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Original article

Behavior of some local and foreign walnut cultivars under the climatic conditions of South Bulgaria

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Summary

Introduction – **The high protein and oil content of walnut kernels makes them essential for human nutrition. Therefore, the walnut is classified as a strategic species included in the FAO list of priority plants. The aim of the present experiment was to study and compare the agrobiological characteristics of some introduced and local walnut cultivars under the climatic conditions of South Bulgaria, as well as to define the cultivars that are perspective for growing in our country.** *Materials and methods* – **The study was carried out on the Bulgarian walnut cultivars Sheynovo and Izvor 10, the US cvs. Serr and Hartley, the French cvs. Lara and Fernor and the Hungarian cv. Tiszacsecsi 83, grown under the ecological conditions of Plovdiv region, Central South Bulgaria.** *Results and discussion* – **The cultivars Fernor and Izvor 10 bore fruits on 80% of the lateral buds along the fruiting shoots. They are followed by 'Lara' (45%), 'Serr' (35%), 'Sheynovo' (25%), 'Tiszacsecsi 83' (15%) and 'Hartley' (10%). The mean fruit weight ranged from 10.63 g for 'Tiszacsecsi 83' to 13.62 g for 'Sheynovo'. The cumulative yield ha^{-1} for the period 2009–2014 was 17,605 kg ha^{-1} for 'Serr', 16,080 kg ha^{-1} for 'Fernor' and 15,301 kg ha^{-1} for 'Izvor 10', followed by 'Lara' and 'Hartley' (13,717 and 13,280 kg ha^{-1}, resp.). The yields were low for 'Sheynovo' and for 'Tiszacsecsi 83' (9,211 and 4,917 kg ha^{-1}, respectively).** *Conclusion* – **The Bulgarian 'Izvor 10' and the French 'Fernor' and 'Lara' can be recommended for commercial growing in South Bulgaria.**

Keywords
Juglans regia, fruit morphological characteristics, fruit tree production

Résumé

Comportement de certains cultivars de noix locaux et étrangers dans les conditions climatiques du Sud de la Bulgarie.

Introduction – **La haute teneur en huile et en protéine de la noix du noyer la rend essentielle en nutrition humaine. Par conséquent, le noyer est classé comme espèce stratégique inscrite dans la liste FAO des plantes prioritaires. Le but de la présente étude est de comparer les caractéristiques agrobiologiques de certains cultivars de noyers locaux et introduits dans les conditions climatiques du Sud de la Bulgarie, ainsi que de définir les cultivars prometteurs pour la culture dans ce pays.**

Matériel et méthodes – **L'étude a été réalisée avec les cultivars de noyers bulgares Sheynovo et Izvor 10, les cvs. américains Serr et Hartley, les cvs. français Lara et Fernor et le cv. hongrois Tiszacsecsi 83, tous cultivés dans les conditions écologiques de la région de Plovdiv, au centre-Sud de la Bulgarie.** *Résultats et discussion* – **Les cultivars Fernor et Izvor 10 portent des fruits sur 80% des bourgeons latéraux le long des pousses fructifères. Ils sont suivis par 'Lara' (45%), 'Serr' (35%), 'Sheynovo' (25%), 'Tiszacsecsi 83' (15%) et 'Hartley' (10%). Le poids moyen du fruit varie de 10,63 g pour 'Tiszacsecsi 83' à 13,62 g pour 'Sheynovo'. Le rendement cumulatif ha^{-1} pour la période 2009–2014 était de 17.605 kg ha^{-1} pour 'Serr', 16.080 kg ha^{-1} pour 'Fernor' et 15.301 kg ha^{-1} pour 'Izvor 10', suivi de 'Lara' et 'Hartley' (13.717 et 13.280 kg ha^{-1}, respectivement). Les rendements étaient faibles pour 'Sheynovo' et pour 'Tiszacsecsi 83' (9.211 et 4.917 kg ha^{-1}, respectivement).** *Conclusion* – **Le cv. bulgare 'Izvor' 10 et les cvs. français 'Fernor' et 'Lara' peuvent être recommandés en culture commerciale dans le Sud de la Bulgarie.**

Mots-clés
Juglans regia, caractères morphologiques du fruit, production fruitière, qualité de la noix

Significance of this study

What is already known on this subject?
- The agrobiological characteristics of walnut cultivars are different when they are grown under different climatic conditions.

What are the new findings?
- One local and two introduced walnut cultivars were found suitable for the growing conditions of South Bulgaria.

What is the expected impact on horticulture?
- Increasing fruit yield and quality of walnut is expected in the Republic of Bulgaria from new commercial walnut plantations made of these cultivars.

Introduction

Walnut became a priority fruit species for Bulgaria after the association of the country with the European Union in 2007. The century-old walnut trees found on the territory of the country are compelling evidence that the soil and climat-

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ic conditions are suitable for the development of that fruit species.

Nowadays the areas in Bulgaria planted with walnut trees are 5,182 ha, representing 13% of the total fruit-growing area in the country. Nut production is characterized by great variability between years, ranging from 2,500 to 6,000 t. The average yield on the country is low, ranging from 500 to 1,150 kg ha^{-1}. That is due to the outdated varietal structure, predominantly of apical fruiting type (Dzhuvinov *et al.*, 2013).

Walnut cultivars, which grow worldwide have been selected from local resources or bred in countries with various climatic conditions. They differ in fruit shape, kernel quality, time of flowering, growth vigor and other agrobiological characteristics (Hendricks *et al*., 1985; Solar, 1990; Frutos, 1990; Malvolti *et al*., 1994, 1996; Draganescu *et al*., 2001; Balci *et al*., 2001; Rouskas and Zakynthinos, 2001; Çağlarirmak, 2003; Dogan *et al*., 2005). It is mentioned in scientific literature (Aleta and Ninot, 1997; Germain, 2004; Germain *et al*., 1999; Botu *et al*., 2014) that changes in growth and fruiting habits of the walnut cultivars are possible when grown under different climatic conditions. Obviously, not only the genetic constitution of the cultivar but also the climatic conditions under which they are grown, are of crucial importance, which affects the characteristics of the cultivars.

The aim of the present experiment was to study and compare the agrobiological characteristics of some introduced and local walnut cultivars under the climatic conditions of South Bulgaria, as well as to define the cultivars which are suitable for growing in the country.

Materials and methods

The plantation was established in spring 2003 on the experimental fields of the Fruit-Growing Institute in the city of Plovdiv, 42°9'N, 24°45'E, 160 m a.s.l. The experiment was carried out under irrigation conditions. The soil was alluvial-meadow, at pH 6.9.

The study was conducted in the period 2009–2014, *i.e.*, the seventh-twelfth vegetation of the walnut trees. On 1st February 2012 a temperature of –24.4 °C was reported, causing frost damages of the flower buds and reducing the yield in that season.

The introduced cultivars 'Serr' and 'Hartley' (US), 'Fernor' and 'Lara' (France) and 'Tiszacsecsi 83' (Hungary), were the object of the study. They were compared with local cvs. 'Izvor 10' and 'Sheynovo', which was considered as a standard cultivar. All the cultivars were grafted on common walnut (*Juglans regia* L.) rootstock. The planting distance was 8 × 8 m, *i.e.*, 160 trees ha^{-1}. The experimental trees were trained to the improved layered crown. Fertigation was applied using micro-sprinkler installation according to tree needs. The soil in the experimental plantation was maintained in black fallow.

We observed and evaluated properties of the trees and the fruits according to UPOV (1999) and Germain *et al.* (1999), as follows: bud breaking time (phenophase Cf), time of female/male flowering peak (phenophase Ff2/Fm2), time of ripening, type of fruiting (terminal, intermediate and lateral); crown volume (m^3); fruit characteristics – size, shell thickness, mean weight, color of the kernel skin and kernel ratio (kernel ratio = [kernel weight / fruit weight] × 100). According to the mean nut weight, the fruits were classified in five groups: very small (< 8.5 g); small (8.5–10.5 g); moderate (10.5–12.5 g); large (12.5–14.5 g) and very large (> 14.5 g). The yield per tree and total yield per ha were also measured (UPOV, 1999). The following scale was used for the tree vigor: low vigor with mean annual shoot length of 10–20 cm, moderate vigor with mean length of 20–30 cm, and over 31-cm vigor.

Five trees per cultivar, randomly selected from the plantation, were included in the study; each tree was regarded as a separate replication. All data were statistically processed following the Duncan test (Steele and Torrie, 1980). The software used in the study was R-3.1.3 and RStudio-0.98 with installed "agricolae" package.

Results and discussion

The results presented in Table 1 show that the standard cv. 'Sheynovo' entered the phenological stage of bud break Cf on 8 April in average for the period of study. 'Serr' was the earliest of the tested cultivars, its vegetation starting eleven days before 'Sheynovo'. 'Izvor 10' also started its development early – eight days before the standard. Table 1 also shows that the Cf stage of 'Hartley' appeared eight days after the standard. The latest cultivars were 'Tiszacsecsi 83', 'Fernor' and 'Lara', where Cf phenological stage was noted 13, 16 and 18 days after the standard 'Sheynovo', respectively.

The results in Table 1 also show that the full bloom of the female flowers (phenological stage Ff2) of 'Serr' and 'Izvor 10' appeared before the standard 'Sheynovo', while the female flowers of 'Hartley', 'Tiszacsecsi 83', 'Fernor' and 'Lara' started to flower after the standard cultivar. The full bloom stage of the male flowers (phenological stage Fm2) also occurred in different periods for the studied cultivars. The earliest catkin flowering was reported for 'Serr' – six days before

Table 1. Beginning of bud break, time of flowering and ripening of walnut cultivars for the period 2009–2014. N/C: Number of days compared to the control 'Sheynovo'.

Cultivars	Beginning of bud break		Full bloom of the female flowers		Full bloom of the male flowers		Time of ripening	
	Dates	N/C	Dates	N/C	Dates	N/C	Date	N/C
'Izvor 10'	31.03	-8	18.04	-12	28.04	+11	15.09	-5
'Sheynovo'	08.04	0	30.04	0	17.04	0	20.09	0
'Serr'	28.03	-11	23.04	-7	11.04	-6	26.09	+6
'Hartley'	16.04	+8	4.05	+4	24.04	+7	01.10	+11
'Fernor'	24.04	+16	12.05	+12	05.05	+18	09.10	+19
'Lara'	27.04	+18	6.05	+6	12.05	+25	08.10	+18
'Tiszacsecsi 83'	21.04	+13	9.05	+9	26.04	+9	08.10	+18

the standard 'Sheynovo'. In the other cultivars catkins flowered from 7 to 25 days after the standard. The latest catkin development was established in 'Fernor' and 'Lara', *i.e.*, 18 and 25 days after the standard, respectively.

Referring to the period of ripening, the results show that 'Izvor 10' was the earliest cultivar, ripening 5 days before the standard cultivar (Table 1). The other cultivars ripened in the period from 26 September to 9 October, which was 6 to 18 days later than the standard cultivar.

Data presented in Table 2 show that 'Sheynovo', 'Serr', 'Hartley' and 'Lara' belong to the group of cultivars of vigorous growth, the mean length of the annual shoots being over 31 cm. 'Serr' and 'Lara' had the largest crown volume – 139.7 m^3 and 130.4 m^3, respectively, but the difference between them is insignificant. The two other cultivars of vigorous growth, 'Sheynovo' and 'Hartley', had a similar crown volume – 104.1 m^3 and 95.2 m^3, respectively, which is significantly smaller than the crown volume of 'Serr' and 'Lara'. 'Izvor 10' and 'Fernor' had moderate growth vigor, the mean shoot length increment in the separate years varying between 20 and 30 cm. The crown volume of these two cultivars was similar – 59.2 m^3 and 65.6 m^3, respectively. 'Tiszacsecsi 83' was characterized by a weak growth vigor, the annual shoot length increment being 10–20 cm and the crown volume 34.8 m^3.

Table 2. Growth vigor, fruiting type and crown volume of walnut cultivars.

Cultivars	Growth vigor	% of laterality (fruiting type)	Crown volume (m^3)
'Izvor 10'	Moderate	80% (lateral)	59.2 c*
'Sheynovo'	Vigorous	25% (intermediate)	104.1 b
'Serr'	Vigorous	35% (intermediate)	139.7 a
'Hartley'	Vigorous	10% (intermediate)	95.2 b
'Fernor'	Moderate	80% (lateral)	65.6 c
'Lara'	Vigorous	45% (lateral)	130.4 a
'Tiszacsecsi 83'	Weak	15% (intermediate)	34.8 d

* Statistical significance at $P=5\%$.

Table 3 shows that fruit height varied from 37.14 mm ('Lara') to 43.79 mm ('Hartley'). The largest fruit width was reported for 'Lara' (35.60 mm) and the lowest for 'Sheynovo' (30.97 mm). The largest fruit thickness was established in 'Lara' (35.62 mm) and the smallest in 'Tiszacsecsi 83' (31.35 mm). The cultivars differed in shell thickness. It was the smallest in the 'Izvor 10' and 'Sheynovo' – 1.1 mm and 1.2 mm, respectively. Shell thickness of 'Serr', 'Hartley', 'Lara' and 'Fernor' varied within 1.4 to 1.7 mm. The largest shell thickness was reported for 'Tiszacsecsi 83' – 1.8 mm. The mean fruit weight of the separate cultivars varied from 10.63 g ('Tiszacsecsi 83') to 13.62 g ('Sheynovo'). Data presented in Table 3 show that 'Sheynovo', 'Serr', 'Hartley', 'Fernor' and 'Lara' belong to the large-fruited group, their fruit weight being from 12.5 g to 14.5 g. 'Izvor 10' and 'Tiszacsecsi 83' belong to the group of cultivars with medium fruits of 10.5 to 12.5 g. It should be noted that 'Izvor 10', 'Sheynovo' and 'Serr' had significantly higher kernel ratio (above 50%) compared to 'Hartley', 'Fernor', 'Lara' and 'Tiszacsecsi 83'. The latest one did not exceed 40%.

The highest average yield per tree for the period 2009–2014 was obtained from 'Serr' (22.01 kg), 'Fernor' (22.10 kg) and 'Izvor 10' (19,13 kg), followed by 'Hartley' with an average fruit yield of 16.60 kg $tree^{-1}$ and 'Lara' – 17.15 kg $tree^{-1}$ for the same period (Table 4). The lowest average yield was established for 'Sheynovo' (11.51 kg) and 'Tiszacsecsi 83' (6.15 kg).

Under the conditions of Čačak region, Serbia, Mitrović *et al.* (2011) also established high yields obtained by 'Fernor'. The average yield per tree of that cultivar was 15.0 kg, which surpassed the yields obtained by the other studied French cultivars 'Fernette' (13.7 kg), 'Franquette' (12.7 kg), 'Marbot' (10.0 kg) and 'Parisienne' (9.7 kg). Studies carried out by Botu *et al.* (2010) showed that the average yield of 'Fernor' grown under the conditions of Oltenia's Hill Area, Romania, was 1.94 t ha^{-1} and it was lower than that of 'Vina' (2.26 t ha^{-1}) and 'Hartley' (2.24 t ha^{-1}). Most probably, that was due to the fact that 'Fernor' was grown under non-irrigation conditions, which hampers the manifestation of its highest fertility potential.

The highest total yield per ha for the period 2009–2014 was obtained from 'Serr' (17,605.33 kg ha^{-1}), followed by 'Fernor' (16,080.00 kg ha^{-1}) and 'Izvor 10' (15,301.33 kg ha^{-1}). The total yield of 'Lara' and 'Hartley' was 13,717.33 and 13,280.00 kg ha^{-1}, respectively. The lowest total yield was obtained by 'Sheynovo' and 'Tiszacsecsi 83' (9,211.67 and 4,917.33 kg ha^{-1}, respectively).

Based on the data of Tables 1, 2, 3 and 4, the complex agrobiological characteristics of the studied cultivars could be set up (Table 5). According to McGranahan and Leslie (2006), the ideal walnut cultivar should have a late leaf emergence period, attaining bearing stage in a short period, be of a lateral fruiting type and a vigorous growth to pre-

Table 3. Mean biometric data* of walnut fruits for the period 2009–2014.

Cultivars	Fruit height (mm)	Fruit width (mm)	Fruit thickness (mm)	Shell thickness (mm)	Mean weight of a fruit (g)	Kernel color	Kernel ratio (%)
'Izvor 10'	41.27 b	31.29 cd	31.70 c	1.1 d	11.56 c	Pale	53.75 a
'Sheynovo'	42.39 ab	30.97 d	32.27 bc	1.2 d	13.62 a	Dark	55.02 a
'Serr'	38.71 c	33.55 b	33.04 bc	1.4 c	12.53 b	Pale	53.64 a
'Hartley'	43.79 a	33.62 b	33.58 bc	1.6 b	13.36 ab	Pale	45.60 b
'Fernor'	41.17 b	32.80 bc	33.70 bc	1.7 ab	12.55 b	Pale	46.36 b
'Lara'	37.14 c	35.60 a	35.62 a	1.4 c	12.68 ab	Pale	42.31 bc
'Tiszacsecsi 83'	37.52 c	31.25 cd	31.35 d	1.8 a	10.63 c	Pale	38.45 c

* Statistical significance at $P=5\%$.

Table 4. Yield per tree, average yield per tree and total yield per ha of walnut fruit production for the period 2009–2014.

Cultivars	Yield (kg tree^{-1})					Average yield (kg tree^{-1})	Total yield kg ha^{-1} (2009–2014)
	2009	2010	2011	2013	2014		
'Izvor 10'	17.87 b	23.00 b	16.77 d	26.00 a	12.00 b	19.13 a	15,301.33 b
'Sheynovo'	9.10 d	15.83 c	12.83 e	15.00 c	4.80 de	11.51 bc	9,211.67 d
'Serr'	20.90 a	29.73 a	35.90 a	8.80 e	14.70 a	22.01 a	17,605.33 a
'Hartley'	17.67 b	20.67 b	23.87 c	13.00 cd	7.80 c	16.60 ab	13,280.00 c
'Fernor'	12.00 c	22.00 b	28.50 b	22.00 b	16.00 a	20.10 a	16,080.00 b
'Lara'	16.87 b	20.23 b	21.67 c	19.67 b	7.30 cd	17.15 ab	13,717.33 c
'Tiszacsecsi 83'	3.93 e	7.50 d	5.50 f	10.00 de	3.80 e	6.15 c	4,917.33 e

Statistical significance at $P = 5\%$.

vent alternative fruit bearing. The cultivar should be resistant or tolerant to walnut blight (*Xanthomonas campestris* pv. *Juglandis*) and anthracnose (*Gnomonia leptostyla*), the shell should be comparatively smooth and the kernel ratio should be at least 50%. The kernel should be pale and full. The summarized results of the cultivars included in the present study (Table 5) show that 'Izvor 10', 'Lara' and 'Fernor', grown under the climatic conditions of South Bulgaria, largely correspond to the above-mentioned modern requirements of a cultivar and possess more advantages than disadvantages. That makes those cultivars suitable for establishing new commercial walnut plantations in the country.

Conclusion

Based on the conducted study, the perspective walnut cultivars suitable to be grown in South Bulgaria were identified. The cultivars 'Izvor 10', 'Lara' and 'Fernor' are recommended to be grown in new commercial plantations.

Table 5. Characteristics of the walnut cultivars 'Izvor 10', 'Sheynovo', 'Serr', 'Hartley', 'Fernor', 'Lara' and 'Tiszacsecsi 83'. Susceptibility of the cultivars to walnut blight and anthracnose is reported in Arnaudov *et al.* (2015).

Cultivars	Major advantages	Major weaknesses	Recommendations
'Izvor 10'	- moderate growth - lateral fruiting type - good yield - pale kernel - high kernel ratio	- early vegetation - susceptibility to anthracnose	Suitable to be grown in the country as a major cultivar.
'Sheynovo'	- large fruits - high kernel ratio	- vigorous growth - intermediate fruiting type - unsatisfactory yield - dark kernel - susceptibility to anthracnose	The cultivar does not correspond to modern requirements. It is not recommended to be grown in the country.
'Serr'	- high yield - pale kernel - high kernel ratio - slight susceptibility to walnut blight	- vigorous growth - early vegetation - intermediate fruiting type - strong susceptibility to anthracnose	The cultivar does not fully correspond to modern requirements. It could be grown in the country to a limited extent.
'Hartley'	- good yield - pale kernel - late beginning of vegetation - slight susceptibility to anthracnose	- vigorous growth - intermediate fruiting type - strong susceptibility to walnut blight	The cultivar does not correspond to modern requirements. It could be grown in the country to a limited extent.
'Fernor'	- moderate growth - late flowering - pale kernel - lateral fruiting type - high yield - resistance to walnut blight - resistance to anthracnose - attractive fruits	- low kernel ratio - thick shell	The cultivar corresponds to modern requirements. Suitable to be grown in the country as a major cultivar.
'Lara'	- late flowering - pale kernel - good yield - slight susceptibility to walnut blight - practically resistant to anthracnose - large and attractive fruits	- vigorous growth - insufficient percentage of laterality, although provides good yield, thanks to the large crown volume - low kernel ratio	The cultivar corresponds to modern requirements. Suitable to be grown in the country as a major cultivar.
'Tiszacsecsi 83'	- slight susceptibility to anthracnose - pale kernel	- intermediate fruiting type - low yield - very low kernel ratio - moderate susceptibility to walnut blight	The cultivar does not correspond to modern requirements. Not suitable to be grown in the country.

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