
FORESTRY

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COMPARATIVE ASSESSMENT OF THE QUANTITATIVE CONTENT OF THE MAIN PHOTOSYNTHETIC PIGMENTS IN THE LEAVES OF THE ENGLISH OAK OF THE FIELD-PROTECTIVE FOREST STRIPS

Research article

Abstract

The article presents experimental results of a comparative assessment of the pigment complex of the leaves of the English oak growing in the protective forest strips of the Stone Steppe. It is shown that the maximum level of chlorophyll *a* content is characteristic of the leaves of oak trees of protective forest strip No. 131 and is equal to 3.02 ± 0.09 mg/g a.d.m. In oak leaves of forest strip No. 226, the content of this pigment is 9.6% lower. It was found that there are no statistically significant differences in the average content of chlorophyll *b* in the leaves of oak trees of the studied forest strips. It is shown that the content of photosynthetic pigments is an environmentally dependent indicator reflecting the vital state of plants, the nature of the ongoing physiological processes, as well as the direction of adaptive reactions when exposed to stress factors.

Keywords: chlorophyll *a*, chlorophyll *b*, pigment complex, English oak, forest belts, Kamennaya Steppe.

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СРАВНИТЕЛЬНАЯ ОЦЕНКА КОЛИЧЕСТВЕННОГО СОДЕРЖАНИЯ ОСНОВНЫХ ФОТОСИНТЕТИЧЕСКИХ ПИГМЕНТОВ В ЛИСТЬЯХ ДУБА ЧЕРЕШЧАТОГО ПОЛЕЗАЩИТНЫХ ЛЕСНЫХ ПОЛОС

Научная статья

Аннотация

В статье представлены экспериментальные результаты сравнительной оценки пигментного комплекса листьев дуба черешчатого, произрастающего в полевых защитных лесных полосах Каменной Степи. Показано, что максимальный уровень содержания хлорофилла *a* характерен для листьев деревьев дуба полевой защитной лесополосы №131 и равен 3.02 ± 0.09 мг/г а.с.в. В листьях дуба лесополосы №226 содержание данного пигмента на 9.6% ниже. Установлено, что по среднему содержанию хлорофилла *b* в листьях деревьев дуба исследуемых лесных полос статистически достоверных различий нет. Показано, что содержание фотосинтетических пигментов является экологически зависимым показателем, отражающим жизненное состояние растений, характер протекающих физиологических процессов, а также направленность адаптивных реакций при воздействии стрессовых факторов.

Ключевые слова: хлорофилл *a*, хлорофилл *b*, пигментный комплекс, дуб черешчатый, лесные полосы, Каменная Степь.

1. Introduction

The Earth's global photosynthetic system forms the basis of the primary bioproductivity of natural and artificial ecosystems. Chlorophyll is the main photosynthetic pigment responsible for the absorption, transmission, and transformation of solar energy [1, P.198–206]. It is known that the composition and properties of pigments of the photosynthetic apparatus play a significant role in the formation of adaptive mechanisms of plant resistance to adverse environmental factors [2, P.192–199]. Changes in the quantitative content and qualitative composition of photosynthetic pigments are important indicators of the physiological state of plants, as well as the direction of adaptive responses under stress [3, P.39–46]. For example, it has been shown that with an increase in aridity from north to south, the proportion of chlorophylls decreased and

the proportion of carotenoids increased [4, P.332–339]. Information about the pigment composition of plants is necessary to assess the carbon sink and productivity of large ecosystems [5, P.295–302]. The contrasting ecological conditions of plant growth make it relevant to study the role of pigments in their resistance to stress factors and the degree of their adaptation.

The aim of the study is to determine the content of chlorophylls *a* and *b* in the leaves of annual shoots of English oak trees growing in contrasting environmental conditions of forest strips: No. 131 and 226 of the Stone Steppe.

2. Methods

For genetic and breeding studies in 2021, 2 forest strips with a predominance of English oak were selected: No. 131 and 226 (according to the plan of forest strips of the Kamennaya Steppe). Forest strip No. 131 is field-protective, located from north to south on a slope type of terrain; occupies an area of 4 hectares. It was founded in 1949–1950 by N.F. Zubovich. It consists of 6 letters: a, b, c, d, e, f. Oak trees (15 pcs.) were not marked and were randomly selected in letter a. Strip No. 226 is also field-protective, located from north to south on an interfluvial undrained type of terrain. It is a narrow single-row forest strip, consisting only of English oak. It is not differentiated into letters. This forest belt was founded in 1963 by E.S. Pavlovsky nesting method. For physiological and biochemical studies, 15 oak trees were selected in it. These trees were not labeled and were randomly selected. Chlorophyll content was determined on a UNICO 2800 spectrophotometer. Chlorophyll *a* was measured at a wavelength of 665 nm, chlorophyll *b* at 649 nm.

The differences were evaluated using a two-sample *t*-test with different variances. Statistical analysis was performed using the Microsoft Excel 2013. Parametric and nonparametric indicators of samples are determined.

3. Results

The data of the physiological and biochemical analysis showed that the maximum level of chlorophyll *a* is characteristic of the leaves of oak trees of the protective forest strip No. 131 and is equal to 3.02 ± 0.09 mg/g a.d.m. with varying values for individual trees from 2.50 to 3.50 mg/g a.d.m. In the oak leaves of forest strip No. 226, the content of this pigment is 9.6% lower and is 2.73 ± 0.07 mg/g a.d.m. (Figure). The differences are statistically significant.

The analysis of the composition of the pigment fund showed that there are no statistically significant differences in the average content of chlorophyll *b* in the leaves of oak trees of forest strips No. 131 and 226. Thus, the average level of chlorophyll *b* accumulation in oak leaves of the analyzed plantings is 1.32 ± 0.07 and 1.32 ± 0.010 mg/g a.d.m. (Figure). It should be noted that the range of variation of the trait in forest strip No. 226 is somewhat wider than in forest strip No. 131 and ranges from 0.89 to 2.12 mg/g a.d.m.

It is shown that due to the higher content of chlorophyll *a* in the leaves of oak trees of forest strip No. 131, the total amount of chlorophylls *a* and *b* in the leaves of trees of this sample is 6.9% higher than in the leaves of oak trees of forest strip No. 226, and is equal to 4.33 ± 0.11 mg/g a.d.m. (Figure). Probably, the differences in the levels of accumulation of the main photosynthetic pigments in the leaves of the analyzed trees are associated with the peculiarities of humidification conditions. It is known that forest strip No. 131 is located on a slope type of terrain and is characterized by more favorable conditions of moisture availability, unlike forest strip No. 226, which is located on the watershed. According to the literature data, the English oak grows only in those conditions where the moisture coefficient is in the range of values from 0.8 to 1.25, while the humidity should be from 52 to 56% with an average annual precipitation of 450–525 mm [6, P.33], [7]. It should be noted that in the Stone Steppe, weather conditions at the beginning of the 2021 growing season are characterized by an uneven distribution of temperature and precipitation. The air temperature in April was within the regional norm, but precipitation fell only 84% of the norm. May was quite warm and humid: the temperature is above the monthly average by 1.1 °C, precipitation fell 159% of the regional norm. In the first decade of June, at the time of selection of plant samples, wet and cool weather was noted. So, on June 5 and 6, 11 and 14 mm of precipitation fell, respectively [8]. In this regard, it can be assumed that the optimal level of soil moisture supply was sufficient for the English oak in the analyzed forest strips. July was hot and dry: the temperature was 2.8°C higher than the monthly average, and the precipitation was 36% of the norm. August is also very hot and dry.

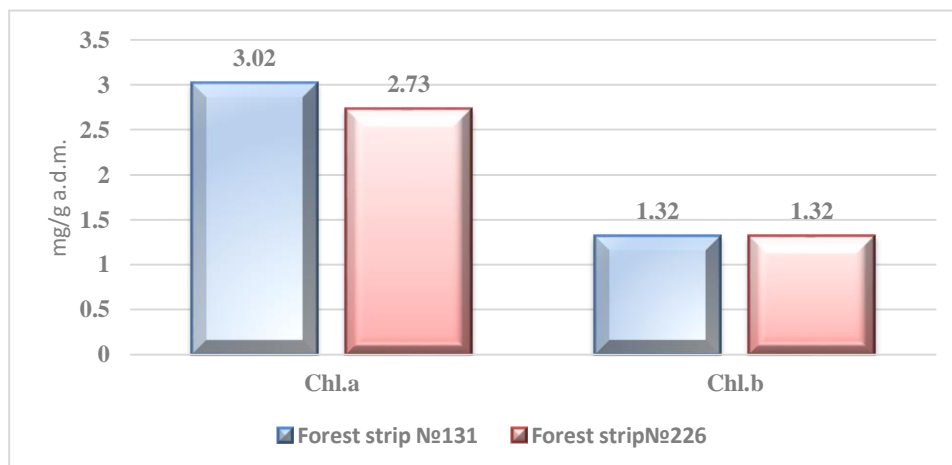


Fig. 1 – The content of chlorophyll *a* and *b* in the leaves of English oak trees of forest strips No.131 and 226 of the Stone Steppe

The potential photochemical activity of the leaves of the English oak can be judged by the ratio of chlorophylls *a*:*b*. Thus, it was revealed that for a sample of trees from forest strip No. 131, this ratio is wider and equal to 2.38:1, and for oak trees from forest strip No. 226 it is already 2.12:1.

The table shows the results of statistical evaluation of the differences between the analyzed groups of oak trees by components of the pigment complex. The arithmetic mean and median were used as a measure of the mean. When analyzing the median of samples for the content of chlorophyll *b*, more significant differences were revealed than when comparing the average values. Thus, the median of the sample for chlorophyll *b* of forest band No. 131 is 1.299 mg/g a.d.m., and the sample of forest band No. 226 is 1.187 mg/g a.d.m. with actual averages of 1.318 and 1.321 mg/g a.d.m. (Table). The calculated coefficients of variation allow us to conclude that the analyzed samples for the content of the main photosynthetic pigments are homogeneous ($c_v < 33\%$). The most homogeneous is the sample of trees of forest strip No. 226 for chlorophyll *a*, c_v is 9.6% (Table).

Table 1 – Statistical indicators of the content of chlorophylls *a* and *b* in English oak leaves in forest strips No. 131 and 226 of Kamennaya Steppe (2021)

Statistical indicator	№ forest strip					
	131			226		
	Chl. <i>a</i> , mg/g a.d.m.	Chl. <i>b</i> , mg/g a.d.m.	<i>a</i> + <i>b</i> , mg/g a.d.m.	Chl. <i>a</i> , mg/g a.d.m.	Chl. <i>b</i> , mg/g a.d.m.	<i>a</i> + <i>b</i> , mg/g a.d.m.
Average	3,022	1,318	4,340	2,732	1,321	4,054
Standart error	0,091	0,067	0,112	0,065	0,100	0,138
Median	3,079	1,299	4,382	2,668	1,187	3,894
Mode	–	–	–	–	–	–
Standard deviation	0,353	0,261	0,433	0,262	0,401	0,552
Sample variance	0,125	0,068	0,187	0,068	0,161	0,305
Interval	1,042	0,948	1,501	0,943	1,228	1,817
Minimum	2,454	0,861	3,660	2,236	0,891	3,310
Maximum	3,496	1,810	5,161	3,178	2,119	5,126
Coefficient of variation c_v , %	11,7	19,8	9,9	9,6	30,4	13,6

4. Conclusion

Thus, the content of photosynthetic pigments is an ecologically dependent indicator that reflects the vital state of plants, the nature of ongoing physiological processes, as well as the direction of adaptive reactions when exposed to stress factors. It has been shown that the maximum level of chlorophyll *a* content is typical for oak leaves of forest strip No. 131 and is equal to 3.02 ± 0.09 mg/g a.d.m. In the oak leaves of forest strip No. 226, the content of this pigment is 9.6% lower. It has been established that there are no statistically significant differences in the average content of chlorophyll *b* in the leaves of oak trees of the studied forest belts. From the conducted physiological and biochemical analysis, it follows that for a more complete understanding of the features of the accumulation of the components of the pigment complex, as well as to identify the degree of influence of weather conditions on the nature of the formation of genotype–environmental relationships, longer annual monitoring is required. The results obtained expand the understanding of the pigment complex of English oak in the forest–steppe zone and can be used for early diagnosis of the state of its photosynthetic apparatus.

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Conflict of Interest

None declared.

Конфликт интересов

Не указан.

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