Environmental and genetic assessment of different versions of crossing of maple and elm in the conditions of the southeast of European part Russian Federation

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Annotation. At present, in world science and practice, hybridization is considered to be one of the promising areas, which allows obtaining material with planned and properties. There was a need to use modern methods of mathematical processing to evaluate the prospects of some variants of crossing, dividing the total phenotypic variability into genetic and ecological. The results suggest the need to continue work on hybridization, taking into account the results obtained over the past 50 years of work on breeding, seed production and for crosses to use created from the offspring of plus trees in the region of maple, elm, which have been tested by natural selection in artificial and natural plantations of the South-East of the European part of Russia in recent decades. For reproduction of the obtained high-value breeding material to use breeding greenhouses and technology «in vitro». We believe that population selection can also be promising, and both natural and artificial populations can be used, in the biocenosis of which two or three seed generations of this species are present. At the final stage, it is necessary to create hybrid forest seed plantations from the material obtained.

1. Introduction
As a result of global warming, continental enhancement and aridization of the territory of the southeast of the European part of Russia, it is necessary to identify sustainable, durable and productive species and forms of woody vegetation in given soil and climatic conditions [1, 2]. European part of Russia is very poor and is represented by native shrubs, pedunculate oak (Quercus robur L), Tatar maple (Acer tataricum L), bark (Ulmus carpinifolia Rupp ex Suckow), aspen (Populus tremula L) and some other species and order to increase the durability and sustainability of plantations, in 1939, under the direction of A V Albensky, hybridization of tree species was initiated at the Kamshin station of the Scientific Research Center [3, 4]. To date, at the the Kamshin station of the Scientific Research Center, there are about 30 hectares of uterine plantings from previously selected hybrid plants. In 2003 - 2007 in the nursery of the station, seedlings were grown from the studied variants of crossing. Within each studied genus, the variability of the height of seedlings is different. The height of 2 000 elm seedlings and 1 250 maple seedlings was studied.

In the course of the work, partial means characterizing the type of crossing were calculated, since the origin and types of crossing for each of the I-VII groups were known. This made it possible to divide the total phenotypic variability into components determined genetically and ecologically. The genetic factor received the name - "A". The second factor that can be identified is eco-climatic - “B”,...
which has a complex nature, depending on soil, climate, plant placement, moisture supply, and also includes genetic differences between mother trees, the fruits of which were used for experiments.

Among the seedlings grown from the harvest each year, we studied samples of seedlings for each type of crossing growing in different parts of the same nursery. The effect of microecological differences within the range of experience on the growth and development of seedlings was considered established. From several hundred seedlings for each variant of the experiment, 30–50 pieces were randomly selected, in which the height was measured. For each sample, there were heights fluctuations that depended on the unaccounted random factor, which received the name “D”. The separation, the existing phenotypic variability according to factors “A”, “B” and “D” made it possible to organize a hierarchical dispersion analysis taking into account the subordination of controlled factors.

2. Materials and research methods

The method for calculating hierarchical dispersion complexes is described in detail in many papers [4-6]. For the study took 5 types of crossing:

- I - Elm squat X Elm smooth - x = 43.8, n = 570;
- II - Elm squat X Elm smooth X Elm smooth - x = 38.8, n = 387;
- III - Elm squat X Elm leafy - x = 41.9, n = 550;
- IV - Elm squat X Elm leaf X Elm leafy - x = 27.3, n = 183;
- V - Elm squat X Elm squat - x = 27.8, n = 180.

For each type of crossing, the height of one-year hybrid seedlings was determined. The measurement results are presented in Table 1.

| A. Type of crossing | B. Ecogenoclimatic replications | C. Ecological replications |
|---------------------|---------------------------------|---------------------------|
|                     | 2003  | 2004  | 2005  | 2006  | 2007  | 2003  | 2004  | 2005  | 2006  | 2007  |
| I                   | 53.4  | 31.0  | 67.4  | 26.8  | 45.0  | 54.4  | 61.2  | 31.4  | 37.4  | 60.6  | 85.9  | 36.1  | 15.1  | 37.8  | 39.6  |
|                     | 51.2  | 30.1  | 73.4  | 24.5  | 48.3  | 52.4  | 60.5  | 31.1  | 23.9  | 67.1  | 55.8  | 34.3  | 21.7  | 47.7  | 49.7  |
| II                  | 71.2  | 8.2   | 75.2  | 25.2  | 35.5  | 78.4  | 82.8  | 8.2   | 9.4   | 35.5  | 37.4  | 21.5  | 29.3  | 41.8  | 37.4  |
|                     | 59.5  | 9.6   | 58.8  | 29.2  | 44.7  | 63.9  | 68.2  | 9.8   | 10.2  | 38.1  | 39.4  | 25.0  | 32.5  | 36.9  | 27.2  |
| III                 | 74.9  | 28.1  | 42.5  | 22.6  | 40.2  | 79.4  | 56.1  | 16.5  | 26.8  | 34.9  | 76.5  | 20.9  | 22.3  | 48.2  | 44.6  |
|                     | 62.7  | 25.3  | 47.9  | 27.4  | 42.0  | 60.7  | 54.6  | 28.2  | 31.2  | 38.7  | 54.1  | 33.1  | 28.3  | 30.5  | 44.8  |
| IV                  | 64.9  | 7.3   | 42.6  | 22.0  | 39.0  | 64.9  | 54.8  | 7.3   | 8.9   | 42.6  | 44.8  | 22.0  | 26.7  | 39.0  | 41.7  |
| V                   | 48.3  | 10.3  | 46.7  | 28.6  | 21.2  | 48.3  | 44.8  | 10.3  | 11.6  | 36.7  | 38.9  | 28.6  | 32.4  | 19.1  | 23.5  |
| VI                  | 33.1  | 34.8  | 35.4  | 32.5  | 48.0  | 48.4  | 17.9  | 31.8  | 37.9  | 35.4  | 367.5  | 35.2  | 39.6  | 48.2  | 47.8  |
| VII                 | 71.4  | 32.6  | 34.8  | 38.4  | 46.2  | 70.7  | 81.9  | 31.7  | 34.4  | 38.4  | 40.1  | 45.3  | 48.4  | 4.4   | 61.6  |
|                     | 39.4  | 47.6  | 48.6  | 49.2  | 54.5  | 36.9  | 53.9  | 53.7  | 33.9  | 40.5  | 52.0  | 47.8  | 50.4  | 68.2  | 55.4  |
|                     | 48.6  | 51.2  | 54.4  | 42.5  | 46.7  | 42.4  | 61.7  | 50.8  | 51.5  | 55.4  | 56.8  | 41.9  | 45.6  | 54.2  | 42.1  |
|                     | 51.9  | 52.1  | 58.8  | 13.0  | 56.7  | 29.7  | 53.9  | 67.4  | 72.2  | 75.9  | 66.8  | 43.3  | 37.6  | 55.2  | 44.4  |

As the data in Table 1 show, seedlings of cross-breeding options were superior in height. When pollinating a hybrid with the pollen of the paternal species — II and IV variant, the height of the growth of the offspring significantly decreased. There was a significant impact on the growth of seedlings of crop quality, which depends on the weather, pests, etc. The variability in height reached 200-300%, and to associate the success of height growth with climatic conditions is not feasible, since in some years, the progeny of the queen mothers of I and II are crossed, in the others III and IV. A strong impact of environmental conditions was noted, the heights of seedlings of the same origin grown in different areas of the nursery differed markedly.

The heights of seedlings of the same origin, grown on different beds in the same year, differ markedly.
3. Results and discussion

A comparative analysis of the results of variance analysis of the variability of the height of hybrid elm seedlings (Table 2) made it possible to establish the absence of the influence of crossing types on the height of elm seedlings. However, the influence of other factors turned out to be significant. Basically, the growth of seedlings was influenced by factor “B” of 67.7%, as well as “C” with a share of influence of 13.8%, only 17% belonged to random factors.

Table 2. Variability of the height of hybrid elm seedlings according to the results of analysis of variance.

| Variability between | types of crossing | ecogenoclimatic replications | ecological replications | random factor |
|---------------------|-------------------|------------------------------|------------------------|---------------|
| Sum of squared deviations | 39497.7 | 504590.2 | 71560.8 | 145748.8 |
| The number of degrees of freedom | 4 | 19 | 32 | 1814 |
| Average square | 9874.4 | 26557.4 | 2236.3 | 80.4 |
| Empirical F values | 0.37 | 11.88 | 27.83 | — |
| Table Values F | 7.2-2.9 | 3.5-1.9 | 2.0-1.5 | — |
| Reliability | 0.0 | 0.999 | 0.999 | — |

Analysis of variability in the height of hybrid and maple seedlings by two types of crossing (Table 1)

VI — Maple X Maple Ash (control)
\[ x = 39.0 \text{ cm}, \ n = 280 \]

VII - white-leaved maple X Norway maple, I - III generation
\[ x = 53.5 \text{ cm}, \ n = 951 \]

showed that hybrid seedlings in the years of study surpassed the control.

Studies have revealed the absence of the influence of the ecogenoclimatic factor, and the environmental components turned out to be reliable with a high probability of 0.99 and 0.999 (Table 3).

Table 3. Variability in height of hybrid maple seedlings.

| Variability between | types of crossing | ecogenoclimatic replications | ecological replications | random factor |
|---------------------|-------------------|------------------------------|------------------------|---------------|
| Sum of squares | 45407.0 | 30289.5 | 128327.2 | 206706.5 |
| The number of degrees of freedom | 1 | 8 | 26 | 1195 |
| Average square | 45407.0 | 3786.2 | 4743.4 | 173.0 |
| Empirical F values | 12.0 | 0.8 | 27.4 | — |
| Table Values F | 25.4 – 5.3 | 4.8 – 2.3 | 2.0-1.5 | — |
| Reliability | 0.99 | — | 0.999 | — |

Of the total phenotypic variability of seedlings in height, the factor A is 23.3, C - 33.4, D - 43.3%. 

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It should be noted that analysis of variance does not replace deep genetic analysis, but only establishes the fact of the difference between the different components of the overall phenotypic variability of the breeding material. The absence of the established type of crossing can be explained by the heterogeneity of both genetic and seed material obtained from mother trees of breeding sites in different climatic conditions years. It can be noted that the abundantly fruiting mother plants, which are about 30%, give the main part of seed production of the hybrid plot, but are inferior to other trees in the height of their seed offspring.

By the genus of maple, the reliable influence of the type of crossing is explained similarly, with the only difference during the observation period, which lasted 5 years, the offspring of the same uterine trees of hybrids with annual and abundant fruiting was studied. To study the maple hybrids, a group of the best trees exceeding control was selected. Consequently, the genetic uniformity of seed in the evaluation of hybrids is the main condition for a reliable assessment.

The properties of hybrid trees of the second and subsequent generations, derived from free, uncontrolled crossing, will differ from the properties of the first generation hybrids by their shift towards the parent (maternal) species.

In hybrid seedlings and initial species of elm, the variability of height by 2/3 (68.7%) is due to the influence of climatic factors. In 2004—2006 weather conditions adversely affected seed quality, and in 2003 and 2005 were quite favorable for pollination, fruit set and quality seed production.

The influence of the environmental factor, which characterizes the difference in the growth conditions of seedlings in different beds, or ecological backgrounds, is statistically significant. The influence of this factor on height is 13.3% for elm, maple - 33.4%. In some approximation, these proportions of influence reflect the reaction rate of various breeds, their requirements for soil fertility. Tolerance to this factor is higher in elm, which can successfully grow on soil differences.

The share of uncontrolled variability accounts for from 13 to 43%. The results obtained during the analysis of variance made it possible to study the mechanism of variability in the height of seedlings of the most important quantitative trait, which is the result of a combination of the most complex evolutionary, genetic and biological factors. Unfortunately, it was not possible to establish the presence of a significant effect of heterosis, which, according to literary data, is much lower in woody plants than in grassy plants [7, 8]. In view of the results obtained, it is necessary to return to the organization of work on hybridization among the introduced tree species used in protective afforestation.

Hybridization work should be carried out on selective forest seed plantations created from biotypes that have passed over the course of at least 30-40 years a long process of natural selection and showing durability and productivity against the background of extreme droughts and frost [9, 10].

We believe that population selection can also be promising, and both natural and artificial populations can be used, in which two or three seed generations of this species are present in the biocinosis.

4. Conclusion

1. By hierarchical analysis of variance, it was found that in elm seedlings climatic factors have a greater effect on variability than crossing options. Maple has a greater influence of genetic (mating) than climatic factors.

The environmental factor depends on the requirements for soil fertility, growing conditions and varied from 13.8 to 57.3%.

2. The obtained results indicate the need to continue work on hybridization, taking into account the results obtained during the last 50 years of breeding, seed production and for carrying out crossings, use seedling plantations of maple, elm, and ash trees from the offspring of plus trees in the region, which were tested by natural selection in artificial and natural plantations of the southeast of the European part of Russia over the past decades.
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