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Evaluation of Some Walnut Cultivars under the Climatic Conditions of South Bulgaria

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Abstract

Introduced walnut cultivars grown as main cultivars in countries with climatic conditions different from Bulgaria, were included in the present study. This evaluation aimed at selecting walnut cultivars with suitable biological and pomological characteristics when grown under the climatic conditions of South Bulgaria.The trial demonstrated that the cultivars 'Fernor', 'Lara' and 'Tiszacsecsi 83'were later blooming than the other cultivars as 'Serr', 'Hartley', 'Izvor 10' and 'Sheynovo'. That phenological characteristic is very important to avoid spring frost damages. During the period of evaluation the results showed that the yields from the cultivars 'Izvor 10', 'Serr', 'Hartley', 'Fernor' and 'Lara' were higher compared to 'Sheynovo' and 'Tiszacsecsi 83'. This is the reason to recommend the first group of walnut cultivars to be grown under the climatic conditions of South Bulgaria.

Key words: *Juglans regia* L., cultivar, growth, fruit characteristics, yield

Introduction

Walnut as a fruit species became a priority after the accession of Bulgaria to the European Union. The century-old walnut trees found on the territory of the country are an indisputable proof that the soil and climatic conditions in our country are favorable for the optimal development of that fruit crop.

The walnut cultivars grown around the world have been selected from local resources or bred in countries with varied soil and climatic conditions. They differ from one another in their pomological and agrobiological characteristics (Solar, 1990; Malvolti et al.,1994 and 1996; Germain et al., 1997; Balci et al., 2001; Rouskas and Zakynthinos, 2001; Dogan et al., 2005).

The prevailing cultivars grown in walnut orchards in Bulgaria are local ones, of a terminal or intermediate bearing type (Nedev et al., 1976). This does not comply with the modern requirements for a walnut cultivar. The only exception is 'Izvor 10' cv., bearing fruit from lateral buds (Nedev et al., 2002). According to Ramos (1985), lateral bearing cultivars are of a higher productivity than terminal and intermediate bearing. Germain et al. (1999) established that the lateral bearing cultivars have a higher productivity due to the larger number of fruit buds than the terminal and intermediate bearing cultivars. According to Dzhuvinov et al. (2013), the productivity of the cultivar depends not only on the type of bearing and on number of female flowers, but also on the percentage of the useful fruit set and the fruit weight. The percentage of useful fruit set is a cultivar specificity, but it could be significantly influenced by some agrotechnical activities, such as pruning, fertilization, irrigation, as well as the larger distance from the pollinator. The yield of each cultivar depends of the kernel weight, which is about 5-7 g for most of the commercial cultivars.

Germain et al. (1999) found out that Californian cultivars are not suitable for growing in France due to the colder climate. In the Carpathian region of Romania the drop down of winter temperatures to minus 22.7ºC does not affect the normal growth and fruiting of the Californian and French lateral bearing cultivars (Botu et al., 2010). According to Nedev et al. (1976) the Bulgarian cultivars could be frostbitten by low winter temperatures below minus 20ºC. The Carpathian walnut is considered to be the most frost resistant in the world, as it can resist without any damages temperatures about minus 32-35 ºC (Mitra et al., 1991; Domoto, 2002).

The aim of the study was to carry out agrobiological evaluation of the introduced walnut cultivars 'Fernor', 'Lara', 'Tiszacsecsi 83', 'Serr' and 'Hartley' and to assess the possibilities of their growing in South Bulgaria.

Material and Methods

The experimental plantation was established in the spring of 2003 and the study was carried out in 2009-2013, i.e. from 7th till 11th vegetation season of the walnut trees. The type of soil is alluvial and the climate is

humid subtropical with considerable humid continental influences. The introduced cultivars 'Serr', 'Hartley', 'Fernor', 'Lara', 'Tiszacsecsi 83' plus 'Izvor 10' and the control 'Sheynovo', grafted on common walnut (*Juglans regia* L.) rootstock, were included in the study. The trees were planted at a distance of 8 x 8 m, trained to the improved layered crown system. Micro sprinkling irrigation was applied in the trial. The soil of the experimental plantation was maintained as black fallow.

Three trees of each cultivar were studied, randomly planted in the orchard, each tree being a separate replication. Data were statistically processed following Duncan's test (Steele and Torrie, 1980).

The following characteristics were reported:

Time of flowering of female and male flowers – early-flowering, 6-8 days before 'Sheynovo'; medium-flowering – their flowering period coinciding with that of the control; late-flowering –10 or more days after 'Sheynovo'. *Growth vigor* – according to the vegetative length increment of the leader and the extensions of the skeletal branches and spurs: poor growth – 10-20 cm length increment; moderate growth –20-30 cm length increment; vigorous growth – length increment over 31 cm. *Crown habit and volume* – shape, density, volume, angle of divergence of the first three skeletal branches to the leader. *Fruit-bearing type* – terminal, intermediate, lateral. *Time of ripening*: very early – 20-25 August; early – 26 August till 5 September; medium-early – 6 September till 15 September; medium-late – from 16 September till 25 September; late – after 26 September. *Yield per tree*–kg/tree. *Morphometric measurements:* fruit size in mm; mean weight of 30 fruits, grouped as: very small < 8.5 g; small –from 8.5 g to 10.5 g; medium–from 10.5 g to 12.5 g; large–from 12.5 g to 14.5 g and very large > 14.5 g. *Shell thickness*: thin – to 1.2 mm; medium thick – from 1.3 to 1.7 mm; thick – over 1.8 mm. *Kernel percentage (output in percentage*): very low–below 40%; low – 40-44%; medium–from 45 to 49%; high–from 50 to 55%; very high–over 55%. Characteristics used follow the methods of studying genetic resources of Nedev et al. (1979) and Germain (2004).

Results and Discussion

Beginning of vegetation and time of flowering are specific biological traits of common walnut (*Juglans regia* L.) and they depend on the genotype of the cultivar and the climatic conditions, under which it is grown (Germain et al., 1999). Table 1 shows that in average for the period, the standard 'Sheynovo' entered the phenological stage Cf (bud

break) on 10th April. Out of the other studied cultivars, the earliest to enter the period of vegetation was 'Serr' – 10 days before 'Sheynovo'. 'Izvor 10' cultivar also developed early, i.e. 6 days before the control. In 'Hartley' the Cf stage began 7 days after the control cultivar. The latest to enter the bud burst stage were 'Lara', 'Fernor' and'Tiszacsecsi 83'. The first one entered Cf phenological stage 15 days after the standard 'Sheynovo' and the others – 16 days after the standard (Table 1).

The mass flowering of the female flowers data (Ff2 phenological stage)shows that 'Serr' and 'Izvor 10' flowered before 'Sheynovo', while 'Hartley' and 'Lara' entered the mass flowering stage immediately after the control. The latest mass flowering season of the female flowers was reported in 'Tiszacsecsi 83' and'Lara' –10 and 11 days after the control.

The mass flowering of the male flowers is also different for the separate cultivars. Catkins of 'Serr' had the earliest mass flowering phenological stage (Fm2) – 5 days before the standard 'Sheynovo'. In all the other cultivars flowering of the male flowers was from 7 to 20 days after 'Sheynovo'. The latest development of the catkins was established for 'Fernor' and 'Lara' cultivars – 13 and 20 days after the control 'Sheynovo'.

The obtained results about fruit ripening time of the studied cultivars confirmed the investigations of Nedev et al. (1983) about the time of fruit ripening of the local cultivars 'Izvor 10' and 'Sheynovo'. 'Izvor 10' was medium early and the standard 'Sheynovo' was medium late. All the other studied cultivars were late ripening. The cultivars 'Serr' and 'Hartley' ripened 8 and 11 days after the standard 'Sheynovo', 'Lara' – 18 days after the control, while 'Tiszacsecsi 83'and'Fernor' – 20 days after 'Sheynovo'. Those results showed that the studied cultivars ripen from 15 September through 10 October under the conditions of South Bulgaria.

Growth vigor, fruiting type and crown habit are very important characteristics of the studied cultivars (Table 2). 'Sheynovo', 'Serr', 'Hartley' and 'Lara' belong to the group of vigorously growing cultivars, their annual length increment of the extensions of the leader and the skeletal branches and spurs being over 31 cm. Crown volume of 'Serr'and 'Lara' was the biggest – 139.7 m^3 and 130.4 m^3, respectively, and significant difference between the two cultivars was not established for that characteristics. The other two cultivars of vigorous growth 'Sheynovo' and'Hartley' had a similar crown volume – 104.1 m^3 and 95.2 m^3, respectively.

Tab. 1. Average phonological data about the walnut cultivars for the period 2009-2013
Prosječni fonološki podaci o sortama oraha za period 2009-2013

Cultivar *Sorta*	Apical bud burst *Pucanje apikalnih pupoljaka*		Flowering of female flowers *Cvjetanje ženskih cvjetova*					Flowering of male flowers *Cvjetanje muških cvjetova*					Time of ripening *Vrijeme zrijenja*	
	Beginning *Početak*	Number of days* *Broj dana* *	Beginning *Početak*	Number of days* *Broj dana* *	Mass flowering *Puno cvjetanje*	Number of days* *Broj dana* *	End of flowering *Kraj cvjetanja*	Number of days* *Broj dana* *	Beginning *Početak*	Number of days* *Broj dana* *	Mass flowering *Puno cvjetanje*	Number of days* *Broj dana* *	End of flowering *Kraj cvjetanja*	Number of days* *Broj dana* *	Ripening *Zrijenje*	Number of days* *Broj dana* *
Izvor 10	04.04.	-6	16.04.	-11	18.04.	-13	24.04.	-13	27.04.	+8	01.05.	+9	06.05.	+8	15.09.	-5
Sheynovo	10.04.	0	27.04.	0	01.05.	0	07.05.	0	19.04.	0	22.04.	0	28.04.	0	20.09.	0
Serr	31.04.	-10	20.04.	-7	27.04.	-4	01.05.	-6	13.04.	-6	17.04.	-5	24.04.	-4	28.09.	+8
Hartley	17.04.	+7	28.04.	+1	04.05.	+3	12.05.	+5	24.04.	+5	30.04.	+8	04.05.	+6	01.10.	+11
Fernor	26.04.	+16	06.05.	+9	12.05.	+11	20.05.	+13	30.04.	+11	05.05.	+13	09.05.	+11	10.10.	+20
Lara	25.04.	+15	02.05.	+5	06.05.	+5	17.05.	+10	07.05.	+18	12.05.	+20	19.05.	+21	08.10.	+18
Tiszacsesi 83	26.04.	+16	06.05.	+9	11.05.	+10	19.05.	+12	25.04.	+6	29.04.	+7	05.05.	+7	10.10.	+20

* Number of days compared to the control 'Sheynovo'
Broj dana uspoređen sa kontrolom 'Sheynovo'

c

Tab. 2. Growth vigor, bearing type and crown habit
Snaga rasta, tip plodonošenja i habitus krošnje

Cultivar *Sorta*	Growth vigor *Snaga rasta*	Bearing type (laterality, %) *Tip plodonošenja (linearnost, %)*	Crown habit *Habitus krošnje*		
			Shape *Oblik*	Angle deviation of skeletal branches *Ugao devijacije kod skeletnih grana*	Volume (m^3) *Obim*
Izvor 10	moderate *umjerena*	lateral (90%) *bočno (90%)*	semi-upright *polu-uspravan*	60 - 70º	59.2 c
Sheynovo	vigorous *jaka*	intermediate (25%) *mješovito (25%)*	spreading *raširen*	70 - 80º	104.1 b
Serr	vigorous *jaka*	intermediate (35%) *mješovito (35%)*	spreading *raširen*	70 - 80º	139.7 a
Hartley	vigorous *jaka*	intermediate (10%) *mješovito (10%)*	semi-upright *polu-uspravan*	60 - 70º	95.2 b
Fernor	moderate *umjerena*	lateral (90%) *bočno (90%)*	upright *uspravan*	40 - 45º	65.6 c
Lara	vigorous *jaka*	lateral (45%) *bočno (45%)*	semi-upright *polu-uspravan*	60 - 70º	130.4 a
Tiszacse-csi 83	poor *slaba*	intermediate (15%) *mješovito (15%)*	semi-upright *polu-uspravan*	60 - 70º	34.8 d

Values followed by the same letter in a column were not statistically different ($P < 0.05$).
Vrijednosti u koloni označene istim slovom nisu statistički različite ($P < 0,05$).

'Izvor 10' and 'Fernor' were of a moderate growth rate, the length increment of the extensions being 20-30 cm and the crown volume was similar – 59.2 m^3 for the former and 65.6 m^3 for the latter cultivar. 'Tiszacsecsi 83' had a poor growth rate, the length increment of the extensions being 10-20 cm and the crown volume – 34.8 m^3.

Table 2 also shows that the cultivars are of different fruit bearing types. None of the cultivars is of a typical apical fruit bearing type. The results showed that the cultivars 'Sheynovo', 'Serr', 'Hartley' and 'Tiszacsecsi 83' had intermediate fruit bearing, the laterality varying from 10 to 35%. "Lara' cultivar was characterized by 45% of lateral bearing and by that trait it fell behind the other lateral bearing cultivars in the present study – 'Izvor 10'and'Fernor', which had 80% of fruits from lateral buds .

'Fernor' is the only cultivar having an upright crown shape, 'Sheynovo' and 'Serr' hada spreading shape of the crown and 'Izvor 10', 'Hartley', 'Lara' and 'Tiszacsecsi 83' – a semi-upright crown.

The morphometric data of the walnut fruits, in average for the period 2009-2013,are presented in Table 3. As it could be considered, the

fruit size of the separate cultivars was different, as well as was the shell thickness.The shell of 'Izvor 10' and 'Sheynovo' was less than 1.2 mm and that determined them as cultivars having a thin shell. The cultivars 'Serr', 'Hartley' and 'Lara' were in the next group with shell thickness of 1.3 mm to 1.7 mm. The shell of 'Fernor' and 'Tiszacsecsi 83' was1.8 mm.

The biggest mean weight of the fruits was reported for 'Sheynovo' – 13.7 g, followed by 'Hartley' (13.5 g), 'Serr' and 'Lara' – 12.7 g and 12.8 g, respectively. However there was no significant difference between 'Serr' and 'Hartley'. The above data describing the cultivars 'Sheynovo', 'Hartley', 'Serr' and 'Lara' show that they belong to the group of cultivars with large fruits (a mean weight from 12.5 g to 14.5 g). 'Izvor 10', 'Fernor' and 'Tiszacsecsi 83' with a mean weight of the fruits 11.6g, 12.4g and 10.6g, respectively, belong to the group with a mean fruit weight varying from10.5 to 12.5 g. The cultivars 'Izvor 10' and 'Sheynovo' had a very high kernel percentage. 'Serr' cultivar was the only one with high kernel output –53.6%, 'Hartley' had a medium kernel percentage–46.7%, 'Fernor' and 'Lara' – low and 'Tiszacsecsi 83' – very low, i.e., 38.5%.

Tab. 3. Average morphometric data of walnut fruits for the period 2009-2013
Prosječni morfometrijski podaci o plodovima oraha za period 2009-2013.

Cultivar *Sorta*	Height *Visina*	Width *Širina*	Thickness *Debljina*	Shell thickness *Debljina ljuske*	Weight of 1 fruit *Težina 1 ploda*	Kernel percentage *Procenat jezgra*
	(mm)	(mm)	(mm)	(mm)	(g)	(%)
Izvor 10	41.0 bc	31.4 cd	32.1 bc	1.0 d	11.6 cd	55.5 a
Sheynovo	42.3 ab	30.8 d	32.7 bc	1.2 c	13.7 a	55.5 a
Serr	38.9 cd	34.1 ab	33.2 bc	1.4 b	12.7 abc	53.6 a
Hartley	44.3 a	33.5 ab	33.7 b	1.7 a	13.5 ab	46.7 b
Fernor	41.7 ab	32.8 bc	34.0 b	1.8 a	12.4 bc	42.8 c
Lara	37.5 d	35.4 a	36.1 a	1.4 b	12.8 abc	42.6 c
Tiszacse-csi 83	37.5 d	31.2 cd	31.4 c	1.8 a	10.6 d	38.5 d

Values followed by the same letter in a column were not statistically different ($P < 0.05$)
Vrijednosti u koloni koje su označene istim slovom (slovima) nisu statistički različite ($P < 0,05$)

In 2009 the highest yield per tree was obtained from 'Serr' cultivar – 20.9 kg (Table 4). The yields from 'Izvor 10', 'Hartley' and 'Lara' were similar and statistically proven to be lower than that of 'Serr'. Those cultivars were followed by 'Fernor' with the yield of 12.0 kg, while the average yield of 'Sheynovo' was significantly lower than all the mentioned cultivars, i.e., 9.1 kg. The lowest yield per tree was harvested from 'Tiszacsecsi 83' – only 3.9 kg per tree.

Tab. 4. Yield per tree for the period 2009-2013
Prinos po stablu za period 2009-2013

Cultivar *Sorta*	Yield per tree (kg) *Prinos po stablu (kg)*				Average yield per tree 2009-2013 *Prosječan prinos po stablu* 2009-2013
	2009	2010	2011	2013	
Izvor 10	17.9 b	23.0 b	16.8 d	26.0 a	20.9 a
Sheynovo	9.1 d	15.8 c	12.8 e	15.0 c	13.1 bc
Serr	20.9 a	29.7 a	35.9 a	8.8 e	23.8 a
Hartley	17.7 b	20.7 b	23.9 c	13.0 cd	18.8 ab
Fernor	12.0 c	22.0 b	28.5b	22.0 b	21.1 a
Lara	16.9 b	20.2 b	21.7 c	19.7 b	19.6 ab
Tiszacsecsi 83	3.9 e	7.5 d	5.5 f	10.0 de	6.7 c

Values followed by the same letter in a column were not statistically different ($P < 0.05$)
Vrijednosti u koloni koje su označene istim slovom (slovima) nisu statistički različite ($P < 0,05$)

In 2010, again 'Serr' cultivar showed the highest yield rate (29.7 kg). It was followed by 'Izvor 10', 'Hartley', 'Fernor' and'Lara'. 'Sheynovo' had lower yield compared to the mentioned cultivars, the difference being statistically significant, and, again the yield of 'Tiszacsecsi 83' was unsatisfactory – 7.5 kg.

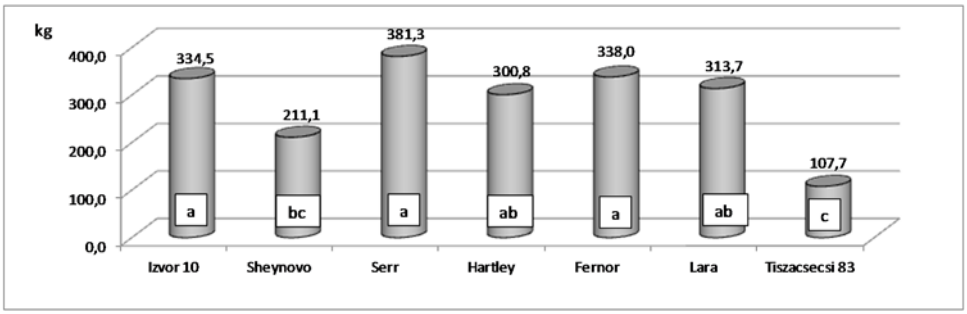
In 2011 the yield of 'Serr'was the highest again – 35.9 kg. It should be noted that referring to the yield per tree, 'Fernor' ranked second with harvested yield amounted to 28.5kg/tree. 'Hartley'and 'Lara' yielded 23.9 kg and 21.7 kg per tree, respectively. The average yield per tree from 'Izvor 10' was 16.8 kg, followed by 'Sheynovo' (12.8 kg) and'Tiszacsecsi 83' (5.5 kg).

In result of the winter frost of minus 24.4ºC on 1 February 2012, the nut yield was compromised to a different degree for the separate cultivars. Those unusual low temperatures are not typical for South Bulgaria.

In 2013 the highest yield per tree was obtained from 'Izvor 10' cv. – 26.0 kg. It was followed by the cultivars 'Fernor' (22.0 kg) and 'Lara (19.7 kg)', whose yields being statistically proven to be lower. The yield obtained from 'Sheynovo' was 15.0 kg per tree and from 'Hartley' – 13.0 kg. The lowest yields were reported from 'Serr' and 'Tiszacsecsi 83' cultivars – 8.8 kg and 10.0 kg, respectively.

The highest average yields per tree for the period 2009-2013 were obtained from the cultivars 'Izvor 10', 'Serr' and'Fernor', the difference between them being statistically insignificant.'Hartley' and 'Lara' ranked

second with average nut yields for the period 18.8 kg and 19.6 kg, respectively. The lowest yield was reported for 'Sheynovo' (13.1 kg) and 'Tiszacsecsi 83' (6.7 kg). The average yield per decare for the period 2009-2013 is presented in Fig. 1.



Values followed by the same letter in a column were not statistically different ($P < 0.05$)
Vrijednosti u koloni koje su označene istim slovom (slovima) nisu statistički različite ($P < 0,05$)

Fig. 1. Average yield kg/da (decare-1000 m^2) for the period 2009-2013
Prosječan prinos po kg/da (decare - 1,000 m^2) za period 2009-2013

From 'Serr' cultivar it were harvested 381.3 kg/da, 338.0 kg from 'Fernor' and 334.5 kg from 'Izvor 10', the difference between the three cultivars being statistically insignificant. The yields from 'Hartley' and 'Lara' cultivars were lower – 300.8 kg and 313.7 kg, respectively. The average yield from 'Sheynovo' was 211.1 kg/da and the difference to the above cultivars was significantly proven to be lower. The lowest average yield was obtained from 'Tiszacsecsi 83' – only 107.7 kg/da.

Conclusion

French cultivars 'Fernor' and 'Lara' are blooming later than the other cultivars – American 'Serr' and 'Hartley', Hungarian 'Tiszacsecsi 83' and Bulgarian 'Izvor 10' and 'Sheynovo'. That phenological characteristic is very important to avoid spring frost damages. During the study period the results showed that the yields from the cultivars 'Izvor 10', 'Serr', 'Hartley', 'Fernor' and 'Lara'were higher compared to 'Sheynovo' and 'Tiszacsecsi 83'. This is the reason to recommend the first group of five walnut cultivars to be grown under the climatic conditions of South Bulgaria.

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Evaluacija nekih sorti oraha u klimatskim uslovima Južne Bugarske

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Sažetak

U ovu studiju su uključene uvedene sorte oraha koje se gaje kao glavne sorte u zemljama sa klimatskim uslovima različitim od onih u Bugarskoj. Cilj ove evaluacije je selektovanje sorti oraha koje imaju odgovarajuće biološke i pomološke karakteristike kada se gaje u klimatskim uslovima Južne Bugarske. Ispitivanje je pokazalo da sorte 'Fernor', 'Lara' i 'Tiszacsecsi 83' kasnije cvjetaju od drugih sorti kao što su 'Serr', 'Hartley', 'Izvor 10' i 'Sheynovo'. Ova fenološka karakteristika je veoma važna da bi se izbjegla oštećenja uzrokovana proljetnim mrazom. Tokom perioda evaluacije rezultati su pokazali da su prinosi sorti 'Izvor 10', 'Serr', 'Hartley', 'Fernor' i 'Lara' viši u poređenju sa 'Sheynovo' i 'Tiszacsecsi 83'. Iz ovog razloga,

preporučuje se prvopomenuta grupa sorti oraha za uzgoj u klimatskim uslovima Južne Bugarske.

Ključne riječi: *Juglans regia* L., sorta, rast, karakteristike ploda, prinos

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