Estimation of genetic gain in progeny trial of pedunculate oak (Quercus robur L.)

Vidaković, Mirko; Kajba, Davorin; Bogdan, Saša; Podnar, Vlatko; Bećarević, Josip

M. Vidaković, et al.: Estimation of genetic gain in a progeny trial of pedunculate oak (*Quercus robur* L.)
Glas. šum. pokuse 37: 375–381, Zagreb, 2000.

UDK 630*165 (Quercus robur L.)

ESTIMATION OF GENETIC GAIN IN A PROGENY TRIAL OF PEDUNCULATE OAK (*QUERCUS ROBUR* L.)

MIRKO VIDAKOVIĆ[1], DAVORIN KAJBA[2], SAŠA BOGDAN[2], VLATKO PODNAR[3], JOSIP BEĆAREVIĆ[3]

[1]Croatian Academy of Sciences and Arts, Zrinski trg 11, HR-10000 Zagreb
[2] Department of Forest Genetics and Dendrology, Faculty of Forestry, University of Zagreb, Svetošimunska 25, HR-10000 Zagreb
[3] Forest District Našice, Strossmayerova 1, HR-34500 Našice

In the central Podravina seed region (Croatia), phenotypic selection of pedunculate oak (*Quercus robur* L.) was made and an experimental clone seed orchard with 40 clones was founded. During 1992, a test consisting of 21 half-sib progenies was established. The progeny trial involved the families from the selected mother trees included in the clonal seed orchards and belonging to the central Drava River seed region, with two populations (Donji Miholjac and Slatina). Total heights were measured at the plantation age of 2 + 3, 2 + 4, 2 + 6 and 2 + 7 years. An estimation of genetic parameters (heritability and genetic gain) was made for in total 21 half-sib progenies, as well as separately for half-sib progenies from each population.

Key words: *Quercus robur*, progeny trial, genetic parameters.

INTRODUCTION

In the Republic of Croatia the pedunculate oak occupies large areas as one of the most important and the most valuable forest tree species. Although the pedunculate oak forests are of high quality, efforts are being made to improve their management, especially due to problems of natural regeneration manifested in the last few decades. The acorn yield is no longer regular, and for a high acorn yield ten years or even more of waiting is required. For this reason there are problems not only in natural regeneration, but also in the filling up of the partly naturally regenerated areas as well as in the afforestation of clearings. To avoid or to reduce this problem, the raising of clonal seed orchards started to enable the control of production concerning both the genetic quality and the acorn yield (Vidaković

1996). Thus, the half-sib progeny trial of pedunculate oak was established with plants raised from selected open-pollinated plus trees, for the purpose of determining the genetic quality of our mother trees.

To ensure the maximum possible objectivity in the genetic gain estimation for the generative progenies grown in the future clonal seed orchard, it is necessary to test the selected plus trees by genotype. On the basis of the growth of their progenies, an estimation as objective as possible of their heritability (h^2) would be made and then, based on their general combining ability (GCA), the secondary selection of mothers in the established clonal seed orchard would be made.

The progeny trial involved the families from the selected mother trees included in the clonal seed orchards and belonging to the central Drava River seed region, with two populations (Donji Miholjac and Slatina).

MATERIAL AND METHODS

In 1988, the work on the establishment of an experimental pedunculate oak clonal seed orchard started in the Forest District Našice. As a part of this work, in 1989, seeds from the selected plus trees were harvested, and in the following years the plants, the half-sib progenies of open-pollinated plus trees, were grown for the purpose of the establishment of a plus tree half-sib progeny trial. The percentage of germinated acorns ranged between 20 and 73 %, the average for all samples being 50.3 % (Vidaković et al. 1992).

Of 40 selected plus trees, aged from 75 to 120 years, twenty-one yielded enough acorns from which plants for the establishment of the field experiment were grown. The amount of acorns borne by another six plus trees was so low that we could not grow a sufficient number of plants, while the remaining 13 plus trees did not fructify at all.

The experiment was established in spring 1992, in the forest unit Krndija, in the locality of Vukojevački Šikar, with plants aged 2 + 0 years. In addition to the acorns from plus trees, acorns were also harvested as a random sample from the Donji Miholjac (DM) and Slatina (S) stands, from where the selected plus trees come, too (Vidaković 1996).

The experiment was established in a random plant distribution with a total of 25 treatments in five blocks, with four plants in a plot. Heights were measured at the plantation age of 2 + 3, 2 + 4, 2 + 6 and 2 + 7 years.

The estimation of genetic parameters (heritability and genetic gain) was made for in total 21 half-sib progenies, as well as separately for half-sib progenies from each population (eight from the Donji Miholjac population and thirteen from the Slatina population).

The statistical model is as follows:

$$Y_{ijk} = \mu + Block_i + Female_j + BF_{ij} + \varepsilon_{ijk}$$

where Y_{ijk} is the k^{th} tree of the j^{th} female in the i^{th} block, μ is the experiment mean, $block_i$ is the i^{th} block, $female_j$ is the j^{th} female, BF is the interaction of the i^{th} block and j^{th} female, ε_{ijk} is random error.

Formulas for family heritability and gain are:

$h^2 = \frac{\frac{1}{4}\delta^2_{fam}}{\delta^2_p}$ and $\Delta G = i\, h^2\, \delta_p$ respectively (van Buijtenen & Yeiser 1989).

The calculation of genetic gain for the selection by phenotype was made according to the formula $\Delta G = i\, h^2$, and for the selection intensity by the genotype 10/21 for the expected genetic gain (Becker 1984).

RESULTS AND DISCUSSION

By the analysis of variances, the statistically significant differences for the height increment trait between the pedunculate oak half-sib progenies were obtained, and this at the population level as well as inside the investigated seed region (Table 1). This indicates the existence of a distinctly marked genetic differentiation inside individual populations (Donji Miholjac, Slatina), that is, in the investigated central Drava River seed region.

The estimated heritability value (h^2) for the total height trait in all half-sib progenies was between 0.74 and 0.87, depending on the year in which the investigation was carried out, which suggests that this trait should be under high genetic control (Table 1). The heritability values in the investigated half-sib progenies from individual stands were also high, from $h^2 = 0.70$ (the Slatina population) to $h^2 = 0.90$ (the D. Miholjac population), depending on the population age, too. The reason for such obtained values is the fact that the pedunculate oak stands underwent several thinnings by which minus trees were eliminated, thus reducing the selection differential. This resulted in an increase in the average total height value in the populations where the selection had been made. The high heritability values for the total height were obtained at the juvenile age in other oak species, too, as stated by Min (1992), Struve & McKeand (1994), Jensen et al. (1997).

The heritability values (h^2) changed at various half-sib progeny ages, but, with the increase of age, mostly the higher estimated values were obtained (Table 1). This referred to the estimation of genetic heterogeneity for both the half-sib progenies inside individual populations (Donji Miholjac, Slatina) and to all tested half-sib progenies inside the seed region. The value was increased because, with ontogenetic ageing, the genetic heterogeneity of the half-sib progenies from the selected trees becomes more distinctive, showing the differences in phenotypical expression during ageing. Estimations of the genetic heterogeneity values (h^2), for the total height trait in *Q. acutissima*, rose with the increase of age in the research made by Toda et al. (1994), too.

From the obtained results of the genetic gain estimations (ΔG), it can be seen that, because of the very early age, they were somewhat lower than the expected

genetic gains, in relation to the control from the seed region. The controls consisted of plants grown from a random sample from the individual populations and from the seed region. The achieved genetic gain in half-sib progenies was lower, in some cases even negative (the Slatina population), than the expected genetic gain in the populations. Although the achieved genetic gain at this juvenile age is lower than the estimated one, the obtained real values are explainable by the fact that the selected plus trees belonged to various populations, which resulted in an increase in genetic heterogeneity value (h^2) and a decrease in genetic differential in the progenies. The average of the grown progenies achieved after the selection criteria (x > + 2 s) of mother (plus) trees, between the phenotypically superior trees only, made it possible to obtain such achieved genetic gain. In relation to the control, the achieved genetic gain in particular populations ranges between negative values and 6.0 % or in total from 1.0 to 2.0 % for the seed region, depending on the stand age (Table 1).

Table 1. Estimation of genetic parameters for the total heights in the progeny trial of *Quercus robur*

Half-sib progenies	F value	Heritability (h^2)	expected ΔG		realised ΔG	
			cm	%	cm	%
1995th Year – Plantation age 2 + 3 yrs						
Seed region Srednja Podravina	3.85**	0.74	12.4	13.0	1.8	2.0
Population Donji Miholjac	6.56**	0.85	14.6	15.0	0.8	1.0
Population Slatina	3.32**	0.70	12.0	13.0	2.8	3.0
Selected half-sibs (10/21)	-	-	10.0	10.5	10.3	11.0
1996th Year - Plantation age 2 + 4 yrs						
Seed region Srednja Podravina	4.63**	0.78	23.0	12.0	2.7	1.5
Population Donji Miholjac	8.47**	0.88	30.4	15.0	4.4	2.0
Population Slatina	3.72**	0.73	19.6	10.0	2.9	1.5
Selected half-sibs (10/21)	-	-	18.5	9.5	18.6	9.7
1998th Year - Plantation age 2 + 6 yrs						
Seed region Srednja Podravina	5.92**	0.87	42.9	15.0	3.0	1.0
Population Donji Miholjac	9.50**	0.89	53.7	20.0	16.0	6.0
Population Slatina	4.52**	0.78	32.6	11.0	-5.5	-2.0
Selected half-sibs (10/21)	-	-	34.6	12.5	34.5	12.4
1999th Year - Plantation age 2 + 7 yrs						
Seed region Srednja Podravina	5.76**	0.83	46.3	13.5	3.3	1.0
Population Donji Miholjac	9.71**	0.90	63.9	20.5	20.2	6.0
Population Slatina	3.80**	0.74	32.6	9.5	-5.9	-2.0
Selected half-sibs (10/21)	-	-	37.3	11.0	37.8	11.0

** significant at 0.01 level

From these results it can be seen that the achievement of a significant genetic gain for the height increment trait is possible, which means a significant improvement of wood mass production, assuming however that there is no change in the height increment dynamics in the progenies (Zobel & Talbert 1984).

On the assumption that the selection intensity is increased by the selection of the best ten half-sib progenies, based on the GCA ability of their mother trees, the achievement of an additional genetic gain from 9.7 to 12.4 % is possible, as seen in Table 1. The estimated genetic gain values corresponded to the obtained ones, so the estimation of selection intensity by Becker (1985) proved to be very accurate.

The achieved additional genetic gain at this age is relatively lower than the expected one, because of the additional selection made with a relatively low selection intensity, but also because of the small number of tested progenies of the selected mother trees. This intensity can be increased by the participation of a larger number of clones in the clonal seed orchard, with an increase in genetic gain, since the selected plus trees will then figure not only as female parents but partially as male ones, too. As the clonal seed orchards serve also for further breeding, as well as for gene preservation, the number of mother trees in an orchard should be higher (at least fifty), and that is our objective. The flowering of the pedunculate oak clones in the orchard will not be synchronised by years either, but also because of the determined significant differences regarding the participation of male and female flowers in particular clones, sterile clones and "transitus" clones as found by Bordasc (1997). It can be expected that some genotypes will prevail as functionally male or female, but a small number of clones with a balanced proportion of female and male flowers can appear, which may also have an effect on the future pedunculate oak plantation from the aspect of ecosystem stability.

CONCLUSIONS

1. By the phenotypical selection of pedunculate oak plus trees and by the progeny trial, the genetic gain (Δ G) for the height increment can be achieved inside the investigated central Drava River seed region as well as in the half-sib progenies from particular populations. The achieved genetic gain at the orchard age from two to seven years was lower than the expected one (Δ G) due to the decreased selection differential in the old pedunculate oak stands.

2. Estimations of heritability values (h^2) were increased with orchard age, and in the tested half-sib progenies these values ranged from 0.74 to 0.87, which suggests that this trait is under a high genetic control level.

3. The statistically significant differences were also obtained for total heights between half-sib progenies inside the investigated populations and the seed region, which indicates the existence of a very marked genetic differentiation in the pedunculate oak populations.

4. By increasing the selection intensity on the basis of mother GCA abilities, it is possible to achieve an additional genetic gain, taking care however of the stability of future pedunculate oak plantations.

REFERENCES

Becker, W. A., 1985: Manual of Quantitative Genetics. Academic Enterprises Pullman. Washington. 188 pp.

Bordacs, S., 1997: Pedunculate oak (*Quercus robur* L.) seed orchard and clonal tests in Hungary. In: Diversity and Adaptation in Oak Species. Proceedings of the second meeting of Working Party 2.08.05, Genetics of *Quercus*, of the IUFRO. University Park (State College), Pennsylvania, U.S.A., p. 209-216.

Enescu, V., 1993: A test of half-sib progenies of greyish oak, *Quercus pedunculiflora* Koch. Ann. Sci. For. 50 (Suppl. 1), Elsevier/INRA. p. 439-443.

Jensen, J. S., H. Wellendorf, K. Jager, S. M. G. De Vries, V. Jensen, 1997: Analysis of a 17-year old Dutch open-pollinated progeny trial with *Quercus robur* (L.). Forest Genetics 4 (3), p. 139 – 147.

Min, Y. T., 1992: Estimation of heritability and genetic gain for 26 open-pollinated plus trees of *Quercus acutissima*. Research Report of the Forest Genetics Research Institute, No. 28. p. 27 – 30.

Rink, G., M. V. Coggeshall, 1995: Potential height gain from selection in a five-year-old white oak progeny test. Southern Journal of Applied Forestry, No. 19, p. 10 – 13.

Toda, T., K. Nishimura, M. Tajima, 1994: Genetic variations of tree height, D.B.H., bark thickness and number of bar fissures of the characters among 12 families in the test plantation of *Quercus acutissima*. Bulletin of the National Forest Tree Breeding Center. No. 12, p. 1 – 26.

Van Buijtenen, J. P., J. L. Yeiser, 1989: Excercises in Quantitative Genetics of Forest Trees. Texas A & M University College Station. 106 pp.

Vidaković, M., 1996: Podizanje klonske sjemenske plantaže hrasta lužnjaka. U: Hrast lužnjak (*Quercus robur* L.) u Hrvatskoj. HAZU Centar za znastveni rad Vinkovci i "Hrvatske šume" p.o. Zagreb, str.127-138.

Vidaković, M., J. Bećarević, I. Hajdek, Š. Keceli, V. Podnar, 1992: Radovi na podizanju klonske sjemenske plantaže hrasta lužnjaka na području Š.G. "Krndija" i Š.G. "Papuk". U: Zbornik radova o Antunu Levakoviću: HAZU Centar za znanstveni rad Vinkovci, str. 153-170.

Zobel, B., J. Talbert, 1984: Applied Forest Tree Improvement. Chap 2. J. Wiley & Sons. New York. 505 pp.

PROCJENA GENETSKOGA POBOLJŠANJA U TESTU POLUSRODNIKA HRASTA LUŽNJAKA (*QUERCUS ROBUR* L.)

Na području sjemenskoga rajona srednje Podravine (Hrvatska) izvršena je fenotipska selekcija stabala hrasta lužnjaka (*Quercus robur* L.) i osnovana je eksperimentalna klonska sjemenska plantaža s ukupno 40 klonova. Tijekom 1992. godine osnovan je test u koji je uključena 21 familija polusrodnika. U testu potomstva uvrštene su familije sa selekcioniranih majčinskih stabala uključenih u klonske sjemenske plantaže, koje pripadaju sjemenskom rajonu srednje Podravine, s dvije populacije (Donji Miholjac i Slatina). Totalne visine izmjerene su kod plantažne dobi 2 + 3, 2 + 4, 2 + 6 i 2 + 7 godina. Procjena genetskih parametara (nasljednosti i genetske dobiti) rađena je za ukupno 21 polusrodnika te odvojeno za polusrodnike iz svake populacije.

Ključne riječi: *Quercus robur*, test potomstva, genetski parametri