

The Productive Capacity and Quality of Several Walnut Cultivars (*Juglans regia* L.) Grown in North Oltenia, Romania

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Abstract

Romania has tradition in walnut culture and favorable climatic conditions. In order to establish the suitable cultivars for growing into the Northern Oltenia area several walnut cultivars of different origin were evaluated for productivity and fruits quality. Twelve Romanian cultivars and two foreign ones with terminal bearing and 10 cultivars with lateral bearing from France and U.S.A. were studied during 18 years of yielding with no irrigation. The group of lateral bearing cultivars proved to be more productive in the environmental conditions of the study area, the highest average yields were recorded for 'Vina' (3.64 t ha⁻¹), 'Hartley' (3.59 t ha⁻¹), 'Ferjean' (3.52 t ha⁻¹), 'Payne' (3.45 t ha⁻¹), 'Pedro' (3.39 t ha⁻¹), etc. The most productive terminal bearing cultivars were: 'Jupânești' (2.88 t ha⁻¹), 'Valcor' (2.77 t ha⁻¹), 'Franquette' (2.71 t ha⁻¹), 'Valcris' (2.62 t ha⁻¹), etc. Although the lateral bearing cultivars emphasized good yields, their extensive culture into the areas with continental type of climatic conditions should be further analysed. The walnut kernel and oil content show that the cultivars are very similar regarding chemical composition when growing under same conditions in Northern Oltenia.

Keywords: breeding; fatty acids composition; genotypes; kernel; oil; yield

Introduction

Common walnut (*Juglans regia* L.), known also as Carpathian, Persian or English walnut, is grown in more than 60 countries all over the world from both hemispheres (Avanzato *et al.*, 2014).

Most of the walnut production, which reached 3,462,731 tons in 2016, is obtained in China, U.S.A., Iran, Turkey, Ukraine, Chile, France, etc. Romania is on the 8th place in the world rank and in the 2nd place in the E.U., after France (FAO Stat Database, 2018).

Although Romania has tradition in walnut culture and favorable climatic conditions, the production is not constant and very variable from qualitative point of view due to the fact that most of the walnuts are harvested from non-grafted individual trees and from small gardens. Organized walnut orchards cover only 1,673 ha (FAO Stat Database, 2018).

In the last years, the interest for establishing new walnut orchards increased a lot in Romania, but also in many other countries, as result of economic benefits and high demands of walnuts on the world market.

Productivity of walnut trees and nut quality are key parameters in assessing the behavior of walnut varieties.

The genetic and geographical origins of the cultivars and the environmental and technical conditions are responsible for increasing the productivity, fruit quality and economic suitability of walnut culture (Burke *et al.*, 1976; Grimo, 1981; Botu and Achim, 1994; Botu, 1998; Botu *et al.*, 2001; Aleta *et al.*, 2014).

In order to achieve high yields and quality in-shell walnuts or kernels, the orchards should be planted with adequate cultivars grafted on suitable rootstocks only in the areas with most favorable environmental conditions.

In the last decades, at University of Craiova - SCDP Vâlcea, a walnut collection and trials have been set up, over 128 local and introduced varieties, biotypes and hybrids

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being under evaluation. The purpose is to determine which the most valuable walnut cultivars are for the environmental conditions of Northern Oltenia in terms of productivity, quality and profitability. Also, a breeding program has been launched in the 1990s having the aim to release cultivars adapted to the local environment, productive, resistant or tolerant to main diseases and producing quality nuts. Till now, seven cultivars were released: 'Valcor' (1999), 'Valrex' (1999), 'Valmit' (2000), 'Unival' (2010), 'Valstar', 'Timval' and 'Valcris' (2012) and one seedling rootstock, 'Portval' (2003).

Current paper presents the results achieved testing practically some of the most used walnut cultivars from the international assortment, along with Romanian cultivars in order to establish the most suitable cultivars to be grown in the Northern Oltenia.

Materials and Methods

Plant material

The research has been carried out at Fruit Growing Research and Extension Station (S.C.D.P.) Vâlcea, belonging to the University of Craiova. The trial is located in Bujoreni, north of Râmnicu Vâlcea (45° 8'22.35"N and 24° 22'36.85"E), in the North of Oltenia Region, where the climate is of Cfb Köppen - Geiger type (Rubel and Kottek, 2010). The annual average temperature is 10.2 °C and annual rainfall of 715 mm in the study area. Taking into account the amount of rainfall, no irrigation of the trees was provided. The trial was set up in 1997, using planting distances of 9.0 by 8.0 meters (density of 139 trees ha⁻¹), on an alluvial soil, having a pH of 6.8.

Twenty-four walnut cultivars were used, all of them being grafted on *Juglans regia* seedlings rootstock. Twelve of the cultivars are Romanian ('Argeșan', 'Germisara', 'Jupânești', 'Mihaela', 'Orăștie', 'Sibișel precoce', 'Sibișel 44', 'Timval', 'Unival', 'Valcor', 'Valcris' and 'Valmit'), seven from U.S.A. ('Adams 10', 'Hartley', 'Payne', 'Pedro', 'Serr', 'Tehama' and 'Vina') and five from France ('Ferjean', 'Fernette', 'Femor', 'Franquette' and 'Lara'). Five trees of each cultivar were planted into the trial. Into the trial the trees were trained in the first six years after planting, pruning was carried out every year. Yield was evaluated each year, samples of 30 walnuts per cultivar per year were collected and carpological analysis has been performed.

The chemical composition of the kernel, oil and residue for the walnut samples collected have been analyzed at the National Research and Development Institute for Cryogenics and Isotopic Technologies - ICSI Rm. Vâlcea (Popescu *et al.*, 2016).

For the analysis of variance (ANOVA) the MS Excel software was utilized and DSAASTAT ver. 1.514 (2015) for the Duncan's Multiple Range Test at significance level of $p < 0.05$. DSAASTAT is an Excel VBA Macro developed by Onofri (2007).

Results and Discussion

The study conducted at SCDP Vâlcea aimed to establish the production capacity of several walnut cultivars in the intensive orchard under the environmental conditions from

North Oltenia. Fourteen of the cultivars used in this study have terminal bearing; twelve of them are of Romanian origin, one from Oregon - U.S.A. ('Adams 10') and one from France ('Franquette'). The ten remaining cultivars are either intermediate or lateral bearers and are originated in the U.S.A. and France (Table 1).

Over the 23 years from planting, 18 years of production were counted. In 2017, due to frost recorded during the blooming period (-2.1 °C on April 22nd, 2017) most of the yield was affected.

The mean yield counted for 18 years period for the terminal bearing cultivars fluctuated between 2.88 t ha⁻¹ ('Jupânești') and 1.97 t ha⁻¹ ('Sibișel 44'). The most productive varieties turned out to be: 'Jupânești' (2.88 t ha⁻¹), 'Valcor' (2.77 t ha⁻¹), 'Franquette' (2.71 t ha⁻¹), 'Valcris' (2.62 t ha⁻¹), 'Valmit' (2.58 t ha⁻¹), 'Unival' (2.55 t ha⁻¹), 'Argeșan' (2.37 t ha⁻¹), 'Orăștie' (2.36 t ha⁻¹). 'Franquette', an old French variety with late blooming is still considered one of the basic cultivars in the orchards from France and U.S.A. and is known for its very good quality fruits.

In case of varieties with intermediate and lateral bearing the mean yield oscillated between 3.64 t ha⁻¹ ('Vina') and 2.96 t ha⁻¹ ('Tehama'). The largest nut yields were obtained at: 'Vina' (3.64 t ha⁻¹), 'Hartley' (3.59 t ha⁻¹), 'Ferjean' (3.52 t ha⁻¹), 'Payne' (3.45 t ha⁻¹), 'Pedro' (3.39 t ha⁻¹), 'Fernette' (3.37 t ha⁻¹), 'Femor' (3.19 t ha⁻¹), etc.

The lateral bearing varieties achieved an average yield of 3.34 t ha⁻¹, with 0.91 t ha⁻¹ higher than the terminal ones (2.43 t ha⁻¹).

These yields were obtained in North Oltenia, in an area where during the study period the minimum temperature recorded was -22.7 °C. In the rest of the study period the low temperatures did not fall below -18 °C; -19 °C.

Botu *et al.* (2017) mention that cultivation of lateral bearing walnut cultivars in continental climate areas is influenced by their susceptibility to low temperatures during winter. Terminal bearing cultivars from warmer climates like 'Franquette' are susceptible to winter temperatures too. Studies carried out by Aslamarz *et al.* (2010), Charrier *et al.* (2013), Gandev (2013), Aletà *et al.* (2014), all cited by Botu *et al.* (2017) confirm the susceptibility to low temperatures of the lateral bearing cultivars.

Such walnut cultivars should be planted only in favorable areas where the climate is milder during winter in order to perform well. Another issue to be taken into account is their susceptibility to diseases, especially to walnut blight (caused by *Xanthomonas arboricola* pv. *juglandis*). The lateral bearing cultivars proved more susceptible to blight on fruits and shoots than the terminal bearing ones (Botu *et al.*, 2017).

In international trade the quality of in-shell and shelled walnut is very important, function of these, the prices vary a lot. The quality of walnuts is influenced by many characteristics, but also by the biometric features and chemical composition of kernels.

In case of the nut samples collected from the trial the nut size index (SI) was calculated:

$SI = (D + d + h)/3$, where D is maximum diameter, d is minimum diameter and h is the nut height.

Table 1. Cumulative and average walnut yield for cultivars grown in Northern Oltenia

No.	Cultivar	Country of origin	Type of bearing fruits	Nut yield over 18 years	
				Cumulative yield (t ha ⁻¹)	Average yield (t ha ⁻¹)
1	'Jupânești'	Romania	terminal	51.87	2.88 a
2	'Valcor'	Romania	terminal	49.92	2.77 ab
3	'Valmit'	Romania	terminal	46.50	2.58 cd
4	'Valcris'	Romania	terminal	47.07	2.62 bcd
5	'Unival'	Romania	terminal	45.90	2.55 d
6	'Sibișel 44'	Romania	terminal	35.40	1.97 g
7	'Germisara'	Romania	terminal	39.89	2.22 ef
8	'Timval'	Romania	terminal	41.70	2.32 e
9	'Orăștie'	Romania	terminal	42.50	2.36 e
10	'Argeșan'	Romania	terminal	42.64	2.37 e
11	'Mihaela'	Romania	terminal	41.03	2.28 e
12	'Sibișel precoce'	Romania	terminal	40.15	2.23 ef
13	'Adams 10'	USA	terminal	37.77	2.10 fg
14	'Franquette'	France	terminal	48.81	2.71 bc
	<i>Mean</i>			<i>43.65</i>	<i>2.43</i>
15	'Hartley'	USA	intermediate	64.68	3.59 ab
16	'Pedro'	USA	lateral	61.09	3.39 c
17	'Vina'	USA	lateral	65.56	3.64 a
18	'Serr'	USA	lateral	56.61	3.15 d
19	'Payne'	USA	lateral	62.16	3.45 bc
20	'Tehama'	USA	lateral	53.23	2.96 e
21	'Fernette'	France	lateral	60.59	3.37 c
22	'Fernor'	France	lateral	57.5	3.19 d
23	'Lara'	France	lateral	57.17	3.18 d
24	'Ferjean'	France	lateral	63.35	3.52 abc
	<i>Mean</i>			<i>60.19</i>	<i>3.34</i>

Note: Means followed by the same letter *do not* differ significantly from one another (Duncan's multiple range test, $p < 0.05$)

The nut size index is on average 37.39 mm for terminal bearing varieties and 36.05 mm for lateral ones (Table 2). The size index fluctuates between 33.7 mm ('Sibișel precoce') and 42.5 mm ('Sibișel 44') for Romanian cultivars, and in case the foreign ones between 33.2 mm ('Fernor') and 40.0 mm ('Adams 10').

The shape of walnuts was determined using the index of roundness (IR).

$$IR = (D + d) / 2h$$

Differences on average are not major between the two groups of walnut cultivars, for the terminal bearing ones the mean of index of roundness was 0.82 while for the lateral ones 0.84. The closer the index of roundness gets to 1.0, the more round is the nut. Among the Romanian varieties there are some with round fruits ('Argeșan', 'Sibișel precoce', 'Valcor', 'Unival', 'Valcris' etc.), but also with elongated ones ('Jupânești', 'Sibișel 44' and 'Orăștie').

Fruits of foreign varieties are round in case of: 'Lara', 'Fernette', 'Adams 10', 'Pedro', etc.) and more elongated for: 'Ferjean', 'Franquette', 'Vina' and 'Hartley'.

Average fruit weight is 13.88 g for the terminal bearing varieties and 12.68 g for the lateral ones (Table 2). Larger fruits regarding weight in the first group were observed for 'Argeșan' (16.6 g), 'Sibișel 44' (15.7 g), 'Orăștie' (14.8 g), 'Germisara' and 'Unival' (14.6 g), 'Valmit' (14.5 g), while in the second one the largest fruits were observed for 'Tehama'

(13.6 g), 'Lara' (13.3 g) and 'Vina' (13.1 g). Smallest fruits were presented by 'Sibișel precoce' (11.3 g), 'Jupânești' (11.7 g) and respectively 'Hartley' (11.5 g). For the in-shell market most of the walnuts sold are in the range of 12 grams.

An important element for the shelled market is the kernel percentage of the cultivars. It is desired that the kernel efficiency to overpass 50%.

The Romanian varieties oscillate between 48.5% ('Sibișel 44') and 53.6% ('Valmit'). The terminal bearing cultivars have an average of 50.34% of kernel; the lowest level was recorded in case of 'Franquette' (46.8%). Lateral bearing cultivars have kernel percentage between 46.5% ('Fernor') and 53.7% ('Serr'). Mean calculated for this group is 50.26%.

The coefficients of variability for the nut size reached in average 19.91% for the terminal bearing cultivars and 17.52% for the lateral ones. The highest coefficients were observed for 'Mihaela', 'Sibișel precoce', 'Argeșan', 'Jupânești' and 'Germisara' while the lowest coefficients were recorded for 'Valcor' (Table 3). In case of lateral bearing cultivars, the lowest coefficients were for 'Hartley', 'Fernor', 'Ferjean' and 'Vina'. The foreign varieties present in this study very little variables in size compared to the Romanian ones. Depending of the equatorial diameter of the walnuts the cultivars can fit into size classes which are used for the in-shell walnut trade.

Table 2. Nut characteristics of the walnut grown in Northern Oltenia

No.	Cultivar	Nut size index (mm)	Nut index of roundness	Average nut weight (g)	Average kernel weight (g)	Kernel percentage (%)
1	'Jupânești'	34.0 g	0.69 l	11.7 mn	5.9 ij	50.4 def
2	'Valcor'	36.9 cde	0.86 ef	13.9 de	7.1 de	50.5 def
3	'Valmit'	36.2 f	0.83 fg	14.5 c	7.7 c	53.6 a
4	'Valcris'	35.6 f	0.85 ef	14.0 d	7.0 def	50.0 efg
5	'Unival'	36.4 def	0.86 ef	14.6 c	7.4 cd	51.0 cde
6	'Sibișel 44'	42.5 a	0.69 l	15.7 b	7.6 c	48.5 ghi
7	'Germisara'	42.4 a	0.78 hi	14.6 c	7.4 cd	50.5 def
8	'Timval'	37.0 cd	0.85 ef	13.9 de	7.1 de	50.9 cde
9	'Orăștie'	39.5 b	0.73 jk	14.8 c	7.8 c	52.8 ab
10	'Argeșan'	38.0 c	0.91 bc	16.6 a	8.3 b	49.8 efg
11	'Mihaela'	35.7 f	0.83 fg	12.6 ijk	6.5 fgh	51.4 bcde
12	'Sibișel precoce'	33.7 g	0.90 bcd	11.3 n	5.7 j	50.4 def
13	'Adams 10'	40.0 b	0.88 cde	13.5 efg	6.5 fgj	48.2 hij
14	'Franquette'	35.6 f	0.79 hi	12.6 ijk	5.9 ij	46.8 ij
	<i>Mean</i>	<i>37.39</i>	<i>0.82</i>	<i>13.88</i>	<i>6.40</i>	<i>50.34</i>
15	'Hartley'	35.8 ef	0.78 hi	11.5 n	5.6 j	49.0 fgh
16	'Pedro'	35.2 f	0.87 de	12.4 ijkl	6.5 fgh	52.4 abc
17	'Vina'	37.6 cd	0.70 kl	13.1 gh	7.0 def	53.4 a
18	'Serr'	35.7 f	0.85 ef	12.4 ijkl	6.7 efg	53.7 a
19	'Payne'	37.1 cd	0.81 gh	12.1 jlm	6.3 a	52.1 abcd
20	'Tehama'	35.4 f	0.83 fg	13.6 def	6.8 efg	50.0 efg
21	'Fernette'	35.4 f	0.92 b	12.6 ij	6.7 efg	53.1 ab
22	'Fernor'	33.2 g	0.81 gh	12.7 hi	5.9 ij	46.5 j
23	'Lara'	37.4 cd	0.99 a	13.3 fg	6.4 gh	48.1 hij
24	'Ferjean'	35.2 f	0.76 ij	12.5 ijkl	6.2 hi	49.6 efg
	<i>Mean</i>	<i>36.05</i>	<i>0.84</i>	<i>12.68</i>	<i>6.46</i>	<i>50.26</i>

Note: Means followed by the same letter *do not* differ significantly from one another (Duncan's multiple range test, $p < 0.05$)

Table 3. Nut sizes depending on diameter for the walnut cultivars grown in Northern Oltenia

No.	Cultivar	Coefficient of Variability of nut size (ϵ %)	Equatorial diameter of nut (mm)	Size classes depending on nut diameter (%)			
				(>32 mm)	(30-32 mm)	(28-30 mm)	(<28 mm)
1	'Jupânești'	22.7 abcd	30.2 g	59.8	33.7	4.7	1.8
2	'Valcor'	16.5 e	36.6 bcd	82.0	16.1	1.9	0
3	'Valmit'	18.6 abcde	34.8 def	79.1	18.1	2.7	0
4	'Valcris'	18.9 abcde	38.8 ab	84.5	14.8	0.7	0
5	'Unival'	18.2 abcde	35.7 cde	77.2	19.6	3.2	0
6	'Sibișel 44'	18.3 abcde	38.1 abc	84.2	15.2	0.6	0
7	'Germisara'	21.2 abcd	40.6 a	81.7	17.7	0.6	0
8	'Timval'	17.5 cde	35.4 cde	75.4	18.4	6.2	0
9	'Orăștie'	20.6 abcde	36.1 bcd	74.6	21.8	3.6	0
10	'Argeșan'	23.1 abc	37.0 bcd	75.2	21.7	3.1	0
11	'Mihaela'	23.7 a	34.2 def	69.7	25.6	4.7	0
12	'Sibișel precoce'	23.5 ab	32.0 fg	67.5	24.7	6.7	1.1
13	'Adams 10'	16.9 de	36.2 bcd	73.9	17.5	8.6	0
14	'Franquette'	19.1 abcde	34.0 def	81.7	16.8	1.5	0
	<i>Mean</i>	<i>19.91</i>	<i>35.69</i>	<i>76.18</i>	<i>20.12</i>	<i>3.49</i>	<i>0.21</i>
15	'Hartley'	15.7 e	32.9 efg	69.3	23.6	7.1	0
16	'Pedro'	17.2 de	34.2 def	76.5	21.7	1.8	0
17	'Vina'	16.9 de	34.2 def	78.9	18.6	2.5	0
18	'Serr'	18.8 abcde	34.2 def	72.4	24.1	3.5	0
19	'Payne'	19.6 abcde	30.4 g	72.9	21.9	4.8	0.4
20	'Tehama'	17.5 cde	34.0 def	69.3	22.3	7.8	0.6
21	'Fernette'	18.8 abcde	35.3 cde	69.0	25.1	5.9	0
22	'Fernor'	16.4 e	31.8 fg	69.2	19.8	9.7	1.3
23	'Lara'	17.8 abcde	38.7 ab	79.5	18.3	2.2	0
24	'Ferjean'	16.5 e	34.8 def	68.3	24.2	6.7	0.8
	<i>Mean</i>	<i>17.52</i>	<i>34.05</i>	<i>72.53</i>	<i>21.96</i>	<i>5.20</i>	<i>0.31</i>

Note: Means followed by the same letter *do not* differ significantly from one another (Duncan's multiple range test, $p < 0.05$)

Table 4. Comparative chemical composition of kernel, oil and residues from walnut cultivars grown in Northern Oltenia

No.	Mean chemical composition	Mean for the 24 walnut cultivars studied	Dispersion measures			Cultivars originating from:		
			Variance (s ²)	Standard deviation (s)	Coefficient of variation (s %)	Romania (*)	U.S.A. (**)	France (***)
a) Kernel								
1	Total fat (%)	70.4	12.00	3.46	4.90	71.0	66.6	73.6
2	Proteins (%)	19.9	0.07	0.26	1.30	20.1	19.8	19.7
3	Carbohydrates (%)	10.0	11.57	3.40	34.0	9.9	13.5	6.7
4	Energy (kcal 100 g ⁻¹)	700	5.50	2.34	0.33	699	703	699
b) Oil								
1	Saturated fatty acids (%molar)	10.6	0.12	0.35	3.30	10.6	10.2	10.9
2	Oleic acid (%molar)	22.5	1.35	1.16	5.10	22.5	23.6	21.3
3	Linoleic acid (%molar)	55.7	0.30	0.55	0.98	55.7	55.2	56.3
4	Linolenic acid (%molar)	11.3	0.04	0.20	1.76	11.3	11.1	11.5
5	Energy (kcal 100 g ⁻¹)	874	676	26.00	2.97	874	900	848
c) Residues								
1	Proteins (%)	40.8	-	-	-	40.8	39.8	41.7
2	Energy (kcal 100 g ⁻¹)	300	-	-	-	300	307	293

(*) 'Argeșan', 'Germisara', 'Jupânești', 'Mihaela', 'Orăștie', 'Sibișel precoce', 'Sibișel 44', 'Timval', 'Unival', 'Valcor', 'Valcris' and 'Valmit';

(**) 'Adams 10', 'Hartley', 'Payne', 'Pedro', 'Serr', 'Tehama' and 'Vina';

(***) 'Ferjean', 'Fernette', 'Fernor', 'Franquette' and 'Lara'.

On average, the terminal bearing walnut varieties present 76.18% of the nuts fitting in the class over 32 mm. Over 80% of the nuts larger in diameter than 32 mm were observed for 'Valcris' (84.5%), 'Sibișel 44' (84.2%), 'Valcor' (82.0%), 'Germisara' and 'Franquette' (81.7%).

The chemical composition of the kernel, oil and residue of the walnut cultivars' samples were analyzed at the National Research and Development Institute for Cryogenics and Isotopic Technologies - ICSI Rm. Vâlcea (Popescu *et al.*, 2016). In case of the walnut kernel, total fat, proteins, carbohydrates and the energy were determined. The average total fat content reached 70.4%, while for the Romanian cultivars is 71%, for the cultivars originated in the U.S. is 66.6% and for the French cultivars 73.6%. The proteins content ranged from 19.7 to 20.1%, while carbohydrates reached 6.7% for the French cultivars, 9.9% for the Romanian ones and 13.5% for the U.S. cultivars. The energy value ranged from 699 to 703 kcal 100 g⁻¹. Also, composition of walnut oil was analyzed. Differences between groups of varieties are very low. Although, the highest level of saturated fatty acids was observed for French cultivars (10.9% mol), highest content in oleic acid was reached by the U.S. cultivars. French cultivars proved to have also higher content of linoleic acid (56.3% mol) and linolenic acid (11.5% mol). The highest energy value was observed in the case of walnut oil extracted from U.S. cultivars (900 kcal 100 g⁻¹).

Among the groups of walnut cultivars grown in Northern Oltenia there is low variation regarding chemical composition of walnut kernel and oil. The coefficients of variation have values less than 10%, with the exception for the carbohydrate content (34.0%). The content of the walnut kernel and oil show that the groups of cultivars are very similar regarding chemical composition when growing under same conditions in Northern Oltenia.

In the environmental conditions of the study area, the most productive lateral bearing cultivars as 'Vina', 'Hartley', 'Ferjean', 'Pedro', 'Fernor', 'Fernette', along with terminal

bearing cultivars like 'Jupânești', 'Valcor', 'Franquette', 'Valcris' are suitable for planting into the new orchards. These cultivars proved also to have good quality nuts and exhibited tolerance to main pests and diseases.

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