Agriculture. Ecology
BULLETIN OF POLTAVA STATE AGRARIAN ACADEMY
ISSN: 2415-3354 (Print)
2415-3362 (Online)
https://journals.pdaa.edu.ua/visnyk

original article | UDC [633.88:582.971.1]:581.522.5(477.5) | **doi: 10.31210/visnyk2021.04.19**

BIOLOGICAL AND ECOLOGICAL PECULIARITIES OF *SAMBUCUS NIGRA* IN THE CONDITIONS OF THE LEFT BANK DNIEPER

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How to Cite

Fedko, R. M., Antonets, M. O., Antonets, O. A., & Viblyi, O. M. (2021). Biological and ecological peculiarities of Sambucus nigra in the conditions of the Left Bank Dnieper. Bulletin of Poltava State Agrarian Academy, (4), 154–161. doi: 10.31210/visnyk2021.04.19

The introduction of rare fruit and berry plants to the culture is associated with the need to improve horticultural products' therapeutic and dietary qualities. Non-traditional fruit plants contain a large number of biologically active substances with antioxidant activity. This is especially true during the COVID-19 pandemic. Among such plants in the medicinal plant growing of Ukraine, the distribution of elderberry is of strategic importance. White and fragrant flowers of elderberry, young shoots, fresh leaves, berries are widely used in phytomedicine. Under natural conditions, this plant is known as a shrub species. Therefore it should be considered as a promising crop in the formation of field-protective forest plantings. The research is aimed at studying the biological and ecological features of elderberry model samples in the natural conditions of the Left Bank of the Dnieper. The research was conducted in 2021 on the territory of the arboretum of the Research Station of Medicinal Plants of the Institute of Agroecology and Environmental Management of the National Academy of Agrarian Sciences of Ukraine. Among the total number of plants, five model samples of 5–6 years of age were selected, which began to generate intensively and grow in different lighting conditions. An important factor for the collection of raw elderberry is its physical availability. Therefore, the assessment of biological and technological yield of inflorescences and fruits was carried out. For this purpose, the crown was conditionally divided into three technological layers. Thus, the effect of lighting was established on morphological features and productivity of model plants 5–6 years of age. The first and second model samples of elderberry in the light 90,000–130,000 lux had the best indicators in plant height, crown projection diameter, and productivity. Studying the dynamics of generative organs' formation within the technical layers during the period of flowering and fruit set, the largest number of formed inflorescences was observed on the second and third technological layers among all model samples. Moreover, the largest number of inflorescences and collective fruit was formed in the first and second model samples. Plants that grow in well-lit areas and have high rates of generative organ formation are offered for analytical selection. This basic material of elderberry can be recommended for seed and vegetative propagation.

Key words: *elderberry, model samples, technological layers, ecological reaction, reproductive organs.*

БІОЛОГІЧНІ ТА ЕКОЛОГІЧНІ ОСОБЛИВОСТІ *SAMBUCUS NIGRA* В УМОВАХ ЛІВОБЕРЕЖНОГО ПРИДНІПРОВ'Я

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Дослідна станція лікарських рослин інституту агроекології і природокористування національної академії аграрних наук україни, с. Березоточа, Україна
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Введення в культуру малопоширених плодово-ягідних рослин пов'язане із необхідністю підвищення лікувально-дієтичних якостей продукції садівництва. Нетрадиційні плодові рослини містять велику кількість біологічно активних речовин з антиоксидантною активністю. Це актуально у часи пандемії COVID-19. Серед таких рослин у лікарському рослинництві України стратегічне значення має розповсюдження бузини чорної. Білі та запашні квіти бузини, молоді пагони, свіже листя, ягоди широко застосовуються у фітомедицині. У природніх умовах ця рослина відома як чагарниковий вид. Тому її варто розглядати як перспективну культуру у формуванні полезахисних лісових насаджень. Метою досліджень є вивчення біологічних та екологічних особливостей модельних зразків бузини чорної у природних умовах Лівобережного Придніпров'я. Дослідження проводилися у 2021 році на території дендропарку Дослідної станції лікарських рослин Інституту агроекології і природокористування Національної академії аграрних наук України. Серед загальної кількості рослин було обрано п'ять модельних зразків 5–6-річного віку, що розпочали інтенсивно генерувати та зростають в різних умовах освітлення. Для збору сировини бузини чорної важливим чинником є її фізична доступність. Тому було проведене оцінювання біологічної та технологічної урожайності суцвіть та плодів. Для цього крона була умовно поділена на три технологічні яруси. Отже, було встановлено вплив освітлення на морфологічні ознаки і продуктивність модельних рослин 5-6 річного віку. Перший і другий модельні зразки бузини при освітленні 90000–130000 лк мали найкращі показники по висоті рослин, діаметру проекції крони і за продуктивністю. Вивчаючи динаміку формування генеративних органів у межах технічних ярусів за період квітування і зав'язування плодів, зазначено найбільшу кількість сформованих суцвіть на другому і третьому технологічних ярусах серед усіх модельних зразків. При цьому найбільша кількість суцвіть і суплідь сформувалася у першого і другого модельних зразків. Для аналітичної селекції пропонуються рослини, що зростають на освітлених місцях і мають високі показники щодо формування генеративних органів. Цей вихідний матеріал бузини чорної можна рекомендувати для насіннєвого та вегетативного розмноження.

Ключові слова: *бузина чорна, модельні зразки, технологічні яруси, екологічна реакція, генеративні органи.*

Introduction

Among dicotyledonous plants, elderberry is known as a plant with a wide range of medicinal properties. In the last chapter of the Bible, you can find a description that also applies to the leaves of elderberry: "And the leaves of the tree [were] for the healing of the nations" [1, Rev. 22: 2]. "Ascorbic acid (up to 280 mg %) and carotene (0.014 %) were found in fresh leaves" [2]. K. Kaack and T. Austed point out that "the content of ascorbic acid and quercetin in the fresh fruits of the cultivars varied from 6 to 25, and from 29 to 60 mg/100 g, respectively" [3].

G. Smyk notes that "the healing properties of elderberry flowers are due to their chemical composition. They contain the glucoside sambunigrin, rutin, essential oil, vitamin C and many organic acids" [4]. L. Nykolaichuk and M. Zhygar claim that "elderberry is an ancient medicine. Flowers are used to treat inflammation of the lungs and bronchi, rheumatism, gout" [5]. V. Korsun and V. Kovalenko write that " decoction of the roots is recommended for diabetes. Young elderberry leaves, boiled in milk, are applied to inflamed areas of skin" [6].

M. Kuznetsova and A. Reznykova noted that "the medical use of elderberry has been known since the time of Pliny. Flowers are an integral part of laxative – Saint-German tea" [7]. In general, elderberry flowers are considered the best diaphoretic and diuretic. Also, in medical practice the elderberry flower extract is used as a means to combat sore throat and flu. Infusion of fruits and bark is recommended for kidney disease, which is accompanied by edemas. In veterinary medicine, this plant is also used for dogs, sheep, pigs and horses. S. Lypnytskyi, A. Pylui and L. Lappo recommend "the infusion of elderberry flowers twice a day for fever" [8].

Australian scientists Torabian Golnoosh, Valtchev Peter, Adil Qayyum, Dehghani Fariba proved that "elderberry extract is effective in the treatment of flu. Their study was aimed to determine the mechanism of effect of elderberry and its primary active compound, cyanidin 3-glucoside against the influenza virus. Elderberry showed a mild inhibitory effect at the early stages of the influenza virus cycle, with a considerably stronger effect in the post-infection phase [9].

Studies by N. Stadnytska, O. Fedoryshyn, A. Mylianych, H. Kosarevych, V. Novikov showed that most drugs are presented in the form of pills (26.4 %); the predominant share of the range (95 %) of the studied drugs are multicomponent drugs; most drugs containing elderberry are produced by pharmaceutical companies in Ukraine, among which the leader (55,56 %) is LLC Research and Production Company "Aim", Kharkiv; most often drugs containing elderberry are anti-inflammatory drugs [10]. The Ukrainian manufacturer PJSC "Liktravy" in Zhytomyr produces only one preparation of elderberry that is one-component.

G. Smyk notes that "the contemptuous attitude to elderberry is not justified by anything and has developed due to little awareness of its useful properties" [4]. Elderberry is mentioned a lot in fiction. For example, the Danish storyteller G. H. Andersen wrote the fairy tale "Elderberry Mother", where he metaphorically showed a beautiful and tender elderberry in the form of a beautiful bush. "The boy looked: the lid of the kettle began to rise higher and higher. Here under it fresh white flowers of elderberry appeared, and then long green branches grew. They were scattered in all directions, even from the spout of the kettle, and soon there was a whole bush in front of the boy. How beautifully the elderberry blossomed and smelled!" [11].

Elderberry Sambucus nigra L. belongs to the family Adoxaceae. The genus *Sambúcus* L. has about 40 species. There are three types in Ukraine. It is a bush, sometimes a small tree 5–6 and up to 7 m tall, crown rounded, dense. It blooms in May-June, the fruits ripen in July-August. Elderberry is propagated in nature by seeds. Vegetatively, when it recovers after felling, hemp and root sprouts grow. M. Atkinson and E. Atkinson note that in the flora of the British Isles it is "a deciduous shrub or more rarely a small tree up to 10 m, often with straight, vigorous erect shoots from the base; branches often arching. The bark is brownish-gray, deeply furrowed, and corky"[12]. S. Klymenko notes that in the department of acclimatization of fruit plants of the Botanical Garden named after M. Hryshko of the National Academy of Sciences of Ukraine "a collection of elderberries *Sambucus nigra* L., *Sambucus racemosa* L. and *Sambucus edulus* L. was formed" [13, p.11].

Red and herbaceous elderberry is also known. B. Holovkin claims that "the Greek name of this bush is bouzia" [14]. It grows wild in deciduous and coniferous forests of the Western Europe, Asia Minor and North America, North Africa. There is a lot of it in the Crimea and the Caucasus. V. Karkhut mentions that it "grows almost all over Ukraine – in the thickets over rivers, in old parks, near country side, houses, in rural cemeteries" [15]. It is known that elderberry is found in the roadside of planted forests and shelterbelts.

The ecological reaction of elderberry is presented by P. Chykov: "Shade-tolerant plant. It grows quickly, especially on moist fertile soils; it tolerates temporary dryness of the air" [2]. Polish scientists Rolbiecki Stanislaw, Rolbiecki Roman, Jagosz Barbara, Ptach Wieslaw, Figas Anna remarked that "in all analyzed regions during the period of 30 years, from 1981 to 2010, there was a tendency to increase the water needs of elderberry during the increased demand for water in the months of June-July" [16]. Elderberry prefers well-drained loam. In conditions of sufficient moistening, it reaches the generative state faster and blooms and bears fruit more abundantly.

Elderberry is an excellent insecticide. Botanist O. Nikolaev found that cockroaches are afraid of both black and red elderberry. Mice and rats also escape from barns around which elderberries grow. But there are 9 species of arthropod phytophagous on black and red elderberry, which damage this plant. Ukrainian scientists believe that "the most numerous and harmful are the fall webworm moth, the elderberry aphid and the two-spotted spider mite" [17]. From 2015–2019 L. Mishchenko, A. Dunich, O. Molodchenkova, L. Hlushchenko "observed 50 % of wild-growing elderberry plants with leaf rolling and mosaics in Poltava region of Ukraine. The number and weight of berry clusters per diseased bush was 4.4-fold and 14.7-fold lower than in healthy plants, and berry sugar concentration also significantly decreased (by 16.5 times)" [18].

N. Sobetska writes that "during the Middle Ages, elderberry flowers were harvested on the day of remembrance of the Apostle Simon Zealot on May 23. Wood and roots were used to make such a sensitive medical instrument as a stethoscope. A musical instrument similar to a harp was made from the branches" [19]. As A. Novikova remarks, "long ago the black-violet fruits of the elderberry contributed to the prolongation of life. In Russia, they were used to obtain paint, added to grape wine to enhance the color and give it a nutmeg flavor" [20]. In the Caucasus, the fruit was used to dye silk in olive color. Elderberry wood

is well polished and used in watchmaking. V. Lykharov notes that "elderberry has a high decorative value. For this purpose, it is planted in parks and health resorts" [21].

As a food product, elderberry has a wide range of uses. For example, young shoots without skin are eaten boiled or pickled. L. Pastushenkov mentions that "elderberries are used to make jam and jelly. Young leaves are used for salads. A fresh drink is prepared by fermentation from fresh flowers with adding lemon juice and water" [22]. Delicious marmalade, jelly, mousse, vinegar is also prepared from the fruit. Berries are used as a seasoning for soups. V. Lykharov notes that "in the South Caucasus and the Crimea, fragrant elderberry inflorescences are added to the dough to give the cookies an almond smell. Housewives make jam from flowers" [21].

The main reserves of raw materials are concentrated in Transcarpathia, Ternopil, Lviv, Volyn, Kyiv, Sumy, Kharkiv, Poltava, Cherkasy and Khmelnytsky regions. In 2020, 7.5 thousand tons of elderberry were exported from Ukraine to Europe. In general, 90 % of elderberry products are exported to Europe. But it has not only nutritional, medicinal and decorative values. Under natural conditions, this plant is known as a shrub species. Scientists of the Research Station of Medicinal Plants recommend the use of elderberry in the formation of field-protective plantings of linear type.

Therefore, the relevance of the topic is to spread the use of elderberry as a non-traditional fruit plant, which has a large number of biologically active substances and is also known for its valuable nutritional properties. Elderberry contains flavonoids and anthocyanins, which can strengthen the body's immune system. Of particular importance is their antioxidant activity. At the time of the COVID-19 pandemic in medicinal plant growing in Ukraine, this plant is of strategic importance. Also, regarding the economic use of elderberry, it should be considered a promising crop in the formation of field-protective zones of the linear type of thinly planted construction.

The *research aims* to study the biological and ecological features of model samples of elderberry in natural conditions of the Left Bank of the Dnieper. To achieve this goal, it is necessary to solve the following tasks: **1**) To establish the effect of lighting on morphological features and productivity of model plants; **2**) To study phenological rhythms during the formation of generative organs; **3**) To find out the peculirities of generative organs formation of the starting material for analytical selection.

Materials and methods of research

The research was conducted in 2021 in natural conditions on the territory of the arboretum of the Research Station of Medicinal Plants (RSMP) of the Institute of Agroecology and Environmental Management of the National Academy of Agrarian Sciences of Ukraine. Among the total number of plants, five model samples of 5–6 years of age were selected, which began to generate intensively and grow in different lighting conditions. Elderberry has such phases of development as the beginning of vegetation, growth of shoots, flowering, fruit ripening, defoliation.

An important factor for the collection of raw elderberry is its physical availability. Therefore, the assessment of biological and technological yield of inflorescences and fruits was carried out. For this purpose, the crown was conditionally divided into three technological layers. The first technological layer is located at a distance of up to 1 m from the ground. The second is from 1 m to 2 m. The third layer is located from 2 m to 3 m.

When conducting field research, the measurement of illumination with LX-1010 BS lux meter was used. Phenological observations were performed according to Y method. Beideman [23]. Analytical selection of model plants was carried out using the biometric method. The method of computer science was also used in the analysis of literature sources.

Research results and their discussion

Observations of the same aged plants growing in different lighting conditions in the arboretum showed significant differences in growth and development. When estimating the height of plants and the diameter of the crown projection of five model plants, it was found that plants that grew in places where the amount of light was 90,000–130,000 lux, entered the generative phase of development faster. Under this lighting, the first model sample had the height of 3.2 m and the crown projection diameter of 3.7 m and the second model sample had the height of 3.8 m and the crown projection diameter of 3.4 m compared to the fifth model sample having the height of 1, 8 m and the crown projection diameter of 2.1 m (table 1). This indicated that one of the limiting factors for elderberry was the illumination of the habitat. In Poltava region, "such ecological reaction of elderberry to light should be used to create thinly planted shelterbelts" [24].

1. The influence of lighting on the morphological features of elderberry model plants

Model samples	Lighting (range), lux	Height, m	Crown projection diameter, m
1	90,000-130,000	3.2	3.7
2	90,000-130,000	3.8	3.4
3	50,000-90,000	2.4	2.7
4	50.000-90,000	2.6	2.5
5	40,000-50,000	1.8	2.1

In 2021, on the territory of the RSMP arboretum, the flowering of elderberry began in the first decade of June, and the mass flowering began on June 13–16. According to Table 2, the largest number of formed inflorescences was observed on the second and third technological layers among all model samples. The first and second model samples formed the largest number of inflorescences. The fifth model formed the fewest number of inflorescences. This plant grows in the shade. During the mass flowering, the process of fruit-set took place in the second and third decade of June. Table 2. shows that the maximum number of fruit clusters was formed in the second model sample and amounted to 289 pieces in the third decade of June. The first model also formed a lot of fruit clusters – 183, while the fifth had only 10 in the shade in the third decade of June. The first and second model samples were the best in reproductive organs' formation due to a good ecological response to light.

2. The dynamics of reproductive organs' formation in elderberry model plants

Model samples	The number of formed inflorescences / fruit clusters on technological layers, pcs.											
	07.06			10.06			15.06			24.06		
	I-th	II	III	I-th	II	III	I-th	II	III	I-th	II	III
1	3	19	9	9	36	23	15	124	22	5	21	6
							9	33	34	17	112	54
2	9	38	23	24	84	42	19	83	21	5	12	7
							28	74	48	38	183	68
3	3	7	-	6	16	-	3	26	-	2	7	-
							5	12		8	29	-
4	3	8	-	7	18	-	4	33	-	2	5	-
							5	13	-	11	42	-
5	1	2	-	3	4	-	1	2	-	-	1	-
							3	5	-	4	6	-

To study the effect of lighting on the productivity of elderberry inflorescences, the number of flowers in the inflorescences of model samples on three technological layers was counted (Table 3). The largest number of flowers was on the second and third technological layers of the first and second model samples. In the third, fourth and fifth model samples, the largest number of flowers was on the second layer (420, 658 and 394, respectively). The maximum number of flowers in the inflorescence among all plants was formed on the third layer of the first sample (785 pcs). The minimum number of flowers in the inflorescence, 259 pcs., had the fifth model on the first layer.

Table 3 shows that the weight of fresh panicles ranged from 4.27 g in the third model sample to 11.28 g in the first model sample. To determine the weight of technical raw materials of elderberry, the flowers were separated from the main axis of the inflorescence and branches of the first order. The maximum weight of flowers with peduncles after separating the from main axis had the first model sample on the third technological layer – 7.59 g, and the fourth model sample on the second technological layer had the minimum weight of 2.21 g. The weight of one flower was 0.009 g. When collecting raw elderberry (flowers, fruits) the main axis of the inflorescence (collective fruits) is not a medicinal raw material, and its size and weight depend on the number of flowers in the panicle. The fresh peduncle of the fourth model sample on the second technological layer had the greatest weight of 6.44 g.

3. The effect of lighting on the performance of elderberry inflorescences

Model samples	Technical layers, m	Number of flowers in the inflorescence, pcs	Panicle			Flowers with peduncles 2-3 order				Pedicel panicle		
			general weight, g		yield of dry raw materials,%	total weight, g		yield of dry raw materials,%	share in the inflorescence,%	weight, g		share in the inflorescence,%
			fresh	dry		fresh	dry			fresh	dry	
1	I	314	4.73	0.33	7.3	2.24	0.15	6.8	48.9	2.49	0.18	51.2
	II	582	8.19	1.28	16.4	6.15	0.90	15.7	71.6	2.05	0.38	28.6
	III	785	11.28	1.53	14.2	7.59	1.02	14.1	48.8	3.70	0.51	33.6
2	I	576	6.92	1.84	26.6	5.75	1.53	26.6	83.1	1.17	0.31	16.9
	II	631	7.74	1.29	16.6	5.08	0.88	17.2	65.4	2.66	0.42	34.7
	III	589	7.84	1.42	18.6	5.68	0.99	17.7	70.3	2.16	0.44	29.7
3	I	248	4.63	0.85	18.4	2.59	0.45	17.3	55.9	2.04	0.40	44.1
	II	420	4.27	0.95	16.6	3.09	0.69	19.8	70.5	1.19	0.26	29.5
4	I	380	4.68	0.79	16.8	3.16	0.53	16.9	68.0	1.53	0.26	38.0
	II	658	8.65	1.06	12.3	2.21	0.27	12.2	25.5	6.44	0.79	74.5
5	I	259	4.37	0.77	17.6	2.82	0.50	17.7	64.1	1.57	0.27	35.9
	II	394	5.14	0.68	13.2	4.07	0.52	12.8	79.2	1.07	0.16	20.8

The fruits of elderberry ripen in early September. To determine the yield, the number of fruits within the technical layers, their weight and size were calculated (Table 4). The maximum number of ripe fruits was 218 pieces, observed in the first model sample on the third technological layer and 170 pieces in the second model sample on the third technological layer. Plants growing in lighted places had these indicators. The fifth model specimen growing in the shade had the smallest number of ripe fruits – 24 pieces on the first technological layer.

4. Productivity of elderberry model plants in natural conditions

Model samples	Technical layers	The average number of fruits in collective fruit, pcs.	The weight of fruits in collective fruit, g		The yield of dry raw material,%	The weight of the main axis of collective fruit and branches, g		The average fruit size, cm
			fresh	dry		fresh	dry	
1	I	102	9.0	1.87	20.8	3.30	0.36	0.52
	II	156	14.72	3.18	21.6	3.29	0.35	0.51
	III	218	39.22	7.54	19.2	7.17	0.77	0.53
2	I	61	6.79	1.90	28.2	2.97	0.29	0.48
	II	161	18.43	4.22	22.9	4.46	0.55	0.56
	III	170	17.94	3.82	21.3	4.33	0.57	0.54
3	I	60	6.74	1.95	28.9	3.95	0.39	0.48
	II	74	5.34	1.31	24.5	1.73	0.39	0.54
4	I	58	5.65	1.87	33.1	2.99	0.23	0.50
	II	143	8.73	2.74	31.4	4.76	0.42	0.50
5	I	24	5.91	1.42	21	2.26	0.22	0.53
	II	38	12.89	2.59	20.1	3.71	0.37	0.48

According to Table 4, the weight of the fruit depended on the number of fruits and ranged from 5.34 g in the third model sample to 39.22 g in the first model sample. The yield of dry raw berries averaged 24.4 %.

The size of the fruits depended on their number in the fruit cluster, lighting and location on the bush. The largest fruit, 0.56 cm in size, had a second model on the second technological layer. The average weight of one fruit was 0.135 g.

When harvesting elderberry, the net weight of the fruit without the main axis of fruit and branches should be taken into account. The weight of the main axis of the fruit with branches ranged from 1.73 g in the third model sample to 7.17 g in the first model sample.

Conclusions

Thus, taking into account the biological and ecological features of elderberry in natural conditions, the effect of lighting on morphological features and productivity of model plants 5–6 years of age was established. The first and second model samples of elderberry in the light 90,000-130,000 lux had the best indicators of plant height and crown projection diameter. These model plants also had the highest rates in terms of productivity. Studying the dynamics of reproductive organs' formation within the technical layers for the period of flowering and fruit-set, the largest number of formed inflorescences on the second and third technological layers among all model samples was registered. The largest number of inflorescences and fruit clusters was formed in the first and second model specimens growing in lighted areas.For analytical selection, it is proposed to use the first and second model samples that grow in well-lit areas and have high rates of generative organs' formation. This basic material of elderberry can be recommended for seed and vegetative propagation.

Prospects for further research. In the conditions of the Left Bank of the Dnieper, elderberry is proposed to be spread as a valuable medicinal, food and ornamental plant. It should also be considered as a promising crop in the formation of field-protective forest afforestation. Thus the correct combination of tree species will ensure the formation of biologically stable mixed forest afforestation.

The results will be used to implement the recommendations of the Food and Agriculture Organization of the United Nations on the use of elderberry as a shrub species in shelterbelts. The use of elderberry is ecologically justified in the formation of thinly planted shelterbelts, as lighting is an important factor in the formation of the main morphological features of this plant.

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Стаття надійшла до редакції: 22.10.2021 р.

Бібліографічний опис для цитування:

Федько Р. М., Антонець М. О., Антонець О. А., Віблий О. М. Біологічні та екологічні особливості *Sambucus nigra* в умовах Лівобережного Придніпров'я. *Вісник ПДАА.* 2021. № 4. С. 154–161.