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STUDY OF THE SEASONAL DYNAMICS OF THE ACCUMULATION OF PHENOLIC COMPOUNDS IN THE LEAVES OF THE ENGLISH OAK FOREST-STEPPE ZONE OF THE EUROPEAN PART OF RUSSIA

Research article

Abstract

The article presents the results of assessing the biochemical diversity of English oak trees in the forest-steppe zone of the European part of Russia. It is shown that at the beginning of the growing season in young oak leaf blades the most significant fluctuations in the levels of accumulation of substances of secondary metabolism occur, and by the end of the growing season their content stabilizes. It was revealed that flavonols are quantitatively the leading group of secondary metabolites. In the leaves of control trees, their content is $3.156 \pm 0.113\%$ of dry weight. It has been proven that an increased level of content of various groups of substances of secondary metabolism takes part in the formation of the potential biochemical resistance of trees when growing in adverse environmental conditions.

Keywords: substances of secondary metabolism, English oak, biochemical diversity, flavonols, forest belts.

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ИЗУЧЕНИЕ СЕЗОННОЙ ДИНАМИКИ НАКОПЛЕНИЯ ФЕНОЛЬНЫХ СОЕДИНЕНИЙ В ЛИСТЯХ ДУБА ЧЕРЕШЧАТОГО ЛЕСОСТЕПНОЙ ЗОНЫ ЕВРОПЕЙСКОЙ ЧАСТИ РОССИИ

Научная статья

Аннотация

В статье представлены результаты изучения биохимического разнообразия деревьев лесостепной зоны Европейской части России. Показано, что в начале вегетации в молодых листовых пластинках дуба происходят наиболее значительные колебания уровней накопления веществ вторичного обмена, а к концу вегетации их содержание стабилизируется. Выявлено, что флавонолы являются количественно ведущей группой вторичных метаболитов. В листьях контрольных деревьев их содержание составляет $3.156 \pm 0.113\%$ от сухой массы. Доказано, что в формировании потенциальной биохимической устойчивости деревьев при выращивании в неблагоприятных условиях внешней среды принимает участие повышенный уровень содержания различных групп веществ вторичного обмена.

Ключевые слова: вещества вторичного метаболизма, дуб черешчатый, биохимическое разнообразие, флавонолы, лесные полосы.

1. Introduction

It is known that to create biologically stable oak plantations, it is necessary to select plants with high immunological properties. Substances of secondary metabolism of phenolic nature are used as markers of resistance of oak forests to unfavorable abiotic and biotic factors. It has been proven that a large number of various substances of secondary metabolism are synthesized in the leaves of English oak. [1]. For a comprehensive assessment of the current state of oak plantations, it is necessary to carry out more extensive long-term biochemical studies using bioindication methods.

The aim of the research was to assess the seasonal dynamics of the accumulation of substances of secondary metabolism in the leaves of model English oak trees growing in contrasting topographical conditions of the forest belt No. 133 of the Kamennaya Steppe.

2. Methods

An assessment was made of biochemical diversity in the seasonal dynamics of control and experimental English oak trees growing in contrasting terrain conditions of the field-protective forest belt No. 133 of Kamennaya Steppe (Voronezh region). This forest belt was created in 1950 by academician E.S. Pavlovsky. It selected 40 model oak trees: 20 trees growing on the upland in litera *a* and *b* (control group), and 20 trees on the slope in litera *c* (experimental group) [2]. Samples were collected twice during the growing season. To determine the groups of substances of secondary metabolism, extraction of previously recorded leaves 96 was carried out; 70 and 50% ethanol. In a 96% extract, low-molecular-weight catechins and flavonols were determined [3;4]; in a 50% extract - condensed tannins, the total amount of phenolic compounds [4], [5] and hydrolysable tannins [6]; 70% extract contains proanthocyanidins [4].

3. Results

The analysis allowed to note differences in the level of synthesis of secondary metabolism substances between groups of control and experimental trees, and in seasonal dynamics. It is shown that in June 2020 the maximum level of accumulation of secondary metabolites is characteristic of flavonols. Thus, in the leaves of control trees, the content of this group of phenolic compounds is $3.156 \pm 0.113\%$ of dry weight (d.w.) (Fig. 1).

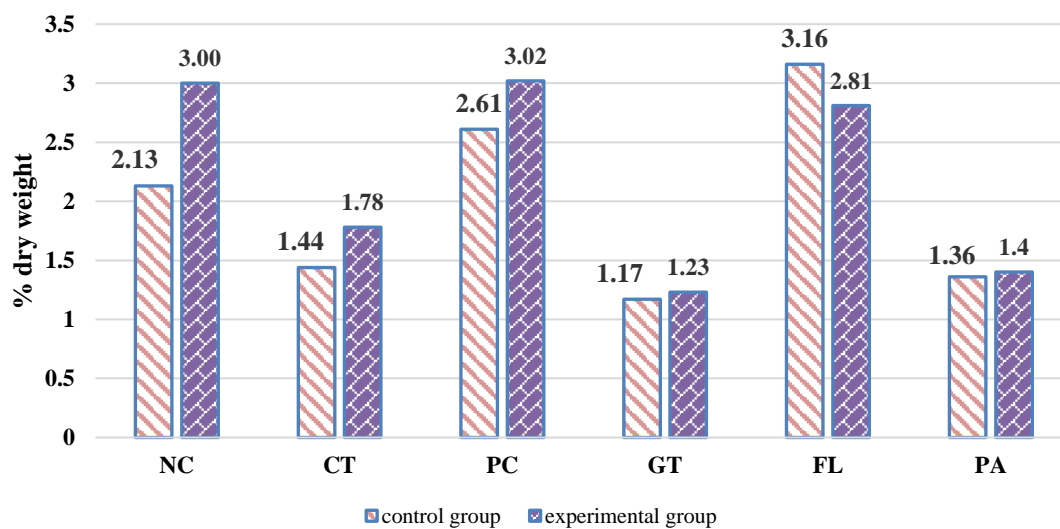


Fig. 1 – The content of secondary metabolism substances in the leaves of model oak trees (forest belt No.133, June 2020):

NC – low-molecular-weight catechins; *CT* – condensed tannins; *GT* – hydrolyzable tannins; *PC* – total amount of phenolic compounds; *FL* – flavonols; *PA* – proanthocyanidins

Probably, such a high level of them in control trees determines the ability of oak to resist the influence of powdery mildew and various phyllophages, which is confirmed by the data of entomo-phytopathological assessment in seasonal dynamics. In the leaves of experimental trees, the level of flavonol accumulation is lower by 11.1% – $2.813 \pm 0.180\%$ d.w. (Fig. 1). In general, the content of these compounds in the leaves of model oak trees in 2020 is lower than in previous years of research: 4.419 ± 0.172 and 3.726 ± 0.332 % d.w. (2019) and 4.683 ± 0.225 and 3.250 ± 0.277 % d.w. (2018), respectively, for control and experimental trees [8]. By August 2020, the level of accumulation of FL decreased in the leaves of both groups of oak trees. Thus, in the leaves of control trees, their content decreased by 20.2% (2.63% d.w.), and in the leaves of experimental trees, by 29.5% (1.98% d.w.) (Fig. 2). The content of FL can serve as a genetic indicator of the potential resistance of English oak trees to the external effects of various stress factors, such as atmospheric drought, increased UV radiation, phyllophagous damage and diseases [9].

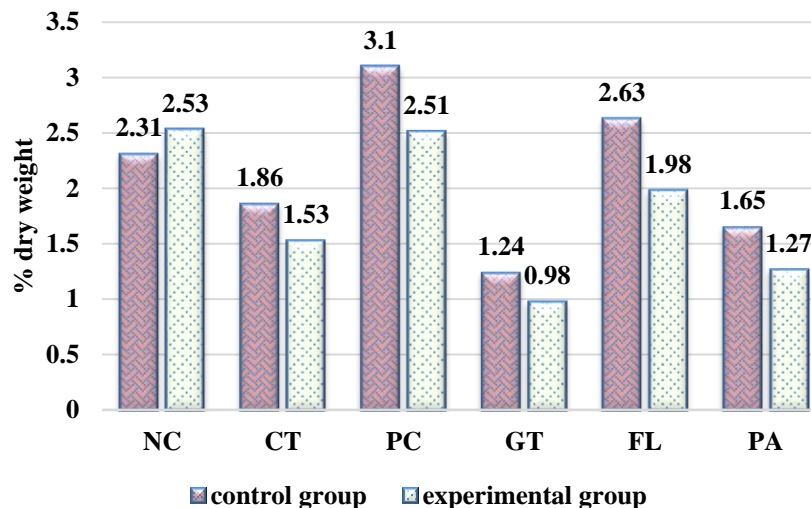


Fig. 2 – The content of secondary metabolism substances in the leaves of model oak trees (forest belt No.133, August 2020)

It was revealed in seasonal dynamics that in the leaves of the experimental oak trees the level of low-molecular-weight catechins (NC) accumulation is significantly higher than in the leaves of the control trees. So, in June 2020, the content of this group of substances of secondary metabolism in the leaves of oak trees growing on the slope (experiment) is $3.000 \pm 0.361\%$ d.w., which is 29% higher than in the leaves of oak trees growing on the upland (control) (Fig. 1). By mid-August, the level of NC accumulation somewhat leveled off in both groups of model trees: 2.314 ± 0.399 and $2.532 \pm 0.405\%$ d.w. A similar trend was observed in previous years of research. By the second decade of August, the content of NC in the leaves of both groups of trees under study was equal: 1.250 ± 0.250 and $1.36 \pm 0.270\%$ d.w. for control and experience, respectively (Fig. 2). Significant differences in the content of NC between the control and experimental oak trees allows us to consider these compounds as performing a certain protective function in unfavorable conditions for growth.

The analysis showed the presence of certain differences in the accumulation of condensed tannins (CT) in the leaves of model oak trees. Thus, as a result of the analysis of the June collection of plant material, it was revealed that in 2020 the level of CT accumulation in the leaves of experimental oak trees is $1.784 \pm 0.244\%$ d.w., which is 19.1% higher than in control trees – $1.435 \pm 0.165\%$ d.w. (Fig. 1). The increased content of this group of substances of secondary metabolism can probably be associated with the induced synthesis of substances in response to damage to the vegetative sphere by pathogenic infections and pests. However, as a result of the analysis of plant material from the August collection, it was shown that in the leaves of control trees there was an increase in the level of accumulation of CT by 29.2% to $1.858 \pm 0.206\%$ d.w., and in the leaves of experimental trees, on the contrary, a decrease to $1.529 \pm 0.173\%$ d.w.

By June 2020, the content of GT in the leaves of control and experimental trees is 1.171 ± 0.159 and $1.235 \pm 0.157\%$ d.w., respectively (Fig. 1). At the same time, June 2019 is characterized by a significantly lower level of accumulation of this group of secondary metabolites: $0.888 \pm 0.131\%$ d.w. (control) and $0.761 \pm 0.180\%$ d.w. (experience). By August 2020, there was a slight variation in the content of GT in the leaves of the analyzed trees. Thus, in the leaves of the control trees, the level of GT accumulation increased by 5.7%, while in the leaves of the experimental trees, on the contrary, it decreased by — 20.3% (Fig. 2).

The analysis showed a difference in the content of proanthocyanidins (PA), in the leaves of the studied trees both at the quantitative level and in the nature of seasonal dynamics. It was noted that at the beginning of the growing season, when the leaf blade had just formed, the levels of PA accumulation in the leaves of the experimental and control trees were almost equal and amounted to $1.447 \pm 0.178\%$ d.w. and $1.356 \pm 0.229\%$ d.w. (Fig. 1). However, by mid-August, the content of PA in mature leaves of control oak trees increased by 17.9% to $1.651 \pm 0.310\%$ d.w., while in the leaves of experimental trees, on the contrary, the amount of PA decreased by 15% to $1.272 \pm 0.117\%$ d.w. (Fig. 2). Thus, an increase in the level of PA accumulation in the leaves of control trees may be associated with the manifestation of an induced defense mechanism in response to damage by pathogens or pests, which leads to additional synthesis of secondary metabolites [9], [10].

5. Conclusion

Thus, the analysis showed the presence of significant biochemical diversity in the leaves of the studied oak trees in the shelterbelts of the Kamennaya Steppe. It was found that, as in previous years of research, flavonols are the quantitatively leading group of secondary metabolites. It was noted that at the beginning of the growing season in young oak leaf blades, the most significant fluctuations in the levels of accumulation of substances of secondary metabolism occur, and by the end of the growing season their content stabilizes. It has been shown that an increased level of content of various groups of substances of secondary metabolism takes part in the formation of the potential biochemical resistance of trees when growing in unfavorable environmental conditions. It should be noted that the resistance of plants to environmental stress under the influence of abiotic and biotic factors is determined not only by the level of accumulation of various groups of phenolic compounds, but also by their combination. Certain co-adaptive complexes of groups of secondary substances of different nature of action are formed in different time periods of the growing season, which have a high level of heritability.

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Conflict of Interest

None declared.

Конфликт интересов

Не указан.

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