

# Hazelnut breeding in the National Dendrological Park “Sofiyivka” of the NAS of Ukraine

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**Purpose.** To evaluate hazelnut cultivars, species and hybrids from the genetic collection of *Corylus* spp. in the National Dendrological Park “Sofiyivka” of the NAS of Ukraine for the complex of economic characters. An attempt has been made to analyze the information on *Corylus* spp. identity, taxonomy and description, dissemination and ecological requirements of the species, possibilities to use the genetic potential for developing new cultivars. **Methods.** The value of the *Corylus* spp. collection representatives was investigated using conventional testing procedures. For summarizing information concerning phylogenetic reconstruction of the *Corylus* L. genus and hazelnut, a number of scientific publications to be proposed for discussion was analyzed. The oil content in hazelnut kernels and the fatty acid composition was determined using official methods. **Results.** The best samples of hazelnut genetic collection were included into the broad hybridization programme, and *C. chinensis* Franch. representatives as well. A number of hybrid seedlings was obtained including new hazelnut cultivars ‘Sofiyivsky 1’, ‘Sofiyivsky 2’ and ‘Sofiyivsky 15’ which were characterized by spherical or almost spherical fruits, high winter hardiness and drought resistance, as well as the absence of rhythmicity in fruiting. **Conclusions.** The collection of varieties, forms, cultivars and species of the *Corylus* L. genus created during the last years can be the base for hazelnut breeding in Ukraine.

**Keywords:** breeding, cultivar, natural area of genus, hybridization programme, nut, species.

## Introduction

As the intensive fruit-growing develops the hazel (*Corylus* spp.) cultivated forms under the name of hazelnut, also known as filbert (*C. domestica* Kos. et Opal.), gain in importance as nuciferous fruit culture in Ukraine. Though, hazelnut takes the honorable second place conceding to almond (*Prunus dulcis* (Mill.) D.A. Webb.), on the nut world market, demand for hazelnut in Ukraine is provided with the own yield for 12–15% only, because of the deficient cultivation of it. The rest of needs are held with the help of import which cause the rise in the cost of the nuts and products of their processing [1]. At the beginning of the 21st century average indices of world hazelnut (in shell) production exceeded 900 thousand tons with fluctuations over the years in the range of 616–1071 thousand tons. In this amount Turkey has 70–75% with an annual production

of 450–800 thousand tons of unshelled nuts. Italy takes the second place with the index of 100–130 thousand tons, the third and fourth places are divided by the USA and Azerbaijan, with the annual production 20–35 thousand tons. Then, Georgia – 25–30, China and Iran at 18–25, then Spain, which in last years have reduced production to 12–17 thousand tons [2]. Now in the world market there is an increase in demand for hazelnut products, which makes its production more profitable. Among the potential buyers of large quantities of nuts, Italy, Germany and Scandinavia are the largest. Thanks to the development of hazelnut culture in Turkey, where over 400 thousand hectares are used for hazelnuts, almost 250 thousand Turkish families are living on its cultivation today and about 8 million jobs are provided by the production, processing and export of nuts.

Turkish hazel dendroid (*C. colurna* L.) and a number of cultivars and forms of *C. maxima* Mill. are widely used in the urban park movement, while the rest of *Corylus* species are still maintained mainly in the collections of botanical gardens, dendrological parks and arboreta. However, cultivation experience of many valuable forms of North American and East Asian species, valuable in decorative qualities indicates the great prospects of representatives of the genus *Corylus* introduction into decorative gardening. Due to the stability of hazel to adverse environmental factors, many

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of its species, as well as hazelnut cultivars and forms can be successfully used to strengthen the slopes and in various protective plantations [1].

Observation of various *Corylus* spp. healing power which has been used in folk medicine since prehistoric times, gradually finds its followers in scientific pharmacological circles. Outlook valuation of the nut oil as a raw material for obtaining the new types of immunoprophylactic drugs deserve attention as well as the tests of vaso-constrictive effects of hazel leaves extracts on laboratory animals [3], antioxidant effects and cytotoxic activity of nut cell membranes extracts on human cancer [4], etc. Creation of medicines based on the species-specific and protective antigens included into the liposomes is considered as one of the promising directions in developing methods of effective protection from the most dangerous infections [5]. Lecithins (esters of choline amino-alcohol and diglyceride phosphoric acids), which are an important representatives of essential (irreplaceable) phospholipids, produced from organisms and tissues of mammals (dorsal and brain of cattle and pigs), chicken eggs, fish, mollusks [6] are used. Essential phospholipids are contained in unrefined vegetable oil of soy (*Glycine max* (L.) Merr.), sunflower (*Helianthus annuus* L.), walnut (*Juglans regia* L.), hazel (*Corylus* spp.), etc. At the same time, phospholipid's average content in nuts *Juglans regia* was 0.3–0.4, whereas in nuts *Corylus* spp. their number reached 0.5–0.9% [7]; it founds the grounds of successful selection on this feature. In addition, hazelnut lecithin can act both as a biologically active additive to food and feed, and as a raw material for the creation of liposomal nanoemulsions and nanodispersions for food products and additives, as well as for the creation of liposomal drugs.

The research purpose consists of estimation of hazelnut cultivars, species and hybrids from the genetic collection of *Corylus* spp. in the National dendrological park "Sofiyivka" of NAS of Ukraine according to the complex of economic and valuable features. We also attempt to discuss the currently available information on *Corylus* spp. identity, taxonomy and description, distribution and ecological requirements of the species, possibilities of exploitation of genetic potentiality for developing new cultivars.

### Materials and methods

Genetic collection of *Corylus* spp. in the National Dendrological Park "Sofiyivka" of NAS of Ukraine counts more than 200 samples, be-

longing to 11 botanical species, acknowledged in different lists of leading world botanical establishments [8, 9]. Including more than 90 cultivars of domestic and foreign breeding and over 50 hybrid seedlings of own breeding, tested in the links of collection and hybrid garden, as well as in the garden of preliminary cultivar testing [1].

In the somatic cells of the genus *Corylus* representatives, chromosomes diploid number is  $2n=22$ , as well as in the cells of species studied by cytologists before; however, there are some reports about other chromosomal numbers of individual representatives of this genus presented in the literature [1]. The question is, foremost, about Robert Woodworth publication [10], who counted on 14-chromosomes during the research of meiotic preparations of *C. americana* Walter, *C. colurna*, *C. cornuta*, *C. heterophylla* var. *sutchuensis* Franch., *C. pontica* K. Koch (it is now considered as the synonym of *C. avellana* var. *pontica* (K. Koch) H.J.P. Winkl.), *C. sieboldiana* Blume and *C. vilmorinii* Rehd., that confirmed  $2n=28$ . This repeatedly quoted article had been published in 1929 in the authoritative botanical magazine "Botanical Gazette" [11–14] caused long-term uncertainty as for the chromosomes diploid number of the *Corylus* species have been mentioned above. Thus, some authors limited the statement of possible  $2n=28$  equally with normative  $2n=22$  [11, 12], had been cited R. Woodworth. Another stated the necessity of experimental confirmation of calculations for  $2n=28$  [15], while Veli Erdogan [16] considered Woodworth determinations as the mistaken one, because of the wrong interpretation of meiotic preparations. Calculation error could arise up because of the application of imperfect methodology by cytological researches, realization of that is laboured by small size of *Corylus* spp. chromosomes. Therefore, nowadays  $2n=2x=22$  is considered to be an avowed standard for *Corylus* spp. [1, 16–19] with the exception of individual cases of chromosomal aberrations and polyploidy [16, 20]. Nearly all the representatives of *Corylus* are diploids, however, Roberto Botta with coauthors (1986) reported about spontaneous tetraploid of *C. heterophylla* Fisch. ex Trautv. [16]. Among the other examples of unusual chromosomes number we should mention the aneuploidies from  $2n=18$  in somatic tissues of *C. colurna* and *C. maxima* f. *atropurpurea* (Dochnahl) H.J.P. Winkl. [14, 16], so as the tetraploids and spontaneous triploid seedlings of *C. avellana* L. induced with the colchicine treatment [12, 16]. Based on N. I. Vavilov ideas have been concerning the work of plant

genetic resources [21], the goals and objectives of our studies were determined. They included *Corylus* spp. have been growing in the park and its environs certification, their systematization, maintenance and collection expansion, including the development and improvement of breeding methods, as well as the study of their breeding value. The first expeditions were conducted in the localities of *Corylus* spp. in Ukraine, the Caucasus and Central Asia, as well as in China and a number of European countries, which significantly increased the species and cultivar and forms collection of hazelnut and hazel, the best representatives of which were involved in to the breeding process.

Selection and isolation of branches with female flowers, inter-cultivar hybridization, and hazelnut cultivars crossing with the help of selected representatives of *C. chinensis* Franch., *C. colurna*, *C. maxima* and other species were carried out during the male inflorescences (before pollination) spring growth. Pollen for crossing was collected from cut branches with catkins, the development of which was awakened in room conditions. Cut branches put in a vessel with water on a large sheet of paper, leaving them overnight in a cool dry (15–16 °C) room. Branches with catkins of the same cultivar were placed in the room, at the same time, to prevent pollen contamination and were left to its rash. Pollination was carried out without removing the insulators, had been untangling only the upper part of the insulator-sleeve and tying it again after pollination or without decoupling, blowing the pollen into the insulator with insufflator MO-03. Pollination had been repeated in 2–3 days. Tight linen FPP-15 (Petrianov filter linen) or parchment paper was used for bagging. Likewise the seedlings obtained from seeds formed from the best cultivars free pollination were used [1].

The oil content in hazelnut kernels was determined by the official method (AOAC, Official Method of Analysis ...: Fatty Acids (Free) in Crude ..., 2000). To analyze the fatty acid composition (the number of saturated and unsaturated fatty acids), a gas chromatography method with a flame ionization detector was used in accordance with GOST 30418-96 "Vegetable oils. Method for determination of the fatty acid composition" [22].

## Results and discussion

Assessment results of the collection of hazelnut cultivars of domestic and foreign breeding up to the combination of economic and valuable feature showed the advantages of such cultivars as 'Dokhidnyi', 'Funduk-85' and 'Bol-

hadska novynka'. These cultivars increased the yield of nuts 4.5–6.4 times (from 61.6–179.2 to 394.8–809.2 kg/ha), with a rather high content (68.7–75.8%) of the oil in the cores during the first three years after the introduction into the fruiting period. In addition to the cultivars mentioned above, the early event of fruiting interstice was relevant for such cultivars as 'Dar Pavlenka', 'Zorinskiy', 'Ziuidivskiy', 'Karamanovskiy', 'Stepoviy' and 'Shedevr', the productivity of which has increased by 1.7–4.5 times during the first three years. At the same time, the high-oil cultivar 'Hrandiozniy' yielded to the best yield grade cultivar 'Dokhidnyi' during the first year of fruit bearing at 171.4 kg/ha, and for the third year fell by 414.4 kg/ha (Table).

Subject to the meteorological conditions of research years with a general tendency of specificity the oil content of hazelnut kernels slightly varied. Such cultivars as 'Urozhainyi-80', 'Funduk-85' and 'Hrandiozniy' with average indexes 74.5; 74.3% and 74.2% exposed to be the best as for the oil content. Almost all studied cultivars should be attributed to the group of high-oil, excepting the cultivars 'Lozivskiy urozhainyi' and 'Dar Pavlenka'.

Taking into account the results of the assessment, as well as data from previous studies [1], the parameters of breeding task for hazelnut were determined: potential yield – 3.5 t/ha; weight of nut – 3,0–3,5 g; kernel outlet is not less than 50% from the total mass of the fruit; shell thickness – no more than 1.0 mm; the number of fruits in the collective fruit – more than 4 pcs. The pollinating ability was also evaluated, paying attention to samples that formed large catkins with a large amount of pollen and with corresponding sets of *S*-genes that did not block reciprocal pollination, the use of which made it possible to reduce the number of pollinating plants on the plantation [1]. Pollinators were selected without the undesirable effects of xenia; particularly relatively the scales of the pellicle on the kernel, which is usually formed from the fertilization with pollen of *C. colurna* and reduce the nuts quality [1, 23]. In addition to cross-breeding crossings, the representatives from the collection of the NDP "Sofiyivka" were included. They were *C. chinensis*, *C. avellana*, *C. cornuta*, *C. heterophylla*, *C. maxima* and other species.

During the observations of hybrid seedlings growing methods, the efficiency of early autumn seedlings with the help of collective fruits had been confirmed (that is, nuts unrefined from cupule), which provided about 100% germination, while had been remaining the least labo-

Table

**Hazelnut cultivars yield during the first three years after the introduction into the fruiting period, kg/ha**

Cultivar	Yield year			Total yield during the first three years
	2012	2013	2014	
'Dokhidnyi'	179.2	355.6	809.2	1344.0
'Ziuidivskiy'	114.8	392.0	638.4	1030.4
'Funduk-85'	140.0	338.8	456.4	935.2
'Zorinskiy'	64.4	254.8	509.6	828.8
'Stepoviy'	86.8	266.0	470.4	823.2
'Shedevr'	86.8	263.2	459.2	809.2
'Dar Pavlenka'	95.2	226.8	380.8	702.8
'Bolhradaska novynka'	61.6	229.6	394.8	686.0
'Lozivskiy urozhainiy'	16.8	98.0	518.0	632.8
'Morozivskiy'	19.6	117.6	467.6	604.8
'Karamanovskiy'	53.2	176.4	355.6	585.2
'Koronchatyi'	5.6	86.8	462.0	554.4
'Hrandioznyi'	7.8	117.6	257.6	383.0
'Urozhainiy-80'	5.6	100.8	271.6	378.0
LSD <sub>0,05</sub>	3.6	11.6	24.8	—

rious [24]. Derived seedlings  $F_1$  were grown in containers under controlled conditions of vegetative construction with fine-dispersed moistening, and were transplanted to grow and evaluate in the hybrid garden-producing section of the NDP "Sofiyivka" of NAS of Ukraine, where they carried out a comprehensive assessment of both seedlings and nuts according to generally accepted methods [1].

The best seedlings were propagated according to the technology developed by us as a result of a comparative evaluation of various methods of hazelnut reproduction, taking into account the use of growth stimulants, different timing and methods of harvesting the cuttings material [25].

The number of hazelnuts cultivar patterns the best of which were prepared for submission to the State Veterinary and Phytosanitary Service of Ukraine (a modern analogue of the State Variety Test Commission) for testing, including the cultivars 'Sofiyivsky 1' ('Ukraina-50' × *C. avellana* 'Fuscorubra'), 'Sofiyivsky 2' ('Dar Pavlenka' × *C. avellana* 'Fuscorubra'), 'Sofiyivsky 3' ('Cherkeskyi-2' × *C. chinensis*), 'Sofiyivsky 4' ('Shedevr' × *C. avellana* 'Fuscorubra') and 'Sofiyivsky 15' ('Garibaldi' × *C. chinensis*). These cultivars are characterized by spherical or almost spherical fruits ('Sofiyivsky 3', 'Sofiyivsky 15'), raised winter hardiness and drought resistance, as well as the lack of periodicity of fruiting in comparison to the Turkish and Azeri cultivars.

Such cultivars as 'Garibaldi', 'Dar Pavlenka', 'Ukraina-50', 'Cherkeskyi-2', and 'Shedevr' which were used as the maternal plant had been the best in hybridization; whereas *C. avellana* 'Fuscorubra' and *C. chinensis* were the

best pollinators. Findings concerning *C. chinensis* in hybridization with hazelnut cultivars used as the maternal plants, somewhat contradict the literature data of successful hybridization of *C. chinensis* × *C. avellana* so as incompatibility in reciprocal crossing. This discrepancy between the results of crosses can be explained by the limited number of *C. avellana* genotypes in the cited experiments [23] and/or by the fact that the samples of *C. chinensis* were introduced not from the initial natural area, but from the collection of Berlin Botanical Garden (Botanischer Garten Berlin-Dahlem) where they had been imported from the natural area (China). We should suppose that seed populations of *C. chinensis* were subjected to the action of natural selection in the conditions of Berlin-Dahlem, and then in Uman, which influenced the fertilizing ability of the pollen.

The oil content in the studied samples ranged from 61.4% to 65.1% of the kernel mass. Under suitable conditions and with this amount of oil in hazelnut kernels, it is possible to obtain approximately 1000 kg of oil per hectare, which is very advantageous in comparison with the amount of soybean oil produced (~ 500 kg/ha). Such high oil content in hazelnut nuts makes it a promising source of plant material for potential commercial value.

It is important that each hazelnut sample characterized with the fatty acid compositions of a higher percentage (%) of oleic C18: 1ω9 (77.8–81.0) and linoleic C18: 2ω6 (9.6–15.7) acids with a significantly lower amount of palmitic C16: 0 (5.0–5.7), stearic C18: 0 (2.4–3.6) and linoleic C18: 3 (0.07–0.14) acids (Figure).

Hazelnut kernels of such cultivars as 'Sofi-

yivsky 2' and 'Sofiyivsky 4' showed the greatest amount of unsaturated acids. Such cultivars should be considered as the prospective as a raw material for the production of hazelnut oil and essential phospholipids for industrial cultivation, as well as for the inclusion into the

hybridization to improve the hazelnut in fruit quality. At the same time, it should be noted that, according to the fatty acid composition of the oil, the hazelnuts mentioned above are not differ much. We have every reason to concede the cultivar 'Sofiyivsky 15' as the most prom-

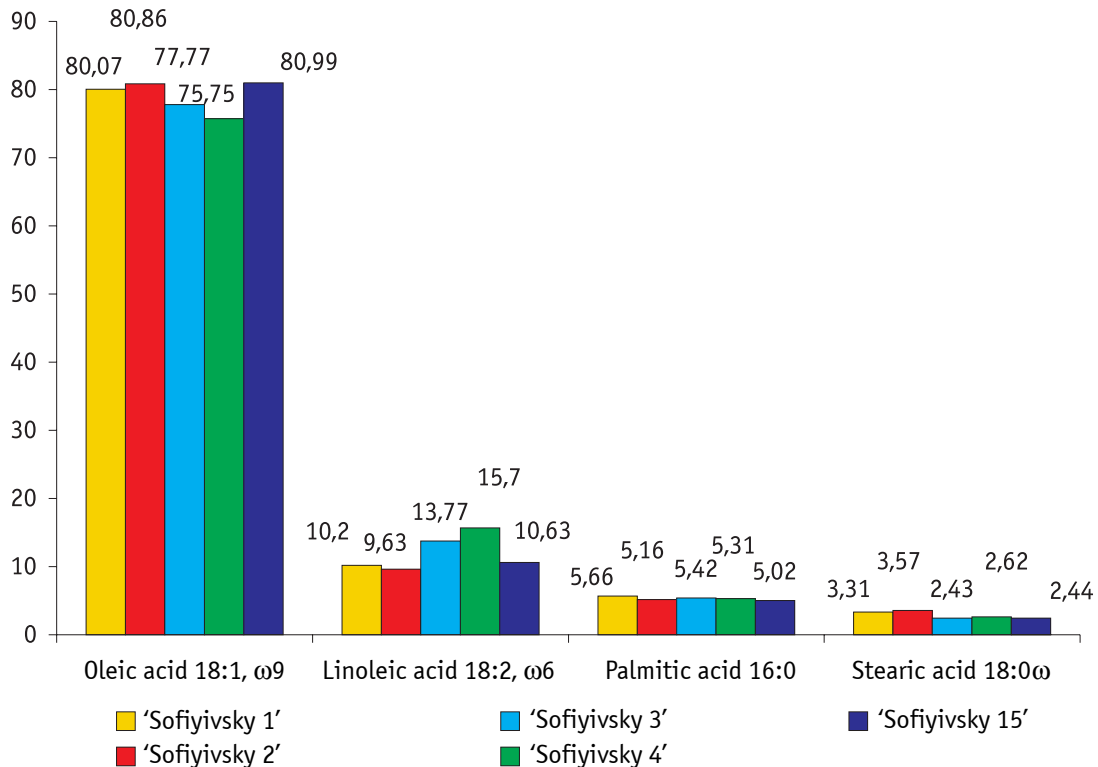


Figure. Fatty-acid oil content of the new hazelnut cultivars

ising, taking into consideration the high productivity and early-maturing, suitable for treatment almost spherical nut shape. The total content of oleic and linoleic acids in the kernels of researched hazelnuts was over 90% from the total fatty acid content in the kernels of these cultivars.

Such an amount of unsaturated fatty acids in hazelnut kernels of the new cultivars indicates the prospect of using extraordinary raw potencies of newly created cultivars with parallel further genotypes improvement, as well as the development of effective schemes of lecithin production adapted to the specific composition of hazelnut fatty acids.

## Conclusions

Cultivars and species efficiency of *Corylus L.* collection of the National dendrological park "Sofiyivka" of NAS of Ukraine in the hybridization is confirmed by the creation of valuable breeding material where a number of applicants for the cultivar have already been selected, 'Sofiyivsky 15' in particular, combined

super-early fruiting period introduction with a rapid yield increase. Winter and drought resistance, high oil content and the prevalence of the most valuable unsaturated fatty acids in hazelnut oil are also very important.

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**Мета.** Оцінити види, гібриди та сорти фундука з генетичної колекції *Corylus* spp. Національного дендропарку «Софіївка» НАН України за комплексом господарсько-цінних ознак. Зроблено спробу проаналізувати інформацію про *Corylus* spp. ідентичність, таксономію та описи, поширення та екологічні вимоги видів, можливості використання генетичного потенціалу для створення нових сортів. **Методи.** Цінність представників колекції *Corylus* spp. досліджували за допомогою загальноприйнятих методів випробувань. Для узагальнення інформації про філогенетичну реконструкцію роду *Corylus* L. та фундука було проаналізовано ряд наукових публікацій, запропонованих для обговорення. Вміст олії в ядрах горіхів фундука та склад жирних кис-

лот визначали офіційними методами. **Результати.** Кращі зразки генетичної колекції фундука були включені в широкую програму гібридизації, в тому числі з представниками *C. chinensis* Franch. Отримано ряд гібридних сіянців, зокрема нових сортів фундука 'Софіївський 1', 'Софіївський 2' та 'Софіївський 15', що характеризуються сферичними або майже сферичними плодами, підвищеною зимостійкістю та стійкістю проти посухи, а також відсутністю періодичності плодоношення. **Висновки.** Колекція різновидів, форм, сортів та видів роду *Corylus* L., створена останніми роками, може бути базою для селекції фундука в Україні.

**Ключові слова:** селекція, сорт, природний ареал роду, програма гібридизації, горіх, види.

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**Цель.** Оценить виды, гибриды и сорта фундука из генетической коллекции *Corylus* spp. Национального дендрологического парка «Софиевка» НАН Украины по комплексу хозяйственно-ценных признаков. Сделана попытка проанализировать информацию о *Corylus* spp. идентичности, таксономии и описании, распространении и экологических требованиях видов, возможности использования генетического потенциала для создания новых сортов. **Методы.** Ценность представителей коллекции *Corylus* spp. исследовали с помощью общепринятых методов испытаний. Для обобщения информации о филогенетической реконструкции рода *Corylus* L. и фундука было проанализировано ряд научных публикаций, предложенных для обсуждения. Содержание масла в ядрах орехов фундука и состав жирных

кислот определяли официальными методами. **Результаты.** Лучшие образцы генетической коллекции фундука были включены в широкую программу гибридной селекции, в том числе с представителями *C. chinensis* Franch. Получен ряд гибридных сеянцев, в частности новые сорта фундука 'Софиевский 1', 'Софиевский 2' и 'Софиевский 15', которые характеризуются сферическими или почти сферическими плодами, повышенной зимостойкостью и засухоустойчивостью, а также отсутствием периодичности плодоношения. **Выводы.** Коллекция разновидностей, форм, сортов и видов рода *Corylus* L., созданная в последние годы, может служить базой для селекции фундука в Украине.

**Ключевые слова:** селекция, сорт, естественный ареал рода, программа гибридной селекции, орех, виды.

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