Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2021, 11(4), 70-80, doi: 10.15421/2021_201

ORIGINAL ARTICLE

Aronia: Promising new forms and varieties in fruit selection and ornamental gardening

V.V. Moskalets[1*], O.B. Ovezmyradova[2], O.A. Sayuk[2], O.M. Nevmerzhytska[2], A.B. Marchenko[3], O.V. Knyazyuk[4]

[1]Institute of Horticulture, National Academy of Agrarian Science of Ukraine
[2]Polissia National University, Zhytomyr, Ukraine
[3]Bila Tserkva National Agrarian University, Ukraine
[4]Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Ukraine
**Corresponding author E-mail: moskalets7819@i.ua*
Received: 14.06.2021. Accepted: 21.07.2021.

The study of Aronia original selection material and selection of the best varieties and forms on the economically valuable parameters are presented. In 2017–2021 two chokeberry varieties (Viking and Hugin) and three forms (Mavka, Form 4-17, and Form 11/2-17) in the collection of the Institute of Horticulture of NAAS of Ukraine were selected according to the complex biological characteristics (weight of 1 brush, yield from the bush, organoleptic properties, biochemical composition of fruits, resistance to pathogens) for further selection work. Organoleptic parameters and biochemical composition evaluate the chokeberry fruits; the best of them are selected by the content of dry matter (Mavka and Form 11/2-17), dry soluble substances (Mavka and Viking), polyphenolic compounds (Hugin and Form 11/2-17), P-active substances, taste and aftertaste (Form 4-17, Hugin). All studied genotypes of Aronia are characterized by high decorativeness (shape and coloк of inflorescences, duration of flowering, color, and shades of leaves during the growing season). As a result of a phytosanitary assessment of Aronia plantations, it was found that the plants are in excellent condition, the degree of manifestation of the leaf spot is insignificant, the presence of quarantine diseases was not detected. Viking variety, Mavka, and Form 11/2-17 were immune and practically resistant to *Phyllosticta arbutifolia* and Erwinia amylovora for four years of research. The analysis of the obtained results confirms the appropriateness of using Aronia varieties (Hugin and Viking) and new forms (Mavka, Form 4-17, and Form 11/2-17) in fruit and ornamental horticulture.
Keywords: Chokeberry, fruits; yield, P-active compounds, leaves spots, resistance, *Phyllosticta arbutifolia*.

Introduction

The genus of *Aronia* includes such species: *Aronia arbutifolia* (L.) Elliot (red chokeberry) with red late-ripening fruits, *Aronia melanocarpa* (Michx.) Elliot (black chokeberry) with black early-ripening fruits, *Aronia mitschurinii* A.K. Skvortsov & Maitul. and *Aronia prunifolia* (Marsh.) Rehd. (purple chokeberry)-a natural hybrid between the above species ([=*Aronia arbutifolia* (L.) Pers. × *Aronia melanocarpa* (Michx.) Elliott]) (Vinogradova et al., 2018; Shipunov et al., 2019). The genus *Aronia* is related to the genus *Photinia* (*Photinia* Lindl., 1820), because of which some botanists united them together in the genus Photinia (Guo, 2011). Aronia is cultivated as an ornamental plant and has high nutritional value, antioxidant properties, and characteristic taste (Persson et al., 2004; Deineka et al., 2020).

Genus name comes from the Greek word 'aria', the name for a species of *Sorbus* of which the fruits resemble chokeberry. Specific epithet comes from the words 'melano,' meaning black, and 'carpa' meaning fruit about the color of this species' ripe fruits (Shipunov et al., 2019). The dark blue color of chokeberry fruit is caused by the high concentration of anthocyanins, proanthocyanidins, and hydroxycinnamic acids, including cyanidine 3-glucoside 3-galactoside, 3-xyloside, and 3-arabinoside (Gajic et al., 2020).

Lack of varieties of The State Register of Plant Varieties Suitable for Dissemination in Ukraine. Now Aronia berries are widely distributed in Europe USA, Canada and cultivated as an important industrial crop. It is a valuable raw material for the juice and wine industries and it is used as a source of food-grade colourant and natural antioxidants (Denev et al., 2019). The high content of different polyphenol compounds and multiple health benefits of chokeberry determine the increasing scientific interest in the fruit and its industrial processing (Sidor & Gramza-Michałowska, 2019). In Ukraine, the industrial area of this crop is insignificant (about 40 hectares). Its industrial distribution is being burned. Today it is only one variety-Vseslava, introduced in 2020 (Moskalets et al., 2019).

Health benefits of chokeberry include hypotensive, lipid-lowering, gastroprotective, hepatoprotective, and anticarcinogenic effects (Gajic et al., 2020).) More recently, Aronia products and preparations have shown antiviral activity, anti-aging effect, and anti-inflammatory effect in patients with mildly elevated blood pressure (Balansky et al., 2012); furthermore, Aronia has potential in the control of type 2 Diabetes also shown (Park et al., 2013; Denev et al., 2019). Chokeberry fruits are a rich source of dietary fiber, which amounts to about 70% of dry matter. More than 60% of chokeberry dietary fiber is composed of insoluble fractions (lignin, cellulose, and hemicellulose) (Olsson et al., 2004). Aronia fruits also contain vitamin B, carotenoids, tocopherols, vitamin C, and vitamin K (Zlatanov, 1999; Tanaka, Tanaka, 2001). The fruits contain macroelements (K, Ca, P, Mg, and Na), and microelements (Zn, Fe, Se, Cu, Mo, Cr, Mn, Si, Ni, B, and V) (Sidor & Gramza-Michałowska, 2019).

Chokeberry fruits have 8-12 times more quinic acid than cranberry; they are recommended by nutritionists and because of their high vitamin P content (higher than any other fruit) (Cristina & Parascovia, 2018). Vitamin P has, among other things, the role of fixing vitamin C in the body and restoring the tonus of the capillary vessels. Chokeberry contains five times more vitamin P than grapes (Olsson et al., 2004). 100 ml of chokeberry juice per day or 15 grams of chokeberry are sufficient to cover daily needs with important vital substances (Valcheva-Kuzmanova & Belcheva, 2005). Fruits of Aronia contain 15 times more antioxidants than blueberries (Yaneva et al., 2002; Tolic et al., 2017).

Polyphenols are biofactors that determine the high bioactivity of chokeberries, some of the richest polyphenols sources, including anthocyanins, proanthocyanidins, and flavonols, proanthocyanidins, and phenolic acids (Cristina & Parascovia, 2018). Chokeberry fruit and products have significant antioxidant and health-promoting potential as they reduce the occurrence of free radicals (Sidor & Gramza-Michałowska, 2019).

Materials and Methods

The research was conducted at the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine during of 2017–2021 years, where chokeberry plans (A. melanocarpa (Michx.) Elliot, A. mitschurinii and A. prunifolia) were studied. The studies were conducted in accordance with the Program and the Method Study by Syedov (1995), Syedov & Ogoltceva (1999), Tkachyk (2005). The chokeberry fruits were harvested from the experimental collection of rare fruit crops of the Breeding and Cultivation Technology Berries Crops Laboratory. The experimental research (biometric measurements, analytical investigations, mathematical and statistical processing of the experimental data) were carried out at the Institute of Horticulture of NAAS of Ukraine.

The phenological observations over the plants' growth and development and the biometric indicers were carried out following Beydemann's (1974) methods. The estimate of yield plants the weight method, forming the total fruit sample (0.1 kg) of which 100 fruits were selected to establish the qualitative and quantitative characteristics. The chokeberry fruits were harvested manually in September, on dry time, at full maturity. The morphological characteristics were identified by means of the visual assessment and measurements or calculations depending on the type of their detection. The identification of the morphological traits on generative plants was carried out (Syedov & Ogoltceva, 1999; Tkachyk, 2005).

The dry substances (solids) content was determined applying the weighted method in keeping with SSU 7804:2015; the polyphenolic compounds-amount utilizing the Folin-Dennis reagent spectrophotometric method on the spectrophotometer Spekol 1500 under the wavelength of 270 nm with a photometric accuracy of 0.004 (SSU ISO 4373:2005; Pochynok, 1976).

Catechin content was determined by titration with a 0.1 N solution of $KMnO_4$ the test mixture with a volume of 10 cm^3. The appearance of a golden-yellow hue of the solution indicated the completion of the titration process. The result was multiplied by the conversion factor-5.5 (to convert 0.1 N solution of $KMnO_4$ in 1 mg of phenolic compounds contained in 10 cm^3 taken for titration). The determination of anthocyanin content was performed spectrophotometric method at a wavelength of 530 nm (Giusti & Wrolstad, 2000). A weighed portion of fresh berries (1 g) was extracted with a mixture of 96% ethyl alcohol and 1.5 N hydrochloric acid in a ratio of 85:15. The filtrate was brought to a certain volume with the extractant. The extract was transferred into flasks with a ground stopper and kept in the dark. Under such conditions, there is a complete transformation of anthocyanins into a cationic, coloured form. The anthocyanin content was calculated using the formula:

$$A = \frac{E.V.100.K}{n},$$

Where *A*-is the concentration of anthocyanins in mg per 100 g of the sample; *E*-is the optical density of the solution; *V*-volume, ml; *n*-is the weight of the sample in g; *K*-98.2-coefficient calculated on the basis of extinction coefficients of 1% solutions of anthocyanins (cyanidin-3-galactoside and cyanidin-3-arabinoside).

The biochemical analyses were conducted by Pochynok (1976) in the three-fold repetition in each variant of the experiment. Phytopathological examinations of plants were performed according to the Syedov & Ogoltceva (1999); the degree of plants damage to pathogens was expressed as a percentage (Khokhryakov, 1976), the gradation of plants resistance was performed on a scale of Table 1.

Resistance, point	**The degree of damage to the leaf surface,%**	**Characteristics of the plant resistance, their susceptibility**
9-8	absent	high resistance
7-6	≤ 5	practical resistance
5-4	5–25	weak susceptibility
3-2	26–50	average susceptibility
1	>50	strong susceptibility

Table 1. Scale for assessing the resistance of chokeberry plants to pathogens.

Phytopathological investigation of plants were performed according to the Method of State Variety Testing (2000), and Treyvas & Kashtanova (2016). Microscopic preparations were prepared using standard methods (Methods of determination, 1987). Identification of pathogens was performed by Blagoveshchenskaya (2015); Hoult et al. (1997). Pathogens were determined by light microscopy (trinocular microscope ST60-24T2) at a magnification of 100–600 times.

Morphological characteristics pathogens identification included the belonging to a specific taxonomic group, the structures of mycelia (presence or absence of superficial mycelium, and texture thereof), conidiophores (arrangement, branching, pigmentation), conidiogenous cells (placement, proliferation, scar type), and conidia (formation, shape, septation, and pigmentation), the presence on the leaves of oily, wet spots, necrosis of veins.

Climate and weather conditions place where chokeberry is growning are characterized by moderate continentality. The average air temperature is 6.9°C with significant fluctuations by months and average annual rainfall of 538 mm, which during the growing season unevenly distributed: in summer it is much more than in the spring and fall. Probability years with rainfall less than 350 mm about 33%. Soil-black humus earth general, deep, medium humic and clay-loam soil, with humus content-2.6% low-duty hydrolizable nitrogen (for Kornfild)-140 mobile phosphorus and exchangeable potassium (by Chirikov)-respectively 131 and 85 mg/kg soil.

The soil is characterized by average nitrifiable ability-20–35 mg/kg totally dry soil and average the gross providing compounds P_2O_5 and K_2O. Years of research have varied by hydrothermal regime. May 2017, 2018 years research were active plant growth and development-characterized by the most extreme weather conditions and negatively affected plant development. 2017, 2019, 2020 marked deficits rainfall and increased temperatures above average long-term norms in blooming leaves, flowering, fruit filling of formation spike compared with favorable enough wet spring period (2018 and 2021), which gave opportunity to comprehensively evaluate the adaptability the studied Aronia genotypes to climate in Forest-Steppe and Polissia–Forest-Steppe conditions and the ability to realize theirs biological potential.

All research results are presented as mean ± SD. A two-tailed Student's t-test determined the significance of differences between groups. Differences are regarded as statistically significant if $p < 0.05$.

Results and Discussion

During 2017-2020, we selected three varieties and 2 forms of chokeberry by a complex of economically valuable traits from the collection of the Institute of Horticulture of NAAS of Ukraine. Their brief description is as follows: Viking chokeberry-variety of Finnish selection, a relatively small upright shrub up to 2 meters tall. The shape of the crown is wide. The leaf is deep green glossy; in autumn, it is painted in fiery burgundy-red scarlet tones. Blooms in May-June, creamy-white flowers are collected in umbrella inflorescences (Fig. 1a).

A good honey bear. It can be used for landscaping. Hugin chokeberry (Fig. 1b)-late variety of Swedish selection, low multi-stemmed shrub up to 2 m tall with a rounded crown. Blooms in June with lush snow-white inflorescences. An excellent honey bear. Dark green glossy leaves become fiery scarlet by autumn. The harvest ripens in September. The bush is beautiful throughout the season and is suitable for single planting and for tree-shrub composition.

Form Mavka-seedling of unknown origin by the morphological traits belongs to Sorbaronia mitschurinii (Fig. 1c) is a tall (up to 4 m) shrub. The crown is spherical, oval, and dense. Branches and twigs are light gray-brown. Young shoots are light green. Leaves are ovoid, widening towards the petiole, dark green above and green-light green from the bottom of the leaf blade. The flowers are white (sometimes with a light pink tint).

Form 4-17 *Aronia* (Fig. 1d)-(seedling from free pollination of Hugin variety seeds) multi-stemmed shrub 2.5-3.0 m tall with an oval crown. The leaf is shiny, dark green in summer, fiery red in autumn. Blooms in May-June, the inflorescences-creamy-white umbrellas, ripen in August-September. It can also be used for urban landscaping, in parks, squares, in landscaping.

Form 11/2-17 (Fig. 1e)-seedling obtained from seeds as a result of free pollination of the Chornookaia variety. Shrub 1.7 m tall, thick crown, 1.5 m wide. Shoots from reddish-brown to dark gray. The leaves are elliptical, shortly pointed dark green above, glossy-shiny, glabrous, slightly pubescent below, turn brownish-red in autumn. The flowers are white, 1.2 cm in diameter, collected in inflorescences of 12-20 pcs. The hybrid fund (52 samples) was formed by sowing seeds of selected fruits, which were formed from free pollination of different varieties. We conducted a series of experiments that included evaluation of the quality of hybrid fruits by organoleptic properties, components of productivity, yield, and resistance to pathogens to select the best samples from hybrids and translate them into elite selection forms (Table 2). As a result of the primary assessment of the collection and hybrid chokeberry's fund, five selected forms were identified that exceeded the control on a number of features (fruit weight, taste, or yield).

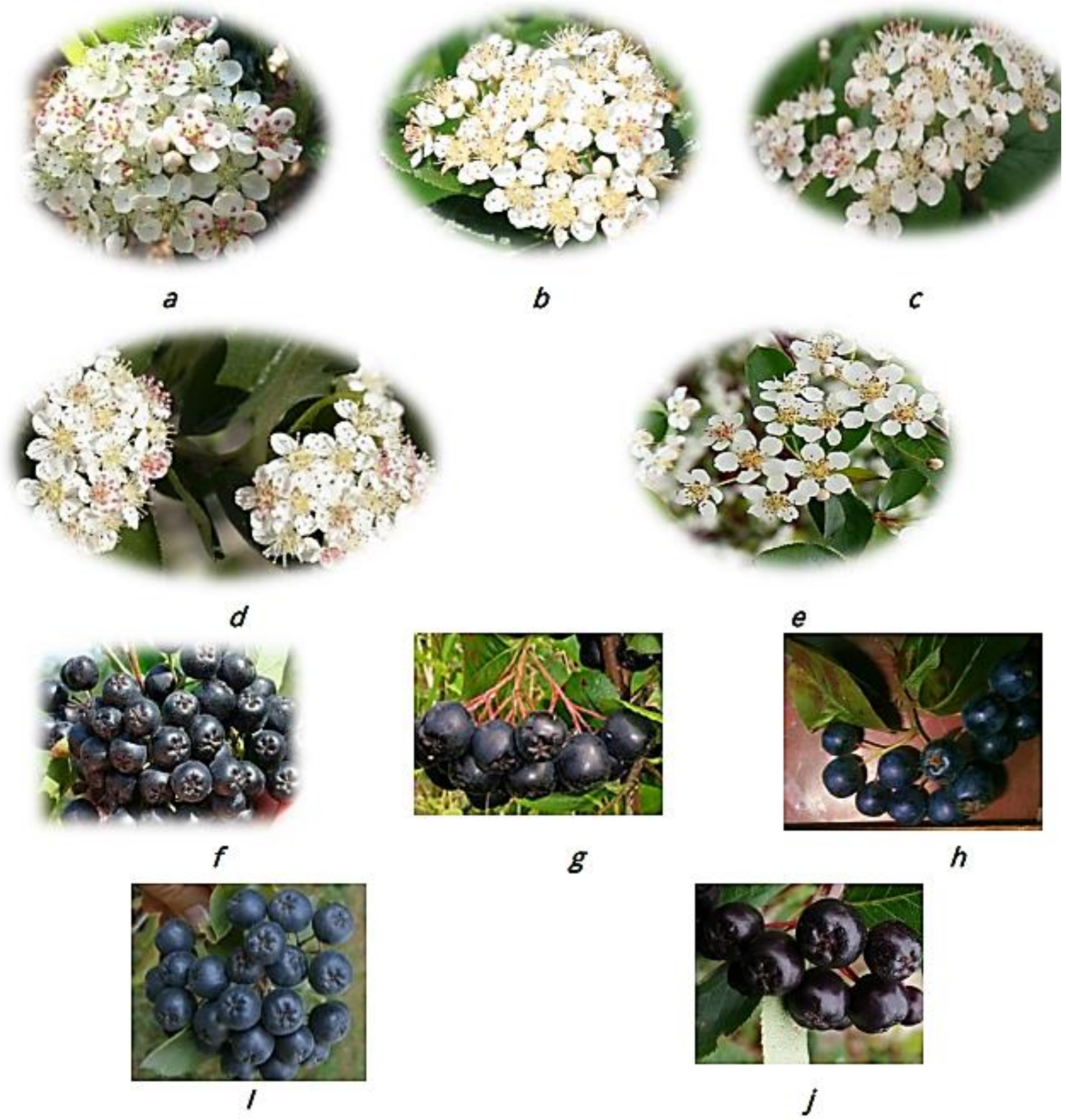

Fig. 1. Chokeberry inflorescence and fruits of varietie, selected forms: a, f-Viking variety; b, g-Hugin variety; c, h-Mavka form; d, i-Form 4-17; e, j-Form 11/2-17

During the two years of fruiting (2019–2020), harvesting was carried out from registered plants. The condition of the plants in 2019 (the first fruiting), a very dry year was satisfactory, because the plants are growning in the absence of watering and the period of pouring and ripening of the fruit was very hot and without precipitation. In 2019, the yield of the chokeberry five-year-old plants during the study period averaged 0.10–0.16 kg per plant. On average, for two years of research, the maximum yield was characterized by Form 4-17 (0.32 kg per bush). The number of flowers in the raceme in varieties varied within 11…29 pcs., fruits in the raceme 8… 23 pcs. (Table 2). The minimum number of fruits in the raceme in Form 11/2-17 and Mavka form (8-13 pieces) was noted; Form 4-17 and Viking variety have the maximum number of flowers. This variability of generative features is due primarily to the affiliation of selected samples to different species of the *Aronia* genus.

Variety, form	The average diameter of the inflo-rescence, cm	The average number of flowers in the inflorescence, pcs.	The average number of fruits in the brush, pcs.	The average weight of 1 fruit, g	The average weight of 1 brush, g	The diameter of the fruit, cm	The fruit yield, kg/bush
Viking (control)	12.4 ± 0.5	26 ± 2	20 ± 2	1.1 ± 0.1	23.4 ± 1.2	0.9 ± 0.0	0.11 ± 0.08
Hugin	11.9 ± 0.7	29 ± 2	17 ± 1	0.8 ± 0.0*	13.2 ± 0.8*	0.8 ± 0.0*	0.16 ± 0.07**
Mavka form	9.3 ± 0.8*	17 ± 3*	11 ± 3*	0.7 ± 0.0*	7.5 ± 0.4*	0.7 ± 0.1*	0.12 ± 0.04**
Form 4-17	13.5 ± 0.4**	28 ± 2	19 ± 2	1.2 ± 0.1	25.6 ± 1.5**	0.9 ± 0.0	0.28 ± 0.05**
Form 11/2-17	6.5 ± 0.5*	11 ± 1*	8 ± 2*	0.6 ± 0.0*	5.2 ± 0.7*	0.6 ± 0.0*	0.10 ± 0.02

Note: *-significance P<0.05 as compared to the control (lower than Viking variety); **-significance P<0.05 as compared to the control (above Viking variety).

Table 2. Biometric parameters of chokeberry flowers and fruits selected varieties and forms (n=9, p ≤ 0.05), average 2019-2020.

The average fruit weight in chokeberry varieties ranged 0.6-1.2 g, the highest was observed in Form 4-17 (1.2 g), the lowest-in Form 11/2-17 (0.6 g). Form 4-17 (25.6 g) had the highest average weight of the brush during the study period, and Form 11/2-17 (5.2 g) had the lowest (Fig. 1). Some varieties of chokeberry fruits are suitable for fresh consumption (the taste score of varieties was 6.3… 8.6 points) (Table 3). Hugin variety and Form 4-17 had the best score by the result of the evaluation of the taste fruits properties.

Variety, form	Colour	Shape	The surface of the fruit	Aftertaste		Taste	
				Characteristic	Mark	Characteristic	Mark
Viking	purple-black	flat-rounded	dim	liqueur-plum	8.5	sweet, slightly tart	8.5
Hugin	black glossy	flat-rounded	dim	spicy-sweet	9.0**	sweet with a slight tartness	8.7**
Mavka form	purple-black	orbed	glossy	tart-sweet	7.0*	sweet and sour with a pronounced tartness	7.9*
Form 4-17	purple-black	flattened-spherical	dim	tart-sweet-sour	8.5**	sweet and sour with a slight tartness	8.6**
Form 11/2-17	purple-black	oval	glossy	tart	7.2*	tart	6.3*

Note: *-significance P<0.05 as compared to the control (lower than Viking variety); **-significance P<0.05 as compared to the control (above and at the control level).

Table 3. Morphometric parameters and organoleptic properties of chokeberry fruits varieties and selected forms, (n=9, p ≤ 0.05), average 2019-2020.

According to organoleptic evaluation, aronia berries of all studied varieties had a purple-black or black glossy color with a dove-coloured tinge. The taste of the fruit also varied slightly from sweet and sour to sweet, with a light and pronounced tartness. The taste of the fruit also varied from slightly sweet and sour to sweet, with a light and pronounced tartness. Analysis of the chemical composition of fruits of chokeberry varieties and forms showed that it is a rich source of biologically active compounds: polyphenolic compounds, catechins, anthocyanins (Table 4). The cultivars fruits differ in the high content of soluble dry matter; their share is 15.8–21.5% (Fig. 2).

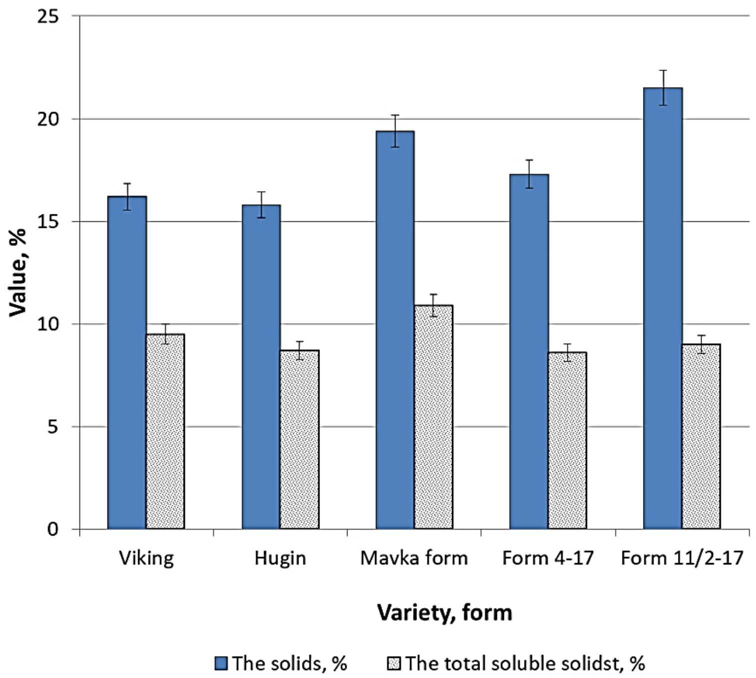

Fig. 2. The solids and the total soluble solidst of chokeberry fruits, %.

The biological activity of chokeberry fruits is largely related to the content of vitamins and vitamin-like substances, the main of which are substances that have P vitamin activity: catechins, anthocyanins, leukoanthocyanidins, flavonols, and phenolic acids (Jurikova et al., 2017; Tolic et al., 2017; Gill et al., 2020). Biochemical analysis of fruits revealed the content such P-active compounds: catechins-810–1114 mg/100 g, anthocyanins-1002–1385 mg/100 g, polyphenols-4460–5950 mg/100 g (Table 4).

Variety, form	Catechins, mg/100 g FM	The amount of anthocyanins (in terms of cyanidin 3-O-glucoside), mg/100 g FM	Polyphenolic compounds, mg/100 g FM
Viking	1114 ± 12.3	1025 ± 15.1	4710 ± 18.3
Hugin	925 ± 7.5	1255 ± 17.0**	5750 ± 22.0
Mavka form	810 ± 12.1	1110 ± 14.5	4890 ± 11.2
Form 4-17	1102 ± 17.7	1002 ± 20.4	4460 ± 17.9
Form 11/2-17	1085 ± 13.8	1385 ± 11.2**	5950 ± 22.5

Note: *-significance P<0.05 as compared to the control (lower than Viking variety); **-significance P<0.05 as compared to the control (above and at the control level).

Table 4. Biochemical composition of chokeberry fruits (n=9, p ≤ 0.05), average 2019–2020.

The studied fruits differ in the content of the dominant groups of biologically active substances, and the richest in anthocyanins are Hugin variety and Form 11/2-17, catechins-Viking variety and Form 4-17, polyphenolic compounds-Form 11/2-17. It should be noted that we did not find a clear relationship between the content of catechins and anthocyanins, catechins and polyphenols, anthocyanins and polyphenols. Thus, the correlation coefficient between catechins and anthocyanins is positive medium and strong (*r*=+0.55...+0.91), but Hugin variety is weakly negative (*r*=-0.16). There are between the content of polyphenols and catechins both a negative average and strong (*r*=-0.64...-0.93) and a positive strong correlation-in Mavka form, form 11/2-17 (*r*=+0.81...+0.90). Varieties were divided ambiguously and by correlation between anthocyanins and polyphenols: negative medium and strong (r=-0.59...-0.85) is observed in most varieties, with the exception of Mavka form, which has a strong positive correlation (*r*=+0.77).

In *Aronia*, the four major anthocyanins are 3-galactoside, 3-arabinoside, 3-glucoside, and 3-xyloside of cyaniding (Dorneanu et al., 2017). Anthocyanins function as antioxidants and offer numerous other health benefits, such as antiatherogenic (Kulling, Rawel, 2008; Kokotkiewicz et al., 2010) and anti-inflammation protection, and may aid in the prevention of degenerative diseases (Brand et al., 2017; Jurikova et al., 2017). Logvinova et al. (2017), as a result of the identification of major and minor anthocyanins in the fruits of chokeberry by the HPLC method, the same profile were revealed for the main component of them, cyanidin-3-galactosides (60.6-71.4% of the total amount of anthocyanins). Slimestad et al. (2005) reported total anthocyanins content in chokeberries 481 mg/100 g fw the such anthocyanidins cyanidin 3-*O*-galactoside (65% of total anthocyanins) and cyanidin 3-*O*-arabinoside (30%); flavonols (quercetin glycosides) and flavanols (flavan-3-ols, epicatechin in proanthocyanidins) are also present in the berries, but only as minor components.

Over the past decades anthocyanins of fruits and berries have become the subject of numerous studies (Castro-Acosta et al., 2016; Spinardi et al., 2019; Ponder et al., 2021). Their composition and quantity largely determine the suitability of varieties for freezing and technological processing, antioxidant properties of fruits and berries (Fan et al., 2020). Epidemiological studies have shown that moderate consumption of foods high in anthocyanins can reduce the risk of cardiovascular disease. In addition, they are characterized by anti-inflammatory, antimicrobial, hepatoprotective properties (Spinardi et al., 2019; Fan et al., 2020).

In terms of chemical composition, anthocyanins belong to glycosides-substances whose molecules consist of a non-carbohydrate part (aglycone) and a carbohydrate residue. According to calculations by the WHO Expert Committee on Food Additives (JECFA), the admissible daily intake of anthocyanins (ADI) for humans is 2.5 mg/kg body weight (Kylli, 2011). This can be explained by the fact that the content of these compounds is in a state of chemical equilibrium. Catechins are a reduced form of flavonoids; anthocyanins are a more oxidized form. The most oxidized form is flavonols. Shifting the balance toward a particular compound depends on many factors: acidity, light intensity (Cherviakovskiy et al., 2009).

Ochmian et al. (2012), Jurikova et al. (2017) have noted flavonols (quercetin glycosides) and flavanols (flavan-3-ols, epicatechin in proanthocyanidins) are also present in the berries, but only as minor components, and a mixture of four different flavonols is present, mainly quercetin-3-galactoside (hyperoside), quercetin-3-glucoside (isoquercetin), quercetin-3-rutinoside (rutin) and quercetin-3-robinobioside. Furthermore, quercetin 3-vicianoside was found in *A. melanocarpa* fruit, though in the lowest concentration. Further, another flavonol identified in *Aronia*-kaempferol, is present only in a much smaller amount.

Numerous studies (Valcheva-Kuzmanova & Belcheva, 2005; Ochmian et al., 2012; Brand et al., 2017; Jurikova et al., 2017) confirmed the beneficial effects of *Aronia melanocarpa* L. varieties consumption on hypertension, glucose metabolism disorders, dyslipidaemia, proinflammatory conditions, and reducing the risk factors of the metabolic syndrome. Results also showed the probable potential of black chokeberry to inhibit the development of some types of cancers (Choi et al., 2018; Buda et al., 2020; Gill et al., 2020). Further research is necessary to understand the interactions with other compounds which may affect the activity of chokeberry components. The antioxidant potential of chokeberry fruit and its products indicates that all fractions could be utilized as a source of antioxidants (Gao et al., 2018) and valuable nutrients with potential applications in food industry. Studies conducted to date (Sidor & Gramza-Michałowska, 2019; Buda et al., 2020; Gill et al., 2020) have indicated numerous benefits resulting from chokeberry fruits and its biologically active substances inclusion in a daily diet.

The analysis of the results of studies on chokeberry juice shows that the antioxidative potential of chokeberry products depends on the period and the year of raw material harvesting (Tolic et al., 2017). However, the main factor affecting the antioxidative properties of the products that needs to be considered is the technological production processes (Bolling et al., 2015). The antioxidative activity is influenced by crushed raw material used for the production of juices and chokeberry powders, the method and drying parameters during the production of dried fruit and powder extracts, as well as the extraction solvent and temperature (Borycka & Stachowiak, 2008; Oszmianski & Lachowicz, 2016).

Our study of the influence of biotic factors on chokeberry plantations in the period from 2017 to 2021 showed that this culture is quite resistant to diseases and pests. The mechanism of resistance of chokeberry is its high volatile content, which plays an important role in the immunity of plants. According to some authors (Pascal & Pirone, 1978; Andrienko, 1992; Kuklin, 2015), this species is affected by 18 species of pathogenic fungi that cause significant damage. Among them are pathogens of leaf spot (Pascal & Pirone, 1978; Kwon et al., 2016), monilial burns, fruit rot, rust, powdery mildew, scab (Andriienko, 1992; Horst, 2013; Farr & Rossman, 2016).

During 2017–2021 we found only the presence of brown spot of leaves on chokeberry plants, the defeat of which was insignificant (8–6 points). Mavka and Form 11/2-17-were resistant to *P. arbutifolia* (9 points); their leaves are not affected by the pathogen over the years allows them to be used as sources of resistance to the pathogen in further breeding work (Fig. 3). The leaves of the

Hugin variety reach a defeat of 5 percent or more, the leaves of the Viking variety and Form 4-17-more than 5% (7-14%) characterize them as resistance and correspond to 7-6 points.

The causative pathogen of chokeberry phyllosticosis is a pathogenic fungus of the genus *Phyllosticta (Phyllosticta arbutifolia*) refers to the department *Deuteromycota*. The mushroom overwinters on fallen leaves. In July, the leaves appear rounded brown spots up to 5 mm in diameter (Fig. 3g, 3h). In July-August, the center of the spot turns gray and dark spots of fruit formations of the fungus filled with spores are formed on it (Fig. 3h). Wind-borne spores infect healthy leaves and infect them.

Our studies are consistent with Kuklin (2015), which found in the forests of the European part of Russia three chokeberry pathogens of fungal diseases (brown spotted leaves-*Phyllosticta piricola, P. arbutifolia, Septoria piricola*). Also, in early July of 2020, the bacteria *Erwinia amylovora* we identified during phytopathological examination by microscopy (Fig. 4).

In 2019–2021 during May-first half of June, favorable weather conditions positively affected the spread of this pathogen. Viking, Hugin, Mavka, and Form 11/2-17 plants are immune to *E. amylovora* (the degree of leaf damage 0%). Form 4-17 is resistance (7-6 points) with a degree of the leaf surface damage 5-6%. Rain and high humidity cause it to spread rapidly, and it is particularly severe in temperatures between 25-32°C. However, according to Pascal & Pirone (1978), *Erwinia amylovora* bacterium commonly affects leaves, rarely serious enough on chokeberry to warrant control measures were detected pathogen of the blight.

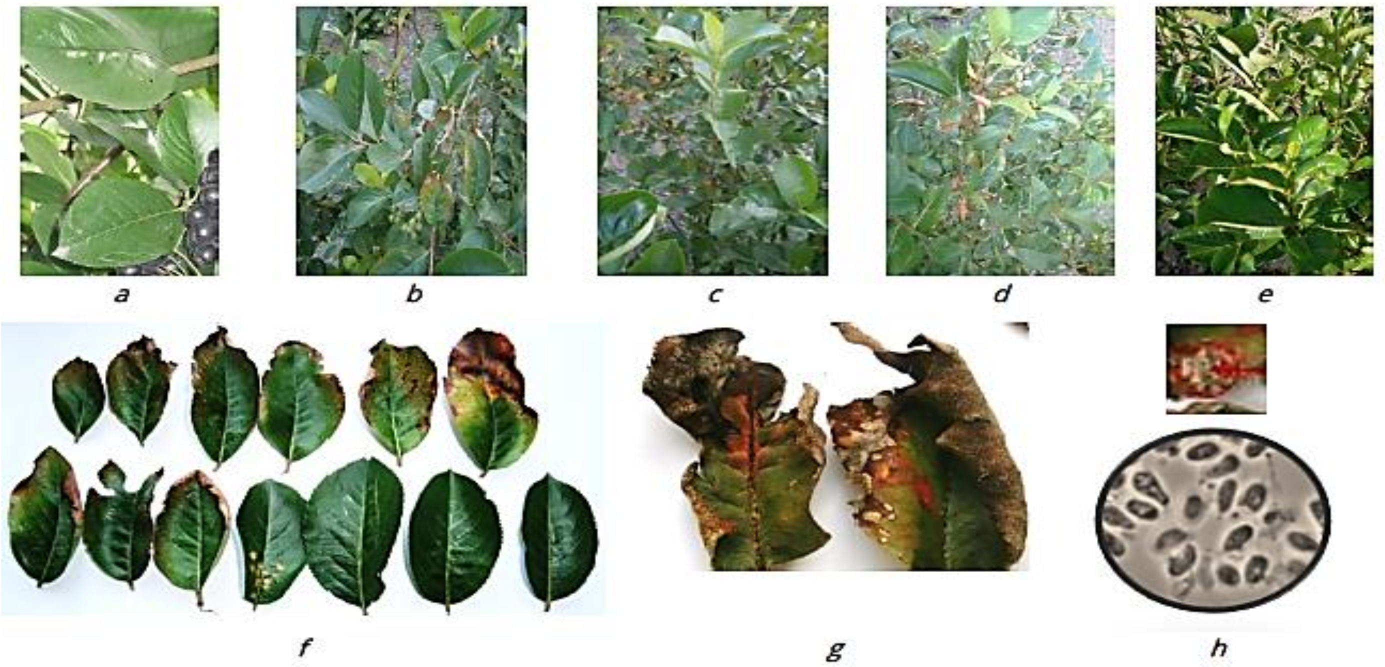

Fig. 3. Leaf spot symptoms on chokeberry plants (Institute of Horticulture of NAAS of Ukraine): *a*-Form 11/2-17 (the leaves healthy, without spots); *b*-Hugin; *c*-Viking; *d, f, g*-the plant Form 4-17 affected by spots; *e*-Mavka form (healthy plant, without spot); *f, g*-brown spots on the black chokeberry, degree of damage 8-14% (Form 4-17, healthy and damaged leaves); *h-Phyllosticta arbutifolia* .

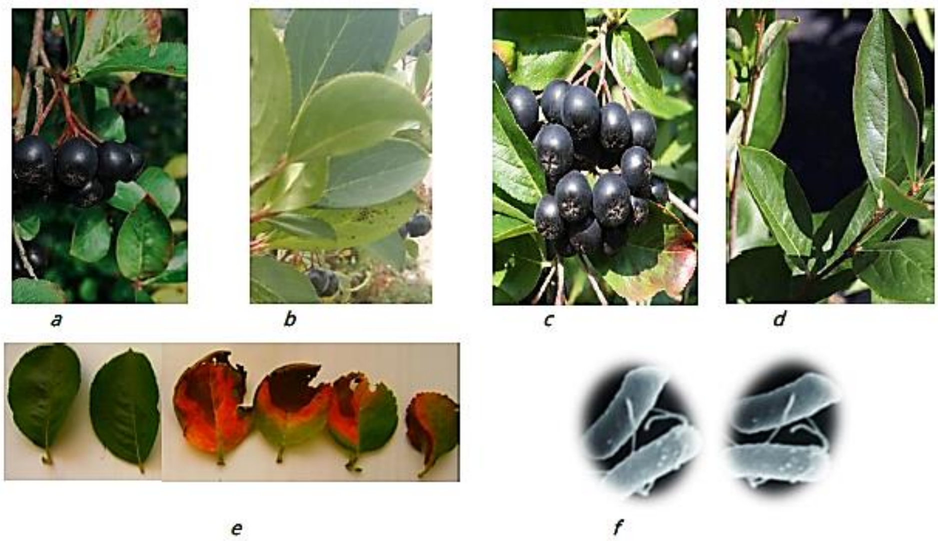

Fig. 4. Symptoms of chokeberry leaf spot on plants, pathogen bacterium *Erwinia amylovora*: *a,e*–Form 4-17 (degree of leaf damage 5-6%); *b*-Viking; *c*-Hugin; *d*-Form 4-17; *f*-*Erwinia amylovora.*

Other researchers (Park et al., 2017) in Korea several places have identified the pathogen *Pseudocercospora pyricola* for the first time on *Aronia melanocarpa* leaf. Leaf spots were distinct, scattered over the leaf surface and along the leaf border, subcircular to irregular and brown surrounded by a distinct dark colour, and were expanded and coalesced into irregularly shaped lesions. Recently Gao et al. (2021) in China first report about leaf spot on black chokeberry caused by *Alternaria tenuissima* as another leaf spot pathogen on chokeberry.

Known fungal pathogens of black chokeberry include, according to Farr et al. (2016): *Venturia* sp., *Cercosporella* spp., *Gymnosporangium* spp., Isariopsis sp., *Mycosphaerella arbutifoliae*, *Phymatotrichopsis omnivore*, and *Podosphaera clandestina*. Brown leaf spot caused by *Alternaria alternata* has recently been reported in Korea (Kwon et al., 2016). During July, diseased leaves on black chokeberry with circular or irregular brown spots were observed at farmhouses in the Danyang region and subsequently in Gochang, South Korea (Wee et al., 2017). Phytopathologists noted the disease continued its progression throughout August. The leaf symptoms observed were circular to irregular brown or light brown spots ranging 4–11 mm.

Pascal & Pirone (1978) found five fungi species that cause leaf spotting of chokeberry (*Ascochyta pirina, Cercospora mali, C. pyri, Mycosphaerella arbutifolia, and Phyllosticta*). Pascal & Pirone (1978) identified rust (*Gymnosporangium fraternum*) infected chokeberry leaves, fruits, and stems develop gall-like overgrowths which bear the long, horny aecial cups. These split open and scatter their spores widely during the summer. The spores are carried to the alternate host, southern whitecedar; upon its leaves are formed brown rust pustules which bear the telial stage of the parasite. The rust is unknown on *Aronia* in the absence of the cedar, and is of little importance in ornamental plantings except where the southern whitecedar is also grown.

Other phytopathologists (Pascal & Pirone; Horst, 2013) provided messages about *Septoria* appearance on the chokeberry leaves. A fungus, *Septoria,* causes septoria leaf spots. It is one of the most destructive diseases of *Aronia* foliage and is particularly severe in areas where wet, humid weather persists for extended periods. Septoria leaf spot usually appears on the lower leaves after the first fruit sets.

Conclusion

The study of Aronia original selection material and selection of the best varieties and forms on the economically valuable parameters are presented. In 2017–2021 two chokeberry varieties (Viking and Hugin) and three forms (Mavka, Form 4-17, and Form 11/2-17) in the collection of the Institute of Horticulture of NAAS of Ukraine were selected according to the complex biological characteristics (weight of 1 brush, yield from the bush, organoleptic properties, biochemical composition of fruits, resistance to pathogens) for further selection work.

Organoleptic parameters and biochemical composition evaluate the chokeberry fruits; the best of them are selected by the content of dry matter (Mavka and Form 11/2-17), dry soluble substances (Mavka, Viking), polyphenolic compounds (Hugin and Form 11/2-17), P-active substances, taste and aftertaste (Form 4-17 and Form 4-17). The biological value of the *Aronia* fruits lets to consider them promising raw materials for healthy nutrition and pharmaceutical branch. Widespread use of the new genotypes into the culture of the fruit and ornamental horticulture will make it possible to replenish the consumption and pharmaceutical market with the organic raw material for the manufacturing of the food and medicinal products. All studied genotypes of *Aronia* are characterized by high decorativeness (shape and colour of inflorescences, duration of flowering, color, and shades of leaves during the growing season). As a result of phytosanitary assessment of *Aronia* plantations, it was found that the plants are in good and excellent condition, the degree of manifestation of the leaf spot is insignificant, the presence of quarantine diseases was not detected. During 2017–2021 we found only the presence of brown spot of leaves on chokeberry plants, the defeat of which was insignificant (8–6 points). Mavka and Form 11/2-17-were resistant to *P. arbutifolia* (9 points); their leaves are not affected by the pathogen over the years allows them to be used as sources of resistance to the pathogen in further breeding work. (Fig. 3). The leaves of the Hugin variety reach a defeat of 5 percent or more, the leaves of the Viking variety and Form 4-17-more than 5% (7-14%) characterize them as resistance and correspond to 7-6 points. Favorable weather conditions had a positive effect on the spread of *E. amylovora*. Viking, Hugin, Mavka, and Form 11/2-17 plants are immune to this pathogen (the degree of leaf surface damage 0%). Form 4-17 is resistance (7-6 points) with a degree of the leaf damage 5-6%.

The analysis of the obtained results confirms the appropriateness of using *Aronia* varieties (Hugin, Viking) and new forms (Mavka, Form 4-17, and Form 11/2-17) in fruit and ornamental horticulture.

References

Andrienko, M.V. (1992). Aroniia Chornoplidna na Ukraiini [Chokeberry in Ukraine], Land & People of Ukraine, Kyiv.

Balansky, R., Ganchev, G., Iltcheva, M., Kratchanova, M., Denev, P., Kratchanov, C., De Flora, S. (2012). Inhibition of lung tumor development by berry extracts in mice exposed to cigarette smoke. International Journal of Cancer, 131:1991-1997.
Blagoveshhenskaya, E.Yu. (2015). Blagoveshchenskaya E.Yu. Phytopathogenic Micromycetes: Determinant, Mir, Moskow.
Bolling, B.W., Taheri, R., Pei, R., Kranz, S., Yu, M., Durocher, S.N., Brand, M.H. (2015). Harvest date affects aronia juice polyphenols, sugars, and antioxidant activity, but not anthocyanin stability. Food Chemistry, 187:189-196.
Borycka, B., Stachowiak, J. (2008). Relations between cadmium and magnesium and aronia fractional dietary fibre. Food Chemistry, 107:44-48.
Brand, M.H., Connolly, B.A., Levine, L.H., Richards, J.T., Shine, S.M., Spencer, L.E. (2017). Anthocyanins, total phenolics, ORAC and moisture content of wild and cultivated dark-fruited Aronia species. Scientia Horticulturae, 224:332-342.
Buda, V., Brezoiu, A.M., Berger, D., Pavel, I.Z., Muntean, D., Minda, D., Danciu, C. (2020). Biological evaluation of black chokeberry extract free and embedded in two mesoporous silica-type matrices. Pharmaceutics, 12:838.
Castro-Acosta, M.L., Lenihan-Geels, G.N., Corpe, C.P., Hall, W.L. (2016). Berries and anthocyanins: promising functional food ingredients with postprandial glycaemia-lowering effects. Proceedings of the Nutrition Society, 75:342-355.
Cherviakovskiy, Ye.M., Kucherenko, V.P., Kostiuk, V.A. (2009). The role of flavonoids in biological reactions with electron transfer. Proceedings of the Belarusian State University. Series of Physiological, Biochemical and Molecular Biology Sciences, 4:9–26.
Choi, H.S., Kim, S.L., Kim, J.H., Deng, H.Y., Yun, B.S., Lee, D.S. (2018). Triterpene acid (3-Op-coumaroyltormentic acid) isolated from aronia extracts inhibits breast cancer stem cell formation through downregulation of c-Myc protein. International Journal of Molecular Sciences, 19:2528.
Rusnac, C., Sava, P. (2018). Study about the biochemical composition of chokeberries fruits. Fruit Growing Research, 34:50-52.
Deineka, V.I., Tretyakov, M.Y., Oleiniz, E.Y, Pavlov, A.A., Deineka, L.A., Blinova, I.P., Manokhina, L.A. (2020). Determination of anthocyanins and chlorogenic acids in fruits of Aronia genus: the experience of chemosystematics. Russian Journal of Bioorganic Chemistry, 46:1390–1395.
Denev, P., Kratchanova, M., Petrova, I., Klisurova, D., Georgiev, Y., Ognyanov, M., Yanakieva, I. (2018). Black chokeberry (Aronia melanocarpa (Michx.) Elliot) fruits and functional drinks differ significantly in their chemical composition and antioxidant activity. Journal of Chemistry, pp:2-11.
Dorneanu, R., Cioanca, O., Chifiriuc, O., Albu, E., Tuchiluş, C., Mircea, C., Salamon, I., Hăncianu, M. (2017). Synergic benefits of Aronia melanocarpa anthocyanin-rich extracts and antibiotics used for urinary tract infections. Farmacia, 65:778-783.
Fan, R., Sun, Q., Zeng, J., Zhang, X. (2020). Contribution of anthocyanin pathways to fruit flesh coloration in pitayas. Plant Biology, 20:361.
Farr, D.F., Rossman, A.Y. (2016). Fungal Databases. Systematic Mycology and Microbiology Laboratory, ARS, USDA. Washington, DC: Agricultural Research Service.
Gajic, D., Saksida, T., Koprivica, I., Vujicic, M., Despotovic, S., Savikin, K., Jankovi, T., Stojanovic, I. (2020). Chokeberry (Aronia melanocarpa) fruit extract modulates immune response *in vivo* and *in vitro*. Journal of Functional Foods, 66:2-9.
Gao, J., Yang, M.J., Xie, Z., Lu, B.H., Hsiang, T., Liu, L.P. (2020). Morphological and molecular identification and pathogenicity of Alternaria spp. associated with ginseng in Jilin province, China. Canadian Journal of Plant Pathology, 1:1-14.
Gill, N., Rios, D., Osorio-Camacena, E., Mojica, B., Kaur, B., Soderstrom, M., Gonzalez, M., Plaat, B., Poblete, C., Kaur, N. (2020). Anticancer effects of extracts from three different chokeberry species. Nutrition & Cancer, 1–7.
Giusti, M.M., Wrolstad R.E. (2000). Characterization and measurement with UV-visible spectroscopy. In Current Protocols in Food Analytical Chemistry. New York.
Guo, W., Yu, Y., Shen, R.J., Liao, W.B., Chin, S.W., Potter, D. (2011). A phylogeny of Photinia sensu lato (Rosaceae) and related genera based on nrITS and cpDNA analysis. Plant Systematics & Evolution, 291:91-102.
Horst, R.K. (2013). Westcott's Plant Disease Handbook. Springer Science, New York.
Hoult, J., Krieg, N., Snit, P. (1997). Bergey's bacteria guide; In 2 volumes, Mir, Moskow.
Jurikova, T., Mlcek, J., Skrovankova, S., Sumczynski, D., Sochor, J., Hlavacova, I., Snopek, L., Orsavova, J. (2017). Fruits of black chokeberry aronia melanocarpa in the prevention of chronic diseases. Molecules, 22:944.
Kulling, S., Rawel, H. (2008). Chokeberry (Aronia melanocarpa)–A Review on the characteristic components and potential health effects. Planta Medica, 74:1625-1634.
Kokotkiewicz, A., Jaremicz, Z., Luczkiewicz, M. (2010). Aronia plants: a review of traditional use, biological activities, and perspectives for modern medicine. Journal of Medicinal Food, 13:255-269.
Kwon, J.H., Kang, D.W., Lee, S.Y., Choi, O., Kim, J. (2016). First report of brown leaf spot caused by Alternaria alternata on Aronia melanocarpa in Korea. Plant Disease, 44:187-190.
Kuklina, A.G. (2015). Naturalisation aronia Mitschurinii in the forests of European Russia. Forestry Information, 2:46-53.
Kylli, P. (2011). Berry phenolics: isolation, analysis, identification, and antioxidant properties: Academic Dissertation, University of Helsinki Department of Food & Environmental Sciences Food Chemistry, Helsinki.
Li, J., Deng, Y., Yuan, C., Pan, L., Chai, H., Keller, W., Kinghorn, A. (2012). Antioxidant and quinone reductase-inducing constituents of black chokeberry (Aronia melanocarpa) fruits. Journal of Agricultural & Food Chemistry, 60:11551–11559.
Logvinova, E.E., Brezhneva, T.A., Slivkin, A.I., Perova, I.B., Eller, K.I. (2017). Comparative analysis of compounds of fruits anthocyanin black chokeberry different varieties HPLC Sorption & chromatographic processes. 17:117-121.
Moskalets, T., Moskalets, V., Vovkohon, A., Shevchuk, O., Matviichuk, O. (2019). Modern breeding and cultivation of unpopular fruits and berries in Ukraine. Ukrainian Journal of Ecology, 9:204–213.

Ochmian, I., Grajkowski, J., Smolik, M. (2012). Comparison of some morphological features, quality and chemical content of four cultivars of chokeberry fruits (Aronia melanocarpa) Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 40:253–260.
Olsson, M.E., Gustavsson, K.E., Andersson, S., Nilsson, A., Duan, R.D. (2004). Inhibition of cancer cell proliferation in vitro by fruit and berry extracts and correlations with antioxidant levels. Journal of Agricultural & Food Chemistry, 52:7264–7271.
Oszmianski, J., Lachowicz, S. (2016). Effect of the production of dried fruits and juice from chokeberry (Aronia melanocarpa L.) on the content and antioxidative activity of bioactive compounds. Molecules, 21:1098.
Oszmianski, J., Sapis, J. (1988). Anthocyanins in fruits of Aronia melanocarpa (Chokeberry). Journal of Food Science, 53:1241-1242.
Park, S., Choi, I., Seo, K., Kim, J., Galea, V., Shin, H. (2017). Identification and characterization of pseudocercospora pyricola causing leaf spots on Aronia melanocarpa. Mycobiology, 45:39-43.
Park S., Kim, J., Lee, I., Lee, S., Hwang, M., Bae, J., Heo, J., Kim, D., Han, S., Park, M. (2013). Aronia melanocarpa and its components demonstrate antiviral activity against influenza viruses. Biochemical & Biophysical Research Communications, 440:14-19.
Pascal, P., Pirone, P. (1978). Diseases and Pests of Ornamental Plants. The New York Botanical Garden, USA, pp:144-145.
Persson, H.A., Jeppsson, H.N., Bartish, I.V., Nybom, H. (2004). RAPD analysis of diploid and tetraploid populations of Aronia points to different reproductive strategies within the genus. Hereditas, 141:301-312.
Pochynok, Kh.N. (1976). Methods of Biochemical Analysis of Plants. Scientificthought, Kyiv.
Ponder, A., Hallmann, E., Kwolek, M., Srednicka-Tober, D., Kazimierczak, R. (2021). Genetic differentiation in anthocyanin content among berry fruits. Molecular Biology, 43:36-51.
Popkova, K.V., Shmygli, V.A. (1987). Methods for Determining Diseases and Pests of Agricultural Plants. Agropromizdat, Moskow, p:224.
Recommended Levels of Consumption of Food and Biologically Active Substances: Methodical Recommendations. (2004). Federal Center for State Sanitary and Epidemiological Supervision of the Ministry of Health of Russia, Moscow.
Sidor, A., Gramza-Michałowska, A. (2019). Black chokeberry Aronia melanocarpa L. a qualitative composition, phenolic profile and antioxidant potential. Molecules, 24:3710.
Shipunov, A., Gladkova, S., Timoshina, P., Lee, H.J., Choi, J., Despiegelaere, S., Connolly, B. (2019). Mysterious chokeberries: new data on the diversity and phylogeny of Aronia Medik. (Rosaceae). European Journal of Taxonomy, 570:1-14.
Slimestad R., Torskangerpoll K., Nateland H.S., Johannessen T., Giske N.H. (2005). Flavonoids from black chokeberries, Aronia melanocarpa. Journal of Food Composition & Analysis, 18:61-68.
Spinardi A., Cola G., Gardana C., Mignani I. (2019). Variation of anthocyanin content and profile throughout fruit development and ripening of highbush blueberry cultivars grown at two different altitudes. Frontiers in Plant Science, 19:3-5.
Syedov, Ye.N. (1995). Program and methods of selection of fruit, berry and nut crops, Oryol.
Syedov, Ye.N., Ogoltceva, T.P. (1999). Program and Methods of Sorting Fruit, Berry and Nut Crops, Oryol.
Tanaka, T., Tanaka, A. (2001). Chemical components and characteristics of black chokeberry. Nippon Shokuhin Kagaku Kogaku Kaishi, 8:606-610.
Tkachyk, S.O. (2016). Guidelines for the conduct of tests plant varieties forest group for distinctness, uniformity and stability. Nilan-LOD, Vinnytsia.
Tkachyk, S.O. (2016). Guidelines for the conduct of tests plant varieties fruit, berry, nut crops and grapes for distinctness, uniformity and stability. Nilan-LOD, Vinnytsia.
Tkachyk, S.O. (2005). Guidelines for the conduct of tests plant varieties fruit, berry, nut crops and grapes. Nilan-LOD, Vinnytsia.
Treyvas, L., Kashtanova, O. (2016). Diseases and Pests of Fruit Plants. Determinant, Atlas. Moskow.
Tolic, M., Krbavcic, I., Vujevic, P., Milinovic, B., Jurcevic, I., Vahcic, N. (2017). Effects of weather conditions on phenolic content and antioxidant capacity in juice of chokeberries (Aronia melanocarpa L.). Polish Journal of Food & Nutrition Sciences, 67:67-74.
Valcheva-Kuzmanova, S., Belcheva, A. (2005). Current knowledge of Aronia melanocarpa as a medicinal plant. Folia Medica, 48:11-17.
Vinogradova, Y., Shelepova, O., Vergun, O., Grygorieva, O., Kuklina, A., Brindza, J. (2018). Differences between Aronia Medik. taxa on the morphological and biochemical characters. Environmental Research, Engineering & Management, 74:43-52.
Wee, J.I., Park, J.H., Back, C.G., You, Y.H., Chang, T. (2016). First report of leaf spot caused by Alternaria tenuissima on black chokeberry (Aronia melanocarpa) in Korea. Mycobiology, 44:187-190.
Zlatanov, M.D. (1999). Lipid composition of Bulgarian chokeberry, black currant and rose hip seed oil. Journal of the Science of Food & Agriculture, 79:1620–1624.
Yaneva, M.P., Botushanova, A.D., Grigorov, L.A., Kokov, J.L., Todorova, E.P., Krachanova, M.G. (2002). Evaluation of the immunomodulatory activity of Aronia in combination with apple pectin in patients with breast cancer undergoing postoperative radiation therapy. Folia Medica, 44:22-25.

Citation:
Moskalets, V.V., Ovezmyradova, O.B., Sayuk, O.A., Nevmerzhytska, O.M., Marchenko, A.B., Knyazyuk, O.V. (2021). Aronia: promising new forms and varieties in fruit selection and ornamental gardening. Ukrainian Journal of Ecology, 11 (4), 70-80.