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QUANTITATIVE COMPOSITION OF *QUERCUS ROBUR* L. FLOWERING ORGANS DEPENDING ON THE BIOLOGICAL CHARACTERISTICS OF CLONES AND THE EFFECTS OF CHLOROCHOLINE CHLORIDE

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The pedunculate oak (Quercus robur L.) is a valuable tree species not only in Ukraine but also globally, being a cornerstone of many forest ecosystems. Due to its significant ecological and economic roles, the need arises for creating superior stands of this species that can meet the growing demand for high-quality seeds and seedlings of Quercus robur. These stands are essential for reforestation, biodiversity conservation, and wood production. One of the main challenges in forming and maintaining these stands is the periodicity of the oak's reproductive phase. This irregularity in flowering and seed production reduces the overall productivity of oak populations. To overcome this limitation, various approaches have been tested, including the use of plant growth regulators. Chlorocholine chloride has shown promise as an effective tool in regulating the reproductive development of plants.

***Keywords**: pedunculate oak; Quercus robur; chlorocholine chloride; plant growth regulator; reproductive development; flowering.*

КІЛЬКІСНИЙ СКЛАД ОРГАНІВ ЦВІТІННЯ *QUERCUS ROBUR* L. ЗАЛЕЖНО ВІД БІОЛОГІЧНИХ ОСОБЛИВОСТЕЙ КЛОНІВ ТА ДІЇ ХЛОРХОЛІНХЛОРИДУ

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Дуб звичайний (Quercus robur L.) є цінною деревною породою не лише в Україні, а й у світі загалом. У зв'язку з цим, виникає потреба у формуванні плюсових насаджень цієї культури, які б забезпечили попит на насіння і саджанці Qercus robur. Однак, однією з проблем формування і функціонування таких насаджень є періодичність репродуктивної фази дуба, яка знижує їх продуктивність. Для нівелювання цієї проблеми використовують різні підходи, одним із яких є застосування регуляторів росту рослин, наприклад, хлорхолінхлориду. У результаті проведених досліджень нами було встановлено, що застосування вказаної речовини позитивно впливало на чисельність маточкових та тичинкових квіток у Quercus robur. Крім того, було виявлено залежність кількості генеративних органів дуба від клону, який використовувався у ході дослідів. Таким чином, нами встановлено, що генеративний розвиток дуба звичайного істотно залежить від

клону, умов року, що передує цвітінню і може бути простимулюваним водним розчином хлорхолінхлориду, дія якого виражається у збільшенні кількості як маточкових так і тичинкових квіток.

Ключові слова: *дуб звичайний; Quercus robur; хлорхолінхлорид; регулятор росту рослин; репродуктивний розвиток; цвітіння.*

The formation of clonal stands of *Quercus robur* contributes to the expansion of areas planted with trees that exhibit the traits of superior specimens, improving care practices and, consequently, increasing the quantity of high-quality seed material. Moreover, this enhances the efficiency of breeding work. However, over time, periodicity in fruiting returns in clonal plantations, growth processes intensify, and their advantages diminish [1]. The transition of a plant to flowering, as well as the overall process of ontogenesis, is controlled by three interrelated systems: trophic, hormonal, and genetic [2; 3]. Research aimed at influencing these systems is extensively and comprehensively described in the scientific literature [2; 3]. One of the effective measures is the application of physiologically active substances, particularly the gibberellin biosynthesis inhibitor – chlorocholine chloride [4; 5].

To study the growth and development of individual *Quercus robur* clones and to assess the potential for influencing their reproductive process, we established a collection plot at the local nature monument «Dub Karpa» (Carp's Oak). On a 0,15-hectare area of young common oak plantations, trees of an early phenological form were selected, onto which grafts from superior trees were applied. The cuttings were obtained from the *Quercus robur* clonal plantation of the Vinnytsia forestry, and according to the official registry, they bear the numbers A-1, A-97, A-82, and A-83. The experiment was repeated three times on trees of each clone. Statistical analysis was performed using multifactorial analysis of variance at the 5 % significance level.

The degree of shoot sexualization determines the qualitative composition of the flowering organs in the studied *Quercus robur* clones. During the observation period, the number of female inflorescences and flowers varied significantly depending on the shoot type. On complex combined shoots – 3, rarely 2–4, each containing 3–4 flowers. On female growth shoots, the number of inflorescences was 1–2 per shoot, with 2–3, occasionally 4, flowers per inflorescence. Therefore, the sexualization of the shoots also defines the quantitative nature of the female flowering. Throughout the observations, no significant differences were noted in the number of inflorescences and flowers per shoot in the grafted trees of the studied clones.

According to our research (table 1), the quantitative composition of the female flowering organs varied significantly depending on the clone and was notably higher in the variant with the application of an aqueous solution of chlorocholine chloride.

In the 2022 experimental year, the number of female flowers on trees of clone A-1, treated with a 0,9 % solution of chlorocholine chloride, amounted to 457,3 flowers per tree, compared to 218,3 flowers per tree in the control group, with LSD_{05} = 3,01. A noticeably lower number of flowers was observed on trees of clone A-97, with 270,3 flowers per tree under the influence of chlorocholine chloride and 184 flowers per tree in the control group. For *Quercus robur* clones A-82 and A-83, the number of female flowers was 487,3 and 256 flowers per tree, and 593 and 424,6 flowers per tree, respectively.

The year 2023 was characterized by unfavorable conditions for the formative processes preceding flowering, resulting in a significantly lower number of flowers compared to the previous year. During this period, the lowest number of female flowers recorded in the study was on trees of clone A-97, with 113,7 flowers per tree in the control group and 183,7 flowers per tree under stimulation. The most favorable conditions for the formation of female flowers were those preceding the 2024 flowering season, where a significant increase in the number of flowers was noted, with the highest count observed in trees of clone A-83–696,3 flowers per tree in the control group and 991 flowers per tree under the influence of an aqueous solution of chlorocholine chloride.

Table 1

Flowering of female flowers in individual *Quercus robur* clones, units/tree

Years of experiment	chlorocholine chloride concentracion, %	Clones			
		A-1	A-97	A-82	A-83
2022	0,9	457,3	270,3	487,3	593,0
	Control	218,3	184,0	256,0	424,6
2023	0,9	263,6	183,7	369,7	559,7
	Control	114,7	113,7	253,3	416,3
2024	0,9	593,3	491,6	652,3	991,6
	Control	341,0	315,3	416,0	696,3
LSD_{05}	A	3,69			
	B	4,26			
	C	3,01			

As a result of multifactorial analysis of variance, it was established that the number of female flowers in individual *Quercus robur* clones significantly varies depending on the year of the study. In 2022, the average number of female flowers was 361,38 flowers per tree, in 2023 – 288,2, and in 2024 – 502,17 flowers per tree, with LSD_{05} = 3,69. The quantitative composition of female flowers also significantly differed based on the biological characteristics of the clone. For example, the number of flowers on trees of clone A-83 was 613,83 flowers per tree, A-82 – 405,78, A-1 – 336,33, and A-97 – 259,7 flowers per tree, with LSD_{05} = 4,26.

Under the influence of a 0,9 % solution of chlorocholine chloride, the number of female flowers significantly increased to 492,92 flowers per tree, while in the control, this figure was 314,94 flowers per tree, with LSD_{05} = 3,01. The impact of the experimental factors (fig. 1) was predominantly determined by the research years (factor A) – 33 %, and the biological characteristics of the clone (factor B) – 42 %. The concentration of chlorocholine chloride (factor C) also had a notable effect – 19 %. The contribution of the interaction effects between factors A and B, A and C, and B and C ranged from 1 % to 3 %.

Thus, the primary determinant of the number of female flowers is the biological characteristics of individual clones, which are significantly influenced by the conditions of the year preceding flowering. The application of a 0,9 % concentration of chlorocholine chloride reliably promoted an increase in the number of female flowers, regardless of environmental conditions.

The flowering of male flowers on trees of the studied *Quercus robur* clones begins with the start of vegetation and is characterized by the solitary placement of male inflorescences, which are grouped into catkins. Typically, the inflorescences are found singly on the shoots, with the number of catkins in the inflorescence ranging from 3 to 7. Occasionally, on complex combined shoots, two inflorescences are observed, one of which has an irregular shape, and the anthers are located on shortened catkins. Observations of the number of male inflorescences in individual *Quercus robur* clones revealed significant differences in their quantity (table 2).

In 2022, the number of male inflorescences on the control trees was, for clones A-1, A-97, A-82, and A-83, 30, 17, 30,6, and 67,3 per tree, respectively, with a significant difference (LSD_{05} = 1,17). Under the influence of a 0,9 % chlorocholine chloride solution, the number of male flowers significantly increased, reaching 46, 27, 47, and 109,2 per tree, respectively. In 2023, observations on the trees of clones A-1 and A-97 showed no significant changes in the number of male flowers between the control and experimental trees, with 40,7 and 39,3 per tree, and 27,2 and 28,3 per tree, respectively. The highest number of male inflorescences was observed in 2024 on the trees of clone A-83 – 63,4 per tree in the control and 80,7 per tree in the stimulated variant (LSD_{05} = 0,96).

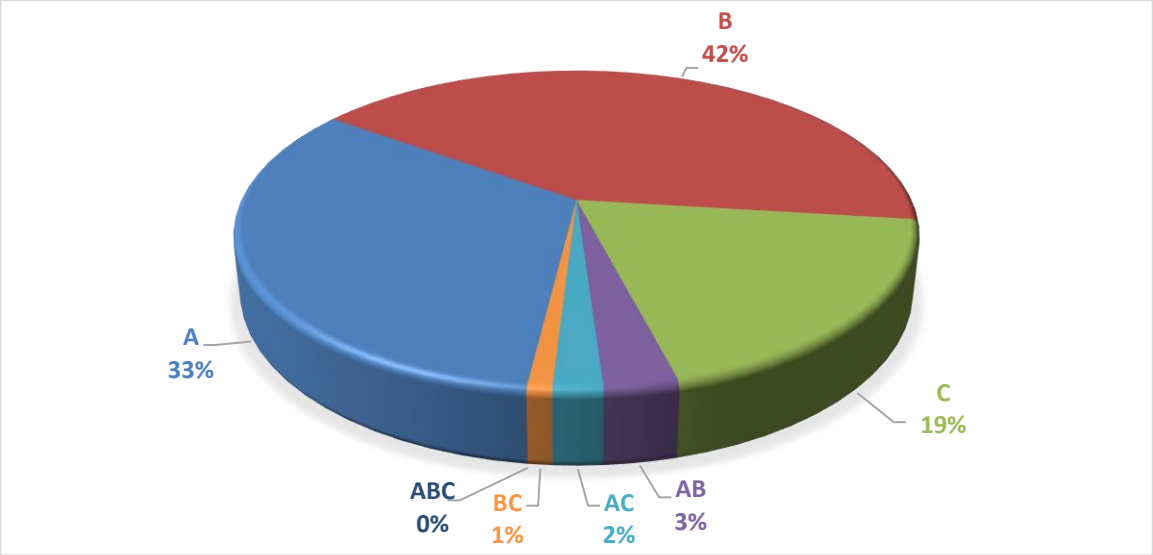

Fig. 1. Female flowering of individual *Quercus robur* clones depending on the studied factors

A – years of study; B – clones; C – concentration of chlorocholine chloride, % in the working solution; AB, AC, BC, ABC – interaction of the studied factors.

Table 2

Male flowering of individual *Quercus robur* clones, flowers per tree

Years of experiment	chlorocholine chloride concentracion, %	Clones			
		A-1	A-97	A-82	A-83
2022	0,9	46,0	27,0	47,0	109,2
	Control	30,0	17,0	30,6	67,3
2023	0,9	39,3	28,3	41,1	61,2
	Control	40,7	27,2	37,3	53,3
2024	0,9	62,6	51,3	59,2	80,7
	Control	49,0	32,4	38,6	63,4
LSD_{05}	A	1,17			
	B	1,35			
	C	0,96			

Multifactorial analysis of variance revealed that the number of male inflorescences significantly changed depending on the year of observation. The highest number was recorded in the conditions preceding the 2024 flowering season – 54,42 per tree, while the lowest was observed in 2023 – 41,0 per tree, and in 2022, it amounted to 46,58 per tree (LSD_{05} = 1,17). Significant changes in the number of male flowers were also noted based on the biological characteristics of the clones. Specifically, the most intense male flowering was observed on trees of clone A-83 – 72,22 per tree, while clone A-97 exhibited the lowest number of male inflorescences throughout the study period – 30,39 per tree. On the trees of clones A-1 and A-82, the number of male inflorescences changed less significantly, reaching 44,61 and 42,11 per tree, respectively (LSD_{05} = 1,35).

The application of a chlorocholine chloride solution significantly increased the number of male inflorescences to 54,25 per tree, while in the control group, this number was 40,42 per tree (LSD_{05} = 0,96). Changes in the number of male inflorescences within the gradation of the studied factors define a significant degree of their impact on the quantitative composition of male flowering (fig. 2). The influence of the year conditions (factor A) that preceded flowering accounted for 8 % of the effect. The number of male inflorescences was most significantly influenced by the biological characteristics of the clone (factor B), accounting for 60 % of the effect. The influence of the chlorocholine chloride solution (factor C) was 12 %. The interaction

between factors AB accounted for 12 %, while the interactions AC, BC, and ABC contributed 2–4 % of the effect.

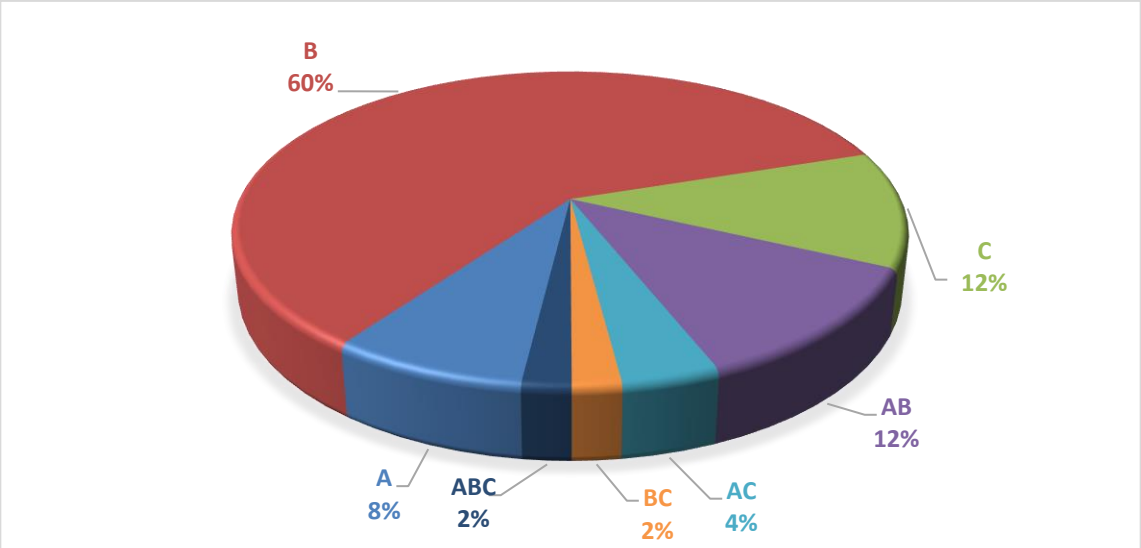

Fig. 2. Male flowering of individual *Quercus robur* clones depending on the studied factors
A – Years of research; B – Clones; C – Chlorocholine chloride concentration, % in working solution; AB, AC, BC, ABC – Interaction of the studied factors.

Thus, the determining factor in the quantitative composition of male flowers in *Quercus robur* is the biological characteristics of the clones, which are significantly influenced by the conditions of the year preceding flowering. The stimulating effect of the aqueous solution of chlorocholine chloride is expressed in a statistically significant increase in the number of male inflorescences throughout the entire period of the study. However, such an effect may vary depending on genetic properties of trees, climate, concentratoin of the solution, timing of application and many other factors which can determine a direction of further scientific search.

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