Douglas-fir Breeding in Saxony

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Summary

Due to its high productivity as well as good ecological and silvicultural characteristics, Douglas-fir plays a special role among the introduced species in Germany. A decisive factor in successful stand establishment is the genetic suitability of the plants for the specific plantation site. Therefore, in Graupa the investigations done were focused on provenance research as well as on studies of locally selected stands and on the supply of tree types from hybrid breeding. Results are presented on (1) progeny experiments of 1982 to 1983 based on the seed collection in older stands, and (2) hybrid breeding beginning in the 1960s. Progenies from interspecific hybridisation combine highly heterotic rate of growth and high resistance to frost, better than pure Douglas-fir land races.

Key words: Douglas-fir, hybrid breeding, progeny testing, seed orchards.

1. Introduction

Forestry's central role is the establishment and management of ecologically-stable and productive forest ecosystems and at the same time maintaining their beneficial functions. Suitable exotic species can help to attain this goal.

An important factor for cultivating an exotic tree species is its genetic potential for adaptation to the site conditions of the new locality. Together with a reorientation of silvicultural objectives away from pure stands towards uneven-aged, mixed stands, with a focus on the individual tree, the genetic component is more and more important. In this context, due to its high productivity as well as good ecological and silvicultural characteristics, among the exotic species, Douglas-fir (*Pseudotsuga menziesii* (MIRB.) FRANCO) plays a particular role in Saxony.

In Graupa Research Station, Douglas-fir breeding activities started with the evaluation of natural seed sources. Field tests provided basic knowledge on provenance's suitability for the various growing regions of East Germany (SCHMIEDEL, 1981; DITTMAR, KNAPP and SCHULSEN, 1985). Still questions remain on Douglas-fir natural variability because of the political order limited the participation in international projects like the IUFRO range-wide collection.

In the 80's Douglas-fir breeding was oriented towards the improvement of local genetic resources:

- selection of artificial stands growing in the GDR and progeny testing,
- new hybridisations between coastal and interior land races based on results of previous interracial crossings made by SCHÖNBACH in the 60's (BRAUN and SCHMIEDEL, 1985; BRAUN, 1988, 1992, 1996).

Results obtained at juvenile stage in the above two fields are presented in this paper. Perspectives of transfer into practice of forest reproductive material resulting of the breeding work will also be discussed.

2. Progeny Testing of Native Stands and Using the Results

In 1981 and 1982, 21 Douglas-fir stands were selected in cooperation with the local forest service. The selected stands as well as the subsequent progeny trials and the two seedlings seed orchards are located on the map in *figure 1.*

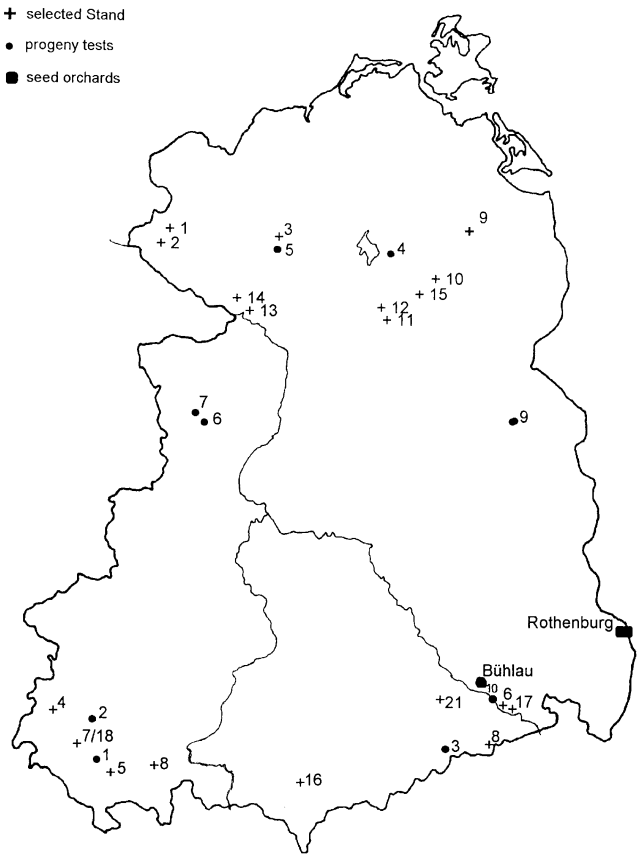


Fig. 1. – Map of stands, trials and seed orchards.

Our programme for using the results of progeny testing to produce suitable plants for afforestation is presented in *figure 2* and briefly described here after.

More information on data assessments and on the progeny trails are given by BRAUN (1992).

The results, which are only partly presented in this paper, permit an initial judgement of the provenances under test. Naturally, a comprehensive evaluation of growth can not be

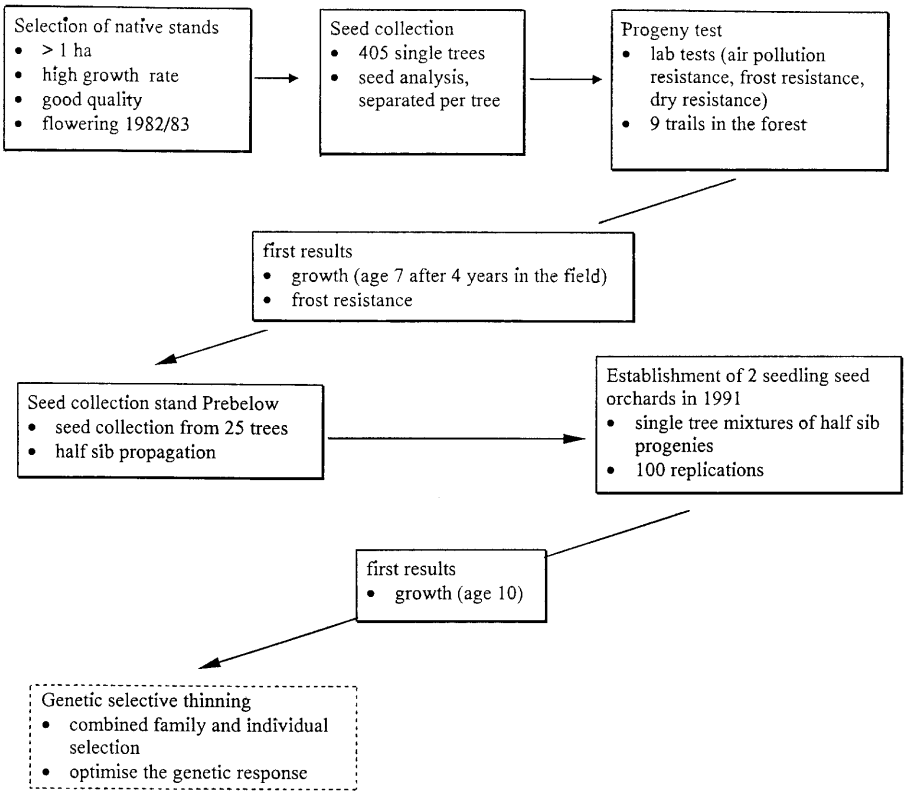


Fig. 2. – Progeny test of native stands and possibilities of using the results.

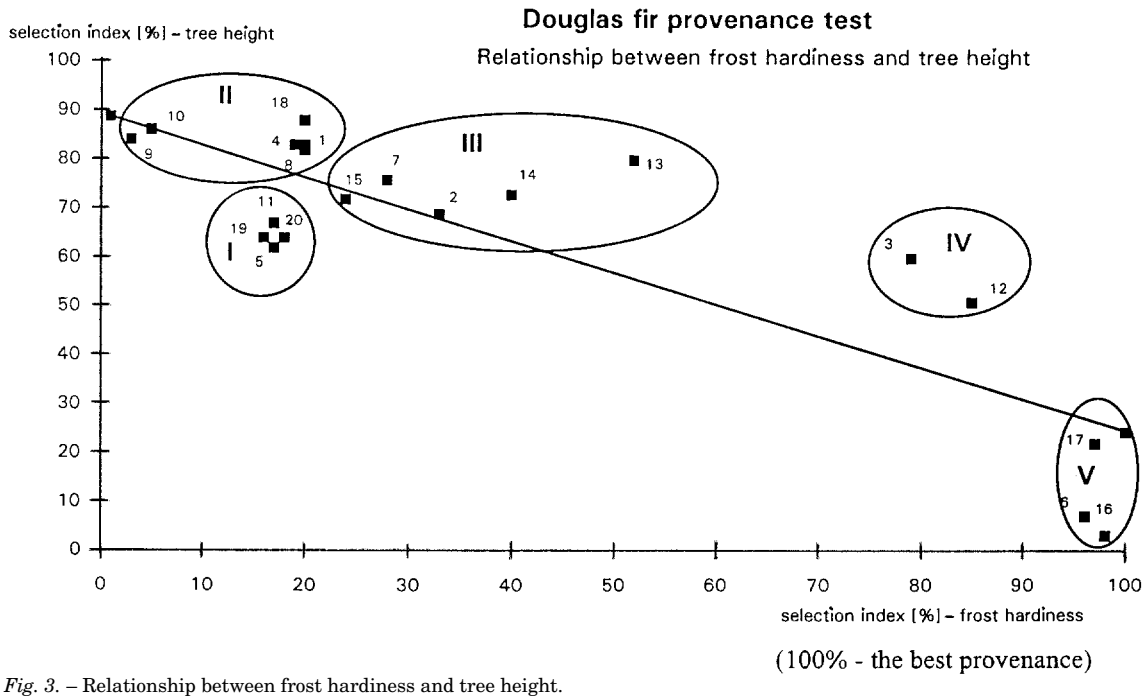


Fig. 3. – Relationship between frost hardiness and tree height.

based only on the performance of juvenile progenies. Frost resistance, phenological traits and resistance to air pollution may also be judged with some degree of confidence. But this test series is a sound basis for long-term provenance testing, by providing comprehensive material for further basic research on population genetics and for breeding. Using cluster analysis grouping of the tested material was now possible.

The material as a whole can be subdivided into two large groups: (1) the more vigorous but frost-sensitive provenances and (2) the less vigorous but frost-resistant provenances. The critical factors in provenance evaluation, the frost hardiness and vigour, are reflected by their relationships as shown by cluster analysis and illustrated in *figure 3*. The results allow preliminary recommendations for provenance selection.

One group of provenances *(Figure 3,* group I) is neither distinguished by vigour nor by other good desirable properties. The group includes the provenances 11, 5, 19, and 20. The two standard provenances Ashford and Darrington also belong to this group.

The provenances Kiekindemark II (3) and Prebelow (12) shown in *figure 3* as group IV, are of special interest for planting in the low range of mountainous regions. Both provenances are in the lower third of the entire set with respect to growth. In an analysis using a combined selection quotient considering both vigour and frost resistance on all nine plots, Kiekindemark II ranks first and Prebelow ranks second.

As a result of the progeny tests, the observations that locally adapted Douglas-fir is often superior to imported material could also be confirmed.

The genetic variability of the progenies within provenances should be greater than the provenance variability. In this reason we start a programme to establish seed orchards with the best progenies. The first step was to use the provenance Prebelow for the establishment of two seedling seed orchards in Saxony.

For this purpose seed from 25 trees was collected and propagated. The two orchards were established in 1991 with single tree progenies and 100 replications. After a measurement of the height in 1997, first results on the growth of tested progenies are available *(Figure 4).*

The correlation between total height on both sites as an expression of the stability is $r^2 = 0.63$.

Based on these results a genetic selective thinning will be done as a combined family and individual selection in order to optimise the genetic response.

Estimation of variance components and heritability were computed for total height at age 10 as follow. Values obtained are presented in *table 1* and *figure 5.*

It is anticipated to thin both seed orchards in 2 steps. In a first step all families significantly less vigorous than the aver-

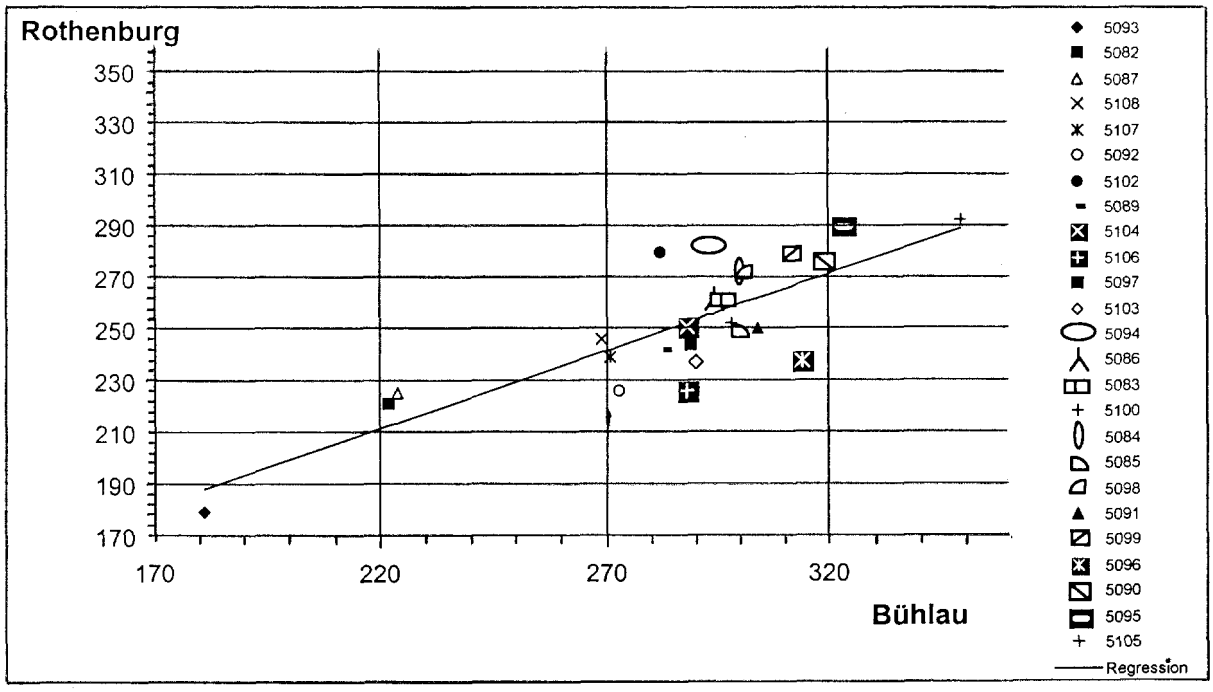


Fig. 4. – Seedling seed orchards, height 1997 (age of plants 10 years).

Table 1. – Genetic variance (σ^2_g), environmental variance (σ^2_u) and narrow sense heritability (h^2) of total height at age 10 in the seedling seed orchards of Bühlau and Rothenburg.

$$\sigma_a^2 + \sigma^2 = \sigma_g^2 * (\frac{1}{4}k + \frac{3}{4}) + \sigma_u^2$$

$$\sigma^2 = \frac{3}{4}\sigma_g^2 + \sigma_u^2$$

σ_g^2 = genetic variance

σ_u^2 = environmental variance

	σ_g^2	σ_u^2	h^2
Bühlau	3806,79	3784,14	0,50
Rothenburg	2564,55	2827,09	0,48

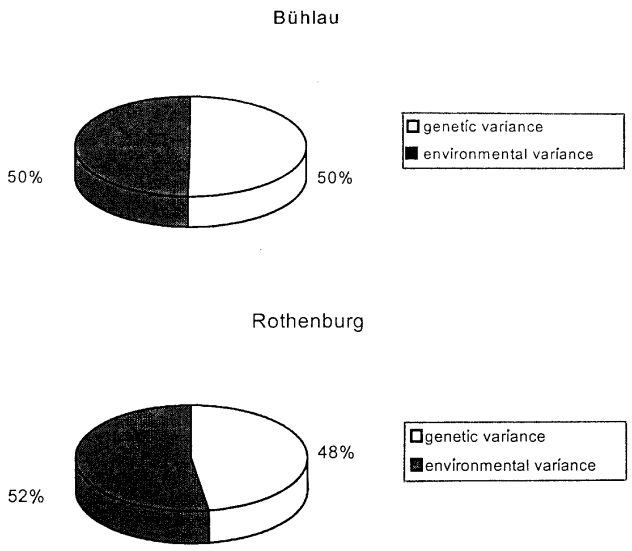


Fig. 5. – Genetic variance (σ^2_g), environmental variance (σ^2_u).

age will be removed. In a second step all trees under the average of their family will be removed. The expected genetic response after thinning is presented in *figure 6.*

For the future it is necessary to have more information on other characteristics of the half-sib families such as frost resistance or branchiness. In winter 1997/1998, these characteristics were evaluated. Based on the results, the genetic selective thinning will be done as soon as possible.

3. Results of Hybrid Breeding

In the parts of Europe with more continentally influenced climate especially in the low range of the mountainous regions low resistance to frost has always been a limiting factor for growing Douglas-fir. Therefore forest tree breeders tried, under the leadership of SCHÖNBACH, to increase frost resistance of the fast-growing Green Douglas-fir. In the early 1960s an effort was made to combine the frost hardiness of *glauca* with the vigour of *viridis* .

Figure 7 shows the results of hybridisation made by BELLMANN on old trees in the early 60's. As control, a seed lot of the

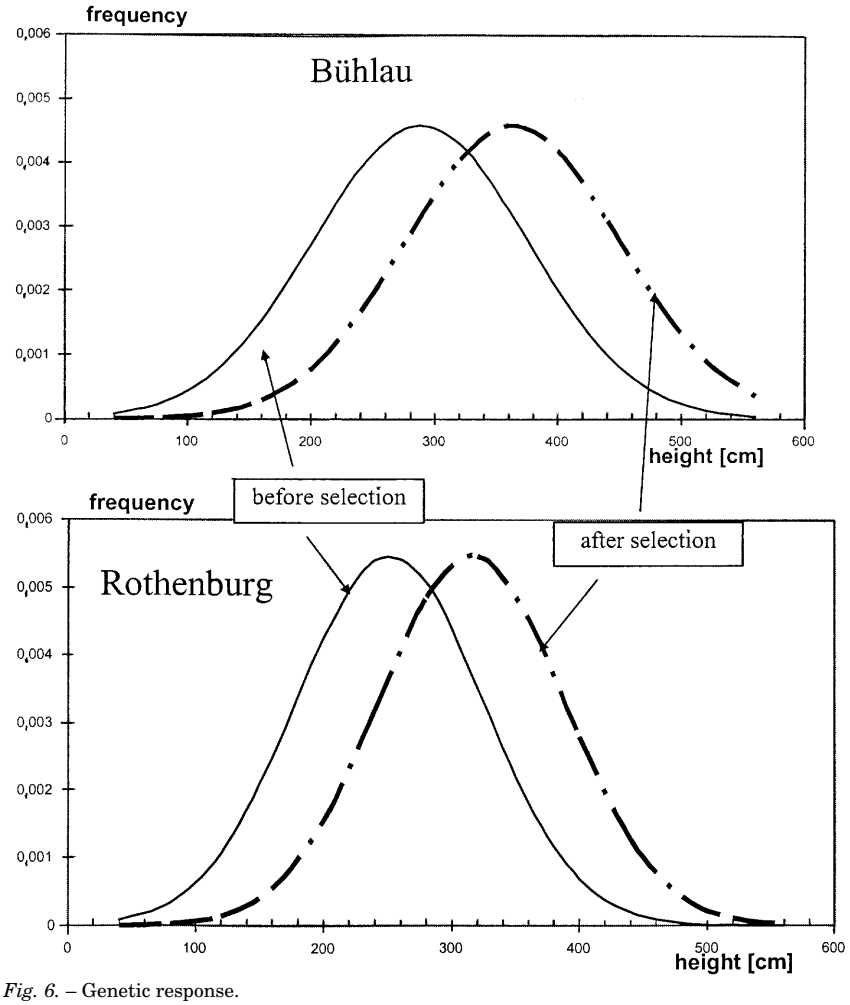


Fig. 6. – Genetic response.

imported provenance Upper Fraser River Valley (British Columbia – altitude 700 m) was introduced in the progeny test. More information about the results of this programme are given by BRAUN (1992).

Based on the former results of hybrid breeding in Douglas fir a new hybrid programme was started at the end of the 80's. The objectives were (1) to reproduce the most suitable hybrid combinations, (2) to test a large number of trees by using the topcross procedure, and (3) extend the work with interracial hybridisation. As tester clones were used: 24 *(viridis),* 84 *(glauca)* and 58 (*caesia,* provenance Kamloops).

Figure 8 shows the crossing plan.

In addition to these activities, a breeding programme was started within the hybrids to produce a second generation (F2).

A percentage of the material derived from these two breeding programmes was sown in 1990 and trials were established at 4 different sites in spring 1993 *(Figure 9, Table 2)*. First observations on growth are now available.

Figure 10 shows the results in the nursery.

2 years after establishment of the trial plots in forest (5 years since sowing) the first observation of the tree height was made in all trials. The results are presented for the trial plots Tharandt and Cunnersdorf *(Figure 11* and *12)*.

The results of growth at Graupa after 7 years are shown in *figure 13.*

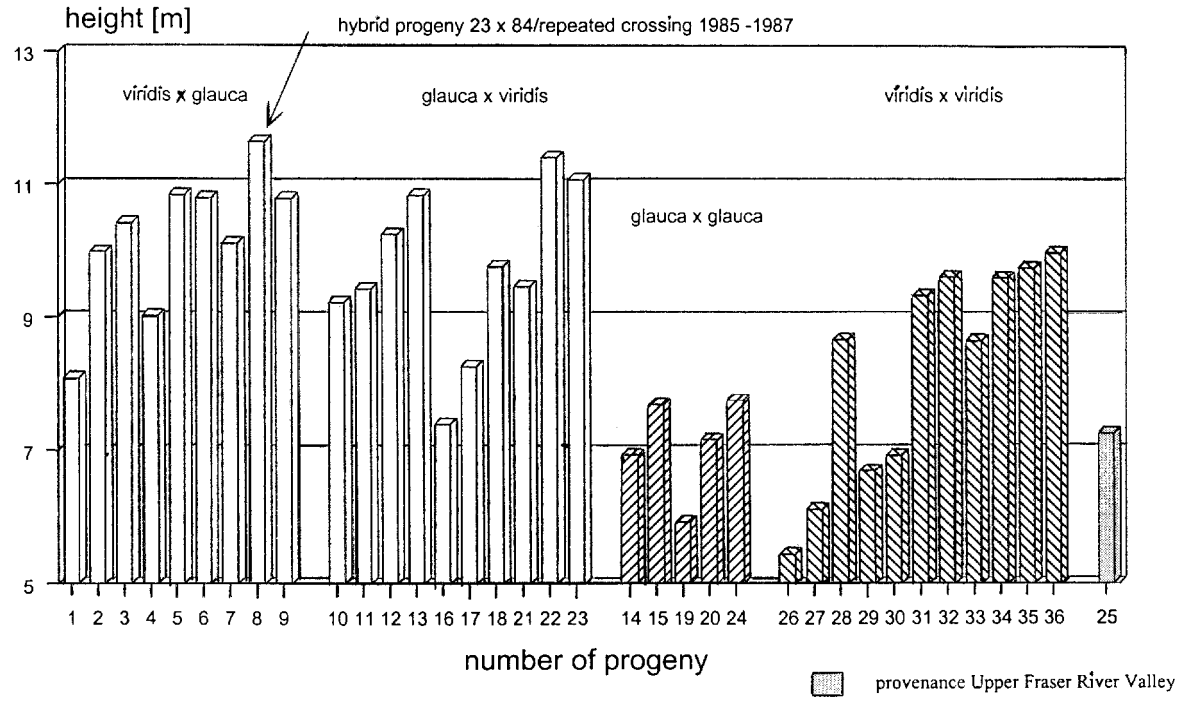


Fig. 7. – Progeny test of Douglas fir hybrids. Height growth at age 16 after planting.

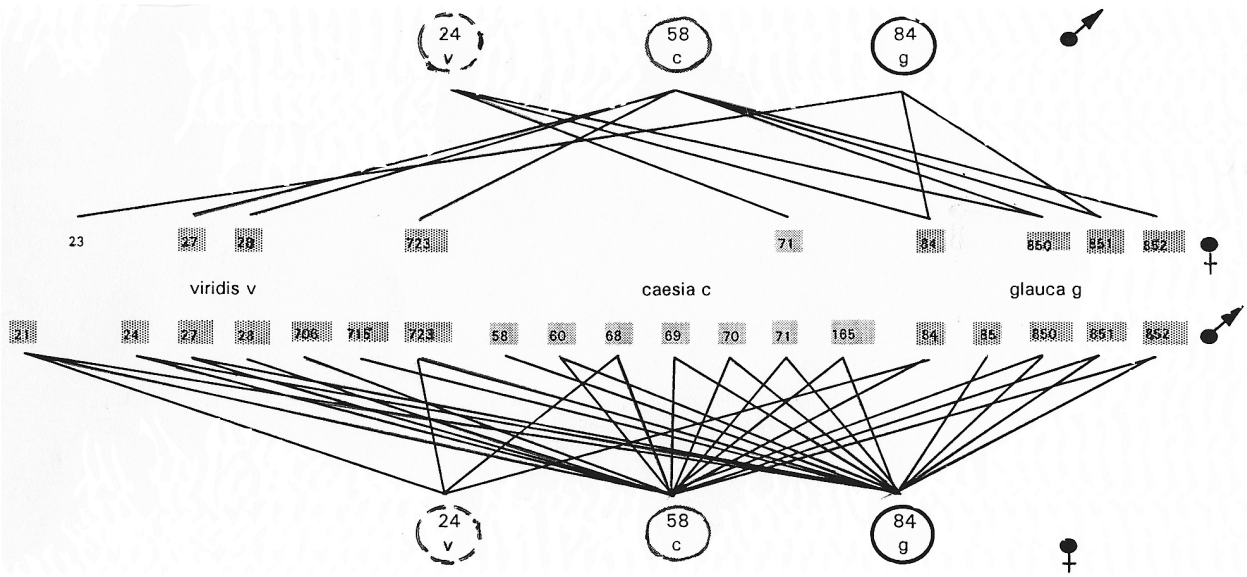


Fig. 8. – Plan of cross-breeding in Douglas-fir.

Fig. 9. – Location of the trial plots.

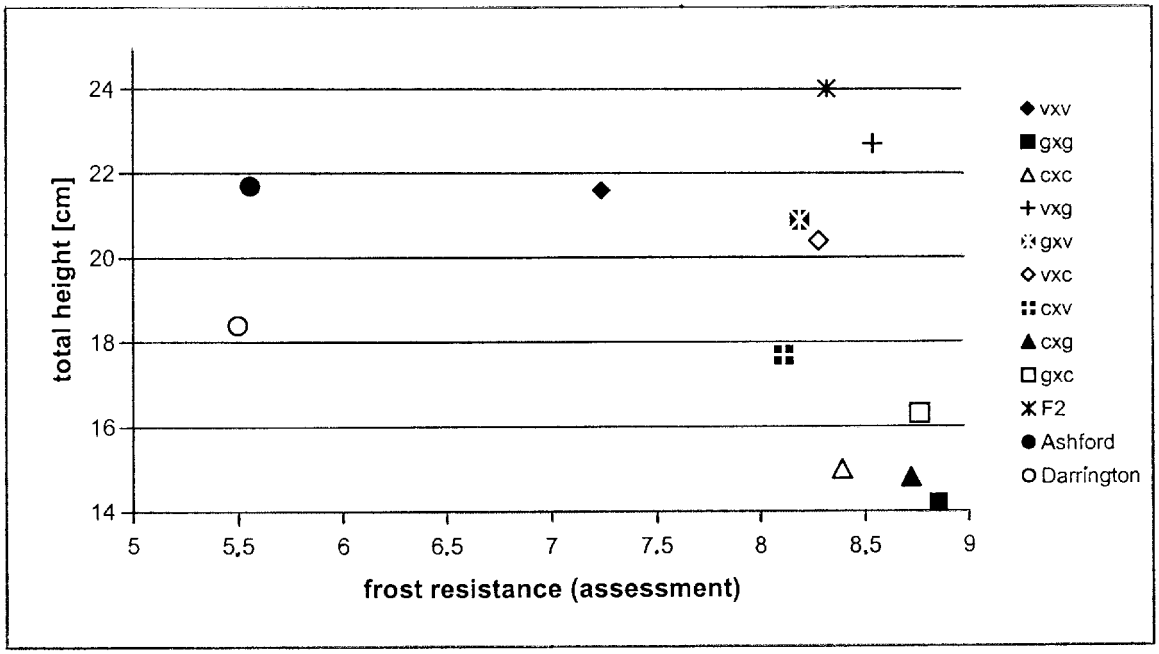


Fig. 10. – Progeny test of Douglas fir hybrids, age 1/1, nursery results (frost resistance – 9 – no damage).

Early data collection on height growth in the hybrid family tests in Saxony shows that the best progenies in growth are the blue-green hybrids, the best of all combinations is number 3311 (green mother and blue father). It is very interesting to notice, that this hybrid combination was already identified as the best 30 years ago *(Figure 7, 12* and *13)*.

At the location Graupa it was possible to test 3 combinations of the second generation. The results after 7 years are presented in *figure 14.*

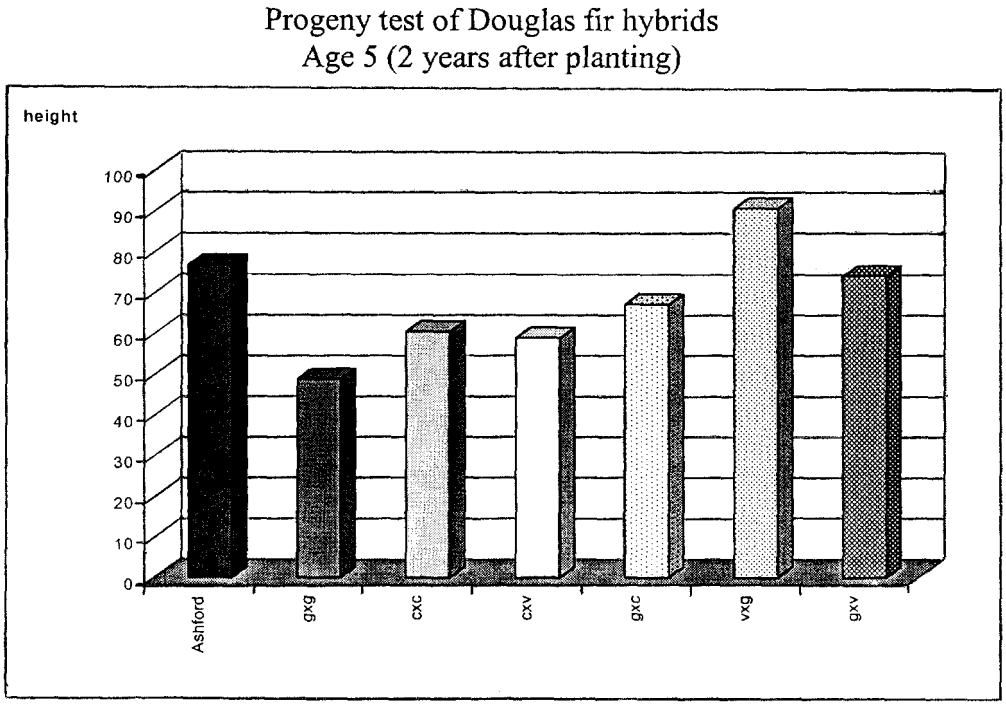
After 7 years, the first generation of interracial hybrids is significantly faster growing than the second generation. The variability in height of the second generation is a little bit higher than in the first generation.

The desirable properties of the hybrid progenies include a good juvenile vigour, a high rate of increment of the individual tree, an excellent vitality and a high degree of frost hardiness. It would be desirable now to transfer breeding results into forestry practice. The modes of implementing the results are indicated in *figure 15.*

The so-called repeated crossing (crossings between the parents of the tested progenies) in the crowns of old trees and in the gene archives at Graupa would be the most rapid, safe, and effective method and, in fact presently the single method of reproducing the hybrids. An increase of the existing plant material by mass vegetative propagation would be feasible. In using this way we got more than 15.000 filled seeds in 1998.

Table 2. – Site information to experimental plots of Douglas-fir (1993).

	Cunnersdorf	**Graupa**	**Hetzdorf**	**Doberschütz**
forest office	Cunnersdorf	LAF Graupa	Tharandt	Doberschütz
forest district / site	Cunnersdorf	tree nursery	Hetzdorf	Wartha
area	402a3	Quartier 2	527a4	632a1
latitude	50°52'	50°59'	50°58'	51°32'
longitude	15°8'	13°56'	13°28'	12°39'
altitude (m asl)	350	125	405	98
exposition	east		north-east	
inclination	low	flat	low	flat
smoke damage (class)	II	II	II	I
soil type	cambisol (on loamy sand)	gravel of the elbe river	cambisol (on porphyr)	cambisol (on sand)
site unit	Uf-Z2 (S) medium wet, range of hills; nutritional value: medium to poor soil humidity: medium	Ut-M2 dry, range of hills; nutritional value: medium soil humidity: medium	Uf-M2 medium wet, range of hills; nutritional value: medium soil humidity: medium	Tm-M2 medium dry, lowland; nutritional value: medium soil humidity: medium
climate:				
mean temperature (year)	6,9°C	8,7°C	7,6°C	8,5-8,7°C
mean temperature (may - august)	14,6°C	may - september: 15,7°C	15,2°C	
mean precipitation (year)	839mm	745mm	816mm	550-600mm
mean precipitation (may - august)	386mm	may-september: 402mm	april-september: 475mm	



v - *viridis*, g - *glauca*, c - *caesia*

Fig. 11. – Forest district Tharandt.

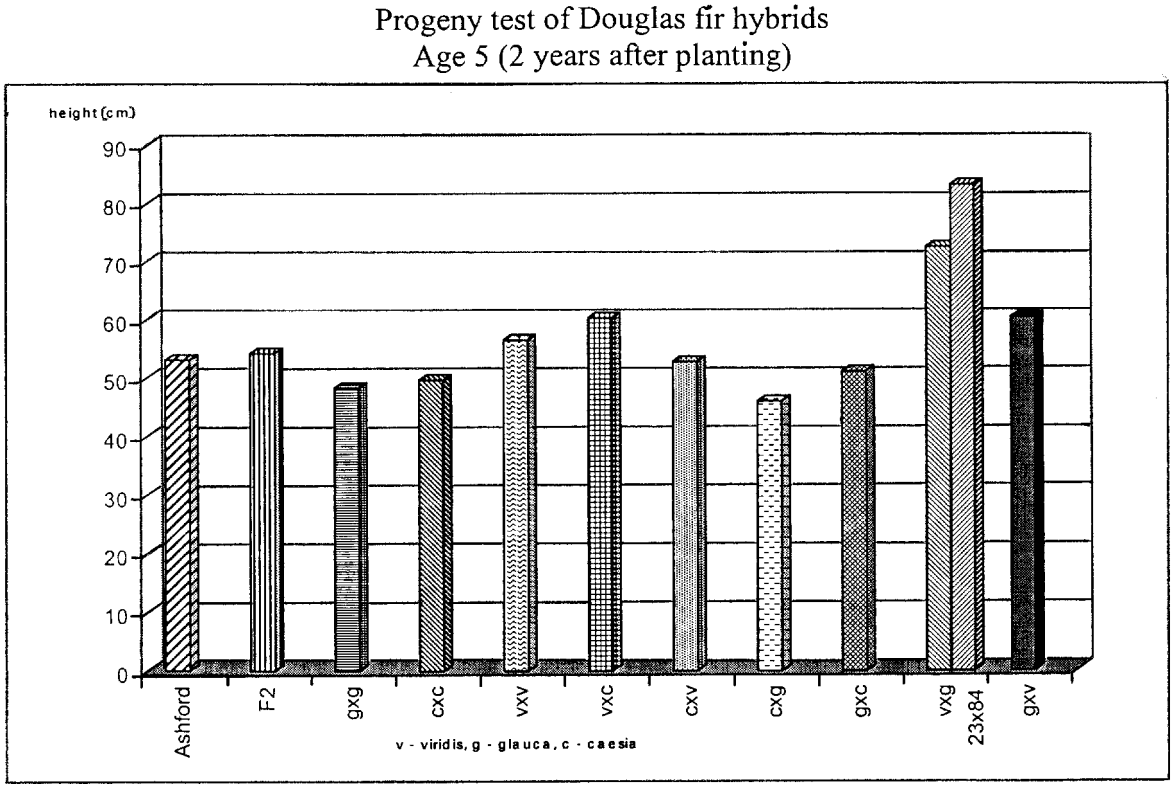


Fig. 12. – Forest district Cunnersdorf.

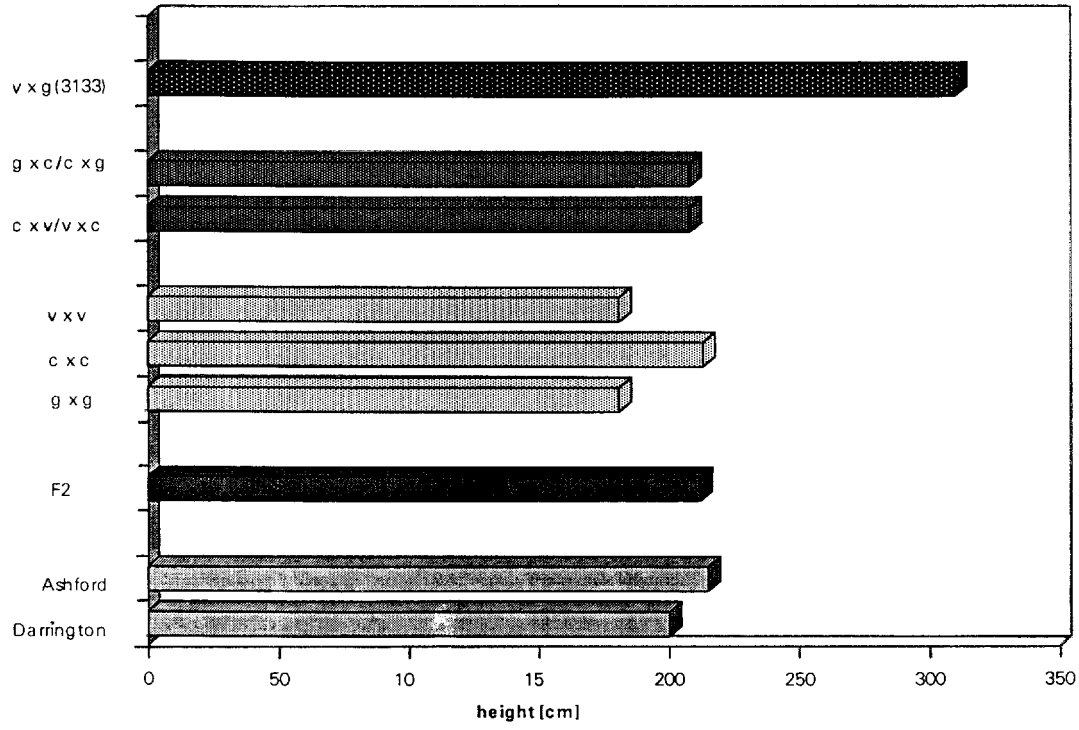


Fig. 13. – Progeny test of Douglas fir hybrids. Age of plants 7 years.

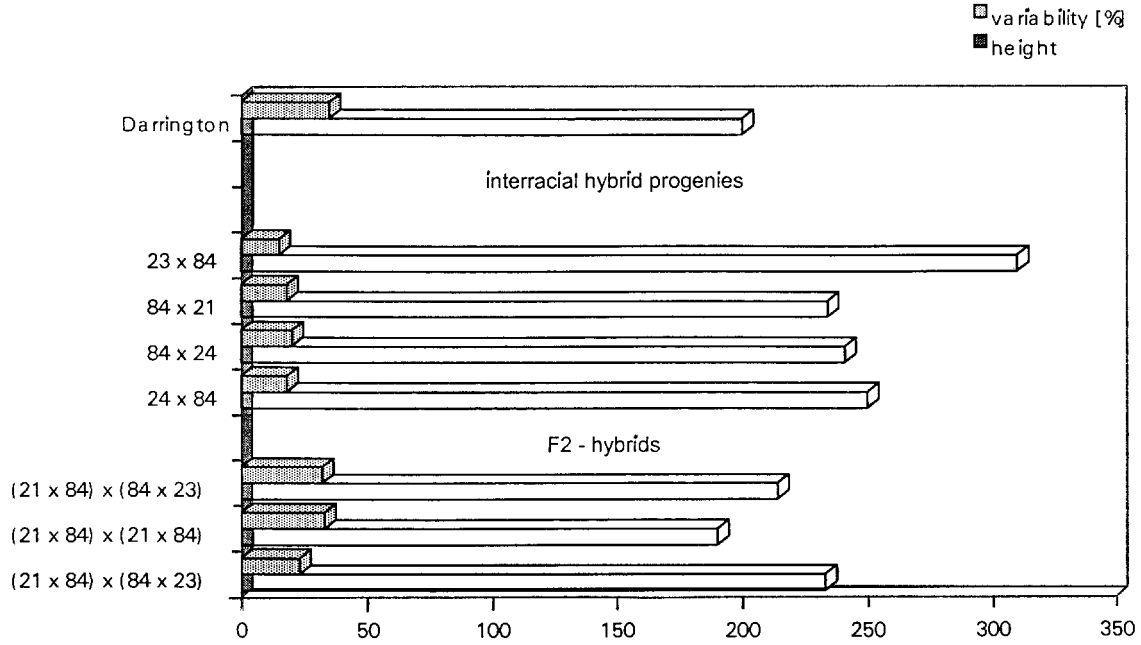


Fig. 14. – Growth and variability of F_2-Douglas fir hybrids in comparison with F_1-hybrid progenies of the same parents. Age of plants 7 years.

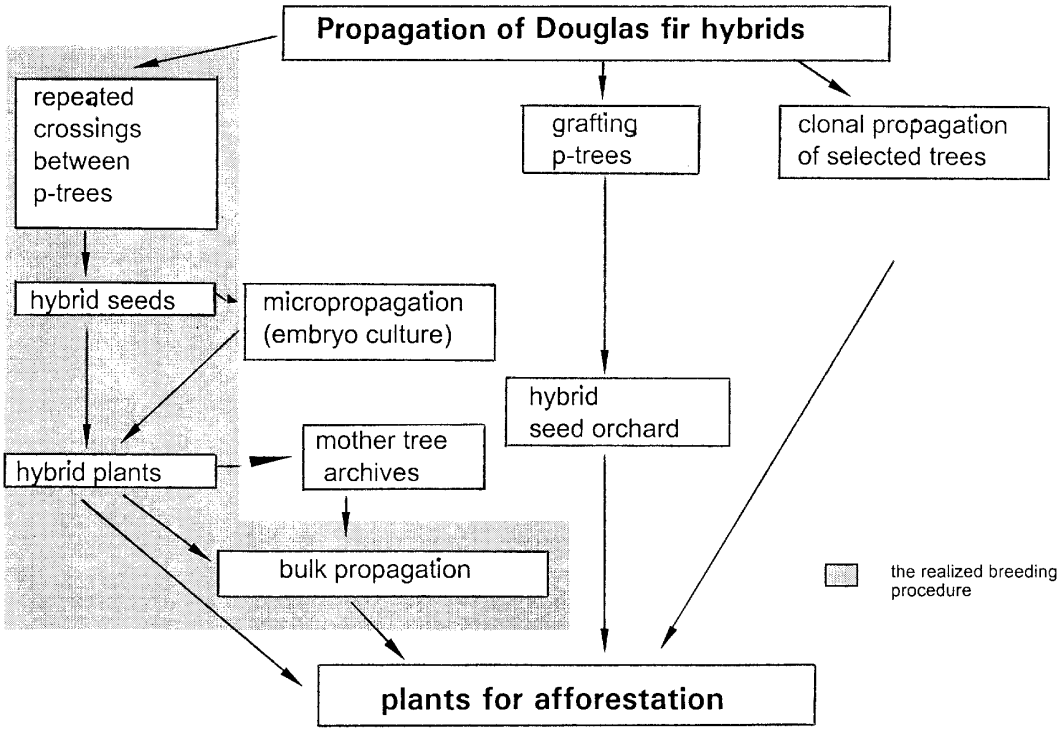


Fig. 15. – Propagation of Douglas-fir hybrids.

Literature

BRAUN, H.: Ergebnisse der Hybridzüchtung bei Douglasie *(Pseudotsuga menziesii* (MIRB.) FRANCO). Beitr. f. d. Forstwirtschaft **22**, 1–7 (1988). — BRAUN, H.: Some Results of Douglas-fir Breeding at Graupa. Silvae Genetica **41**(3), 188–195(1992). — BRAUN, H.: Einige Ergebnisse der züchterischen Bearbeitung der Douglasie. AFZ/Der Wald **51**, München, 14, 770–772 (1996). — BRAUN, H. und SCHMIEDEL, H.: Ergebnisse der Anbauprüfung intraspezifischer Douglasienhybriden unter besonderer Berücksichtigung der Frostresistenz. Beitr. f. d. Forstwirtschaft **19**, 69–73 (1985). — DITTMAR, O., KNAPP, E. und SCHULSEN, B.: Ergebnisse des internationalen Douglasienprovenienzversuches 1961 im Pleistozän der DDR. Beiträge f. d. Forstwirtschaft **19,** 8–18 (1985). — HENGST, E.: Ertragstafel – Douglasie – gestaffelte Durchforstung. Neumann Verlag, Radebeul (1958). — SCHEUMANN, W. und SCHMIEDEL, H.: Die Prüfung der Frostresistenz von Kreuzungsnachkommenschaften der Douglasie (*Pseudotsuga menziesii* [MIRB.] FRANCO) im Labortest und die Bestätigung der Ergebnisse im Anbauversuch. Biologisches Zentralblatt **91**, 707–713 (1971).