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RESULTS OF 50-YEAR TESTING OF PROGENIES OF ENGLISH OAK PLUS-TREES AND BEST TREES

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The article presents the results of investigations of 50-year progeny tests of plus-trees and best trees of English oak in the Kharkiv region. The best progenies in terms of growth and quality of stem had been identified in the study. Two progenies, Zhovtnevyy-26 and Trostyanets-2, exceed the control by more than 10% in height and more than 30% in diameter fitting the elite trees criteria. The progenies of 27 trees (51%), including the control, are the fast-growing ones by S. S. Pyatnytskyy evaluation method. The dynamics of progeny growing by diameter, height, and volume of an average tree trunk during the whole period of observation was analyzed. The changes of progenies growth rates and their differentiation in diameter had been noted to be greater than in height. Moderate correlations between diameters of 10 and 20, 10 and 30 years were identified (r = 0.4 and 0.61 respectively). Strong relationship (r = 0.86) is observed for diameters in 45 and 50 years. The importance of such indicators as the stem straightness and the branchless part of the stem was confirmed for the plus trees selection.
Key words: plus trees, progeny, progeny trial, English oak, height, diameter, quality, dynamics.

Introduction. The main problem that hinders the further development of forest tree improving is the lack of long-term test data on plus trees and stands tested by growth and development of their progenies. Modern molecular genetics methods solve many important issues of forest tree improving, but do not allow predicting the expected growth rate and stemming straightness of plus trees progenies [9]. For this reason, creation and investigations of progeny trials are the part of forest tree improving programs of many countries [10, 11]. In this regard, the progeny trial studies continue to be relevant, especially over the age of 20–30 years. According to “The guidelines of forest seed growing” [4], plus trees whose progenies exceed the control more than 10% in height and more than 30% in a trunk diameter at the age up to 20 years old are considered to be the candidates to elite. Plus trees the progenies of which meet these criteria in older progeny trials get an elite category.

It should be noted that the consensus on the progenies testing timing is absent. E. Romeder and H. Shenbah [12] believed that a reliable assessment can be obtained in 20–30 years. V. N. Rone has extended this period to 60–100 years [8]. According to N. I. Davydova [2], progenies in the 1958 year creation trials kept growth rates up to 17 years. She believed it possible to evaluate the genotypes prospectivity by the results of 3–4-year-old progeny growth. In general, the short and long testing is assumed to consider particularly. According to Baliuckas V. et al. [9] selection effect can be evaluated by 7–15-year-old progenies growth and development. An important evaluation criterion is stem quality of plus trees progeny – stem straightness and the absence of faults. In our opinion, only the progenies evaluation based on a complex of indicators provides a possibility to transfer plus trees to the elite category.

However, the value of the progeny trials is not limited to progenies testing. The results of progeny testing give a possibility to analyze the objective laws of characteristic inheritance of forest woody plants and to identify the features of growth and development dynamics at the individual and family levels.

The aim of the work is to summarize the results of the plus and best English oak trees progeny testing in the 50-year old trials in Kharkiv region.

Objects and methods. The studies were carried out in oldest progeny trial of English oak in Ukraine created in 1958 by N. I. Davidova under the direction of S. S. Pyatnytskyi in 98 quarter of Pivdenne Forestry of Kharkiv Forest Research Station of URIFFM. Plot area of 3 hectares is characterized by fertile and loamy soil. The acorns from the 313 open-pollinated progenies of plus and best normal English oak trees selected in 12 forest enterprises in the Kharkiv, Sumy, Donetsk, Mykolayiv, Poltava and Vinnitsa regions were sown during the object creation. The acorns from local provenance bulked sample were sown every 2–3 rows as a control. The investigation was carried out in 2008–2009 when the biological age of plants was 50 years old.

Age of selected trees ranged from 44 to 300 years. This explains the significant differences in their heights (21–32 m) and diameter (25–175 cm). Some trees were distinguished by prominent height and diameter values due to the significant age. It is significant that in the 1960s the plus-trees selection criteria were still under construction. The height of branchless part of stem of some trees was quite small and amounted to 3–5 m. Therefore, according to actual legislation, not all of them can be called "plus" and not all of them later were included in the State Register of plus trees.

For each tree, the survival, DBH, height, and selection category were recorded. The condition of the trees was determined by a modified scales based on oak viability categories and sanitary condition [3, 8]. The data were processed by variation statistics methods with the estimation of the significance of differences between the variants (offspring of certain trees) and the control. The variants indicators were compared to the data from growth course tables [5].

Additionally, we used index of growth rate proposed by S. S. Pyatnitsky [1], which is calculated using the formula (1):

$$\text{Growth Rate} = (D_v / D_c) \times (H_v / H_c) \cdot 100, \tag{1}$$

where D_v is an average diameter of a variant, D_c is an average diameter of the control, H_v is an average height of a variant, and H_c is an average height of the control.

To assess the selection quality of offspring in progeny trials the scale based on the distribution of trees by plant breeding categories within the variant [4] were used:

Group 1 (high-quality progeny) – there are 20% or more trees of I and II breeding categories in the variant;

Group 2 (progeny of satisfactory quality) – there are less than 20% of trees of I and II breeding categories in the variant; furthermore, there are at least 50% of trees of I, II, and III breeding categories;

Group 3 (progeny of poor quality) – there are more than 50% trees of IV selection category in the variant.

Results and Discussion. The methodological imperfection of observed trials is their high initial density (planting scheme is 1.5 × 0.2 m), which resulted in a high loss of growing trees in the early years. In addition, after the inclement winter 1959–1960 a significant number of plants had died. In 33 variants all the plants had died, and 280 variants remained in the experiment. Their survival ranged from 0.8 to 96.8%. 10–20% of trees had survived in almost half of the remaining variants [2]. Progenies from the Rivne region (Polissya) had completely died, and from the Vinnytsya region (Right-bank Steppe) had the worst survival (2% of the progenies). Among the progenies from the Kharkiv region, only 12% had survived, from Poltava region, 9%. However, variants from the steppe region rose above investigated progenies in Left-bank Forest-Steppe due to their high values of survival (the Mykolayiv region – 50% of the progeny had survived and the Donetsk region, 44%). Progeny from the Sumy region was different because of the best survival (70% of the variants). We have observed only 53 of 313 variants, in which more than 5 trees had survived [7].

Averages values of DBH of 50-year-old progenies ranged from 14.4 cm (Mykolayiv-4) to 32.9 cm (Trostyanets-2) with the average value of the control 22.4 cm. Intrafamily coefficient of variation is 14.1%. Only one progeny (Trostyanets-2) rises above the control significantly by the diameter (by 46.8%), and 9 progenies (Mykolayiv-4, -6, Slovyansk-15, -17, Lubny-39, Kremenchug-12, and Trostyanets-3, -5, -16) are significantly behind the control (by 12.4–32.7%). Most of the variants (86%) grow on the control level (Table. 1).

Table 1

Grown indicators of 50-year old progenyes of plus-trees and best trees of English oak

Origin of plus-tree (forest enterprise-number of tree)	Average DBH, sm			Average height, m			Growth class	Average tree volume, m^3
	M	*m*	*t*	*M*	*m*	*t*		
Vinnitsa-1	24.0	1.8	0.8	20.6	1.4	0.7	1	0.460
Vovchansk-10	24.8	1.7	1.2	21.8	1.4	1.6	1	0.534
Zmiyiv-2	23.3	3.5	0.2	19.1	1.0	-0.3	1	0.400
Zmiyiv-9	23.2	4.0	0.2	19.5	1.0	0.0	1	0.405
Zmiyiv-12	20.2	1.6	-1.2	19.4	0.9	-0.1	2	0.309
Zmiyiv-16	19.4	1.4	-1.9	18.0	0.8	-1.1	2	0.270
Mykolayiv-1	20.6	1.0	-1.4	18.5	0.5	-0.9	2	0.290
Mykolayiv-2	21.5	1.5	-0.6	21.7	1.2	1.6	1	0.360
Mykolayiv-4	14.4	0.4	-8.4*	16.0	2.0	-0.7	3	0.139
Mykolayiv-6	19.7	2.2	-1.2	17.3	2.3	-0.3	2	0.270
Mykolayiv-8	20.5	3.1	-0.6	16.0	1.8	-1.8	2	0.275
Slovyansk-1	25.4	2.7	1.0	20.2	0.7	1.5	1	0.500
Slovyansk-8	23.6	1.8	0.6	16.5	3.0	-1.0	1	0.340
Slovyansk-9	21.8	3.0	-0.2	20.2	0.5	2.2*	1	0.380
Slovyansk-10	23.0	1.3	0.3	19.9	0.4	0.7	1	0.416
Slovyansk-11	24.6	2.1	0.9	20.8	0.7	2.3*	1	0.500
Slovyansk-13	21.1	1.3	-0.8	21.0	1.4	0.9	1	0.366
Slovyansk-15	18.1	2.0	-2.0*	17.8	1.3	-1.2	2	0.230
Slovyansk-16	22.4	2.6	0.0	19.8	1.1	0.2	1	0.390
Slovyansk-17	18.5	1.1	-2.9*	17.6	0.9	-1.9	2	0.230
Slovyansk-20	24.1	1.6	0.9	20.2	0.8	0.8	1	0.470
Slovyansk-21	17.6	2.5	-1.8	20.5	0.6	1.4	2	0.260
Zhovtnevyy-5	23.4	1.7	0.5	21.4	0.6	2.7*	1	0.450
Zhovtnevyy-12	20.3	3.0	-0.7	16.0	1.3	-1.4	2	0.260
Zhovtnevyy-18	22.2	1.5	-0.1	19.6	0.6	0.9	1	0.375
Zhovtnevyy-20	24.0	2.0	0.7	21.8	1.0	2.2*	1	0.490
Zhovtnevyy-25	19.0	3.1	-1.1	20.0	0.8	1.0	2	0.288
Zhovtnevyy-26	31.9	9.5	1.0	22.5	1.8	1.0	1	0.870
Lubny-4	23.7	0.5	1.2	20.0	0.0	3.2*	1	0.430
Lubny-7	24.3	1.2	1.2	20.5	0.5	2.7*	1	0.450
Lubny-35	22.4	1.0	0.0	18.9	0.8	-0.1	1	0.360
Lubny-39	19.3	0.9	-2.5*	19.2	1.1	0.1	2	0.276
Lubny-41	19.7	1.1	-1.9	19.7	0.6	0.2	2	0.285
Lubny-43	21.5	4.2	-0.2	19.2	0.6	-0.4	1	0.340
Lubny-44	20.9	3.8	-0.4	20.3	1.7	0.5	1	0.350
Lubny-55	21.6	1.8	-0.4	20.7	0.9	1.5	1	0.360
Lubny-57	22.4	1.8	0.0	21.0	0.9	1.6	1	0.400
Kremenchug-12	19.0	1.1	-2.5*	19.9	0.9	0.8	2	0.288
Kremenchug-14	19.0	2.6	-1.3	17.4	1.7	-0.5	2	0.255
Trostyanets-2	32.9	3.4	3.0*	22.3	1.1	2.1*	1	0.910
Trostyanets-3	16.8	1.0	-4.2*	18.9	0.9	-0.1	2	0.222
Trostyanets-4	20.2	1.3	-1.5	20.5	0.7	1.8	2	0.325
Trostyanets-5	15.2	1.2	-5.0*	19.6	0.2	1.7	2	0.180
Trostyanets-6	23.2	1.6	0.4	21.1	1.1	1.4	1	0.420
Trostyanets-8	21.9	2.5	-0.2	19.8	1.7	0.2	1	0.380
Trostyanets-9	20.5	2.4	-0.8	20.3	1.5	0.5	1	0.325
Trostyanets-11	22.6	1.4	0.1	20.7	0.7	2.3*	1	0.390
Trostyanets-12	21.5	2.5	-0.3	19.8	0.9	0.7	1	0.365
Trostyanets-13	24.2	2.2	0.7	19.8	1.8	0.2	1	0.460
Trostyanets-15	19.9	1.6	-1.4	21.7	0.5	4.4*	2	0.340
Trostyanets-16	18.6	1.3	-2.5*	21.2	0.6	2.9*	2	0.280
Trostyanets-18	24.1	2.1	0.7	21.6	0.6	4.0*	1	0.480
Trostyanets-19	20.1	1.8	-1.1	19.9	1.6	0.2	2	0.317
Control	22.4	0.9	×	19.5	0.5	×	1	0.370

Note. The level of significance for *t* = 95%;
* – significant exceedance (lag)

Average height of the progenies in 50 years was from 16.0 m (Mykolayiv-8, Zhovtnevyy-12) to 22.3 m (Trostyanets-2) with a height of control amounted to 19.5 m. Variation rate among the families was 7.2%. 11 progenies (Slovyansk-9, -11 Zhovtnevyy-5, -20, Lubny-4, -7, Trostyanets-2, -11, -15, -16, -18) exeed significantly the control in height (by 5.2–17.0%). Most of the progenies (77%) grow on the level of control (Table. 1). Only two of them (Zhovtnevyy-26 and Trostyanets-2) exceed the control more than 10% by the height and more than 30% by diameter, and only the plus-trees of these progeny meet the criteria of elite trees. Evaluating the progenies for growth class, we see that 87.7% of them (as well as the control) are characterized by growth class 1. So, the slight excess over the control is primarily due to high productivity of the control itself.

The indicator of stem volume of an average tree is not often used to evaluate the growth intensity of plus-tree progenies, while it may allow evaluating the productivity of the progeny in the best way. Indicators of an average tree volume of studied plus-trees progenies ranged from 0.139 to 0.910 m^3 in 50 years (Table. 1). 23 progenies rose above the control by 28.8% on average (Fig. 1) and 30 progenies were behind by 21.1% on average. The best were Slovyansk-1, -11, Volchansk-10, Zhovtnevyy-26 and Trostyanets-2, the exceedance of the control ranged from 35.1 to 145.9%. Comparison of the variants values with table ones [5] reveals their significant excess which ranged from 14.4 to 278.4%; control exceeds the tabular data on 53.9%.

Calculation of growth rate allowed selecting 27 fast-growing progenies, that is 51% of all observed ones. It is interesting to note that 10 of them were selected by N. I. Davidova in the age of 11 years as those characterized by intensive stable growth in height and diameter and high frost resistance [2]. Thus, 37% of the progenies retain these properties up to 50 years of age.

The stems quality (their straightness and absence of defects) is as important indicator as the rate of growth. Quality evaluation of plus-trees 50-year old progenies has shown that the normal trees dominate in most variants. The trees of I and II selection categories were absent in 28 variants. Their share in the remaining progenies was from 5.9 (Trostyanets-13) to 50.0% (Trostyanets-19) (Fig. 1), with 20.4% for the control. All three stem quality groups are represented in the progeny trials. The first group (high stem quality) included 17 variants (32% of progenies) – Trostyanets-2, -4, -6, -11, -12, -15, -16, -18, -19; Slovyansk-8, -11, -13, -16; Zhovtnevyy-18, Mykolayiv-2, 8; Vinnytsya-1). The second group (satisfactory stem quality) included 17 progenies – Trostyanets-5, -9, -13; Slovyansk-1, -10, -17, -20, -21; Zmiyiv-12, -16; Mykolayiv-1; Zhovtnevyy- 5, -12, -25, -26; Lubny-7, -57. The other 19 variants were characterized by unsatisfactory stem quality. Fig. 1 illustrates that families with high growing intensity are not always characterized by high stem quality and vice versa. For example, the extremely high productive variant Zhovtnevyy-26 has stems of satisfactory quality.

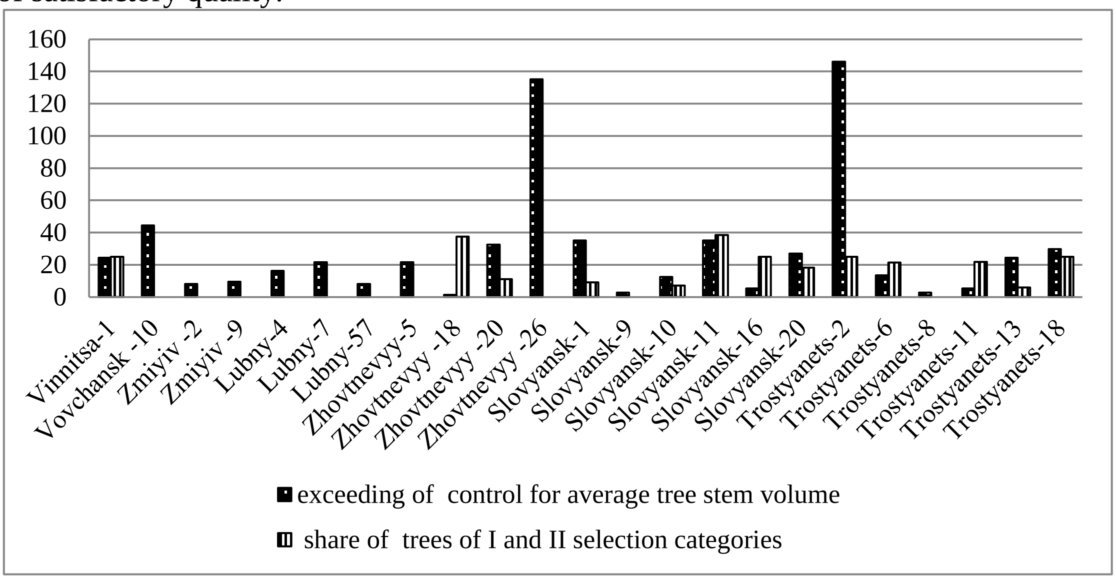

Fig. 1 – Progenies characteristics by exceeding the control by an average tree stem volume and share of trees of I and II selection categories (%)

Correlation analysis showed the moderate direct relationship between the height of the branchless part of parent trees and the share of trees of I and II selection categories in a progeny ($r = 0.33$).

Analysing the age dynamics of progeny's average height, it is difficult to detect certain patterns. There are quite a number of variants that were leaders in 5–10 years old and had reduced the growth rate to 50 years of age. Fig. 2 shows the growth dynamics by height of three the best and three the worst variants by results of the latest observation. As one can see, one of the best variants in the 2009 – Trostyanets-2 – was among slow growers by height at a young age, and three variants of Mykolayiv origin which have the lowest height now, grew up in the early stages at the control level. Correlation analysis revealed no significant relationships between growth rates by height in younger and older age. There is only moderate correlation between the height in the age of 45 and 50 years ($r = 0.46$).

A completely different situation is observed in the analysis of progenies' growth dynamics by stem diameter. The most slowly growing variants were characterized by weak growth intensity at a young age also, and some fast-growing variants rose above the control as early as in 10 years. An exception to this is the variant Trostyanets-2, which is being slowly growth in 10 years, significantly increased the rate of growth after 30 years and was the leader in 50 years. Correlation analysis have showed moderate dependence between diameters in 10 and 20, and 10 and 30 years ($r = 0.4$ and 0.61, respectively). A close relationship ($r = 0.86$) is observed between diameters in 45 and 50 years of age.

The different inherited rates of the progenies' growth may serve as a possible explanation of a change in their relative rank position. The different nature of height differentiation process of the trees (and thus variants) because of excessive density of the trial at a young age may be another explanation for the changes in the ranks of height growth.

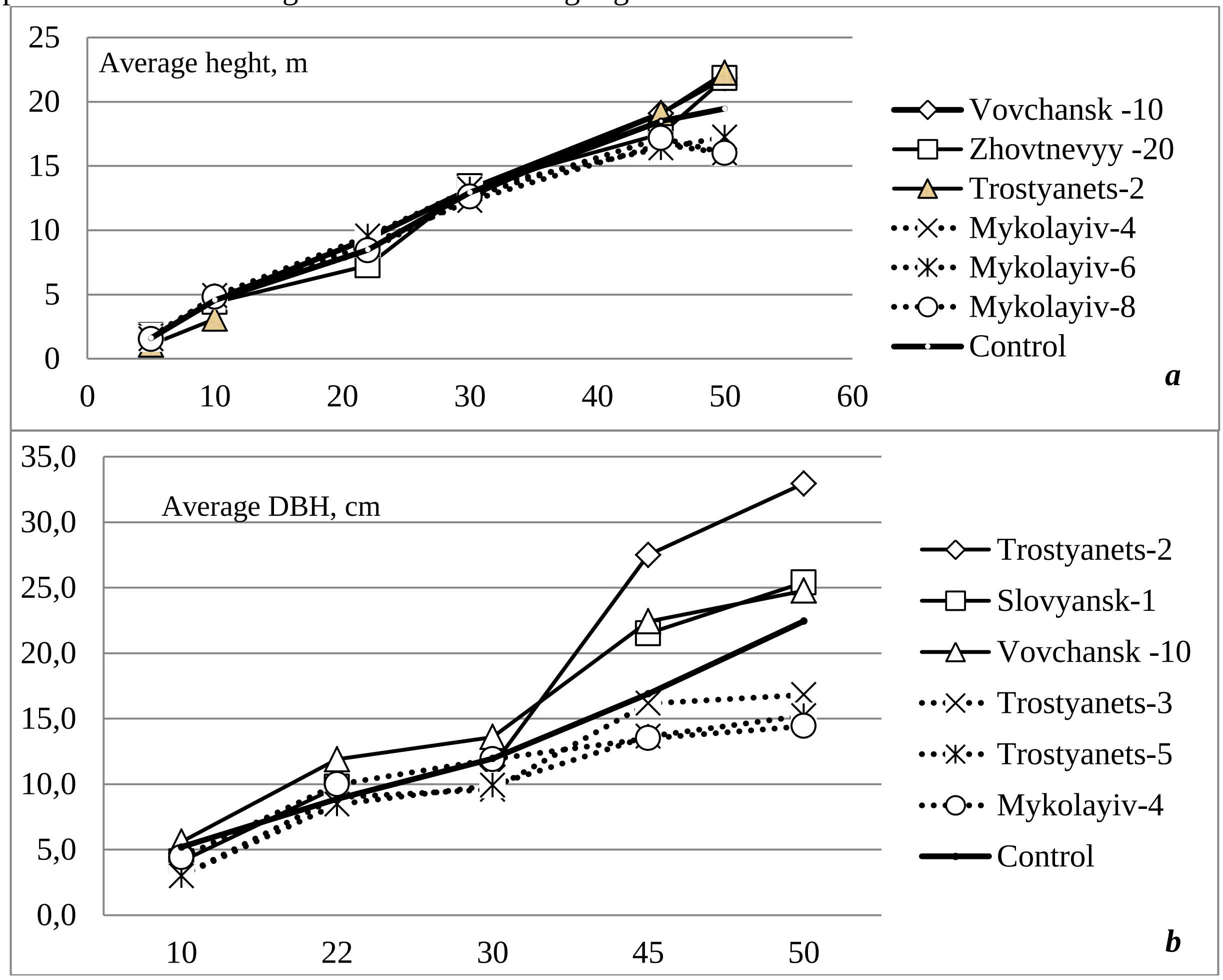

Fig. 2 – Dynamics of the average height (*a*) and diameter (*b*) of the best and worst progenies

Fig. 3 presents the dynamics of the average values of diameter, height, and volume of the average tree in progenies by forest enterprises (conditioned populations). There are slight differences between the progeny groups in height. This is confirmed by the low variation coefficients between the height values of families at different ages (5.3–7.2%). The largest variation was observed in 50 years. Somewhat larger differences between average indicators of progenies of certain forest enterprises were marked for diameter and average tree stem volume. The variation coefficients at different ages are 13.0–17.5% for the diameter and 13.5–15.3% for the volume.

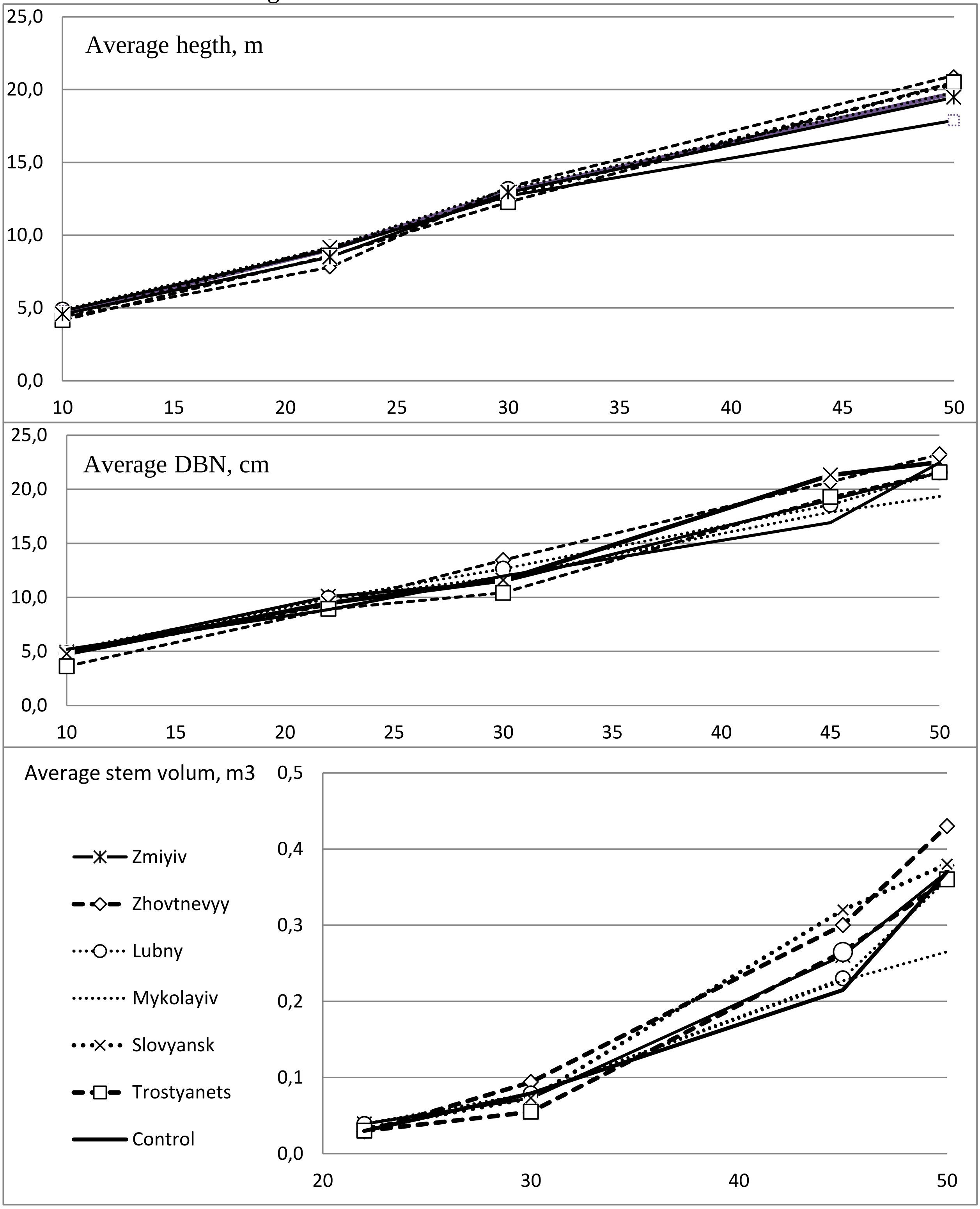

Fig. 3 – Dynamics of progenies' average height, DBN and stem volume by Forest

All three graphs in Fig. 3 show intensive growth of progenies from Mykolayiv enterprise in the early stages at the control level and their growth rate reduction in 50 years of age. Variants from Trostyanets, on the contrary, had a slowly growth in the early stages and were some of the best by height in 50 years. Their average diameter and volume are on the control level. The increase in the growth rate has been noted for the families from Slovyansk and Zhovtnevyy Forestries also. Thus, the best plus trees progenies in terms of growth intensity were selected in Trostyanets (the Sumy region), Slovyansk (the Donetsk region), and Zhovtnevyy (the Kharkiv region) Forestries.

The average values of share of trees of I and II selection categories among progenies groups by forestry enterprises ranged from 0 (Lubny Forestry) to 21.0% (Trostyanets Forestry). The high stem quality of the control (Danilovska population) (the share of trees of I and II selection categories is 20.4%) and the progenies group of Slovyansk origin (15.8% of the trees, on average, are of I and II selection categories) should be noted also. The shares for other populations are as follows: Zmiyiv Forestry – 2.3%, Zhovtnevyy Forestry – 8.1%, and Mykolayiv Forestry – 9.4%.

As mentioned above, not all of best trees selected in 1957 were included in the State Register of plus trees. Accordingly, the observed progenies were divided into three groups: I – the progenies of trees which had not been included in the State Register in 1971; II – the progenies of trees which had been included in the State Register in 1971, but have not been included in the current State Register for a variety of reasons; and III – the progenies of trees, which have been included in the current State Register (true plus trees). Comparing these groups by grown intensity and stem quality showed that 42.9% of progenies from the I group can be attributed to the fast-growing ones. This group also includes the most of progenies, which are significantly falling behind the control and those that are characterized by satisfactory and unsatisfactory quality (on average, 10% of the trees are of I and II categories of selection). The share of fast-growing variants is 50% in the progenies of group II. The trunks quality is close to that of I group – on average, 10.4% of trees are of I and II selection categories. The group III of progenies deserves special attention. 70% of the progenies are the fast-growing ones. Qualitative indicators of the group are also the best. The average share of trees of I and II selection categories is 16%.

Conclusions

1. The progenies of the plus and best oak trees from Sumy (Left-bank Steppe), Mykolayiv and Donetsk (Step) have the best survival ability in Left-bank Forest-Steppe conditions in 50 years; the progenies from the Rivne (Polesie) and Vinnitsa regions (Right-bank Forest Steppe) have the worst one.

2. Among the 53 examined progenies, 27 (51%) are the fastest growing ones. 7 progenies (Slovyansk-9, 11, Trostyanets-2, 11, 15, 16, 18) are noted for the best growth and quality. 4 progenies significantly rise over the control by height, but have satisfactory stem quality. 11 progenies are characterized by high stem quality and control-level height and diameter. Two progenies (Zhovtnevyy-26 and Trostyanets-2) exceed the control by more than 10% in height and more than 30% in diameter, so the parent (plus) trees of these progenies match the elite tree selection criteria. These trees can be recommended for creating the clonal seed orchard of second level.

3. 23 of 53 progenies exceed, on average, the control by stem volume of average tree by 28.8%. Slovyansk-1, -11, Volchansk-10, Zhovtnevyy-26, and Trostyanets-2 were the best on them. It should be noted that the control had a relatively high growth rate.

4. Among progenies of best trees, which have not been included in the State Register of plus trees, 42.9% are the fast-growing, but their stem quality is satisfactory. Among the progenies of plus trees included in the current State Register, 70% are fast-growing, and 45% are of high stem quality.

5. The moderate positive correlation between a branchless part of stem of maternal trees and a share of tree of I and II selection categories of progenies has been detected ($r = 0.33$) suggesting the usefulness of branchless part of stem in selecting oak plus trees. Trees with small branchless part of

stem should be rejected in selecting plus trees by productivity. Share of branchless part of stem should be at least 40%.

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ПІДСУМКИ 50-РІЧНИХ ВИПРОБУВАНЬ ПОТОМСТВ ПЛЮСОВИХ ТА КРАЩИХ ДЕРЕВ ДУБА ЗВИЧАЙНОГО

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У статті подано результати досліджень 50-річних випробних культур плюсових та кращих дерев дуба звичайного в Харківській області. Визначено потомства, які є кращими за ростом та якістю стовбурів. Два потомства, Жовтневий-26 та Тростянець-2, перевищують контроль більше ніж на 10 % за висотою, більше ніж на 30 % за діаметром і відповідають критеріям елітних дерев. Потомства 27 дерев (51 %), в тому числі – контроль, визнано швидкорослими за методикою С. С. П'ятницького. Проаналізовано динаміку росту потомств за діаметром, висотою та об'ємом стовбура середнього дерева протягом усього періоду спостережень. Відмічено більші відмінності у темпах росту потомств та диференціації за діаметром, ніж за висотою. Виявлено кореляційні зв'язки середньої сили між діаметрами у 10 і 20 та у 10 і 30 років (r = 0,4; r = 0,61 відповідно). Між діаметрами у 45 і 50 років простежується тісний зв'язок (r = 0,86). Підтверджено важливість таких показників, як прямизна стовбура та очищуваність від сучків, для відбору плюсових дерев.

Ключові слова: плюсове дерево, потомство, випробні культури, дуб звичайний, висота, діаметр, якість, динаміка.

Лось С.А.

ИТОГИ 50-ЛЕТНИХ ИСПЫТАНИЙ ПОТОМСТВ ПЛЮСОВЫХ И ЛУЧШИХ ДЕРЕВЬЕВ ДУБА ОБЫКНОВЕННОГО

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В статье представлены результаты исследований 50-летних испытательных культур плюсовых и лучших деревьев дуба обыкновенного в Харьковской области. Определены потомства, лучшие по росту и качеству стволов. Два потомства, Жовтневый-26 и Тростянец-2, превышают контроль более чем на 10 % по высоте и больше чем на 30 % по диаметру и соответствуют критериям элитных деревьев. Потомства 27 деревьев (51 %), в том числе контроль, признаны быстрорастущими при оценке по методике С. С. Пятницкого.

Проанализирована динамика роста потомств по диаметру, высоте и объему ствола среднего дерева в течение всего периода наблюдений. Отмечены большие различия темпов роста потомств и их дифференциации по диаметру, чем по высоте. Выявлены корреляционные связи средней силы между диаметрами в 10 и 20, в 10 и 30 лет (r = 0,4 и r = 0,61 соответственно). Между диаметрами в 45 и 50 лет прослеживается тесная связь (r = 0,86). Подтверждена важность таких показателей, как прямизна ствола и очищаемость от сучков, при отборе плюсовых деревьев.

Ключевые слова: плюсовое дерево, потомство, испытательные культуры, дуб обыкновенный, высота, диаметр, качество, динамика.

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