AGROBIOLOGICAL EVALUATION OF THE INTRODUCED WALNUT CULTIVAR HARTLEY IN THE CLIMATIC CONDITIONS OF SOUTH BULGARIA

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SUMMARY

By contrast with the other fruit species, the range of walnut cultivars in Bulgaria has not been changed since the 70s of the last century. Obviously, cultivar improvement is the first necessary condition for the advance of walnut production in our country.

The aim of the present study was to make an agrobiological evaluation of the walnut cultivar Hartley, widely spread worldwide, and to analyze the possibilities of its growing in Bulgaria.

The investigation was carried out in the period 2006-2010. The biological characteristics and the economic properties of the fruits obtained from the introduced American cultivar Hartley were studied and compared to those of the standard Bulgarian cultivars Izvor 10 and Sheynovo.
The results of the study show that the walnut cultivar Hartley has vigorous growth.

At the end of the eighth vegetation the crown volume reaches 21.9 m³. The vegetation of the cultivar starts later than the control Bulgarian cultivars Izvor 10 and Sheynovo. Hartley is moderately resistant to late spring frosts, similar to the standard cultivar Sheynovo. Flowering of Hartley is protandrous, exhibiting imperfect dichogamy.

The fruits are large, the mean nut weight being 13.9 g and the kernel output - 47.5%. In the bearing years the average yield per tree of Hartley cultivar does not differ statistically from the yields of Izvor 10, both cultivars surpassing Sheynovo cultivar in that characteristic.

The leaves and fruits of Hartley cultivar are more resistant to anthracnose and more susceptible to walnut blight compared to the Bulgarian cultivars Izvor 10 and Sheynovo.

Data obtained about the chemical composition of the walnut fruits of the cultivars Hartley, Izvor 10 and Sheynovo show no great differences in the content of lipids. 65.57% of fats were reported for Hartley, while for Izvor 10 and Sheynovo the fat content was 64.75% and 66.35%, respectively.

**INTRODUCTION**

The walnut cultivars Sheynovo, Izvor 10, Silistrenski, etc., spread in Bulgaria, are well adapted to the climatic conditions in the country.

They are characterized by their good resistance to frosts during the period of deep dormancy, the wood resisting negative temperatures as low as -28°C and the catkins - about -
28°C, a ресите до около -20°C (Недев и др., 1983). Повреди по ореха могат да причинят и застудяванията в началото на пролетта. При рано развиващите се сортове се отчита по-голямо измръзване, отколкото при тези с по-късно развитие (Гандев и др., 2009). Поради тази причина у нас се препоръчва отглеждането на орехови сортове с късно начало на развитие и цъфтеж (Джувинов и др., 2010).

Очевидно климатичните изисквания на даден сорт са от значение при избора му за отглеждане в даден район, но те не са единственото условие, на което трябва да отговаря. Наред с тях трябва да се има предвид количеството и качеството на добива му, неговата устойчивост на болести и неприятели и не на последно място химичния състав на плодовете. Редица автори (Hendricks et al., 1985; Germain and Prunet, 1999; Джувинов и др., 2010) съобщават, че от латерално плододаващите сортове се получават по-високи добиви, отколкото от тези с апикално и междинно плододаване, каквито всъщност са и повечето български сортове. Противоречиви са данните относно устойчивостта на българските сортове на причинителя на антракнозата и недостатъчно пълна е информацията за 20°C (Nedev et al., 1983). "Spells of cold weather at the beginning of spring can also cause damages in walnut. More frost damages were reported in the early developing cultivars compared to the later developing ones (Gandev et al., 2009)."

That is why, later developing and flowering walnut cultivars are recommended to be grown in our country (Dzouvinov et al., 2010).

Obviously the climatic requirements of a certain cultivar are important when choosing a cultivar to be grown in a given region. However, this is not the only issue that should be kept in mind.

The quantity and quality of the harvest, the cultivar resistance to diseases and pests and, last but not least - the chemical composition of the kernel, should also be taken into consideration. A number of authors (Hendricks et al., 1985; Germain and Prunet, 1999; Dzouvinov et al., 2010) mentioned that cultivars of lateral fruit-bearing produce higher yields than those of apical or intermediate fruit-bearing, as the case with most of the Bulgarian cultivars.

Controversial data were obtained about the resistance of the Bulgarian cultivars to the causative agent of anthracnose and the information on their susceptibility to walnut blight is insufficient. It was mentioned that
many of the Bulgarian cultivars possess good resistance to the causative agents of the two economically most important diseases in walnut – walnut anthracnose (Gnomonia leptostyla (Fr.) Ces et de Not., anamorph Marssonia juglandis) and walnut blight (Xanthomonas arboricola pv. juglandis) (Nedev et al. 1976; 1983; Kovachevski et al., 1987; Kornova (following Germain, 2004).

Concerning two of the most widely spread in our country cultivars – Izvor 10 and Sheynovo – it was published that the former one was practically resistant to both diseases, while the latter was resistant to walnut blight and slightly susceptible to anthracnose (Nedev et al., 1976; 1983).

After carrying out observations under field conditions, Rosnev and Tsanova (1980) came to the conclusion that the Sheynovo cultivar is strongly susceptible to anthracnose, while after similar investigations Petrova-Dimova (2003) established that the same cultivar is resistant to the disease.

At present there are no data available in Bulgarian literature about the growth, fruiting and the chemical composition of the kernels of the American cultivar Hartley, as well as about its response to economically
important diseases, when grown under irrigation in South Bulgaria.

The aim of the present study was to make an agrobiological evaluation of the introduced cultivar Harley and to assess the possibility of growing it in Bulgaria.

MATERIAL AND METHODS

The experimental plantation was established at the Fruit-Growing Institute – Plovdiv in the spring of 2003 and the study was carried out in the period 2006-2010.

Biological characteristics and the economic properties of the fruit produce obtained from the introduced American cultivar Hartley were studied and compared to those of the standard Bulgarian cultivars Izvor 10 and Sheynovo. In our country Izvor 10 cultivar was adopted as a standard of lateral fruit-bearing and Sheynovo cultivar – as a standard of late flowering (Nedev et al., 1979).

All the cultivars were grafted on common walnut rootstock (Juglans regia L.). Micro-sprinkling irrigation was used in the orchard. The trees were trained to a central leader system.

The vegetative and reproductive habits of the cultivars were reported following the
methods of investigating fruit plant resources (Nedev et al., 1976) and the adopted international standard for description of walnut genetic resources (Germain, 2004).

Susceptibility to the economically important diseases anthracnose (Gnomonia leptostyla) and walnut blight (Xanthomonas arboricola pv. juglandis) was evaluated by the infection index calculated following the formula of McKinney (1923), using collected walnut leaves and fruits.

The level of G. leptostyla infection was detected from randomly collected 100 leaves and 50 fruits from 5 different walnut trees of each cultivar, reporting the affected tissue with developed acervuli.

The attacks of X. arboricola pv. juglandis were reported as a percentage of the leaves and fruits infected by the bacterium. Necrotic spots of a diameter less than 3 mm were analyzed using a stereo microscope.

All the studied cultivars were distributed in 6 different levels of susceptibility to a given pathogen based on the degree of attack.

The chemical composition of the walnut kernel oil obtained from Hartley cultivar was studied and compared to the control cultivars. The kernel oil was extracted with petroleum ether using the Soxhlet
The tocopherol composition of the oil obtained was determined by liquid chromatography and the individual content of fats and acids in the triacylglycerols by gas chromatography, investigating the obtained pure methyl esters by gas chromatography (Metcalfe, Wang 1981; Kyriakidis, Katsiloulis, 2000).

Data were statistically processed by Duncan's test (Steele and Torrie, 1980).

The largest stem cross-section area was reported in Hartley cultivar – 359.5 cm² and the smallest one – in Izvor 10 cv. – 278.3 cm².

Sheynovo cv. occupied an intermediate place, its stem cross-
316.4 cm². However, the differences in crown volume among the compared cultivars were not so obvious. In Sheynovo and Hartley cultivars there was not a statistically significant difference. The former cultivar had a crown volume of 18.8 m³ and the latter - 21.9 m³. Izvor 10 cultivar had a crown volume of 9.1 m³ which was significantly proven to be smaller than those of Sheynovo and Hartley cultivars.

In the two experimental years Hartley cv. started its vegetation later than the two Bulgarian cultivars Izvor 10 and Sheynovo (Table 2).

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Izvor 10</td>
<td>2009</td>
<td>02.04.</td>
<td>16.04.</td>
<td>22.04.</td>
<td>02.05.</td>
<td>30.04.</td>
</tr>
<tr>
<td>Izvor 10</td>
<td>2010</td>
<td>30.03.</td>
<td>10.04.</td>
<td>26.04.</td>
<td>16.04.</td>
<td>30.04.</td>
</tr>
<tr>
<td>Sheynovo</td>
<td>2009</td>
<td>04.04.</td>
<td>23.04.</td>
<td>02.05.</td>
<td>04.05.</td>
<td>18.04.</td>
</tr>
<tr>
<td>Sheynovo</td>
<td>2010</td>
<td>06.04.</td>
<td>26.04.</td>
<td>30.04.</td>
<td>02.05.</td>
<td>16.04.</td>
</tr>
<tr>
<td>Hartley</td>
<td>2009</td>
<td>12.04.</td>
<td>26.04.</td>
<td>07.05.</td>
<td>12.05</td>
<td>18.04.</td>
</tr>
<tr>
<td>Hartley</td>
<td>2010</td>
<td>10.04.</td>
<td>24.04.</td>
<td>04.05.</td>
<td>10.05.</td>
<td>22.04.</td>
</tr>
</tbody>
</table>

Table 2. Начало на вегетация и цъфтеж на ореховите сорта Извор 10, Шейново и Хартли през 2009 и 2010 г.

Table 2. Beginning of vegetation and flowering of the walnut cultivars Izvor 10, Sheynovo and Hartley in 2009 and 2010.
Hartley flowering being protandrous, while in Izvor 10 — protogynous.

The results of the observation showed that in all the three cultivars the dichogamy was imperfect, i.e. there was a partial overlapping period of maturing of female and male flowers. In could be seen in Table 2 that the overlapping period in Hartley cv. was about 9 days in the two experimental years, which is a precondition of successful pollination of the cultivar.

The drop down of the air temperature to -4.4°C on 27 March 2008 gave the opportunities to study the resistance of Hartley trees to low temperatures in spring and to compare the resistance to Sheynovo cultivar adopted in our country as a standard (Nedev et al., 1976).

In Sheynovo cultivar the reported frost-damaged young vegetative organs were 41% versus 33.5% in Hartley cultivar. At the time of the low spring temperatures both cultivars were at the phonological stage Df (leaf division) that resulted in the similar percentage of frost damages.

The results presented in Table 3 showed that the largest nut weight was reported for Hartley cultivar — 13.9 g.

The nuts of the control cultivars Izvor 10 and Sheynovo
masa на плодовете 10.6 g за първия сорт и 12.5 g за втория.

Table 3. Average biometric data about walnut fruits of the cultivars Izvor 10, Sheynovo and Hartley for the three-year period of study (2008-2010)

<table>
<thead>
<tr>
<th>Сорт Cultivar</th>
<th>Форма на плода Nut shape (mm)</th>
<th>Дължина на плода Nut length (mm)</th>
<th>Диаметър на плода Nut diameter (mm)</th>
<th>Средна маса на 1 плод Mean nut weight (g)</th>
<th>Цвят на ядката Kernel color</th>
<th>Рандемен Kernel output (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Izvor 10</td>
<td>Oblong</td>
<td>40.6 b</td>
<td>30.7 b</td>
<td>10.6 b</td>
<td>light</td>
<td>53.5 a</td>
</tr>
<tr>
<td>Sheynovo</td>
<td>Oblong</td>
<td>42.3 ab</td>
<td>31.7 ab</td>
<td>12.5 ab</td>
<td>amber</td>
<td>54.3 a</td>
</tr>
<tr>
<td>Hartley</td>
<td>Oblong</td>
<td>45.9 a</td>
<td>34.0 a</td>
<td>13.9 a</td>
<td>light</td>
<td>47.5 b</td>
</tr>
</tbody>
</table>

Po отношение на рандемена на плодовете, прави впечатление, че българските сортове Izvor 10 и Sheynovo имат по-високи стойности на този показател в сравнение с Хартли. Рандеманът при Хартли e 47.5% срещу 53.5% при Izvor 10 и 54.5% при Sheynovo.


От представените данни в

Concerning the kernel output, it should be mentioned that the Bulgarian cultivars Izvor 10 and Sheynovo had higher values of that characteristic compared to Hartley.

The kernel output of Hartley was 47.5% versus 53.5% for Izvor 10 and 54.5% for Sheynovo.

The period of ripening was different for the three cultivars. Izvor 10 has medium early period of fruit ripening. In the separate experimental years it ripened between 6th and 15th of September. Sheynovo has a medium late period of ripening – its fruits ripened between 16th and 25th September and Hartley has a later period of ripening – from the end of September to the first decade of October.

From the data presented in
Table 4, it could be seen that in 2009 and 2010 the yields per tree were similar for the cultivars Izvor 10 and Hartley, the difference between them being statistically insignificant.

<table>
<thead>
<tr>
<th>Сорт / Cultivar</th>
<th>Среден добив от дърво Average yield per tree, (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2009</td>
</tr>
<tr>
<td>Izvor 10 / Izvor 10</td>
<td>17.8 a</td>
</tr>
<tr>
<td>Шейново / Sheynovo</td>
<td>9.1 b</td>
</tr>
<tr>
<td>Хартли / Hartley</td>
<td>17.7 a</td>
</tr>
</tbody>
</table>

In 2009 the amount of yield per tree was 17.8 kg in average for Izvor 10 and 17.7 kg for Hartley. In 2010 the yields increased in both cultivars.

The yield per tree for Izvor 10 cultivar was 23.0 kg in average and for Hartley – 20.7 kg in average. In the two experimental years the yield of Sheynovo cultivar was significantly lower than that of Hartley and Izvor 10. In 2009 it was 9.1 kg and in 2010 – 15.8 kg, respectively.

The results of the studies carried out for establishing the susceptibility of the investigated walnut cultivars to the causative agents of the two economically most important diseases anthracnose and walnut blight were presented in Tables 5 and 6.

At the leaf level, Hartley cultivar showed to be less susceptible to the attacks of G.
Table 5. Response of walnut cultivars to G. leptostyla attacks in the period 2006-2010, Fruit Growing Institute – Plovdiv

<table>
<thead>
<tr>
<th>Сорт Cultivar</th>
<th>Чувствителност на листата Leaf infestation index, by McKinney</th>
<th>Чувствителност на плодовете Fruit infestation index, by McKinney</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006 2007 2008 2009 2010 Средно Average 2008 2009 2010 Средно Average</td>
<td></td>
</tr>
<tr>
<td>Извор 10 Izvor 10</td>
<td>50.8 39.3 31.2 5.0 16.0 28.46 a 0.60 1.40 3.30 1.77 n.s.</td>
<td></td>
</tr>
<tr>
<td>Шейново Sheynovo</td>
<td>47.5 30.9 15.3 3.4 12.8 21.98 ab 0.50 0.65 0.50 0.55 n.s.</td>
<td></td>
</tr>
<tr>
<td>Хартли Hartley</td>
<td>37.0 7.3 18.0 3.0 13.4 15.74 b 0.16 0.21 0.05 0.14 n.s.</td>
<td></td>
</tr>
</tbody>
</table>

The means followed by the same letter do not differ significantly from one another (p = 0.05).

Leaves of the later developing cultivars Hartley and Sheynovo,
are less susceptible to anthracnose in comparison with those of Izvor 10, cultivar characterized by its earlier development.

The fruits of Hartley had the lowest percentage of the areas infected by anthracnose - 0.14% in Sheynovo cultivar it was 0.55% and in Izvor 10 - 1.77%.

Regarding X. arboricola pv. juglandis, Hartley cultivar was more highly susceptible at the leaf and fruit level compared to the other two studied cultivars – Izvor 10 and Sheynovo. At the leaf level, Hartley cultivar was less susceptible compared to the cultivars Izvor 10 and Sheynovo, which were characterized as resistant. At the fruit level, the Hartley cultivar proved to be very highly susceptible in contrast with the cultivars Izvor 10 and Sheynovo, which were characterized as highly resistant (Table 6).

The fruits of Hartley cultivar were extremely susceptible to the attacks of X. arboricola pv. juglandis at the early stages of their development, which was more significantly expressed in the years with frequent rainfalls. The symptoms of the disease were most often observed as apical necrosis of the young fruits immediately after their initiation. A large share of those fruits most often blackened and premature abscission was often observed,
Table 6. Response of walnut leaves to X. arboricola pv. juglandis attacks in the period 2006-2008, Fruit Growing Institute – Plovdiv

<table>
<thead>
<tr>
<th>Сорт</th>
<th>Cultivar</th>
<th>Чувствительност на листата</th>
<th>Leaf infestation index, by McKinney</th>
<th>Чувствителност на плодовете</th>
<th>Fruit infestation index, by McKinney</th>
</tr>
</thead>
<tbody>
<tr>
<td>Izvor 10</td>
<td>4.0</td>
<td>8.2</td>
<td>27.8</td>
<td>1.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Izvor 10</td>
<td>1.1</td>
<td>4.9</td>
<td>18.6</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Шейново</td>
<td>15.8</td>
<td>21.9</td>
<td>22.2</td>
<td>7.6</td>
<td>13.4</td>
</tr>
<tr>
<td>Hartley</td>
<td>7.6</td>
<td>4.0</td>
<td>6.5</td>
<td>7.6</td>
<td>4.0</td>
</tr>
</tbody>
</table>

The means followed by the same letter do not differ significantly from one another ($p = 0.05$).

Leaf cultivar susceptibility: (1) Highly resistant (0 - 3% infected area); (2) Resistant (3 - 10% infected area); (3) Slightly susceptible (10 - 25% infected area); (4) Susceptible (25 - 50% infected area); (5) Highly susceptible (50 - 75% infected area); (6) Very highly susceptible (75 - 100% infected area).

Fruit cultivar susceptibility: (1) Highly resistant (up to 0.25% % infected area); (2) Resistant (0.25 - 0.5% infected area); (3) Slightly susceptible (0.5 - 1.5% infected area); (4) Susceptible (1.5 - 3.5% infected area); (5) Highly susceptible (3.5 - 5% infected area); (6) Very highly susceptible (> 5% infected area).

Големите различия по отношение осъществяването на липидите няма големи разлики при отделните сорта. При Хартли са отчетени 65.57% мазнини, а при Извор 10 и Шейново съответно - 64.75% и 66.35%, respectively. Data obtained about the chemical composition of the walnut fruits of the cultivars Hartley, Izvor 10 and Sheynovo showed that there were no great differences among the cultivars concerning the content of lipids. 65.57% of fats were reported for Hartley and for Izvor 10 and Sheynovo – 64.75% and 66.35%, respectively.
66.35%. The ratio of saturated to unsaturated fatty acids was similar in the studied oils of the three cultivars - 8.9:91.0 in Izvor 10 and Sheynovo and 9.5:90.5 in Hartley, respectively.

The obtained results showed that Sheynovo had a lower content of linoleic acid, which is one of the reasons for the higher oxidative stability of the oil – 11 h. The oxidative stability of the oils of Izvor 10 and Hartley cultivars was similar – 8 and 9 h, respectively.

The content of tocopherols was the highest in the oil of Hartley cultivar – 448 mg/kg and in Izvor 10 and Sheynovo it was 242 mg/kg and 272 mg/kg, respectively.

The individual tocopherol content in the oils did not differ significantly. All of them were characterized by high contents of γ-tocopherol: in Hartley – 81.9%, in Izvor 10 – 76.6% and in Sheynovo – 68.2%, respectively.

At that stage of the investigation the above results show that the growth of Hartley is more vigorous than the moderate growth of Izvor 10 cultivar and similar to the vigorous growth of Sheynovo cultivar. It determines Hartley cultivar as the one belonging to the group of cultivars of vigorous growth.

The growth vigour of the control cultivars Izvor 10 and Sheynovo, established in the
present study, confirmed the earlier results of other authors (Nedev et al., 1983).

Although the vegetation period of Hartley started later than that of Sheynovo, the latter adopted as a standard of late developing cultivar in our country (Nedev et al., 1979), frost damages of vegetative structures were reported both in Hartley and in Sheynovo.

At the same time, there are data in our literature about other introduced cultivars, such as Lara and Fernette, in which damages caused by late spring frosts were not observed (Gandev et al., 2009).

In the two years of the experiment the yield of Hartley cultivar was higher compared to Sheynovo and close (statistically insignificant) to the yield of Izvor 10.

Despite the similar yields of Hartley and Izvor 10, the former cultivar bears large-size fruits of a mean weight 13.9 g versus 10.6 g for the latter cultivar.

The fruit size of Hartley makes the cultivar attractive in growing in new orchards.

On the other hand, the kernel output of Hartley is 47.5%, and it is lower than the output of the Bulgarian cultivars Izvor 10 and Sheynovo – 53.5% and 54.3%, respectively.

Hartley cultivar is comparatively resistant to
anthracnose at the leaf and fruit levels. Its susceptibility to the disease is comparable with that of Sheynovo cultivar and significantly lower than that of Izvor 10.

That good property of the cultivar, probably due to the later leaf emergence, is minimized to a certain degree by its high susceptibility to the other economically important disease in walnut, i.e. walnut blight.

Great differences in the chemical composition, that could determine one of them as more perspective than the others, were not reported among the cultivars.

CONCLUSIONS

Under the conditions of South Bulgaria the Hartley cultivar is characterized by vigorous growth, a late flowering period, moderately good fertility, moderate resistance to late spring frosts, low susceptibility to anthracnose (G. leptostyla) and high susceptibility to walnut blight (X. arboricola pv. juglandis). The mean weight of its nut is 13.9 g and the kernel output is 47.5%. The fat content of the cultivar is 65.57%. Under the climatic conditions of Bulgaria fruits ripen from the end of September till the first decade of October.

The good qualities of Hartley cultivar allow its growing in South Bulgaria. It is recommended not to
use the cultivar as the major one in the new walnut plantations and not to grow it in closed valleys, in which high levels of atmospheric humidity is maintained during the greater part of the day and night and air drainage is lacking. Unsuitable for its cultivation proved to be also regions characterized by high frequency of precipitation and recurring spring frosts.

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