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# GROWTH OF HALF-SIB PROGENIES OF EUROPEAN CHESTNUT AT THE POLE STAND STAGE

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## Abstract

In the present paper, the performance of 54 half-sib progenies at 35 years of age was investigated. Progenies were derived from old chestnut trees grown at different sites in Slovakia. Each progeny was planted as one unreplicated block 20 x 30 m in size and with a tree spacing of 2 x 1 m. The field experiment was established at Castanetarium Lefantovce, 20 km north of the city of Nitra (48°27'N, 18°10'E). A high mortality rate caused by ink disease (*Phytophtora* spp.) resulted in a drastic decrease of basal area in most of the progenies in the last five years. Diameters at breast and stem heights were less influenced by mortality, while ranking of progenies by provenances in both of the above characteristics were similarly maintained in younger growth stages. Variation of growth characteristics was significantly influenced by progenies within provenances as well as between provenances. The present results will enable selection of parent trees and their progenies to produce seed for establishing highly productive chestnut plantations.

Key words: *Castanea sativa*, half-sib progenies, mortality, basal area, stem height, diameter at breast height, Slovakia

# *RAST POLSESTRSKIH DRUŽIN PRAVEGA KOSTANJA V RAZVOJNI FAZI DROGOVNJAKA*

## *Izvleček*

*V prispevku je predstavljena rastnost 54 polsestrskih družin pravega kostanja, starih 35 let. Izvor družin so stara kostanjeva drevesa z različnih lokacij na Slovaškem. Vsaka družina je bila posajena kot blok brez ponovitve (velikost 20 x 30 m, razmik med posameznimi drevesi 2 x 1 m). Poskus je potekal v kostanjevem nasadu Lefantovce, 20 km severno od Nitre (48°27' S, 18°10' Z). Za večino družin je bila zaradi črnilovke pravega kostanja (Phytophtora spp.) značilna visoka stopnja smrtnosti, ki je imela za posledico izrazito zmanjšanje temeljnice v zadnjih petih letih. Smrtnost dreves je imela manjši vpliv na prsni premer in višino drevja. Razlike v prsnem premeru in drevesni višini, ugotovljene med družinami in proveniencami v mlajših razvojnih fazah, so ostale podobne tudi v fazi drogovnjaka. Rastne značilnosti so se statistično značilno razlikovale med potomstvi znotraj posamezne provenience; značilne so bile tudi razlike med proveniencami. Predstavljeni rezultati omogočajo izbiro semenskih dreves in družin za oblikovanje visoko produktvnih kostanjevih nasadov.*

*Ključne besede: Castanea sativa, polsestrske dužine, smrtnost, temeljnica, drevesna višina, prsni premer, Slovaška*

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# 1 INTRODUCTION
UVOD

European chestnut (*Castanea sativa* Mill.) is rare species in the Slovak Republic and its distribution is limited to the southern part of the country. For centuries, it has been grown primarily as an orchard tree, for fruit production; only during the previous four decades have some chestnut forest stands – plantations been established to test the capability of chestnut for timber production in this area. Because of the previously mentioned history of the chestnut, research activities were also first aimed at studying the morphology and variability of the traits associated with reproduction: male flowers (BENČAŤ 1964, 1967, BENČAŤ / BOLVANSKÝ 1983) and fruits (BENČAŤ 1968, BENČAŤ / BOLVANSKÝ 1984, BOLVANSKÝ 1988, BOLVANSKÝ / MENDEL 1999) for example. During the last two decades, research activities on chestnut for timber production have increased. In several experimental plots, established for this purpose in the 1960s, periodical dendrometrical and bio-ecological surveys commenced and the first results on growth and production of both pure and mixed chestnut stands have been reported (TOKÁR 1985, 1990). In addition to the mixed seed lots from local sites, seed from simple old chestnut trees from different sites of Slovakia were also used for establishing experimental plots. This method was chosen in order to find a suitable source of seed for establishing future chestnut stands, with good quality timber production. Most of the selected parent trees have been grown in orchards, as only one old chestnut forest exists in Slovakia. However, orchard trees are also wild types; grafting of chestnut was not used in past and is very rare now.

The aim of the present work was to evaluate the growth and production characteristics of half-sib chestnut progenies established, as pure chestnut stands tended with low thinning, and to assess the effect of provenance and individual parental trees on the studied growth characteristics.

## 2 MATERIAL AND METHODS
## MATERIAL IN METODE

The study was carried out in the series of 54 out of 86 unreplicated plots, which were established in the spring of 1966 and 1967 with 1-year old transplants of *Castanea sativa* Mill. derived from 86 old chestnut trees of seed origin, grown at 12 different localities of Slovakia, predominantly in orchards. Each plot, with some exceptions, was of 0,06 ha in area (20 x 30m) with spacing of 2,0 x 1,0 m (between rows x within rows) in a triangular pattern. The experimental plots were established at an experimental station for chestnut called Castanetarium Lefantovce, situated about 20 km north of Nitra, at the foothill of the Tríbeč mountains (48°27'N, 18°10'E). It covers an area of 14,27 ha, has a SW aspect and an altitude of 250 m a.s.l. The climate is warm continental with an average annual rainfall of 560 mm and temperature of 9,7 °C. The soil is brown podzolic.

Moderate intensity thinning every five years began in all plots at age 13 years. Before each thinning, stand characteristics, such as number of stems living and dead, diameter at breast height (DBH), and stem height were surveyed in each plot. Tree height measurements were carried out in a sample of 30 trees chosen in each plot according to size and social rank.

Data on number of stems, mortality rate, mean DBH, basal area, mean height and top height per progeny, observed in 1996 and 2001, were subjected to computation of descriptive statistics. Data on stem height and DBH sampled in 1996 from individual trees of the progenies studied were processed by procedures from the statistical package STATGRAPHIC. Data from the last survey were used because at that time, more progenies were surveyed and stem density on plots was not yet so drastically lowered by tree mortality as in the last years. The ANOVA procedure was employed first for individual provenances composed from three and more progenies where the variations of DBH and stem height were divided into two components: the between-progenies component and the within-progenies component. In the ANOVA employed for all experimental data, the variations of DBH and stem height were also divided into between-provenance and within-provenance components. DBH and stem height means for provenances were compared using Bonferroni's multiple comparison procedure. In this procedure, the interval around each mean is constructed in such a way that all the

means are the same and all the intervals overlap 95,0% of the time. Consequently, in the Multiple Range Tests these intervals are used to determine which means are significantly different from others.

## 3 RESULTS
## REZULTATI

Among all stand characteristics surveyed in half-sib progenies, it was the mortality rate, which has differed extremely from values of mortality usually observed in chestnut stands of the pole stage. Abnormally high mortality of trees in the majority of progenies has resulted from damage caused by ink disease which was first observed in the area of the experimental station Horne Lefantovce 25 years ago. Since then, the disease has progressively spread and, in the last decade, it has dramatically reduced number of trees on some plots. To have a better view of the development of the mortality and other stand characteristics, data from the second last inventory, in 1996, have been included in the evaluation (Table 1). Among progenies studied, the highest variation was observed in mortality rate (coefficient of variation, v% = 117,7 and 109,5 in 1996 and 2001 respectively). The next highest variation among progenies was observed in stem density (v% = 39,9 and 47,6 and in basal area (v% = 26 and 50,3), which are the characteristics most influenced by mortality rate. Variations of mean DBH, mean height and top height were considerably lower (v% from 12,7 to 15,3%) as these characteristics were not directly affected by mortality of trees.

Table 1: Selected stand characteristics of half-sib progenies derived from old trees grown at different sites of Slovakia, established as a series of unreplicated blocks

*Preglednica 1: Izbrane lastnosti sestojev polsestrskih družin kostanjev iz različnih delov Slovaške, zasnovanih kot vrsta blokov brez ponovitev*

| Progeny *Družina* | Number of stems *Število dreves* | | Mortality *Mortaliteta* | | Mean DBH *Srednji prsni premer* | | Basal area *Temeljnica* | | Mean height *Srednja višina* | | Top height *Zgornja višina* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N ha$^{-1}$ | | % | | cm | | m$^2$ ha$^{-1}$ | | m | | m | |
| | 1996 | 2001 | 1996 | 2001 | 1996 | 2001 | 1996 | 2001 | 1996 | 2001 | 1996 | 2001 |
| J1 | 1.267 | 1.217 | 2,56 | 2,67 | 18,63 | 20,41 | 34,54 | 41,42 | 15,00 | 15,03 | 17,50 | 16,78 |
| J3 | 883 | 667 | 10,17 | 11,11 | 15,81 | 18,71 | 24,87 | 20,59 | 12,10 | 14,10 | 14,50 | 15,15 |
| J4 | 650 | 417 | 11,11 | 7,41 | 17,08 | 19,51 | 29,03 | 13,72 | 12,90 | 14,47 | 14,50 | 15,35 |
| J5 | 1.233 | 700 | 6,33 | 20,75 | 17,40 | 19,82 | 30,13 | 22,51 | 14,20 | 14,23 | 15,67 | 15,35 |
| J6 | 483 | 250 | 23,68 | 16,67 | 16,62 | 19,02 | 27,49 | 7,48 | 11,60 | 10,55 | 13,00 | 10,90 |
| J8 | 933 | 533 | 12,50 | 11,11 | 17,28 | 19,02 | 29,71 | 16.23 | 12,00 | 11,35 | 13,42 | 12,35 |
| J9 | 1.450 | 1.167 | 1,14 | 4,11 | 14,96 | 17,79 | 22,27 | 29.75 | 12,70 | 14,19 | 13,50 | 15,50 |
| J10 | 1.600 | 1.367 | 3,03 | 0,00 | 15,42 | 17,16 | 23,66 | 32.59 | 12,70 | 12,74 | 13,50 | 15,50 |
| J11 | 1.283 | 1.000 | 9,41 | 6,25 | 17,74 | 19,55 | 31,32 | 31.07 | 16,20 | 18,64 | 17,42 | 19,95 |
| Mean *Povprečje* | **1.087** | **813** | **8,88** | **8,90** | **16,77** | **19,00** | **28,11** | **23.93** | **13,27** | **13,92** | **14,78** | **15,20** |
| HLA | 950 | 817 | 0,00 | 2,00 | 20,31 | 23,44 | 41,05 | 36.64 | 16,50 | 19,00 | 17,67 | 20,55 |
| HL1 | 283 | 217 | 15,00 | 13,33 | 18,23 | 20,23 | 33,07 | 7.61 | 12,70 | 14,75 | 13,83 | 15,30 |
| HL2 | 333 | 167 | 23,08 | 33,33 | 22,40 | 14,63 | 49,93 | 3.34 | 14,90 | 14,37 | 15,33 | 15,40 |
| HL3 | 733 | 583 | 18,52 | 12,50 | 18,93 | 20,81 | 35,66 | 20.23 | 14,30 | 15,25 | 15,67 | 16,15 |
| HL7 | 367 | 100 | 50,00 | 50,00 | 22,54 | 21,33 | 50,56 | 3.61 | 14,30 | 15,10 | 15,33 | 16,10 |
| HL8 | 1.083 | 617 | 15,58 | 24,49 | 15,78 | 18,17 | 24,78 | 16.28 | 12,40 | 14,69 | 13,33 | 15,33 |
| HL9 | 1.133 | 783 | 2,86 | 7,84 | 15,00 | 17,77 | 22,39 | 20.74 | 11,30 | 14,00 | 13,17 | 15,35 |
| HL13 | 711 | 578 | 3,03 | 0,00 | 16,62 | 18,22 | 15,42 | 15.52 | 11,00 | 13,04 | 12,33 | 14,60 |
| Mean *Povprečje* | **699** | **483** | **16,01** | **17,94** | **18,73** | **19,33** | **34,11** | **15.50** | **13,43** | **15,03** | **14,58** | **16,10** |
| TV1 | 1.233 | 917 | 3,90 | 23,61 | 19,40 | 21,34 | 37,45 | 34.80 | 15,20 | 17,50 | 16,00 | 19,10 |
| TV2 | 1.083 | 983 | 1,52 | 7,81 | 18,18 | 20,17 | 32,89 | 35.36 | 14,80 | 17,65 | 16,50 | 19,45 |
| TV2' | 1.217 | 950 | 0,00 | 6,56 | 19,80 | 22,03 | 39,01 | 37.78 | 15,30 | 16,94 | 16,42 | 17,95 |
| TV3 | 900 | 650 | 3,57 | 11,36 | 18,81 | 21,02 | 35,21 | 23.40 | 15,90 | 18,23 | 15,67 | 19,50 |
| TV4 | 1.017 | 617 | 1,61 | 24,49 | 18,52 | 20,53 | 34,13 | 21.23 | 15,70 | 17,20 | 16,50 | 19,50 |
| TV4' | 1.333 | 933 | 3,61 | 9,68 | 17,10 | 18,89 | 29,10 | 26.85 | 14,20 | 14,40 | 15,17 | 16,00 |
| TV5 | 1.317 | 933 | 0,00 | 1,75 | 16,07 | 19,04 | 25,70 | 28.01 | 12,90 | 16,06 | 14,75 | 18,85 |
| TV6 | 1.183 | 900 | 4,05 | 0,00 | 16,28 | 19,29 | 26,37 | 27.87 | 13,70 | 15,86 | 15,42 | 18,10 |
| TV7 | 1.033 | 783 | 8,82 | 2,08 | 17,16 | 20,13 | 29,30 | 25.65 | 13,60 | 15,80 | 15,17 | 16,60 |
| TV8 | 800 | 517 | 5,88 | 11,43 | 18,33 | 21,81 | 33,43 | 19.75 | 14,00 | 15,28 | 15,33 | 16,45 |
| TV9 | 583 | 533 | 7,89 | 0,00 | 20,40 | 24,81 | 41,41 | 26.92 | 14,00 | 16,17 | 16,00 | 17,65 |
| Mean *Povprečje* | **1.064** | **792** | **3,71** | **8,98** | **18,19** | **20,82** | **33,09** | **27.96** | **14,48** | **16,46** | **15,72** | **18,10** |

Table 1: (continuation)
*Preglednica 1: (nadaljevanje)*

| Progeny *Družina* | Number of stems *Število dreves* N ha$^{-1}$ | | Mortality *Mortaliteta* % | | Mean DBH *Srednji prsni premer* cm | | Basal area *Temeljnica* m$^2$ ha$^{-1}$ | | Mean height *Srednja višina* m | | Top height *Zgornja višina* m | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 2001 | 1996 | 2001 | 1996 | 2001 | 1996 | 2001 | 1996 | 2001 | 1996 | 2001 |
| D2 | 1.500 | 1.133 | 0,00 | 1,45 | 14,60 | 21,90 | 21,21 | 44,94 | 15,20 | 18,20 | 17,17 | 19,77 |
| D3 | 1.300 | 1.150 | 0,00 | 0,00 | 17,64 | 20,31 | 30,96 | 39,12 | 15,00 | 17,78 | 16,42 | 19,05 |
| D5 | 1.233 | 1.217 | 0,00 | 0,00 | 20,57 | 20,46 | 42,11 | 41,37 | 10,70 | 17,82 | 12,33 | 19,22 |
| D6 | 650 | 517 | 0,00 | 3,13 | 19,95 | 20,29 | 39,61 | 23,29 | 14,50 | 18,41 | 15,92 | 20,35 |
| D7 | 933 | 550 | 9,68 | 8,33 | 19,64 | 20,88 | 38,38 | 20,00 | 13,80 | 16,41 | 15,58 | 18,40 |
| D9 | 907 | 744 | 0,00 | 3,03 | 17,49 | 19,99 | 30,44 | 24,54 | 13,20 | 17,27 | 14,42 | 20,05 |
| D10 | 1.200 | 950 | 4,00 | 5,00 | 18,33 | 20,98 | 33,43 | 34,41 | 14,50 | 17,08 | 15,75 | 18,65 |
| D12 | 1633 | 1.250 | 2,00 | 0,00 | 17,10 | 19,43 | 29,10 | 38,37 | 15,70 | 19,92 | 17,08 | 21,50 |
| Mean *Povprečje* | **1.169** | **939** | **1,96** | **2,62** | **18,17** | **20,53** | **33,16** | **33,25** | **14,08** | **17,86** | **15,58** | **19,62** |
| R3 | 950 | 383 | 5,00 | 30,30 | 17,16 | 19,09 | 29,30 | 11,43 | 16,10 | 17,52 | 17,50 | 19,43 |
| R5 | 783 | 700 | 11,32 | 2,33 | 16,63 | 19,32 | 27,52 | 22,10 | 12,80 | 20,39 | 14,83 | 22,50 |
| BA2 | 1.783 | 967 | 1,83 | 24,68 | 14,22 | 17,81 | 20,12 | 26,39 | 11,50 | 14,50 | 13,83 | 16,30 |
| BA3 | 1.033 | 617 | 6,06 | 9,76 | 17,42 | 21,28 | 30,20 | 23,32 | 11,80 | 14,98 | 15,75 | 16,95 |
| BA4 | 1.283 | 967 | 4,94 | 1,69 | 18,99 | 22,49 | 35,89 | 39,84 | 15,50 | 18,42 | 17,08 | 20,55 |
| BA5 | 1.244 | 1.356 | 0,98 | 0,00 | 14,51 | 19,30 | 20,95 | **42,04** | 13,50 | 15,78 | 15,58 | 18,35 |
| Mean *Povprečje* | **1.336** | **976** | **3,45** | **9,03** | **16,29** | **20,22** | **26,79** | **32,89** | **13,08** | **15,92** | **15,56** | **18,04** |
| Č1 | 600 | 467 | 7,69 | 3,45 | 14,11 | 17,15 | 19,81 | 12,75 | 12,90 | 15,18 | 14,00 | 16,65 |
| Č2 | 500 | 233 | 9,09 | 12,50 | 17,70 | 20,96 | 31,18 | 9,13 | 13,10 | 14,68 | 15,10 | 15,55 |
| SP11 | 1.250 | 1.117 | 0,00 | 0,00 | 17,84 | 19,81 | 31,67 | 37,03 | 16,50 | 18,64 | 17,92 | 20,15 |
| RO1 | 571 | 514 | 0,00 | 0,00 | 17,80 | 18,73 | 31,53 | 15,42 | 12,70 | 15,27 | 14,00 | 16,10 |
| RO2 | 740 | 700 | 15,79 | 6,67 | 15,00 | 15,44 | 22,39 | 14,24 | 8,50 | 10,25 | 10,83 | 11,15 |
| RO4 | 333 | 429 | 12,50 | 0,00 | 17,43 | 16,90 | 30,23 | 11,50 | 11,90 | 12,00 | 12,33 | 12,20 |
| DP4 | 800 | 700 | 0,00 | 0,00 | 15,83 | 18,62 | 24,94 | 19,67 | 10,20 | 12,28 | 11,00 | 13,65 |
| DP5 | 550 | 183 | 8,33 | 8,33 | 17,51 | 24,40 | 30,51 | 8,79 | 11,00 | 14,17 | 13,58 | 15,20 |
| DP5´ | 1.300 | 200 | 6,02 | 20,00 | 19,13 | 19,71 | 36,42 | 6,24 | 15,70 | 15,21 | 16,75 | 16,40 |
| K1 | 650 | 500 | 11,36 | 14,29 | 13,28 | 16,29 | 17,55 | 11,47 | 8,40 | 13,40 | 11,33 | 14,50 |
| K2 | 1.467 | 367 | 8,33 | 21,43 | 13,64 | 17,75 | 18,51 | 9,71 | 10,40 | 13,11 | 12,42 | 15,25 |
| K5 | 450 | 167 | 20,59 | 28,57 | 11,33 | 15,51 | 12,77 | 3,29 | 9,60 | 12,46 | 10,00 | 14,80 |
| Mean *Povprečje* | **855,67** | **344,43** | **13,43** | **21,43** | **12,75** | **16,52** | **16,28** | **8,16** | **9,47** | **12,99** | **11,25** | **14,85** |
| Mean *Povprečje* | **976** | **703** | **7,30** | **9,76** | **17,33** | **19,62** | **30,12** | **22,91** | **13,35** | **15,51** | **14,86** | **16,99** |
| Stand. Dev. | 368,17 | 334,95 | 8,59 | 10,70 | 2,20 | 2,05 | 7,82 | 11,52 | 2,00 | 2,32 | 1,90 | 2,59 |
| Var. % | **39,89** | **47,64** | **117,68** | **109,55** | **12,67** | **10,44** | **25,96** | **50,26** | **14,98** | **14,94** | **12,77** | **15,23** |

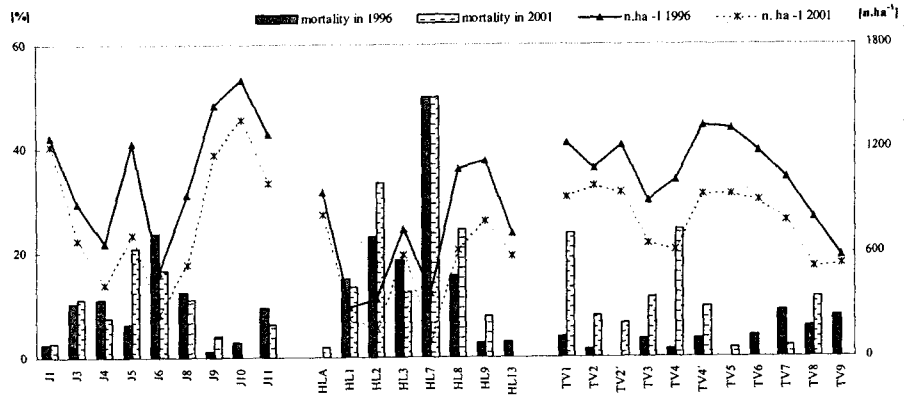


Figure 1: Stem density (N ha $^{-1}$) and mortality rate (%) in half-sib progenies at age 30 (in 1996) and 35 years (in 2001). J 1 - J 11, HL A - HL 13 and TV 1 - TV 9 are progenies derived from old chestnut trees from three different sites - provenances (J - Jelenec, HL - Horne Lefantovce, TV - Tlsty Vrch).

*Slika 1: Gostota drevja (N ha $^{-1}$) in stopnja smrtnosti (%) polsestrskih družin pri starosti 30 let (leta 1996) in 35 let (leta 2001); J 1 – J 11, HL A – HL 13 in TV 1 – TV 9 so družine, ki izvirajo iz različnih delov Slovaške (provenience: J – Jelenec, HL – Horne Lefantovce, TV – Tlsty Vrch)*

The highest mortality rate in both years was observed in progeny HL7 (50%), but mortality was also high (15,0 – 23,0% in 1996 and 12,5 - 33,3% in 2001) in four other progenies belonging to the Horné Lefantovce provenance (HL1, HL2, HL3, HL8). Three remaining progenies of this provenance have exhibited very low mortality rates (Table 1, Figure 1). Similar variations in mortality rate were also observed among progenies within the remaining studied provenances. However, the average mortality rate for these provenances was lower than for Horné Lefantovce with the exception of the Krná provenance, which has showed a slightly higher mortality rate in 2001 than Horné Lefantovce. As a result of high mortality rate, in progenies of both of the above provenances the basal area has decreased by half during the last five years. Abnormally high deaths of trees and consequent decrease of basal area occurred in most of the progenies. In 5 years, basal area was reduced in 40 out of 54 plots by 0,25 to 46,9 $m^2ha^{-1}$. Therefore, altogether in particular plots, current basal area decrement (-0,05 to -9,39 $m^2ha^{-1}yr^{-1}$) has exceeded current basal area increment (0,02 to 4,74 $m^2ha^{-1}yr^{-1}$). Although mortality rate, number of trees and value of basal area varied greatly among progenies

within the same provenance, differences in these parameters were observed also among provenances. For instance, progenies of the Duchonka provenance had, in average, the lowest mortality rate in both years (1,96 and 2,62%), the highest value of basal area ( 33,25 $m^2ha^{-1}$) and the highest top height (19,62 m) in 2001. Progenies of the Bratislava provenance showed, on average, the highest increment of basal area (1,22 $m^2ha^{-1}yr^{-1}$) in spite of an increase in mortality rate for 5 years (3,45 against 9,03 %). It is noteworthy that similar increases in mortality rate in progenies of the Tlsty Vrch provenance (TV) resulted in a decrease of basal area (1,02 $m^2ha^{-1}yr^{-1}$) (Figure 1). On the other hand, the increase in both mean height and top height was similar in stands of both provenances. Mean height, top height and mean DBH, have increased in average in all provenances, apparently because the dead trees were generally lower and thinner; growth performance of surviving trees was also not lowered. Only in some progenies did the mentioned characteristics decrease (DBH at HL2, HL7, D5, RO4, mean height at J6, J8, HL2, DP5', and top height at J1, J5, J6, J8, RO4, DP5', K1), which can be the result of higher mortality by 1996 and the deaths of thicker and/or taller trees (Figure 2).

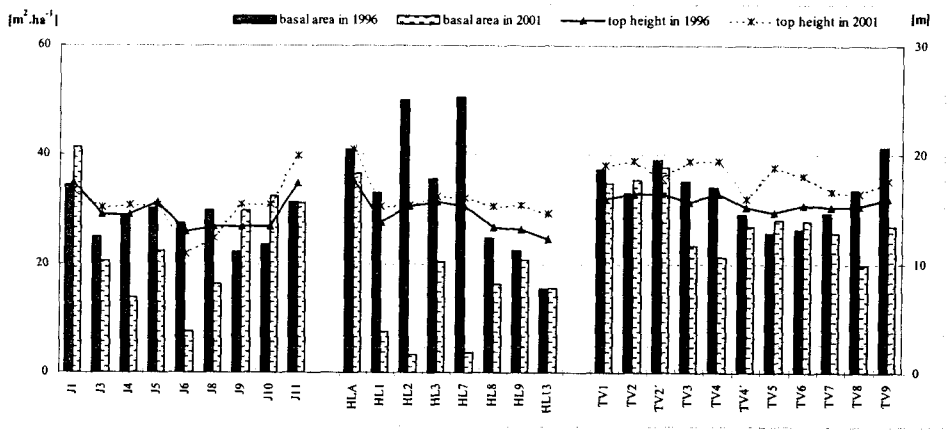


Figure 2: Basal area ($m^2$ $ha^{-1}$) and top height (m) in half-sib progenies at age 30 (in 1996) and 35 years (in 2001). J 1 - J 11, HL A - HL 13 and TV 1 - TV 9 are progenies derived from old chestnut trees from three different sites - provenances (J - Jelenec, HL - Horne Lefantovce, TV - Tlsty Vrch).

*Slika 2: Temeljnica ($m^2$/ha) in zgornja višina (m) polsestrskih družin pri starosti 30 let (leta 1996) in 35 let (leta 2001); J 1 – J 11, HL A – HL 13 in TV 1 – TV 9 so družine, ki izvirajo iz različnih delov Slovaške (provenience:J – Jelenec, HL – Horne Lefantovce, TV – Tlsty Vrch)*

Our results document that the different damage rate and consecutively different mortality in individual progenies can be genetically influenced thus reflecting genotypes of mother trees.

Analyses of variances have proven significant differences of DBH and mean height among progenies within all provenances analyzed. P-values of the F-tests in all analyses were less than 0,01. Similarly, significant differences among provenances have been proven in both assumed characteristics. The P-value of the F test was in both analyses less than 0,01 (Tables 2 and 4). Hence, the high differences among progenies within a provenance in some cases could not superimpose the effect of provenance. Provenances have differed more frequently in DBH than in stem height. While multiple range testing among provenance means detected 27 significant differences out of 54 for DBH (Table 3), it detected only 23 significant differences out of 66 for stem height (Table 5). In both growth characteristics, Krná and Rovňany provenances have differed from most other provenances. Progenies from Krná had significantly lower stem height among all 12 compared provenances. Progenies originating from the localities of Horné Lefantovce, Duchonka and Tlstý Vrch had significantly higher DBH values than remaining progenies, while in stem height only Duchonka and Tlstý Vrch remained among the best ones. It is worth noting that the Krná and Rovňany sites, which have produced the progenies with the worst growth characteristics, are situated the furthest from the Horne Lefantovce experimental area (about 200 km east) while the Duchonka and Tlsty Vrch sites with the best progenies are situated 40 km northwest and 60km east, respectively, from the experimental area. However, further correlation between the performance of the progenies and the geographical origin of their parental trees might be biased with low number of parental trees selected from some sites (1 to 4 trees). Quantitative growth characteristics of chestnut progenies are apparently significantly influenced by geographic origin of seed. However, progenies from individual parental trees also differ significantly within most of provenances in DBH and stem height as well.

Table 2: Analysis of variance between and within provenances for diameter at breast height (DBH) of chestnut stands at age 30 years

*Preglednica 2: Analiza variance prsnega premera kostanjevih sestojev, starih 30 let (med proveniencami in znotraj provenienc)*

| Source of variation *Vir variance* | Sum of squares *Vsota kvadratov* | df* | Mean square *Povprečen kvadrat* | F-value *F-vrednost* | p-value *p-vrednost* |
|---|---|---|---|---|---|
| Between provenances *Med proveniencami* | 4.972,05 | 10 | 497,21 | 28,94 | 0,0000 |
| Within provenances *Znotraj provenienc* | 54.927,20 | 3.197 | 17,18 | | |
| Total *Skupaj* | 59.899,30 | 3.207 | | | |

* df= degrees of freedom / *stopinje prostosti*

Table 3: Bonferoni's multiple range test among the DBH means for provenances

*Preglednica 3: Bonferonijev test med proveniencami glede na povprečni prsni premer*

| Provenance *Provenienca* | Acronym *Oznaka* | Count *Število* | Mean *Povprečje* (cm) | Homogeneous groups *Homogene skupine* | | | | |
|---|---|---|---|---|---|---|---|---|
| Krná | K | 112 | 11,25 | a | | | | |
| Rovňany | RO | 73 | 12,35 | a | b | | | |
| Častá | C | 44 | 12,66 | a | b | c | | |
| Bratislava | B | 353 | 12,89 | | b | | | |
| Dolné Pribelce | DP | 78 | 13,97 | | b | c | d | |
| Radošiná | R | 114 | 14,34 | | b | c | d | |
| Jelenec | J | 699 | 14,76 | | | c | d | |
| Plachtince | PL | 78 | 15,09 | | | c | d | e |
| H. Lefantovce | HL | 373 | 15,62 | | | | d | e |
| Tlstý Vrch | TV | 721 | 15,73 | | | | | e |
| Duchonka | D | 563 | 15,89 | | | | | e |

Note / *Opomba*: 27 pairs of means out of 54 showed statistically significant differences at the 95,0 % confidence level / *pri 27 izmed 54 parov smo ugotovili statistično značilne razlike (95 % stopnja zaupanja)*

Table 4: Analysis of variance between and within provenances for stem height of chestnut stands at age 30 years

*Preglednica 4: Analiza variance drevesne višine kostanjevih sestojev, starih 30 let (med proveniencami in znotraj provenienc)*

| Source of variation *Vir variance* | Sum of squares *Vsota kvadratov* | df* | Mean square *Povprečen kvadrat* | F-value *F-vrednost* | p-value *p-vrednost* |
|---|---|---|---|---|---|
| Between provenances *Med proveniencami* | 3.792,34 | 11 | 344,76 | 33,00 | 0,0000 |
| Within provenances *Znotraj provenienc* | 26.472,48 | 2.534 | 10,45 | | |
| Total *Skupaj* | 30.264,82 | 2.545 | | | |

* df= degrees of freedom / *stopinje prostosti*

Table 5: Bonferoni's multiple range test among the stem height means for provenances

*Preglednica 5: Bonferonijev test med proveniencami glede na povprečno drevesno višino*

| Provenance *Provenienca* | Acronym *Oznaka* | Count *Število* | Mean *Povprečje* (cm) | Homogeneous groups *Homogene skupine* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Krná | K | 128 | 8,69 | a | | | | | | | | |
| Rovňany | RO | 162 | 11,53 | | b | | | | | | | |
| Stredné Plachtince | SP | 83 | 11,68 | | b | c | | | | | | |
| Dolné Pribelce | DP | 104 | 12,13 | | b | c | d | | | | | |
| Častá | C | 48 | 12,77 | | b | c | d | e | | | | |
| H. Lefantovce | HL | 489 | 12,98 | | | c | d | e | f | | | |
| Bratislava | B | 160 | 13,05 | | b | c | d | e | f | g | | |
| Jelenec | J | 311 | 13,09 | | | c | d | e | f | g | h | |
| Modrý Kameň | MK | 110 | 13,50 | | | c | d | e | f | g | h | i |
| Duchonka | D | 426 | 13,58 | | | | d | e | f | g | h | i |
| Radošiná | R | 157 | 13,78 | | | | d | e | f | g | h | i |
| Tlstý Vrch | TV | 368 | 14,25 | | | | | e | | g | | i |

Note / *Opomba*: 23 pairs of means out of 66 showed statistically significant differences at the 95,0 % confidence level / *pri 23 izmed 66 parov smo ugotovili statistično značilne razlike (95 % stopnja zaupanja)*

## 4 DISCUSSION
## RAZPRAVA

The statistical evaluations presented in this study should be treated with caution for the following reasons. First, the progenies were not randomized in the field experiment. Instead, each progeny was planted as one block. Thus, differences among progenies were

confounded by environmental heterogeneity among progeny blocks. This bias may be small because of the apparent uniformity with regard to soil and topography of the plantation. Next, the series of progeny blocks was not rimmed with buffer stands so the progenies planted at the border could be affected with different light and water regimes. Lastly, the rather high source of error may result from a high mortality rate not evenly distributed among progeny blocks. The most recent inventory of damage caused by *Phytophtora spp.*, carried out in 2000 and 2001, has revealed a very adverse situation in all series of experimental plots with half-sib progenies (BERNADOVIČOVÁ / JUHÁSOVÁ 2002). All plots are to a different degree affected by this disease, including those where no mortality has been detected during the last silvicultural survey. However, an index of disease damage and mortality rate (at the same time) remains very low in some progenies, which may suggest an inherited tolerance to ink disease.

In spite of the high mortality rate, the rank of progenies and provenances in DBH and especially in mean height was unchanged based on observations at age 15, 21 and 25 years (BENČAŤ / TOKÁR 1984, BENČAŤ / GOLHA 1990, TOKÁR 1996) until the second last survey in 1996 (at age 30 years). Progenies of Krna provenance, ranked repeatedly as the worst ones in mean height, were also the worst in this characteristic in the last inventory. The progenies from the Tlsty Vrch provenance, with the highest performance until 30 years of age were for last five years overtaken in height by progenies from the Duchonka provenance. This can be the result of the high mortality rate in progenies from Tlsty Vrch during the last ten years.

Similar full-sib family ranking in height at the ages of 11 and of 21 years was also observed in a progeny trial with black walnut. However, family ranking in DBH and volume differed in this trial at different ages (PENG / PARROT / BOUSQUET 1992). This conforms to the finding that in black walnut early height is a good indicator of later height (McKEAND / BEINEKE / TODHUNTER 1979, RINK 1984).

Significant differences among half-sib progenies of chestnut in growth, which have persisted over a period of 15 years, indicate that selection among half-sib families could potentially improve growth and production characteristics in future chestnut stands in Slovakia. Selected parent trees and their half-sib families could be used to produce seeds

for establishment of plantations, which would be, in the long-term, converted to naturally regenerated high forests.

# 5 POVZETEK

*Med štiriinpetdesetimi polsestrskimi družinami pravega kostanja, ki so bile vključene v raziskavo, smo ugotovili veliko variabilnost vseh proučevanih sestojnih značilnosti (gostota drevja, smrtnost, temeljnica, prsni premer, povprečna višina in zgornja višina). Večji del variabilnosti (predvsem glede gostote drevja in temeljnice) lahko razložimo z zelo različnimi stopnjami smrtnosti med družinami; le-ta je ob popisih leta 1996 in 2001 znašala 0 % do 50 %. Nenavadno visoka stopnja smrtnosti je posledica okužbe s črnilovko pravega kostanja (Phytophtora spp.). Posledično se je temeljnica v petih letih zmanjšala v 40 izmed 54 družin; ob upoštevanju vseh ploskev se je v povprečju zmanjšala za 7 $m^2$/ha. Razlike v smrtnosti, številu dreves in temeljnici smo ugotovili predvsem med družinami znotraj iste provenience, vendar so bile značilne tudi razlike med proveniencami.*

*Povprečna višina, zgornja višina in povprečen prsni premer so se v povprečju povečali v vseh proveniencah; predvsem zato, ker je bila večina odmrlih dreves nizkih in tankih, rastnost preživelih dreves pa se ni zmanjšala. Povprečna višina, zgornja višina in povprečen prsni premer so se zmanjšali le v nekaterih družinah, kar je najverjetneje posledica večje smrtnosti leta 1996 in odmrtja debelejšega in/ali višjega drevja. Z analizo variance smo dokazali značilne razlike v povprečnem prsnem premeru in srednji višini med družinami znotraj iste provenience ter med proveniencami; med slednjimi so bile bolj pogoste razlike v povprečnem prsnem premeru kot v višini dreves. Zaporedje provenienc (upoštevaje prsni premer in predvsem srednjo višino), ugotovljeno ob popisih pri starosti 15, 21 in 25 let, se je ohranilo do 30-tega leta starosti sestojev. Krnska provenienca, ki smo jo (upoštevaje srednjo višino) že pri predhodnih popisih uvrstili na zadnje mesto, je bila na začelju tudi ob zadnjem popisu. Provenienco Tlsty Vrch, ki je bila (upoštevaje višino) ob prejšnjih popisih uvrščena na prvo mesto, je v zadnjih petih letih prehitela provenienca Duchonka. To je najverjetneje posledica visoke smrtnosti v družinah provenience Tlsty Vrch v zadnjih desetih letih.*

*Značilne razlike v rastnosti med polsestrskimi družinami kostanja, ki so se ohranile v 15-letnem obdobju, nakazujejo, da bi lahko načrtna izbira polsestrskih družin izboljšala rastne in proizvodne lastnosti kostanjevih sestojev na Slovaškem.*

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