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# Some biochemical parameters of *Scutellaria baicalensis* Georgi herb at introduction into the Non-Chernozem belt of Russia

**ABSTRACT**

**Relevance.** ***Scutellaria baicalensis*** **Georgi is a valuable medicinal plant, its raw material is roots. It is a protected species of the East Asian flora of the Russian Federation. The plant is included in 6 Red Data Books of the Far East and Eastern Siberia. Works on introduction of *Scutellaria baicalensis* carried out in many regions of the Russian Federation. At present, multifaceted biochemical studies of the flowering shoot mass of Baikal skullcap are being carried out everywhere.**

**The aim of the investigation is study of some biochemical parameters of flowering shoot mass of Baikal skullcap by structure in different weather conditions in different years.**

**Materials and methods. The object of the study was the population of Baikal skullcap from the biocollections of All-Russian Scientific Research Institute of Medicinal and Aromatic Plants (Central Region of the Non-Chernozem belt). Studies were conducted in 2018 (optimal weather conditions) and 2020 (stresses weather conditions). The biochemical composition of the shoot of *Scutellaria baicalensis* studied in the Laboratory and Analytical Department of the FSBSI "Federal Scientific Vegetable Center" according to the following parameters: dry matter, ascorbic acid, total content of water-soluble antioxidants and total antioxidants in the alcoholic extract. The accumulation of these substances done in leaves located on the upper, middle and lower levels of leaves, inflorescences and buds, stems.**

**Results. Dry matter content of *Scutellaria baicalensis* herb components did not differ significantly by years. The maximum meaning of this indicator was in stems – 38.89-39.51 %, and the minimum – in inflorescences – 21.07 %, regardless of the level of location on the shoot. The total content of water-soluble antioxidants in the shoot mass under optimal precipitation was statistically significantly higher than this factor under dry weather conditions by 1.5-2.7 times. In inflorescences and buds the content of water-soluble antioxidants was lower than on average in leaves by 2.6-3.6 times. Ascorbic acid accumulation in leaves of *S. baicalensis* in a weather-optimal year (2018) exceeded its content in a year (2020) with numerous extremely changes in precipitation and air temperature during the growing season by 1.5 times. The total antioxidant content in the alcoholic extract in the shoot mass in the year with significant fluctuations in weather conditions (2020) was significantly higher than that in the year with stable weather conditions (2018). In both years of the study, the maximum value the total content of antioxidants observed in the leaves. In a weather-optimal year, these were the leaves of the lower level (77.52 mg-eq GA/g d.w.), and in a year with extremely fluctuations in weather parameters (2020), these were upper level (83.05 mg-eq GA/g d.w.).**

**KEYWORDS:**
**Baikal skullcap, flowering shoot, desiccation coefficient, dry matter, ascorbic acid, water-soluble antioxidants, total antioxidants content in alcohol extract**

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# Некоторые биохимические показатели травы шлемника байкальского (*Scutellaria baicalensis* Georgi) при интродукции в Нечерноземную зону РФ

**АКТУАЛЬНОСТЬ.**
**Шлемник байкальский *Scutellaria baicalensis* Georgi – ценное лекарственное растение, сырьём его являются корни. Это охраняемый вид восточно-азиатской флоры РФ. Растение включено в 6 Красных книг регионов Дальнего Востока и Восточной Сибири. Работы по интродукции *Scutellaria baicalensis* ведутся во многих регионах РФ. В настоящее время повсеместно проводятся многоплановые биохимические исследования цветущей надземной части шлемника байкальского.**

**Цель исследования – изучение некоторых биохимических показателей цветущей надземной массы шлемника байкальского по структуре в разные по погодным условиям годы.**

**Материалы и методы. Объект исследования – популяция шлемника байкальского биоколлекции ФГБНУ ВИЛАР (Центральный район Нечерноземной зоны РФ). Исследования проводили в 2018 г. (оптимальные погодные условия) и 2020 г. (неблагоприятные погодные условия). Анализ биохимического состава проведен по показателям: коэффициент усушки, содержание сухого вещества, аскорбиновой кислоты, суммарное содержание водорастворимых антиоксидантов и антиоксидантов в спиртовом экстракте. Изучали накопление этих веществ в листьях, расположенных на верхнем, среднем и нижнем ярусе побега, соцветиях и бутонах, стеблях.**

**Результаты. Содержание сухого вещества в компонентах травы *Scutellaria baicalensis* существенно по годам не различалось. Максимальное значение этого показателя было в стеблях – 38,89-39,51 %, а наименьшее – в соцветиях 21,07-23,75 %. Суммарное содержание водорастворимых антиоксидантов в надземной массе при оптимальном количестве осадков статистически достоверно превышало этот показатель при засушливых погодных условиях в 1,5-2,7 раза. В соцветиях и бутонах содержание водорастворимых антиоксидантов было ниже, чем в среднем в листьях в 2,6 – 3,6 раза. Накопление аскорбиновой кислоты в листьях *S. baicalensis* в оптимальный по погодным условиям год (2018 год) превышало её содержание в год с многочисленными резкими перепадами осадков и температуры воздуха в течение вегетационного сезона (2020 год) в 1,5 раза. Суммарное содержание антиоксидантов в спиртовом экстракте в надземной массе в год со значительными колебаниями погодных условий достоверно превышало этот показатель в год со стабильными погодными условиями. По обоим годам исследования его максимальное значение отмечено в листьях. В оптимальный по погодным условиям год это были листья нижнего яруса (77,52 мг-экв ГК/г сух. масс), а в год с резкими колебаниями погодных параметров – верхнего (83,05 мг-экв ГК/г сух. масс.).**

**КЛЮЧЕВЫЕ СЛОВА:**
**шлемник байкальский, цветущая надземная часть, сухое вещество, коэффициент усушки, аскорбиновая кислота, водорастворимые антиоксиданты, антиоксиданты в спиртовом экстракте.**

## Introduction

*Scutellaria baicalensis* Georgi is a plant of the family Lamiaceae Martinov (Labiatae Juss.) [1]. *Scutellaria baicalensis* first described in 1775 [2]. Medicinal properties of extracts from its roots noted in the canons of Chinese and Tibetan medicine [3]. Due to its antioxidant, antiviral, antibacterial, anti-inflammatory, anti-allergic properties, the Baikal skullcap (*Scutellaria baicalensis*) is a subject of intensive study. It is included in the Pharmacopoeia of China [4]. It was shown that preparations from root and shoot parts of Baikal skullcap have a pronounced antiradical activity, lipid peroxidation is inhibited [5].

The history of the study of flavonoids of *Scutellaria baicalensis* began in 1923, when Shibata et al. isolated and characterised baicalin from its roots [6]. In the study conducted by Malikov, Yuldashev [7], more than 200 compounds of phenolic nature were isolated and identified from plants of the genus *Scutellaria.* Of these, 125 compounds of this class founded in *Scutellaria baicalensis* [8]. Flavonoids and their glycosides thought to be distinctive elements of *Scutellaria baicalensis* roots, among the more than 40 compounds that have been identified so far [9; 10]. Korean scientists have isolated 4 different compositions of polyphenols from flowers, leaves, stems and roots of *S. baicalensis*. 46 components were characterized, 7 of which were identified for the first time. This group of researchers showed that the antioxidant activity of polyphenolic compounds from roots was the highest, followed by polyphenols from leaves, flowers and stems [11].

Currently, researchers are studying the biochemical parameters of the shoot and root parts of *S. baicalensis* in a multifaceted way not only in the conditions of their natural growth (Eastern Transbaikalia and Priamurye) [8, 12]. This medicinal plant is widely distributed in China, Russia, Mongolia, North Korea and Japan [13]. Thus, the ecological plasticity of the species can assumed [14]. This study [15] presents a comprehensive review of literature data obtained on the roots of *S. baicalensis*. Recently, the interest of researchers directed to the study of the shoot part of the plant [8; 12].

Antioxidants are compounds that prevent undesirable oxidation processes of vital compounds and form a complex multicomponent system of high and low molecular weight compounds [16; 17]. Nonenzymatic components of antioxidant defence include polyphenols, carotenoids, tocopherols, ascorbate glutathione [18]. Antioxidants can act by destroying the radical reaction chain, trapping free radicals that initiate radical reactions [19]. Antioxidant flavonoids founded in the chloroplast, which suggests a role as scavengers of singlet oxygen and stabilizers of the chloroplast outer envelope membrane. Antioxidant flavonoids may effectively control key steps of cell growth and differentiation, thus acting regulating the development of the whole plant and individual organs [20]. The content of organic acids (caffeic acid, ferulic acid, etc.), in the shoot part of *S. baicalensis* was studied [8].

However, we found no data on ascorbic acid (AA) content in *S. baicalensis* herb in the available literature. Ascorbic acid is an abundant component of plants. It reaches a concentration of over 20 mM in chloroplasts and occurs in all cell compartments, including the cell wall. It has proposed functions in photosynthesis as an enzyme cofactor (including synthesis of ethylene, gibberellins and anthocyanins) and in control of cell growth [21].

Ascorbic acid (AA) is not only an important antioxidant but also appears to link flowering time, senescence, programmed cell death and response to pathogens through a complex signal transduction network [22]. The biosynthesis and metabolism of this compound studied in suspension culture of *S. baicalensis* [23]. It recommended intake of AA for adults is 70-80 mg/day. The proportion of the Russian population with AA deficiency is 70-98% [24].

Dry matter determination carried out for many crops (fodder, fruit, etc.) [25]. The influence of the content of dry matter on the processes of growth, development and yield of large-tonnage crops (soybean, maize) has been shown [26; 27].

*S. baicalensis* herb is the medicinal raw material of Baikal skullcap, according to FS 42-453-92. However, it is necessary to take into account the fact that this plant is included in 6 regional Red Data Books of the Russian Federation. All of them note its value as a source of medicinal plant raw materials [28]. When harvesting aerial part, the entire plant destroyed, so industrial harvesting of raw materials is problematic in the regions where it grows. Currently, researchers are actively analyzing other possibilities of obtaining biologically active substances of Baikal skullcap. One of the possibilities is to obtain suspension culture [29]. Another option is to use the flowering shoot mass of Baikal skullcap plants, both together with the roots and instead of the shoot part [30, 31].

The aim of our research was to study the content of some biologically active substances in *S. baicalensis* herb grown in the Central region of the Non-Chernozem belt of Russia. Objectives of the study: to determine the desiccation coefficient, the content of dry matter, AA, water-soluble antioxidants and antioxidants in the alcoholic extract in *S. baicalensis* herb and its constituents.

## Material and Methods

The research carried out using bio-objects of the Unique Scientific Unit “Biocollection of FSBSI of All-Russian Scientific Research Institute of Medicinal and Aromatic Plants”. The material for the study was the shoot of *S. baicalensis*, located in the biocollection of the botanical garden: Moscow: 55.57°N, 37.55°E. Planting material obtained from Chita region in 2008. Plants located on the territory with illumination of 80–88 thousand lx. Row spacing width was 0.3 m. (Fig. 1).

The experiments carried out in 2017-2020, of which the chemical composition of the raw material analyzed in 2018 and 2020 – years with contrasting weather conditions. We analyzed the weather conditions of the growing season by parameters: precipitation and the sum of active temperatures (SAT) above +5 ºC.

The growing season of 2020 was characterised by an

***Рис. 1. Общий вид растений шлемника байкальского (S. baicalensis Georgi). Фотографию предоставил заведующий ботаническим садом ФГБНУ ВИЛАР А.Н. Цицилин***
***Fig. 1. General view of plants of Baikal skullcap (S. baicalensis Georgi). Photo provided by A.N. Tsitsilin, Head of the Botanical Garden, FSBSI VILAR***

extreme phenomenon: from the middle to the end of February, the average daily air temperature was positive. At the same time, negative temperatures observed in all ten-day periods of March and April. Precipitation and SAT fluctuated dramatically during the 2020 growing season. In general, the parameters of air temperature and precipitation in 2020 can be characterised as extremely uneven [32]. While in 2018 (as well as in 2017 and 2019) the beginning of vegetation of the plant was observed at the end of May, in 2020 in the beginning of May. In general, weather conditions in 2018 can characterized as typical for the region, while 2020 had differences in duration of phenological phases [33]. The values of mean temperature and relative humidity during the vegetation period presented in Table 1 and duration of phenological intervals, precipitation, SAT presented in Table 2.

The soil of the site is heavy loamy with content (on absolute dry matter): humus 4.31%, hydrolytic acidity 1.08 mg-eq. /100 g, total nitrogen 0.068–0.072 %, $P_2O_5$ – 0.1%, $K_2O$ – 2.9-3.5%, $Al_2O_3$ – 15.0 %, $Na_2O$ – 1.4%, exchangeable MgO – 100.0 mg/kg, exchangeable Ca – 25.9 g/kg, $pHK_{кα}$ 5.5.

The shoot cut at the phenological phase of mass flowering. The study of the shoot of *S. baicalensis* plants from 5 natural cenopopulations showed that the highest content of biologically active substances in the shoot of plants was observed in the flowering phase [12]. The phase of mass flowering was determined according to the “Methods of research in the introduction of medicinal and essential oil plants” [34]. The leaves of the upper level obtained from 3-4 metamers and above, the middle level between 7-8 and 3-4 metamers, the lower – from 7-8 metamers and lower. The repetition was 20-fold.

The effects of the growing phase differed between years, and influenced by climatic conditions [35]. The species is adapted to conditions of unstable, even arid water regime. *S. baicalensis* occupies open forest-steppe and steppe areas and closely related to nitelistnik steppes; by ecology, it belongs to the group of cryomesoxerophytes [33].

Some biochemical parameters of *S. baicalensis* shoot studied in the Laboratory and Analytical Department of FSBSI “Federal Scientific Vegetable Center”. The shoot by structure (leaves of upper, middle and lower shoot levels, stems, inflorescences) for AA content and total content of water-soluble antioxidants by visual titration method analyzed in fresh form on the day of harvesting. The total content of water-soluble antioxidants was determined according to the method [36]. The standard was AA. The content of AA was determined according to the method of Sapozhnikova and Dorofeeva [37]. Dry matter content determined by gravimetric method. Samples dried in a LabTech desiccator (DaihanLabTechCo, LTD) at 70 °C to constant weight. The change in the mass of plant material was determined by weighing on analytical scales [38].

The content of the sum of antioxidants in the alcoholic extract determined by the titrimetric method [19]. The standard is gallic acid [39]. The ratio of raw materials and extractant was 1:30. Repetition of all analyses was 5-fold. The desiccation coefficient

***Table 1. Monthly temperature and precipitation in 2018 and 2020***
***Таблица 1. Температура и осадки в 2018 и 2020 гг. по месяцам***

| Month | Temperature (°C) | | Precipitation (mm) | |
|---|---|---|---|---|
| | 2018 | 2020 | 2018 | 2020 |
| February | - 9.6 | - 2.1 | 59.5 | 21.6 |
| March | - 7.5 | 3.3 | 38.0 | 36.8 |
| April | 5.7 | 4.1 | 59.6 | 58.1 |
| May | 14.0 | 11.2 | 51.5 | 100.4 |
| June | 15.2 | 17.8 | 35.1 | 124.6 |
| July | 20.8 | 17.9 | 89.8 | 88.5 |
| August | 17.0 | 16.1 | 23.8 | 81.0 |
| September | 11.7 | 12.6 | 57.9 | 82.3 |
| October | 6.7 | 8.3 | 36.8 | 38.6 |

***Table 2. Duration of phenological intervals (day), amount of precipitation (mm) and SAT (º C)***
***Таблица 2. Длительность фенологических интервалов (сутки), количество осадков (мм) и САТ (º C)***

| Phenological intervals | Years | | | |
|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2020 |
| spring growth – budding | 42<br>617.9 / 118.5 | 43<br>432.0 / 39.3 | 43<br>534.3 / 79.5 | 49<br>425.0 / 215.9 |
| budding – beginning of flowering | 10<br>750.8 / 26.1 | 9<br>555.9 / 31.8 | 12<br>633.8 / 37.5 | 7<br>510,7 / 0.7 |
| beginning of flowering – mass flowering | 20<br>1041.8 / 40.4 | 19<br>843.6 / 51.8 | 21<br>855.8 / 51.1 | 8<br>613.7 / 3.4 |

*Note. In the numerator duration of phenological intervals; in the denominator SAT / precipitation amount.*

of the herb structure depending on the year of research was also determined [34]. The repetition was 20-fold.

Data analyzed for both years to establish normality of the samples according to the State Standard R ISO 5479-2002 [40]. Non-parametric criteria analysis performed for pooled data on water-soluble antioxidant and antioxidant content in alcoholic extract by years separately. The one-sample Kolmogorov-Smirnov criterion used to test for normal distribution in the raw data material "Herba". The normality test analysis on the distribution of the content sum water-soluble antioxidants and antioxidants in the alcoholic extract of *S. baicalensis* for each of the organs of the plant in the raw material "Herba" analyzed using Kruskal – Wallis test and Jonckheer-Terpstra ordered alternatives criterion. The choice of criterion was based on the fact that Kruskal-Wallis test and other non-parametric (or distribution free) tests are useful for testing hypotheses when the assumption of normality of the data is not met. They make no assumptions about the shape of the data distributions, which makes them particularly useful when the dataset is small [41].

According to the result of testing for normality of distribution in the structure of the raw material "Herba", criteria for independent samples were applied, where the null hypothesis was the assumption that the distribution is the same for the categories of data on the content of the sum of water-soluble antioxidants and antioxidants in the alcoholic extract for each element in the structure of the raw material "Herba".

We studied the correlations between the contents of the sum of water-soluble antioxidants and antioxidants in alcoholic extract in 2018 and 2020. The data obtained in 2018 and in 2020 considered as different parts of the statistical population due to significantly different weather conditions. Data on raw material "Herba" in general and on the structure of the raw material "Herba" considered. Spearman correlation coefficient chosen as a measure of conjugate variability of traits. It is less sensitive to the parameters of continuous distributions.

Correlation plots by years of experiment to visualize the correlation relationship between the data of the content of the sum of water-soluble antioxidants and antioxidants in the alcoholic extract in the raw material and its elements constructed.

The data were processed using analysis of variance. The separation of mean done using Duncan's multiple range test (DMRT) considering a probability level of 0.05. It is the test for measuring specific differences between pairs of averages [42]. IBM SPSS Statistics software version 27 used.

## Results and Discussing

In the process of the study, we revealed regularities in the distribution of dry matter content and desiccation coefficient by years and in the structure of *S. baicalensis* herb (Tables 3, 4).

In 2020, intensive precipitation at the end of May and in June, i.e. during stemming – beginning of budding caused a high moisture content in leaves, inflorescences+buds. In 2018 precipitation from the beginning of vegetation to herb harvest

***Table 3. Dry matter content in the shoot of S. baicalensis, (%)***
***Таблица 3. Содержание сухого вещества в надземных органах S. baicalensis, (%)***

| Plant part | 2018 | 2020 |
|---|---|---|
| **Inflorescences+buds** | 23.75±0.33 c | 21.07±0.13 c |
| **Cv, %** | 2.8 | 1.3 |
| **Leaves, upper level** | 32.81±0.24 b | 28.31±0.84 c |
| **Cv, %** | 1.5 | 6.0 |
| **Leaves, middle level** | 33.28±0.18 b | 27.09±0.20 c |
| **Cv, %** | 1.1 | 1.5 |
| **Leaves, lower level** | 30.73±0.89 b | 26.70±0.51 c |
| **Cv, %** | 5.0 | 3.8 |
| **Stems** | 39.51±0.18 a | 38.89±0.15 a |
| **Cv, %** | 0.9 | 0.8 |

*Примечание. Значения с одинаковыми буквами статистически не различаются согласно тесту Дункана при p< 0,05.*
*Note. Values with the same letters are not statistically different according to Duncan's test at p<0.05.*

***Table 4. Determination of desiccation coefficient of S. baicalensis herb by structure, 2018-2020***
***Таблица 4. Определение коэффициента усушки травы S. baicalensis по структуре, 2018-2020 годы***

| Harvest year | Inflorescences + buds | Stems | Leaves |
|---|---|---|---|
| **2018** | 2.1±0.1 d | 2.2±0.1 d | 2.5±0.1 c |
| **2020** | 4.8±0.2 a | 2.4±0.2 cd | 3.1±0.1 b |
| **Average** | 3.5±0.2 | 2.3±0.2 | 2.8±0.1 |

*Примечание. Значения с одинаковыми буквами статистически не различаются согласно тесту Дункана при p< 0,05.*
*Note. Values with the same letters are not statistically different according to Duncan's test at p<0.05.*

was uniform and the desiccation coefficient of the most watered parts of herb was significantly lower (Table 4). The desiccation coefficient of stems and their dry matter content did not change significantly by years. The initial low water content in stems and, accordingly, high dry matter content prevail over the influence of weather conditions in the years of the experiment. However, in terms of the effect of weather factors on other parts of the herb, it was shown for inflorescences+buds that dry matter accumulation did not differ significantly between years, but the desiccation coefficient in 2018 was lower by a factor of 2.3 compared to 2020.

Dry matter accumulation in inflorescences was minimal compared to other herb components. The dry matter content in leaf mass (regardless of level) was slightly higher. The leaves analyzed in 2018 had significantly more dry matter than in 2020 (1.2 times on average across all levels). As a result, it can assumed that the control of dry matter content in the shoot of *S. baicalensis* occurs at the genetic level, whereas the desiccation coefficient is more variable and dependent on the conditions of a particular growing season. Our data on the drying coefficient in *S. baicalensis* herb are somewhat higher than in the work of G.V. Chudnovskaya [43]. This is due to the difference in the hydrothermal coefficient in the Central region of the Non-Chernozem zone (1.50-1.54) compared to Eastern Transbaikalia (1.22-1.26; extremely continental climate, insufficient precipitation) [44, 45].

Water-soluble antioxidants are glycosides of phenolic compounds, polysaccharides and monosaccharides, organic acids and other water-soluble substances [19]. It was noted that the total content of water-soluble antioxidants in the shoots in 2018 was statistically significantly higher than in 2020 except for the inflorescences and buds (Table 5). It was shown that the total content of water-soluble antioxidants in the shoot mass of *S. baicalensis* in 2018 was statistically significantly higher than that in 2020, except for inflorescences and buds.

Low duration and precipitation during phenological interval “budding – beginning of flowering” in 2020 (Table 5) resulted in drought conditions. The ecological plasticity of *S. baicalensis* does not indicate that under drought conditions the accumulation of biologically active substances will be the same as under conditions of optimal moisture. Lack of moisture in 2020 reduced the content of the studied substances, represented, among others, by glycosides.

In the leaves of the upper and middle levels, the increase in water-soluble antioxidants in 2018 compared to 2020 averaged 1.6 times, in stems 2.8 times. In 2018, a significantly higher content of water-soluble antioxidants observed in the leaves of the upper and middle levels compared to the leaves of the lower level (1.5 times). In inflorescences and buds the content of water-soluble antioxidants was significantly lower than on average in leaves. The decrease was by years: in 2018 – 3.0 times, in 2020 – 2.3 times. The total content of water-soluble antioxidants under the conditions of favorable 2018 exceeded this parameter in the drought period of 2020 by 1.5 times in the leaves of the middle level and by 2 times in the leaves of the upper level and in the stem. The sum of antioxidants in inflorescences and lower level leaves was comparable in both years of the study.

The minimum accumulation of these substances detected in both years in stems, where cellulose predominates.

The coefficient of variation in the total content of water-soluble antioxidants in inflorescences and buds, stems, leaves of the lower and upper levels was higher in 2018 than in 2020. The variability of this indicator in 2018 in inflorescences, middle level leaves and stems was insignificant, in upper level leaves medium.

A different pattern of variability of water-soluble antioxidants in the herb structure observed in 2020: low in the leaves of the lower part of the shoot and stems; average in the leaves of the upper and middle levels. Especially noteworthy is the significant variability in the leaves of the lower level in 2018 and average in the leaves of the middle and upper levels in 2020.

Although the cross-supronate arrangement of leaves of plants of the Lamiaceae family provides all leaf plates with optimal insolation, in an herbage the illumination of leaves of the lower level may vary greatly. Therefore, the accumulation of BAS will also vary. Thus, the content of water-soluble antioxidants in leaves of *S. baicalensis* with reduced/different illumination varies more strongly than in leaves with stable illumination. In 2020, the plants were under less favourable weather conditions and the coefficient of variation of accumulation of water-soluble antioxidants in the studied organs had a smaller amplitude of variability than in 2018.

The composition of water-soluble antioxidants includes AA. Its content in the shoot mass of *S. baicalensis* varied depending on the plant part (Table 6). The content of AA in the leaf part of the herb is associated with the participation of this compound in photosynthesis and respiration.

The highest concentration of AA in 2018 was found in inflorescences+buds, it was significantly higher than in leaves of the three levels on average 2.7 times and in stems 5.4 times. The level of AA

***Table 5. Total content of water-soluble antioxidants (mg AAE/g f. w.) in inflorescences, leaves of different levels and stems of S. baicalensis, 2018, 2020***
***Таблица 5. Суммарное содержание водорастворимых антиоксидантов (мг-экв АК /г сырой массы) в соцветиях, листьях разных ярусов и стеблях S. baicalensis, 2018, 2020 годы***

| Plant part | 2018 | 2020 |
|---|---|---|
| Inflorescences+buds | 42.20±1.35 e | 35.86±0.66 e |
| Cv, % | 6.4 | 3.7 |
| Leaves, upper level | 152.63±11.84 a | 74.55±5.22 d |
| Cv, % | 15.5 | 14.0 |
| Leaves, middle level | 128.97±4.32 b | 82.66±5.67 cd |
| Cv, % | 6.7 | 13.7 |
| Leaves, lower level | 93.77±16.64 c | 93.30±2.95 c |
| Cv, % | 35.5 | 6.3 |
| Stems | 29.76 ±1.48 f | 10.83±0.49 g |
| Cv, % | 10.0 | 9.1 |

*Примечание. Значения с одинаковыми буквами статистически не различаются согласно тесту Дункана при p< 0,05.*
*Note. Values with the same letters are not statistically different according to Duncan's test at p<0.05.*

***Table 6. Ascorbic acid content in inflorescences, stems and leaves of different levels of S. baicalensis, mg% (fresh weight)***
***Таблица 6. Содержание аскорбиновой кислоты в соцветиях, стеблях и листьях разных ярусов S. baicalensis, мг% (на сырую массу)***

| Plant part | 2018 | 2020 |
|---|---|---|
| Inflorescences+buds | 38.13±2.12 a | 9.68±0.88 d |
| Cv, % | 9.6 | 18.2 |
| Leaves, upper level | 12.32±1.6 c | 9.90±0.66 d |
| Cv, % | 1.5 | 13.3 |
| Leaves, middle level | 15.84±1.3 b | 9.46±0.42 d |
| Cv, % | 1.0 | 8.9 |
| Leaves, lower level | 14.08±2.3 bc | 8.58±0.22 d |
| Cv, % | 1.1 | 5.1 |
| Stems | 7.04±0.6 e | 5.94±0.42 f |
| Cv, % | 1.6 | 14.2 |

*Примечание. Значения с одинаковыми буквами статистически не различаются согласно тесту Дункана при p< 0,05.*
*Note. Values with the same letters are not statistically different according to Duncan's test at p<0.05.*

increases more at the beginning of flower differentiation. It has shown that treatment of plants with AA increased the number of male and female flowers, as well as accelerated ovary formation and reduced ovary drop [46].

In 2018 and 2020 no significant changes in the AA content in leaves by levels were observed.

In general, the accumulation of AA in leaves of *S. baicalensis* in 2018 exceeded its content in 2020 by 1.5 times. The minimum AA content in both years of the experiment was observed in stems. In comparison with the rest of the herb (inflorescences+buds, leaves), on average, the accumulation of AA in stems in 2018 was lower by 3.7 times, and in 2020 by 1.6 times. The coefficient of variation for AA content across the whole structure of *S. baicalensis* herb in 2018 was insignificant. In 2020, the variability was the same in the leaves of the middle and lower levels. Inflorescences, upper level leaves and stems characterized by variability of medium degree.

The data obtained by us on the distribution of AA in the organs of the shoot confirm the previously revealed regularity, that AA accumulated into phloem and transported to root tips, shoots, and floral organs [47]. Our data show the influence of weather conditions on this pattern.

Comparing the accumulation of AA in herb *S. baicalensis* by years with its presence in vegetables, we can note a low amount of this vitamin. On average in 2018, its content is closer to that in tomato fruits, garlic bulbs, onion leaves. In 2020, its content is approximately the same as in courgette fruit and celery root [46].

The antioxidants in the alcoholic extract include carotenoids, chlorophylls, gallic acid derivatives, aglycones of flavonoids and triterpene compounds, essential oil components and others. The total content of these compounds in the shoot mass in 2020 was statistically significantly (1.3 times) higher than in 2018 (Table 7).

Thus, we see a different pattern comparing the content of water-soluble antioxidants by year. In 2018, the maximum accumulation of antioxidants in the alcohol extract founded in the leaves of the lower level. It exceeded the content of these substances in the leaves of the middle and upper part of the shoot by an average of 12.8%. In 2020, the highest concentration of antioxidants in the alcoholic extract detected in the leaves of the upper level, which exceeded their concentration in the leaves of the middle and lower levels by an average of 20.6 %. Also in 2020, *S. baicalensis* inflorescences+buds accumulated 16.7 % more antioxidants in the alcoholic extract than in 2018. Inflorescences+buds contained significantly less antioxidants in the alcoholic extract in 2018 (by 33.1 % on average) than in leaves of all levels. In 2020, these substances in inflorescences+buds were as much as in the leaves of the lower and middle levels and less than in the leaves of the upper parts of the shoot by an average of 19.47 %. The variability of indi-

***Table 7. Total of antioxidant content in the alcoholic extract in the shoot of S. baicalensis, mg GAE/g d.w.***
***Таблица 7. Содержание суммы антиоксидантов в спиртовом экстракте надземной массы S. baicalensis, мг-экв ГК/г сух. масс.***

| Plant part | Total antioxidant content in the alcohol extract | |
|---|---|---|
| | 2018 | 2020 |
| Inflorescences+buds | 53.84±3.44 c | 62.85±2.97 b |
| Cv, % | 12.76 | 9.5 |
| Leaves, upper level | 71.47±1.10 b | 83.05±3.58 a |
| Cv, % | 3.08 | 8.6 |
| Leaves, middle level | 66.03±1.71 b | 71.43±4.80 b |
| Cv, % | 5.18 | 13.4 |
| Leaves, lower level | 77.52±0.10 a | 66.35±5.39 b |
| Cv, % | 0.01 | 16.3 |
| Stems | 29.28±0.41 d | 20.57±0.87 e |
| Cv, % | 2.82 | 8.5 |

*Примечание. Значения с одинаковыми буквами статистически не различаются согласно тесту Дункана при p< 0,05.*
*Note. Values with the same letters are not statistically different according to Duncan's test at p<0.05.*

*A*

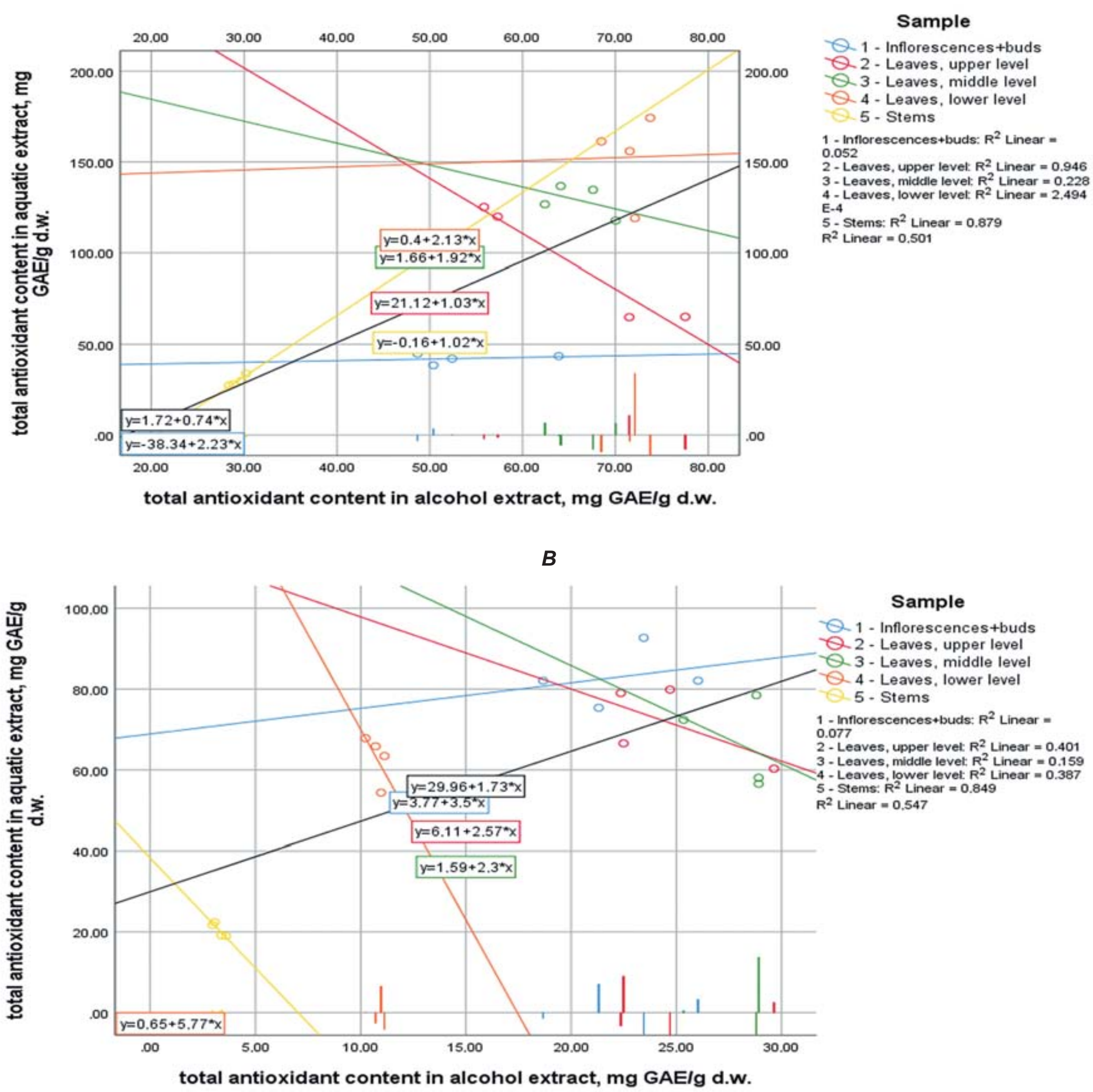


***Рис. 2. Корреляционная зависимость между содержанием антиоксидантов в спиртовом экстракте и суммарным содержанием водорастворимых антиоксидантов в надземной части S. baicalensis за 2018 (A) и 2020 (B) годы исследований***
***Примечание: прямая черного цвета – общая зависимость по сырью трава***
***Fig. 2. Correlation relationship between antioxidant content in alcoholic extract and total water-soluble antioxidant content in the shoot of S. baicalensis for 2018 (A) and 2020 (B)***
***Note: Straight black is a general dependence on medicinal raw material Herba***

cators in 2018 was mostly insignificant, and only for inflorescences+buds - medium.

The analysis of testing for normality of distribution of the content of sum water soluble antioxidants and antioxidants in alcoholic extract in S. baicalensis herb using Kruskal – Wallis test showed that the null hypothesis was rejected. Jonckheer-Terpstra ordered alternatives criterion showed that the null hypothesis is accepted.

Correlation plots between the data of the contents of the sum of water-soluble antioxidants and antioxidants in the alcoholic extract in *S. baicalensis* herb showed a similar relationship across years. It shown that the value of water-soluble antioxidant content varied similarly to the antioxidant content in alcohol extract. Correlation between the antioxidant content of the alcoholic extract and the content of water-soluble antioxidants for medicinal raw material "*S. baicalensis* herba" founded. Spearman's coefficient in 2018 was 0.708 and in 2020 it was 0.461. Further study needed to identify the regularities in the content of both water-soluble antioxidants and antioxidants in the alcoholic extract in the structure of *S. baicalensis* herb depending on the weather conditions of the growing season. The correlations for each raw material element showed a variety of dependencies in 2018 and 2020 (Fig. 2 A, B).

## Conclusions

The dry matter content of *S. baicalensis* herb did not differ significantly between years with different weather conditions. The maximum dry matter content observed in stems - 38.89-39.51%, and the minimum – in inflorescences – 21.07-23.75 %, regardless of the level of location on the shoot.

The content of water-soluble antioxidants, including AA, in the shoot mass under uniform precipitation and optimal air temperature was significantly higher than this indicator under conditions of sharp fluctuations in CAT and precipitation by 1.5-2.7 times. The maximum value of the total antioxidant content in the alcoholic extract in the shoot in both years of the study observed in leaves.

Correlation plots between the data of the contents of the sum of water-soluble antioxidants and antioxidants in the alcoholic extract in *S. baicalensis* herb showed a similar relationship across years. The research will continue.

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