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DYNAMICS OF THE CONTENT OF CHLOROPHYLLS IN THE LEAVES OF THE ENGLISH OAK (*QUERCUS ROBUR* L.) OF THE FOREST-STEPPE ZONE

Research article

Abstract

The article presents experimental data on the dynamics of the accumulation of photosynthetic pigments in the leaves of model trees of the English oak, which grows in the field-protective forest belts of the forest-steppe zone. It is shown that in 2020, the content of chlorophylls *a* and *b* in the leaves of model trees is minimal compared to the previous three years of research. It was revealed that the sum of the main photosynthetic pigments in the leaves of the oak trees of the control group growing on the plakor is 17.1% higher than the sum of the pigments of the trees of the experimental group growing on the slope, and is 4.735±0.188 mg / g a. d. m. It is proved that the content of chlorophylls *a* and *b* is an environmentally dependent feature that reflects the general vital state of plants, as well as changes that occur during growth, development and stress loads.

Keywords: English oak, field-protective forest belts, photosynthetic pigments, chlorophyll a, chlorophyll b.

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ДИНАМИКА СОДЕРЖАНИЯ ХЛОРОФИЛЛОВ В ЛИСТЬЯХ ДУБА ЧЕРЕШЧАТОГО (*QUERCUS ROBUR* L.) ЛЕСОСТЕПНОЙ ЗОНЫ

Научная статья

Аннотация

В статье приведены экспериментальные данные динамики накопления фотосинтетических пигментов в листьях модельных деревьев дуба черешчатого, произрастающего в полезащитных лесных полосах лесостепной зоны. Показано, что в 2020 г. содержание хлорофиллов *a* и *b* в листьях модельных деревьев минимально относительно трех предыдущих лет исследований. Выявлено, что сумма основных фотосинтетических пигментов в листьях деревьев дуба контрольной группы, произрастающих на плакоре, на 17.1% выше суммы пигментов деревьев опытной группы, произрастающих на склоне, и составляет 4.735±0.188 мг/г а.с.в. Доказано, что содержание хлорофиллов *a* и *b* является экологически зависимым признаком, отражающим общее жизненное состояние растений, а также изменения, происходящие при росте, развитии и стрессовых нагрузках.

Ключевые слова: дуб черешчатый, полезащитные лесные полосы, фотосинтетические пигменты, хлорофилл а, хлорофилл б.

1. Introduction

In the context of global climate change, the most urgent tasks of our time are to solve environmental problems, such as the depletion of the Earth's ozone layer, deforestation, increasing aridization and reducing biodiversity. One of the main causes of global climate warming is the increase in the concentration of carbon dioxide in the Earth's atmosphere due to anthropogenic activities. It is known that the share of CO2 in the creation of the greenhouse effect is 43%, methane 23%, and nitrous oxide 3% [1, P. 2-21]. According to calculations using global climate models, if the concentration of carbon dioxide doubles, the average air temperature during the XXI century will increase by 1.5-5.80 C [2, P. 5-21]. It is known that climate warming is uneven in the latitudinal gradient and is more pronounced in winter. As a rule, the increased air temperature negatively affects the germination of seeds and the further development of undergrowth of tree species, which, in turn, negatively affects the processes of natural regeneration of forests.

Woody vegetation is a powerful factor in reducing the amount of carbon dioxide in the atmosphere through the process of photosynthesis. Photosynthesis is the largest synthetic process on Earth. More than 50 billion tons of carbon are recorded by photosynthetic organisms per year [3, P. 5-11]. The main class of pigments that are responsible for the absorption of light energy during photosynthesis are chlorophylls. Chlorophyll *a* and *b* are the main pigments found in all photosynthetic organisms. Currently, for the timely diagnosis of the current life state of plants, various methods of bioindication are used, based on indicators that characterize the course of the processes of primary metabolism. These indicators include the content of the main photosynthetic pigments, since their number determines the functional state of the plant and changes that occur during growth, development and stress loads.

The aim of the study is to determine the dynamics of the content of chlorophylls *a* and *b* in the leaves of annual shoots of English oak model trees growing in contrasting ecological conditions of forest belt No. 133 of the Stone Steppe.

2. Research methods

The plant material was taken from the English oak trees in the field-protective forest belts No. 133 of the Stone Steppe (Voronezh region, Talovsky district). It selected and tested 40 model English oak trees (20 control and 20 experimental trees). Experimental and control model trees grow on the watershed in contrasting environmental conditions. Control trees were sampled in letters *a* and *b* of forest belt located on upland and interfluvial undrained terrain types. The bonitet class of these trees is Ia. Experienced oak trees were sampled in a letter *c* on a slope. Bonitet class III. The content of photosynthetic pigments (chlorophylls *a* and *b*) in the leaves of English oak was determined by the method of leaf extraction in 96% ethanol [4, P. 55-58]. The plant material was taken in the middle of the day from the lower shoots of the current year in the southern exposure of the crowns. The mass of absolutely dry matter was determined by a thermowell method. The experimental data were statistically processed using the Microsoft Excel 2013.

3. Results and discussion

Physiological and biochemical analysis of the content of photosynthetic pigments in the leaves of model oak trees revealed the minimum content of chlorophylls *a* and *b* relative to previous years of research. Thus, in the leaves of control oak trees growing on the upland and partially interfluvial undrained types of terrain (letters *a* and *b* of forest belt No. 133), the average content of chlorophyll *a* is 3.180±0.157 mg/g absolutely dry mass (a.d.m.) with a range of variability of the trait from 2.3 to 4.5 mg/g a.d.m. (Figure 1). At the same time, we showed that in previous years of research, the content of this photosynthetic pigment in the leaves of control trees was as follows: 3.83 mg/g a. d. m. (2017) – 4.35 mg/g a.d. m. (2018) – 4.17 mg/g a.d.m. (2019) (Figure 1).

Figure 1 – The average content of chlorophyll *a* and *b* in the leaves of model oak trees growing on the upland type of terrain of the forest strip No. 133 of the Stone Steppe, mg/g a.d.m.

The average content of chlorophyll *a* in the leaves of experimental trees growing on the slope type of terrain (letter *b* of forest belt No. 133) is lower than the average level of accumulation of this photosynthetic pigment in control trees and is equal to 2.780±0.133 mg/g a.d.m. (Figure 2). The range of variability of this trait is narrower, and ranges from 2.30 to 3.60 mg / g a.d.m. For the trees of the experimental group, a trend similar to the experimental trees is characteristic: the average content of chlorophyll *a* in the leaves as a whole was lower than the previous years of the study –3.71 mg/g a.d.m. (2017) – 4.36 mg/g a.d.m. (2018) – 3.65 mg/g a.d.m.[5, P. 73-75] (Figure 2).

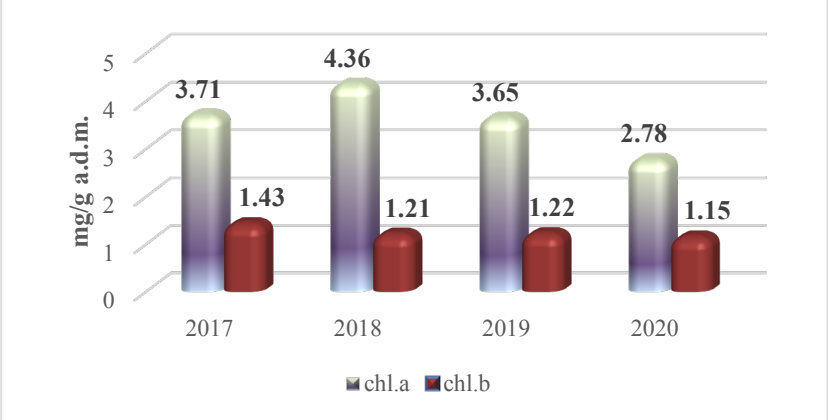

Figure 2 – The average content of chlorophyll *a* and *b* in the leaves of oak trees growing on the slope type of terrain of the forest strip No. 133 of the Stone Steppe, mg/g a.d.m.

The average content of another very important photosynthetic pigment – chlorophyll *b* – in the leaves of oak trees of the control group is 1.553±0.103 mg/g a.d.m. with a variation of the trait from 1.0 to 2.4 mg/g a.d.m. The oak leaves of the experimental group of trees are characterized by a 26% lower content of this photosynthetic pigment – 1.147±0.073 mg/g a.d.m. (Figure 2). We show a narrower range of variability of the indicator for the trees of the experimental group. Thus, the content of chlorophyll *b* varies from 0.7 to 1.7 mg / g a.d.m.

In general, it is necessary to note the trend of a slight increase in chlorophyll *b* in the leaves of control oak trees relative to the previous years of the study: 1.15 (2017) –1.23 (2018) – 1.38 (2019) – 1.55 mg/g a.d.m. (2020). However, the experimental group is characterized by an inverse relationship. The content of chlorophyll *b* has been decreasing for several years and this year reached the minimum value: 1.43 (2017) – 1.21 (2018) – 1.22 (2019) – 1.15 mg/g a.d.m. (2020) (Figure 1).

We found that the sum of the main photosynthetic pigments in the oak leaves of the control group is 17.1% higher than the sum of the pigments of the trees of the experimental group and is 4.735±0.188 mg / g a.d.m. The analysis of the range of variability of the ratio of the content of chlorophylls *a:b* was also carried out. For the current year, a low indicator of the *a:b* ratio was revealed relative to the previous years of the study. So, for the control oak trees, the ratio *a:b* is on average 2.194:1, and for the experimental trees, this ratio is slightly higher –2.539:1. The expansion of the chlorophyll ratio indicates an increased potential photochemical activity of oak on the slope type of terrain. It is noteworthy that, in general, both groups of trees are characterized by a minimal ratio of chlorophylls *a:b* relative to the data of the previous three years. Thus, the ratio of chlorophylls *a:b* in 2017, 2018 and 2019 is: 3.44 (control) and 3.33 (experience); 3.55 (control) and 3.63 (experience); 3.09 (control) and 3.02.

It is known that the genotype of the plant and its habitat conditions determine the optimal water and temperature conditions for the process of photosynthesis [6, P. 331]. Plants of the forest-steppe and steppe regions of the European part of Russia often lack soil moisture during the growing season. For English oak, the most optimal hydrothermal regime is air humidity from 52 to 56%, with an average annual temperature of 8-9°C and precipitation of 450-525 mm per year [7, P. 1-13]. It was found that oak does not grow in conditions where the moisture coefficient is higher than 1.25, or lower than 0.8 [8, p.16]. The weather conditions of the growing season in 2020 in the Stone Steppe were characterized by an uneven distribution of temperature and precipitation. April was quite cold and wet. The temperature deviation from the norm was -1.2 0C, more than 1.5% of precipitation fell (168%). May was also cold and quite humid: the deviation from the norm in terms of air temperature – -1.50 C, 137% of the norm of precipitation (61 mm) fell. At the beginning of June, at the time of the selection of plant samples, wet and cool weather also persisted. Thus, the optimal level of provision of oak trees with productive soil moisture was accumulated. However, the optimal process for photosynthesis is not the complete saturation of tissues with water, but a water deficit of 5 to 20% of the total saturation. This fact has been confirmed by many researchers and is called the Diamond effect. Probably, this phenomenon is adaptive in nature and is explained by the fact that land plants often experience a lack of moisture [3, P. 135-142]. Thus, such a low level of synthesis of the main photosynthetic pigments in the leaves of model oak trees relative to the previous years of the study may be an adaptive mechanism for the level of soil moisture availability.

Using the Microsoft Excel 2013, we conducted a statistical assessment of the differences in the content of chlorophyll in the variants of the experiment. The results are shown in Table 1. The reliability of the differences between the samples was evaluated using a two-sample t-test with different variances. During the statistical analysis, parametric and nonparametric indicators of the samples were determined (Table 1). According to the obtained coefficients of variation, all samples for chlorophyll *a* and *b* are fairly homogeneous with an average degree of data dispersion (coefficients of variation are less than 33%). It was revealed that the most homogeneous sample is the experimental group for chlorophyll *a* — the coefficient of variation is 18.5%.

Table 1 – Statistical indicators of the content of chlorophylls a and b in the leaves of oak petiolate in the forest belt No. 133 of the Stone Steppe (2020)

Statistical indicator	Type of terrain					
	Upland			Slope		
	Chl.*a*	Chl.*b*	*a*+*b*	Chl.*a*	Chl.*b*	*a*+*b*
Mean	3.182	1.553	4.735	2.780	1.147	3.927
Standard error	0.157	0.103	0.188	0.133	0.073	0.169
Median	3.0	1.5	4.6	2.8	1.2	4.1
Mode	2.8	1.2	4.1	2.6	1.1	3.8
Standard deviation	0.649	0.423	0.775	0.514	0.283	0.654
Interval	2.2	1.4	3.2	2.0	1.0	2.4
Minimum	2.3	1.0	3.6	1.6	0.7	2.4
Maximum	4.5	2.4	6.8	3.6	1.7	4.8
Sum	54.1	26.4	80.5	41.7	17.2	58.9
Coefficient of variation c_v , %	20.4	27.2	16.4	18.5	24.7	16.7

4. Conclusion

Thus, it is shown that the content of the main photosynthetic pigments – chlorophylls *a* and *b* is an environmentally dependent feature that reflects the general state of life of plants at the current moment, as well as changes occurring during growth, development and stress loads. The general state of life of plants mainly depends on the habitat (amount of precipitation, temperature, level of solar radiation, type of soil, terrain), despite the individual variability of the trait in the population.

Conflict of Interest

None declared.

Конфликт интересов

Не указан.

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