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## DYNAMICS OF ACCUMULATION OF FLAVONOIDS IN DIFFERENT ORGANS OF *Sambucus nigra* AND *S. ebulus*

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## ДИНАМИКА НАКОПЛЕНИЯ ФЛАВОНОИДОВ В РАЗЛИЧНЫХ ОРГАНАХ *Sambucus nigra* И *S. ebulus*

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**Abstract.** The article is devoted to the phytochemical study of flavonoids in various organs of species of the *Sambucus* L. genus. The results of studying the dynamics of accumulation of the amount of flavonoids in the composition of *S. nigra* and *S. ebulus* species depending on the phases of plant development in various organs showed that during the vegetation period the amount of flavonoids undergoes a sharp change. It was established that in the generative organs of the studied species *S. nigra* and *S. ebulus*, the maximum amount of flavonoids accumulates in flowers (7.34%, 5.58%, respectively), the minimum amount in green fruits (1.91%, 2.83%). In the vegetative organs, the maximum amount accumulates in the leaves (4.94, 4.91%), and the minimum amount in roots (0.95%, 0.67%) and stems (1.46, 1.32%). The results obtained are of practical importance, since they indicate the possibility of using various plant organs as a source of raw materials for the production of flavonoids.

**Аннотация.** Статья посвящена фитохимическому изучению флавоноидов в различных органах видов рода *Sambucus* L. Результаты изучения динамики накопления количества флавоноидов в составе видов *S. nigra* и *S. ebulus* в зависимости от фаз развития растения в различных органах показали, что во время вегетации количество флавоноидов подвергается резкому изменению. Установлено, что в генеративных органах исследованных видов *S. nigra* и *S. ebulus* максимальное количество флавоноидов накапливается в цветках (7,34%, 5,58%, соответственно), а минимальное количество в зеленых плодах (1,91%, 2,83%). В вегетативных органах максимальное количество накапливается в листьях (4,94, 4,91%), а минимальное количество в корнях (0,95%, 0,67%) и в стеблях (1,46, 1,32%). Полученные результаты имеют практическое значение так как указывают на возможность использования различных органов растения как источник сырья для получения флавоноидов.

**Keywords:** flavonoids, generative and vegetative organs.

**Ключевые слова:** флавоноиды, генеративные и вегетативные органы.

### Introduction

The biological activity of flavonoids in a wide range puts the focus on the search and deeper study of plants rich in flavonoids. There is extensive literature information on the antiradiant, antispasmodic, antioxidant, antimutagenic, and other properties of flavonoids [1]. The main biological properties of flavonoids and other polyphenols of plant origin are to improve the

conductivity of capillaries and increase their elasticity. In recent years, most of the research has been aimed at studying the antioxidant properties of flavonoids, preventing the negative effects of free radicals, which are stress factors that give pathological complications in the human body. Plants containing flavonoids are considered a valuable source of raw materials for the production of capillary-strengthening, anticarcinogenic drugs [2, 3].

Species of the genus *Sambucus* have a rich flavonoid composition. Various species of the genus, in particular *Sambucus nigra*, are included in the pharmacopeia of many countries and are used as raw materials for the production of various medicines. The main reason for this is that the composition of the plant is dominated by biologically active substances, especially flavonoids [4, 5].

One of the important issues of scientific and practical importance when using any plant as a source of raw materials is the establishment of patterns of maximum accumulation of substances in various organs and the phase of plant development. Considering the use of *S. nigra* and *S. ebulus* species as a source of raw materials, the main goal of this study was to determine the pattern of accumulation of flavonoids depending on the phase of plant development, their distribution in various organs, and to identify the optimal time for accumulation of flavonoids.

#### Material and methods

The plant material was collected in the north-eastern part of the village of Urva, Gusar district and in the village of Tengealti, Quba district, during the period of early flowering, the mass flowering and the phase of fruit ripening.

Each vegetative (root, leaves) and generative (flowers, fruits) organ of the plant was collected separately. The analyzes were carried out on material collected from one population. The wet and dry weight of the yield of the aerial part (per 100 m<sup>2</sup>) was determined. Dry plant material was crushed to a size of 1 mm for analysis. The dry matter content was set on the MX-50 Moisture Analyzer. The amount of total flavonoids in various organs was determined by the spectrometric method [6]. The total amount of flavonoids is calculated by the following formula:

$$x = \frac{D * 100 * 100 * 25}{330 * m * (100 - w)}$$

Where, D — the optical density of the material; 330 — indicator of rutin with AlCl<sub>3</sub> at 410 nm absorption; m — the weight of the material (g); w — the weight lost after drying (%).

Each analysis was carried out 3 times, the average figure was determined.

#### Results and discussion

The study of the dynamics of accumulation of the amount of flavonoids in the composition of *Sambucus nigra* and *Sambucus ebulus* species depending on the phases of plant development in various organs showed that during the growing season the amount of flavonoids undergoes a sharp change (Table 1).

It has been established that in the generative organs of the studied species *S. nigra* and *S. ebulus*, the maximum amount of flavonoids accumulates in flowers (7.34%; 5.58%, respectively), the minimum amount — in green fruits (1.91%, 2.83%). In vegetative organs, the maximum amount accumulates in the leaves (4.94%, 4.91%), the minimum amount in roots (0.95%, 0.67%) and stems (1.46%, 1.32%). Depending on the phase of development of both species, the amount of flavonoids in the leaves underwent a sharp change. The maximum amount of flavonoids in the flowers and leaves of *S. nigra* species accumulates at the beginning of the flowering phase (7.57%, 4.94%), and in *S. ebulus* — in the mass flowering phase (4.91%, 5.49%, respectively). The minimum amount of flavonoids in both species accumulates in the leaves (3.03%, 3.06%) in the phase of fruit ripening.

Table 1

DYNAMICS OF ACCUMULATION OF FLAVONOIDS IN VARIOUS ORGANS  
 OF *S. nigra* AND *S. ebulus*, BY DEVELOPMENTAL PHASES (% of dry weight)

The plant organs	Years	Development phases				
		Early growing period	Budding	Early flowering period	The mass flowering	Fruit ripening
<i>Sambucus nigra</i>						
Stem	2017	1.25	1.09	1.06	0.81	0.71
	2018	1.73	1.43	1.37	1.04	0.82
	2019	1.41	1.26	1.23	0.93	0.75
	Average	1.46	1.26	1.22	0.92	0.76
Leaf	2017	2.85	4.16	4.25	3.85	2.98
	2018	3.87	5.52	5.63	5.03	3.35
	2019	3.34	4.67	4.96	4.48	2.87
	Average	3.35	4.78	4.94	4.45	3.06
Generative organs	2017	—	6.56	6.08	6.58	1.72
	2018	—	8.60	8.34	8.43	2.83
	2019	—	7.56	7.61	7.49	2.96
	Average	—	7.57	7.34	6.48	2.50
Aboveground part	2017	2.07	2.60	4.08	4.06	1.92
	2018	2.95	3.63	4.97	4.75	2.65
	2019	2.60	4.09	4.57	4.38	2.64
	Average	2.54	3.44	4.54	3.39	2.40
Root	2017	0.59	0.85	0.76	0.75	0.40
	2018	0.78	1.05	0.98	0.98	0.53
	2019	0.63	0.95	0.83	0.78	0.48
	Average	0.66	0.95	0.85	0.83	0.47
<i>Sambucus ebulus</i>						
Stem	2017	0.80	1.08	1.09	0.98	0.76
	2018	1.04	1.54	1.64	1.54	0.93
	2019	0.95	1.36	1.52	1.04	0.83
	Average	0.93	1.32	1.41	1.18	0.84
Leaf	2017	3.23	3.91	4.02	4.35	2.65
	2018	4.01	4.88	4.89	5.28	3.51
	2019	4.39	4.03	4.34	5.12	2.93
	Average	3.87	4.27	4.41	4.91	3.03
Generative organs	2017	—	4.27	4.85	5.18	2.76
	2018	—	5.58	6.47	5.98	3.48
	2019	—	4.67	5.43	5.32	2.85
	Average	—	4.84	5.58	5.49	3.03
Aboveground part	2017	2.03	3.35	4.07	4.16	2,28
	2018	2.84	4.06	4.78	4.58	3,03
	2019	2.67	4.38	4.03	3.89	2.68
	Average	2.51	3.93	4.29	4.22	2.66
Root	2017	0.34	0.46	0.58	0.37	0.47
	2018	0.46	0.55	0.79	0.49	0.56
	2019	0.39	0.47	0.65	0.41	0.38
	Average	0.39	0.49	0.67	0.42	0.47

Note: Deviation  $\pm 0.1 \div 0.2$



Compared to other vegetative organs, flavonoids accumulate little in the roots. The maximum amount of flavonoids in the roots of *S. nigra* (0.95%) accumulates during budding and in the roots of *S. ebulus* in the primary phase of flowering (0.67%).

It has been established that the minimum amount of flavonoids in the aerial part of the studied species accumulates in the stems. The maximum amount of flavonoids in the stems of *S. nigra* accumulates in the primary phase of vegetation — 1.46%, in the stems of *S. ebulus* in the budding phase — 1.32%. The minimum amount of flavonoids accumulates in the stems of *S. nigra* during fruiting (0.76%), in the stems of *S. ebulus* in the primary phase of vegetation — 0.93%. The content of flavonoids in the aerial part of the studied species varies from 4.29% to 4.54%. In the aerial part of the species *S. nigra*, the maximum amount of flavonoids coincides with the phase of mass flowering (4.54%), *S. ebulus* — with the beginning of the flowering phase (4.29%). On plants used for raw material purposes, it is of practical importance to establish the patterns of maximum accumulation of active substances, their productivity in various organs and phases of plant development. Of the species studied, *Sambucus nigra* is the official medicinal plant. The study of the amount of flavonoid in the terrestrial part of the *Sambucus ebulus* species showed that this plant also contains flavonoids in an amount that meets the requirements of the pharmacopeia and can be used as a source of raw materials.

The main goal for using species of the genus *Sambucus* L. as a source of raw materials is to determine the pattern of accumulation of flavonoids depending on the phase of development of their distribution in various organs, flavonoid yield, and the optimal time for collecting plant materials.

The obtained results showed that it is advisable to collect *Sambucus nigra* and *Sambucus nigra* plants in the phase of mass flowering for use as raw materials. However, in order to produce the latter flavonoid product in large quantities, it is necessary to determine the optimal time for harvesting the plant. To do this, we determined the density of plants and the yield of flavonoids per 1 m<sup>2</sup> (Table 2).

Table 2

DYNAMICS OF PLANT GROWTH BY DEVELOPMENT PHASES OF SPECIES OF THE GENUS *Sambucus* L. ON ONE PLANT (% of dry weight)

Indicators	Early growing period	Budding	Early flowering period	The mass flowering	Fruit ripening
<i>Sambucus nigra</i>					
Wet weight	5.70	21.60	27.36	49.40	43.60
Dry weight	0.62	2.46	3.36	9.24	10.24
<i>Sambucus ebulus</i>					
Wet weight	4.46	26.64	36.20	52.60	45.20
Dry weight	0.50	2.98	5.18	10.78	9.84

According to the data of Tables 1 and 2, the yield of flavonoids per 100 m<sup>2</sup> and 1 hectare was calculated, the results are shown in tables 3 and 4. The table shows that from the dry aerial parts of both species, the maximum amount of flavonoids can be obtained in the phase of mass flowering (480 g/100 m<sup>2</sup> and 335.9 g/100 m<sup>2</sup>).

Table 3

YIELD OF FLAVONOIDS PER 100 m<sup>2</sup> AT DIFFERENT DEVELOPMENT PHASES OF *Sambucus ebulus* (average data for 2017–2019)

Development phase	Dry weight per 100 m <sup>2</sup> (g)	Quantity of flavonoids, g/100 m <sup>2</sup>	The amount of flavonoids, per 1 ha (kg)
Early growing period	930.0	23.62	2.36
Budding	3649.0	111.7	11.2

<i>Development phase</i>	<i>Dry weight per 100 m<sup>2</sup> (g)</i>	<i>Quantity of flavonoids, g/100 m<sup>2</sup></i>	<i>The amount of flavonoids, per 1 ha (kg)</i>
Early flowering period	5040.0	192.02	19.2
The mass flowering	33740.0	480.12	48.0
Fruit ripening	13860.0	300.6	30.0

Table 4

YIELD OF FLAVONOIDS PER 100 m<sup>2</sup> AT DIFFERENT STAGES OF DEVELOPMENT  
 OF *Sambucus nigra* (average data for 2017–2019)

<i>Development phase</i>	<i>Dry weight per 100 m<sup>2</sup> (g)</i>	<i>Quantity of flavonoids, g/100 m<sup>2</sup></i>	<i>The amount of flavonoids, per 1 ha (kg)</i>
Early growing period	13478.0	17.68	1.76
Budding	4768.0	162.58	16.26
Early flowering period	8288.0	338.0	33.8
The mass flowering	17408.0	671.8	67.18
Fruit ripening	16288.0	554.4	55.4

The aerial part of both studied plants in the flowering phase shows the mass productivity and the amount of flavonoids obtained on an area of 100 m<sup>2</sup>, which is of practical importance and can be used as a source of raw materials for the production of flavonoids.

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