALNUT CULTIVARS AND THOSE WITH LATERAL BEARING FROM WARMER AREAS

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Abstract. *Walnut (Juglans regia L.) is a fruit tree crop grown in over 50 countries around the world with a total production of over 3,458,046 tons/year in 2013 (FAO State Database, 2016). The production is growing from year to year, however demand is higher than production globally. In recent decades, in the walnut culture, two kinds of cultivars are used: terminal fruit bearing cultivars from the temperate zone (Romania, Germany, England, Serbia, Czech Republic, Russia, Republic of Moldova, etc.); lateral fruit bearing cultivars originating in the warmer areas of Iran, Spain, USA (California), and more recently in countries such as France, Chile, Greece, Australia, etc. Terminal fruit bearing cultivars (including Romanian walnut cultivars) differ from those with lateral fruit bearing habit: better resistance to low temperatures (tolerate temperatures of -26ºC, -28ºC, those with lateral fruit bearing are affected at -20ºC, -22ºC); lower susceptibility to blight (caused by Xanthomonas campestris pv. juglandis); lower fruit yields (2.0-3.0 t/ha for terminal bearers and from 3.2 to 3.8 t/ha for lateral bearers); less expensive cultivation technology.*

Keywords: nut crops, walnut, *Juglans regia*, cultivars, growing.

1. Introduction

The walnut (*Juglans regia* L.), named Carpathian, English or Persian, is grown in more than 50 countries worldwide in both hemispheres.

The global walnut culture is booming because of its economic benefits and high demands on the market.

The request for walnut kernels is much higher than the current world production.

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World walnut production was in 2014 over 3,462,731 tons and the area harvested was of 994,738 ha (FAO Stat Database, 2016). Romania is in the top 10 countries in the world with a production of 30,000 – 35,000 tons/year. Romania ranks in the second place in the E.U. after France. In 2014 the domestic production reached 31,275 tons of in-shell walnuts.

The food value of walnuts, complex content in useful compounds for the human health status, high energy value, the special value of the wood for the furniture industry, maintenance of the environmental balance and the alelopathic effect of walnut orchards, etc., (Jenkins ș i Ebeling, 1985; Duke, 1985; Botu et al., 2013), made this crop very important (Jenkins and Ebeling, 1985; Duke, 1983; Botu et al., 2014).

Botu and Botu (2000) state that the primary genetic diversity region for walnut is Central Asia. The natural distribution of walnut is restricted to central Asia, where it is threatened by fruit collection, livestock grazing and cutting (IUCN Red List, 2007). From this part of the world (Persia) walnut came to Rome from Greece and then the Romans spread walnut in Southern Europe to England (Goodell, 1984). An important secondary genetic diversity centre for walnut seems to be located in the Balkans, including Romania (Botu et al., 1994).

2,000 years ago, the Latin poet Ovid (43 B.C. - 17 A.D.), exiled in Tomis (nowadays, the city of Constanţa, on the shores of the Black Sea) mentioned the existence of walnut trees in Dobrogea Region (Ghena, 1964). The genetic diversity of the *Juglans* genus is very high because it includes a large number of species. Among these, *Juglans regia* L. holds an utmost importance for the walnut production, the surface of the cultivated area and distribution.

Due to the increased polymorphism regarding the trees and fruiting characteristics two distinct types of cultivars are grown in different countries:

- terminal bearing walnut cultivars;
- lateral bearing walnut cultivars.

Genetic and geographical origin of walnut cultivars

A germplasm walnut collection has been established at Vâlcea Fruit Growing Research & Extension Station (SCDP Vâlcea). Since 2010 the research station belongs to the University of Craiova. The germplasm collection is part of the national collection (field gene bank) and comprises 118 walnut accessions. The accessions are formed of domestic and foreign cultivars (30), autochthonous biotypes, selections, hybrids, etc. 5 accessions are different *Juglans* species, the rest of 113 accessions belong to *Juglans regia* L.

Juglans regia is a diploid species (2n = 32). Genetic analysis using RAPD markers, ISSR and microsatellites known as simple sequence repeats (SSRs) have highlighted the genetic variability of the walnut provenances studied (5 to19 alleles per locus) and a high heterozygosity (0.597 to 0.644) (Fornari et al., 1999, Malvolti et al., 2001; Pollegioni et al., 2005, Pop et al., 2013; Pollegioni et al., 2005).

In the walnut collection located at SCDP Vâlcea cultivars, biotypes and natural hybrids of various origins are present. The genotypes formed into the conditions of temperate climate have terminal fruit bearing. Cultivars and selections from California (S.U.A.), SW France and the Caucasus, which have lateral bearing, are provenances with origins in warmer climates (Central Asia, Iran, Afghanistan, etc). Although the accessions with lateral bearing belong to *Juglans regia* L., their genetic and phenotypic characteristics are different if compared to terminal bearing cultivars.

2. Materials and Methods

The biological material used for this study consists of 18 walnut cultivars with terminal bearing (Table 1) and 9 with lateral bearing (Table 2) from the SCDP Vâlcea germplasm collection.

The cultivars have been grafted on *Juglans regia* seedlings. The planting was done in a trial belonging to SCDP Vâlcea, at 9.0 by 8.0 meters (density of 139 trees/ha) on an alluvial soil with slightly acid reaction. No irrigation was provided to the trees. The mean annual rainfall reaches 715 mm. The age of the trees is of 20 to 22 years.

Pruning was carried out annually for the walnut trees. The soil between rows was tilled annually.

Table 1. List of studied walnut cultivars with terminal bearing

No.	*Cultivar name*	*Geographical origin*	*No.*	*Cultivar name*	*Geographical origin*
1	'Adams 10'	Oregon (U.S.A.)	10	'Sarmis'	Hunedoara (Romania)
2	'Argeşan'	Argeş (Romania)	11	'Sibişel 44'	Hunedoara (Romania)
3	'Franquette'	Isère (France)	12	'Valcor'	Vâlcea (Romania)
4	'Geoagiu 65'	Hunedoara (Romania)	13	'Valcris'	Vâlcea (Romania)
5	'Germisara'	Hunedoara (Romania)	14	'Valmit'	Vâlcea (Romania)
6	'Idaho'	Idaho (U.S.A.)	15	'Valrex'	Vâlcea (Romania)
7	'Jupâneşti'	Argeş (Romania)	16	'Valstar'	Vâlcea (Romania)
8	'Muscelean'	Argeş (Romania)	17	'Velniţa'	Iaşi (Romania)

9	'Orăştie'	Hunedoara (Romania)	18	'Univał'	Vâlcea (Romania)

Table 2. List of studied walnut cultivars with lateral bearing

No.	*Cultivar name*	*Genetic origin*	*Geographical origin*
1	'Ferjean'	'Grosvert' x 'Lara'	Bordeaux (France)
2	'Fernette'	'Franquette' x 'Lara'	Bordeaux (France)
3	'Fernor'	'Franquette' x 'Lara'	Bordeaux (France)
4	'Hartley'	'Franquette' x 'Mayette' ?	California (U.S.A.)
5	'Lara'	Seedling of 'Payne'	Gironde (France)
6	'Payne'	Seedling selection	California (U.S.A.)
7	'Pedro'	'Conway Mayette' x 'Payne'	California (U.S.A.)
8	'Serr'	'Payne' x PI 159568	California (U.S.A.)
9	'Vina'	'Franquette' x 'Payne'	California (U.S.A.)

Sprays against pests and diseases were also carried out (6 ÷ 7 per year) depending on the alerts issued by Vâlcea Phytosanitary Office. Observations were done regarding the growth elements, yielding and adaptation to the specific ecological condition of the Vâlcea area.

3. Results and Discussions

The researches conducted over two decades at SCDP Vâlcea, into the Subcarpathian area of Oltenia, on walnut cultivars with various geographical origins and different agro-biological characteristics have highlighted their growth and yielding under the ecological conditions of this area.

The walnut cultivars with terminal fruit bearing habits (15 from Romania, 2 from U.S.A. and one from France) showed very different behaviours in comparison with those with lateral bearing (4 from France and 5 from U.S.A.).

The growth of the terminal bearing walnut cultivars proved to be higher than the lateral bearing ones, although the same type of rootstocks have been used for both types of cultivars.

The trunk cross sectional area (TCSA) taken into account was 1,151 cm^2 on the average in the 22nd year after having been planted in the orchard. In case of lateral bearers, mean TCSA reached 991 cm^2 in the same year (Table 3). The growth difference of TCSA between the two types of walnut cultivars was of 160 cm^2 those with terminal bearing being on the average by 16.1% more vigorous. The crown volume (CV) of the trees was of 235 m^3 on the average in the case of terminal bearers, while lateral bearers reached 183 m^3. The difference between the two groups of walnut cultivars was of 37 m^3, which represents 28.4% more for the

terminal ones. Taking into account both TCSA and CV levels as indicators of growth vigour, the walnut cultivars having terminal bearing habit proved 20 to 30% more vigorous than the lateral ones.

Table 3. Growth differences between terminal and lateral bearing walnut cultivars depending on age

No.	*Specification*	*Age of trees* (years)	*TCSA* (cm^2)	*Trunk diameter* (cm)	*Crown volume* (m^3)	*The average length of annual growth* (cm)
1	Cultivars with terminal bearing (mean for 18 cultivars)	15	679	29.4	151	36
		22	1151	38.3	235	30
		Difference	*472*	*8.8*	*84*	*-6*
2	Cultivars with lateral bearing (mean for 9 cultivars)	15	579	27.1	136	64
		22	991	35.5	183	59
		Difference	*412*	*8.4*	*47*	*-5*
	Difference between cultivars groups	-	*160*	*2.8*	*37*	*29*

The lateral bearing walnut cultivars show a tendency to have, on average, stronger annual growth (64 to 59 cm) than the terminal ones (36 to 30 cm) in the 15th and 22nd leaf.

The difference of 29 cm (96.6%) for lateral bearing cultivars is due to the genotype and phenotype both giving the character of bearing fruits. When there is not enough long annual growth, the ability of these cultivars to produce fruits on lateral branches decreases. Taking into account the growth vigour of the studied walnut cultivars the suitable density in the orchard should be between 100 to 150 trees/ha, depending on the cultivar and 150 to 200 trees per hectare for lateral bearers.

Table 4. Advantages and disadvantages of cultivation of different walnut cultivars in the Subcarpathian area of Oltenia

No.	*Specification*	*Cultivars with terminal bearing*	*Cultivars with lateral bearing*
1	Growth vigour	High	20-30% lower
2	Tree density per hectare (*J. regia* seedling rootstock)	100 - 150	150 - 200
3	Flowering time (limits)	April 15-May 17	April 16-May 15
4	Precocity in bearing fruits (age)	4 - 6	3 - 4
5	Yield (kg/ha)	2010 - 2950	3260 - 3730
6	Fruit quality (shape, size, core yield, etc.)	Good	Good
7	Resistance to low temperatures	Good (-20°C; -28°C)	Weak (-18°C; -22°C)
8	Resistance to blight	Relatively good	Weak

	(*Xanthomonas campestris* pv. *juglandis*)		
9	Dependence on climate factors	Medium	Very high
10	Dependence on culture technology	Medium - high	Very high

The blooming time for the male and female flowers of the studied walnut cultivars ranged from the 15th of April till May 17. Out of the 27 cultivars the latest regarding blooming of female flowers proved 'Fernette' and 'Fernor' (lateral bearing cv.) and 'Franquette' (terminal bearer).

Coming into bearing fruits time takes place earlier for the lateral bearing cultivars, these cultivars being more precocious by 1 to 3 years (on average) than the terminal ones, although the fruit yields in the first productive years do not overpass 200-500 kg of dry fruits/ha.

Table 5. Fruit yields of terminal bearing walnut cultivars grown at SCDP Vâlcea

No.	*Cultivar*	*Cumulative yield (6th to 22nd leaf)* (t/ha)	*Average production (17 years)* (t/ha)
1	'Argeșan'	41.31	2.43
2	'Geoagiu 65'	41.65	2.45
3	'Germisara'	38.42	2.26
4	'Muscelean'	43.35	2.55
5	'Orăștie'	41.14	2.42
6	'Sarmis'	38.76	2.28
7	'Sibișel 44'	34.17	2.01
8	'Jupânești'	50.15	2.95
9	'Valcor'	42.28	2.84
10	'Valmit'	45.05	2.65
11	'Valrex'	45.37	2.67
12	'Velnița'	44.54	2.62
13	'Valcris'	45.56	2.68
14	'Valstar'	43.18	2.54
15	'Univall'	44.37	2.61
16	'Franquette'	47.60	2.80
17	'Idaho'	35.70	2.10
18	'Adams 10'	36.55	2.15
Mean		***42.18***	

The lateral bearing walnut cultivars are generally known to be more productive per hectare than the terminal bearing ones. This can be explained not only due to

larger yields per tree but also as a result of higher tree density per hectare in the case of lateral bearers and counting their precocity in producing yields.

In the given study condition from the trial located in Rm. Vâlcea which has no irrigation, the average yield of terminal cultivars was 2.50 t/ha (Table 5), while the average yield of lateral bearing cultivars reached 3.48 t/ha on average (Table 6). The terminal bearing cultivars' mean yields over 17 years of production oscillated from 2.01 t/ha ('Sibişel 44') to 2.95 t/ha ('Jupâneşti'). In the case of lateral bearing cultivars the yields were between 3.26 t/ha ('Fernor') to 3.73 t/ha ('Vina').

Table 6. Fruit yields of lateral bearing cultivars grown at SCDP Vâlcea

No.	*Cultivar*	*Cumulative yield (6^{th} to 22^{nd} leaf)* (t/ha)	*Average yield (17 years mean)* (t/ha)
1	'Fernette'	58.65	3.45
2	'Fernor'	55.42	3.26
3	'Ferjean'	61.51	3.62
4	'Hartley'	63.41	3.69
5	'Lara'	55.42	3.26
6	'Pedro'	59.33	3.49
7	'Payne'	61.03	3.59
8	'Vina'	62.73	3.73
9	'Serr'	55.59	3.27
Mean		***59.23***	***3.48***

The quality of the fruits for the two groups of cultivars (shape and size of walnuts, kernel efficiency and quality, exocarp thickness, etc.) is, on average, very similar.

One of the problems of cultivation of lateral bearing walnut cultivars in continental climate areas is their susceptibility to low temperatures during winter. Also, terminal bearers from warmer climates like 'Franquette' might be also susceptible to winter temperatures in colder growing areas.

Research carried out by Aslamarz et al. (2010) showed that one year old twigs (annual growth) of lateral bearing walnut cultivars can be affected in November at -7.5°C ('Serr'), -8.3°C ('Hartley'), -10.0°C ('Lara') and -11.6°C ('Pedro') and in December at -14.1°C ('Serr'), -10.8°C ('Hartley'), -19.1°C ('Lara') and -20.0°C ('Pedro'). Charrier et al. (2013) mention that buds of 'Franquette' and 'Lara' walnut cultivars resist during winter to -18.5°C.

Aletà et al. (2014) report over one year observation on frost hardiness of several cultivars including 'Franquette' (-20.9°C), 'Serr'(-20.5°C), 'Fernor'(-21.3°C) and 'Chandler' (-24.5°C). Almost the same behaviour of these walnut cultivars on

frost hardiness might be explained by their closely related origin (Germain et al., 1999; cited by Aletà et al., 2014).

Gandev (2013) speak about the effect of extreme low temperatures (6 days with temperatures ranging from -13.0°C to -24.4°C) recorded in Plovdiv - Bulgaria on February 2012 on reproductive organs of lateral bearing cultivars 'Lara', 'Izvor 10' and 'Fernor'. 'Lara' proved to be most affected by low temperatures (98% of male buds and 90% of the females ones), followed by 'Fernor' (84.7%, respectively 32%) and 'Izvor 10' (40.7% and 23.3%).

Table 6. Minimum temperatures and recording times in 50 years. (Source: ANM Bucharest http://www.meteoromania.ro)

No.	Different areas from Romania	Lowest temperature in the last 50 years (°C)	Year of recording the absolute minimum temperature	Number of years with temperatures below -20°C	Ratio between number of years (50) and temperatures below -20°C	Number of years with temperatures between -26°C to -30°C	Ratio between number of years (50) and temperatures between -26°C to -30°C	Minimum annual mean temperatures over 50 years period (°C)
1	Bacău	-30.8	1963	26	1.9	2	25.0	-20.5
2	Brăila	-25.5	1985	5	7.4	-	-	-16.3
3	Galați	-23.4	1963	6	8.3	-	-	-16.2
4	Constanța	-17.8	2010	-	-	-	-	-12.3
5	Craiova	-29.4	1963	6	8.3	1	50.0	-16.6
6	Iași	-30.6	1963	23	2.7	4	12.5	-19.8
7	Mangalia	-19.5	2010	-	-	-	-	-12.6
8	Oradea	-22.8	1964	10	5.0	-	-	-16.7
9	Pitești	-23.8	1963	5	7.4	-	-	-15.7
10	Ploiești	-29.5	1963	23	2.2	5	10.0	-19.9
11	Rm. Vâlcea	-27.0	1967	2	25.0	-	-	-13.6
12	Satu Mare	-30.4	1961	27	1.8	6	8.3	-20.7
13	Timișoara	-35.3	1963	11	4.5	1	50.0	-16.4
14	Tg. Mureș	-32.8	1963	28	1.8	5	10.0	-20.8
15	Brașov	-32.3	1985	43	1.1	17	2.9	-24.1

Over the last 20 years, in Romania, in locations like Constanţa and Mangalia minimum temperature below -20°C were not recorded, while in Rm. Vâlcea such temperatures occurred twice in 50 years (Table 6). Extreme low temperatures were recorded in 1985 in Brăila (-25.5°C) and Braşov (-32.3°C).

In Braşov, Tg. Mureş, Satu Mare, Bacău, Iaşi, Ploieşti temperatures below -20°C occur once every 3-4 years. Below -26°C temperatures during winter can be recorded in Braşov, Satu Mare, Ploieşti, Tg. Mureş, etc. In such areas, lateral bearing cultivars can be affected more than the terminal bearing cultivars. Lateral bearers have longer vegetation period (till mid November) and, in some years, when winter comes earlier, the trees suffer badly because they are not prepared for low temperatures. In such conditions, young trees (1st to 4th leaf) can be totally compromised. The behaviour of walnut cultivars to early and late frosts and to

low temperatures during winter should be taken into serious account when establishing new orchards.

Carpathian walnut cultivars, which are terminal bearing ones, prove to be less susceptible to such events compared to lateral bearing cultivars, which come from warmer areas of the world.

During the studied period, lateral bearing cultivars proved more susceptible to blight (caused by *Xanthomonas campestris* pv. *juglandis*) on fruits and shoots. Contrariwise, these cultivars were less susceptible to anthracnose (caused by *Gnomonia leptostyla* fungus) than the terminal bearers.

Investment in large walnut orchards should be carefully planned taking into account long term analysis of the local ecological conditions and choosing appropriate cultivars and orchard management.

Conclusions

(1) Domestic walnut cultivars and some foreign ones with terminal bearing habits are adapted to the specific ecological conditions from favourable walnut growing areas of Romania.

(2) Lateral bearing walnut cultivars from U.S.A. and France are susceptible to temperatures below -20°C; -23°C during winter and for that reason establishing orchards with such cultivars should be done only in favourable ecological areas.

(3) In adequate ecological conditions and with proper management the lateral bearing walnut cultivars can be more productive than the terminal bearing ones.

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