The products of larch improvement through breeding can be used in several ways. A use is conceivable for short rotation plantations or as a pioneer phase forest, for example on abandoned agricultural land. The material can also be used in longer-rotation plantations. In such cases, because of ecological consideration, suitable broadleaved tree species should be interplanted with the larch at the time of afforestation or later.

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Some Results of Douglas-fir Breeding at Graupa

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Summary

Due to its high productivity and good ecological and silvicultural characteristics, Douglas-fir plays a special role among foreign species in Germany. A decisive factor in successful cultivation is the genetic suitability of the plants for the specific cultivation site. Therefore, the work undertaken in Graupa was focused on provenance research as well as on studies of established stands and on the supply of tree types from hybrid breeding. Results will be presented of (1) progeny experiments of 1982—83 based on the harvesting of older stands, and (2) hybrid breeding that began in the 1960s. Progenies from interspecific hybridization have highly heterotic rate of growth and are also highly resistant to frost. Quantitative genetic methods were used to analyze hybrid effects.

Key words: Pseudotsuga menziesii, progeny test of seed stands, hybrid breeding.

1. Introduction

Forestry's central role is the culture of ecologically-stable and productive forest ecosystems, while at the same time maintaining their beneficial functions. Suitable exotic species may help to attain this goal by supplementing the comparatively scanty spectrum of tree species encountered in Central Europe.

Among the exotic species, Douglas-fir (*Pseudotsuga menziesii* /Mirb./ Franco) plays a particular role. Douglas-fir has been grown in Central Europe for more than 100 years, its success being dependent on provenance of seeds. Its special position among the exotics is due to its high productivity linked with favourable ecological and silvicultural characteristics.

According to Hermann (1981), the genus *Pseudotsuga* was native to Europe before the glacial epochs. If so, we are, in effect, discussing a "reintroduction" rather than an exotic.

For various reasons, partly due to unfavourable managerial regulations and partly due to trade-policy constraints (foreign currency for imports), the increase in the proportion of forest in Douglas-fir in East Germany was far below expectations, except in a few districts. At present in eastern Germany it is only 0.42%, and in Saxony only 0.08%.

A decisive criterion for cultivating an exotic tree species is its genetic potential for adaptation to the site conditions of the new locality. Along with a reorientation of silvicultural practice away from pure stands toward uneven-aged, mixed stands, with a focus on the individual tree, the genetic component is becoming increasingly recognized as critical to good survival and growth.

As a result of international provenance research, we now have good information on provenances suitable for the various growing regions of the former East Germany (SCHMIEDEL 1981; DITTMAR, KNAPP and SCHULSEN 1985).

Naturally, there are still questions to be resolved, since previous political relationships limited participation in international research projects.

The intraspecific crossing started by SCHÖNBACH yielded some noteworthy results (BRAUN, and SCHMIEDEL 1985, BRAUN 1988), leading to an intensification of research on Douglas-fir breeding at Graupa.

These efforts to increase the area of Douglas-fir on the one hand and the limiting factors on the other, coupled with a growing awareness that progenies of existing stands of Douglas-fir are often more easily evaluated than those of exotics, led to efforts to make the best use of the existing stands. Results obtained from progeny testing and hybrid breeding are presented in the following.

2. Progeny testing of native stands

2.1. Selection, characteristics, and cone collection

The selection of stands included in the test was made in cooperation with practising foresters in the years 1981—82. The stands named in Table 1 had been included in the seed collection.

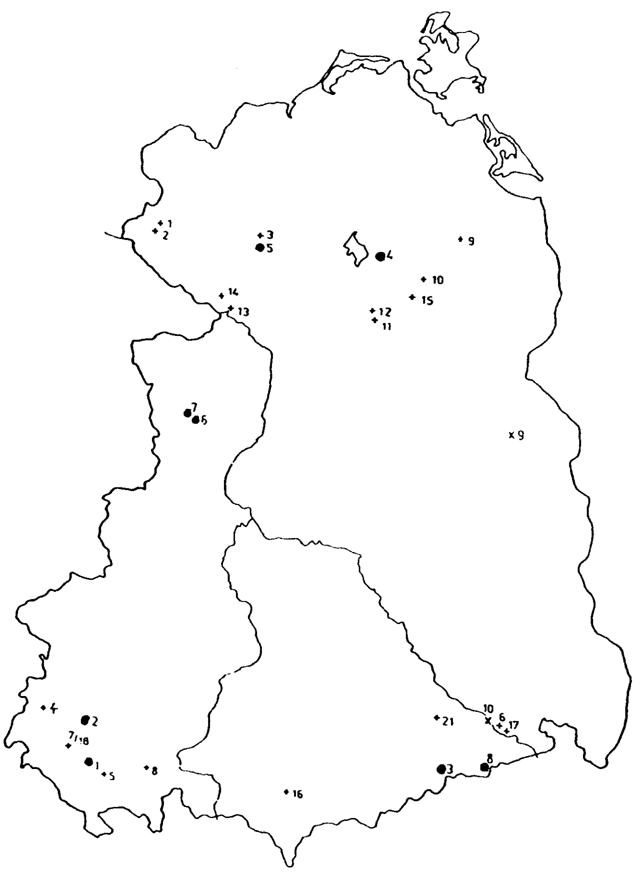
The stands Kiekindemark 6223 a^5 and Spechtshausen 315 a^6 could only be included in the trials to a limited extent because of extensive destruction of seed within the cones by *Megastigmus spermotrophus*. Cones were kept separate by individual trees by the use of a miniature seed kiln.

Seed was mixed according to stands only after a count of the number of filled seeds per tree. Quantitative and qualitative characters were assessed for each tree from which seed was harvested. Seed samples of the provenances Herlasgrün, Hohnstein II and Wernshausen obtained from the Flöha seed kiln supplemented the material. To this material the imported provenances of Ashford and Darrington were added as standard provenances for comparative purposes.

Table 1. — Survey of the harvested stands or imported provenances

No. of	Designation	StFB*	Forest Range	Compartment prov.	harvested trees/stand
1	Schildfeld I	Hagenow	Schildfeld	51 a^3	25
2	Schildfeld II	Hagenow	Schildfeld	52 a^3	20
3	Kiekindemark II	Güstrow	Kiekindemark	6234 b^1	16
4	Marksuhl	Eisenach	Eckhardtshausen	3341 c^2	25
5	Kloster Veßra	Hildburgshausen	Kloster Veßra	1022 a	26
6	Bastei	Königstein	Lohmen	2316 a^5/a^6	26
7	Roßdorf	Meiningen	Roßdorf	4438 b^2	21
8	Ilmenau	Ilmenau	Langer Berg	205 a^2	29
9	Johannisberg	Torgelow	Johannisberg	3539 a^3/3541 a^1	27
10	Lychen	Templin	Lychen	4406 a^2	25
11	Buchheide	Gransee	Buchheide	277 b^3	16
12	Zechliner Hütte	Gransee	Prebelow	76 a^2	29
13	Gadow	Perleberg	Gadow	4087 a^1/a^6	25
14	Ferbitz	Perleberg	Lanz	3006 a^1	27
15	Dabelow	Neustrelitz	Dabelow	4422 a^2	25
16	Herlasgrün	Oelsnitz	HSN 2466	harvests by	
17	Hohnstein II	Königstein	HSN 2260	enterprises	
18	Wernshausen	Meiningen	HSN 4001		
19	Ashford	USA, zone of harvest 422, HSN 5030 imported			
20	Darrington	USA, zone of harvest 403, HSN 5033 imported			
21	Spechtshausen (only tested at Graupa, Oelsengrund and Seyde)	Tharandt	Grillenburg	316 a^6	12
22	Schmiedefeld (only tested at Glasbach and Schwarzbach)	Ilmenau	Schmiedefeld	938 a^2	26

*StFB = State-owned Forestry Enterprise - a designation common in the former East Germany



\+ tested seed stands × nursery test ● progeny test

Figure 1. — Map of stands and trials.

2.2. Nursery cultivation of test material

Sowing took place in May 1984 in the half-shade nursery of the Waldsieversdorf station for forest tree breeding. The seed density varied with proportion of filled seed in order to give approximately equal numbers of filled seeds per square meter. Seedling emergence was evaluated and counted periodically. The transplanting of seedlings for the trial areas was carried out in the tree nurseries of Dabelow, Zillbach, and Hetzdorf (former forestry enterprises Neustrelitz, Meiningen, and Tharandt) as well as in the nurseries of Waldsieversdorf and Graupa. In the transplant beds assessments were made of frost hardiness, of plant mortality, and plant height.

2.3. Trial plantations

In the spring of 1987, experimental plantations were established with 4 replicates each at altogether 9 forest localities:

Test sites of the institute Graupa:

StFB	Forest Range, Comp.	altitude	soil type	immission
Meiningen	Glasbach, 5736 a^3	600m	granite brown soil	
Meiningen	Schwarzbach, 3434 a^1	350m	sandstone brown soil	
Tharandt	Seyde, 111 a^2	740m	gneiss brown soil	medial damaged area
Tharandt	Oelsengrund, 207 c^3	580m	gneiss brown soil	extreme damaged area
Graupa	(tree nursery trail)	172m	loessic loam brown soil	

The number of plants per plot ranged from 24 to 30 (tree nursery trial) and from 49 to 56 in the cultivation tests of the various forest enterprises.

2.4. Data assessments in the trials

2.4.1. Height growth

Tree height was recorded in the autumn of 1990 in the forest enterprise plantations by the use of a measuring rod. The data were taken at age 7 after 4 years in the field. In the nursery trails, measurements were made annually.

2.4.2. Frost hardiness assessments

Estimates of frost damage had already been made in the transplant stage on the following dates:
Dabelow, 10 June 1986
Waldsieversdorf, 29 April 1986
Graupa, 28 April 1986
Hetzdorf, 14 May 1986
Graupa, 17 May 1987
Zillbach, 20 April 1987

The following index was used to assess frost hardiness:
0= no frost damage
1= few small brown needle tips
2= more pronounced needle damage, shoot undamaged, terminal bud healthy
3= heavy needle damage, slight to medium-extent needle damage, dry terminal bud
4= heavy shoot damage, up to 50% of the shoot dried up
5= complete damage, whole plant brown-coloured

2.4.3. Needle damage

The test plantations of Seyde and Oelsengrund in the subsequently-named Saxon forest ranges of Bärenfels and Altenberg, located in fume-damage zones II or I (extreme) were assessed in May 1989 for needle damage to the 1988 needle whorl according to the following index:
1= undamaged
2= damaged
3= heavily damaged

In the Oelsengrund trial (now forest range Altenberg) the 1987 annual needle whorl was also evaluated. To do this, the index had to be extended to grade 4 — annual needle whorl not existing.

2.4.4. Laboratory determination of frost resistance

The laboratory test method developed by Scheumann (1965, 1966, 1968) formed the basis of frost resistance determinations in the refrigerator testing. Side-shoots were separated from the 3-year-old plants at Graupa, which were then placed in plastic bags and exposed to changing conditions in a climate chamber. The critical freezing temperature was the 50%-damage point, which could be determined by simultaneously freezing subsamples at five different temperatures and by comparison with the control that was not frozen, by interpolation.

2.4.5. Mathematical-statistical evaluation procedures

All primary data were recorded by personal computer equipment and processed by the software developed at Graupa (Weissleder 1990). Standard statistical procedures were used as follows (Rasch et al. 1978—81): test for homogeneity of variance, analysis of variance (cross classification with unequal subclass number, model I), comparison of mean values (modified Welch test); significance level = 0.05. The multivariate evaluation procedure used for grouping populations in test cluster analysis was that developed by Ward and published by Deichsel and Trampisch (1985).

For the selection of provenances evaluated for several characters, and for representing the respective trait formation of a certain population in relation to the entire collection a selection quotient (AQ) was calculated as follows:

$$AQ = \frac{x - x_{pess}}{x_{opt} - x_{pess}} \times 100$$

whereby:
x = mean value of the particular progeny
x_{pess} = value of the worst progeny in terms of the trial
x_{opt} = value of the best progeny in terms of the trial

The following results relate only to that part of the whole test series which was evaluated by the research group at Graupa.

2.5. Results and their evaluation

2.5.1. Height growth

Annual measurements of height in the nursery trial provide a continuous survey of the development of progenies up to the seedling age of eight years. Over the years, the differences in the progenies appear to be significant. The following tendencies were apparent:

No essential rank shifts of provenances were recognizable (Fig. 2).

Mean tree height was
1987 46.4 cm
1988 88.9 cm
1989 1.44 m
1990 2.15 m
1991 2.80 m

In 1991, extreme values varied between 3.38m (provenance Wernshausen), and 1.70 m (provenance Herlasgrün). The comparison provenances, Ashford and Darrington, ranked 7th at 2.90 m, and 18th at 2.64 m, respectively.

Mean height in the two Thuringian experiments (Glasbach, Schwarzbach) was 1.15 m. Ashford ranked 10th, whereas Darrington ranked 14th. In all, 6 provenances had a significantly better growth than Ashford.

Both of the tests situated in the Ore Mountains (Oelsengrund, Seyde) were characterized by a high level of emmission loads. In these tests a mean tree height was only 0.67m and only one progeny (Wernshausen) averaged significantly higher than one of the comparative provenances (Ashford).

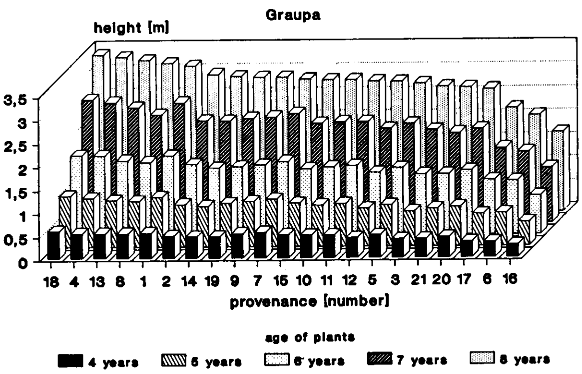


Figure 2. — Height growth of Douglas fir provenances. Nursery test.

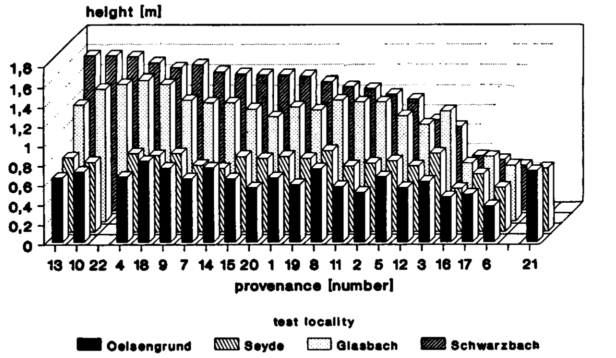


Figure 3. — Douglas fir provenance test. Height growth at age 4 after planting.

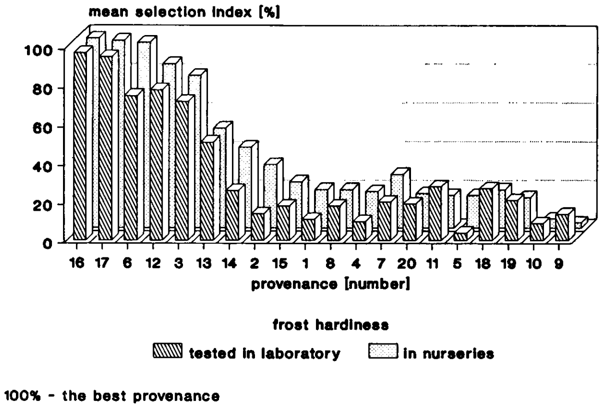


Figure 4. — Douglas fir provenance test. Winter frost hardiness.

2.5.2. Frost resistance

2.5.2.1. Frost damage in transplant nurseries

Figure 4 summarizes all results.

The frost injury that occurred over the two years at the five different localities varied. The 1986-87 winter season was characterized by the highest frost injury at Graupa (mean assessment grade 2.75). Due to the high selective effect of this winter period at Graupa, the results have special importance. Taking into account the two age levels and all the outplanting localities, the provenances of Bastei, Herlasgrün, Hohnstein II, Zechliner Hütte, and Kiekindemark II appear to have by far the highest degree of frost hardiness. The provenances of Johannisberg (9) and Lychen (10) are the most frost-sensitive. Low frost resistance was also obvious in a number of other provenances, including both the imported provenances of Ashford and Darrington (19 and 20) and the progenies of Wernshausen (18), Buchheide (11), Ilmenau (8), Roßdorf (7), Kloster Veßra (5), Marksuhl (4), and Schildfeld I (1).

2.5.2.2. Frost resistance test based upon artificially imposed frost stress

Another test of frost resistance was conducted between November 5 and 25 in 1986. Results are shown in Figure 4.

Again there was an unambiguous grooping of the progenies according to their frost hardiness, with a regression coefficient of 0,97. In relation to the open-field assessments after the winter of 1986—87, it was possible to recognize beforehand in the laboratory that the provenances with the most frost-hardy trees in the field were also characterized by significantly higher frost-hardiness in the laboratory (Spechtshausen was not tested in the laboratory).

2.5.3. Needle damage

It was not possible to unambiguously determine the cause of needle damage, i. e. whether it was an effect of emissions and/or frost, or a combination of both factors.

After the winter of 1988—89, needle damage occurred only in the test localities of Seyde and Oelsengrund situated in the emissiondamaged area. This suggests that the damage was the exclusive result of emissions, especially in view of the fact that the Oelsengrund test was under an aspen shelter.

All progenies of both trials exhibited needle damage (Fig. 5). In the Syde trial, the damage range of the annual needle whorl of 1988 extended from 1.37 (slight, isolated damage) to 2.49 (almost all plants heavily damaged). Provenances 17, 6, 3, 21, 16, and 12 were significantly better than the average. Provenances 11, 4, 5 and 2 had the most susceptible trees; most were no longer viable. Considerable damage was apparent among trees of all other provenances.

In the trial area of Oelsengrund the 1987 needle whorl was also measured. Provenances 21, 17, 6, 12, 16, 3 ranked clearly higher than the others.

The number of annual needle whorls was recorded in the assessments made in the autumn of 1990. Here, too, very distinct differences were found. Trees from provenance of Spechtshausen still had more than three annual needle whorls at Oelsengrund (x = 3.23), in comparison with the provenance of Buchheide, which had an average of less than 2 annual needle whorls (x = 1.7). At Seyde, the average number of annual needle whorls was even lower. The provenance with the greatest number of needle whorls (x = 2.13) was Kiekindemark II, with the lowest was Lychen with an average of only 1.55 annual needle whorls.

2.6. Discussion of results and evaluation of progenies

The results, which are only partly presented in this paper, permit an initial judgement of the provenance under test. Naturally, a comprehensive evaluation of growth can not be based solely in the performance of juvenile progenies. Frost resistance, phenological traits and resistance to air pollution may be judged with some degree of confidence. This test series laid a solid foundation for long-term provenance testing, by providing comprehensive material for furter basic research on population genetics and for breeding. Using cluster analyses a 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

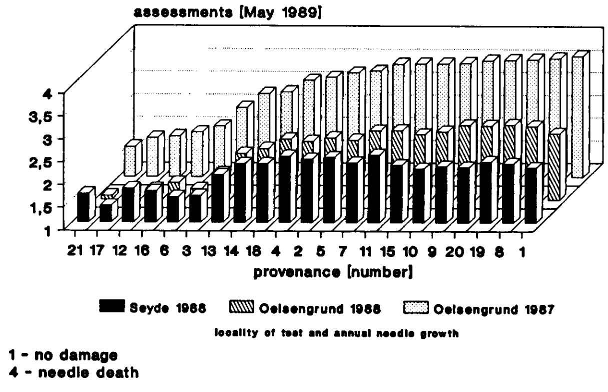
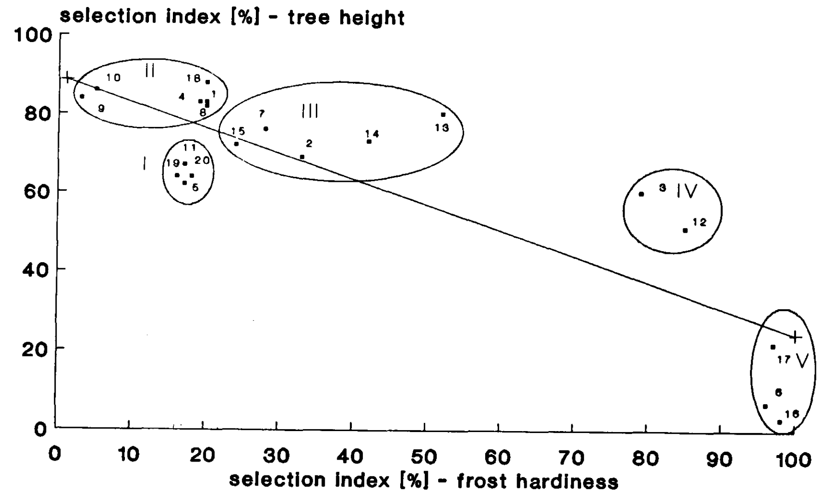


Figure 5. — Douglas fir provenance test. Needle damage in localities with high air pollution.



100% - the best provenance

Figure 6. — Douglas fir provenance test. Relationship between frost hardiness and tree height.

provenances; and (2) the less vigorous but frost-hardy progenies. The critical factors in provenance evaluation, the frost hardiness and vigour, are reflected by their relationships as judged by cluster analysis and illustrated in Figure 6. The results make possible initial recommendations for provenance selection.

One group of progenies (Fig. 6, group I) is neither distinguished by vigour nor by other good desirable properties. The group includes provenances 11, 5, 19, and 20. The two standard provenances of Ashford and Darrington also belong to this group. As a result of the progeny tests, the statement made by a number of research workers in regional experimental institutions (WEISGERBER, KLEINSCHMIT, GÜNZL) that "indigenous" Douglas-fir is often superior to the imports has also been demonstrated.

As to the joint evaluation of all tests, including lowland trials, the progenies of Lychen, Wernshausen, MarkSuhl, Schildfeld I, Johannisberg, and Ilmenau (group II, Fig. 6) rank first in height growth but are very frost-susceptible. Hence, growing them in the open is risky. This risk may in part be lessened by appropriate silvicultural measures, such as opening of the canopy and the strip cutting method. Nevertheless, total failures, especially in the juvenile stage must be expected as a result of certain winter wheather conditions, i.e. warm periods with subsequent frost onset. Growing these trees in the low range of mountains is not possible.

Of the progenies summarized under group III the provenance of Gadow (13) is of particular interest. This provenance has a high rate of growth in all cultivation trials and at the same time a moderately-high level of frost resistance (Fig. 6). Judged by selection quotients taking into account combined growth and frost resistance on all nine trial plots, this provenance is ranked third highest. If only the two Thuringian trials are considered, it ranks first. Considering time of flushing and of growth cessation (mid-period flush, early dormancy) it is more closely related to the blue-gray forms than to the green varieties. In addition it rates high in laboratory tests for frost resistance. In the two trials exposed to heavy emission stress (Oelsengrund and Seyde) and tested for needle damage and number of annual needle whorls, it had a distinctly higher resistance than most of the other provenances. The progeny of the Gadow population has, on the average, the lowest mortality of test plots.

During harvesting in the region of Gadow, it was evident that stands were mentioned in which all variaties from green to blue occured. It seems possible that in this area some hybridization between the varieties of the progenies is taking place, causing this positive result of the test. The original provenance is unknown to the author. Its importance was emphasized by GALONSKA (1991).

The provenance of Kiekindemark II (3) and Zechliner Hütte (12) shown in Fig. 6 as group IV, are of special interest for cultivation in the low range of mountains even under high air pollution conditions. Both provenances lie 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 Zechliner Hütte ranks second. At both Seyde and Oelsengrund, the two provenances are distinctly higher in vigour (needle damage, average number of annual needle whorls) than the other provenances. Taking all traits into consideration including needle colour, both provenances can be assigned to the group of graycoloured forms of Douglas-fir. A similar assessment was made for the provenance of Spechtshausen, which although represented only in the nursery test at Graupa and the tests at Oelsengrund and Seyde, was also analysed in the laboratory assay. The results agree with earlier field experience with the Spechtshausen provenance (SCHMIEDEL 1981, BRAUN 1985, TAUTKUS 1990).

Two seedling orchards were established in Saxony with trees of the provenance Zechliner Hütte.

The progenies of group V in Fig. 6 had very poor growth. Coincidentally, these populations ranked last in all the tests, although they are the most frost-hardy of all. Even in open-field areas, no frost damage occurs. If only parameters of vigour, including frost hardiness, needle damage, and number of annual needle whorls, are considered with respect to the AQ values, Hohenstein II ranks first, Bastei second, and Herlasgrün fourth. In view of these results, cultivation with intentional disregarding of growth under such extreme conditions as open-field areas with emission stress could merit serious consideration in the low range of mountains. Since it possesses these properties, the provenance Bastei, for example, has special importance for breeding work.

In this Douglas fir provenance test only a minor part of East German provenances were being tested. The results show, on the one hand, that artificial provenances are often superior to the imports, but also that artificial populations are not in general and under all site conditions distinguished by a higher adaptability. This is strikingly demonstrated by the results dealing with frost resistance. In view of these results, it would be useful to stepwise include all larger "indigenous" Douglas-fir stands in future test. The laboratory results of the frost resistance testing show that seedlings can be assessed in a safe, relatively uncomplicated, and rapid way. It would be possible to also test in this way all the other commercially available provenances and to classify them according to frost hardiness.

3. Objectives and results of hybrid breeding

Low resistance to frost has always been a limiting factor in the growing of Douglas-fir in this part of Europe, particularly in that part of the low range mountains that is more continental in its climate. For this reason, forest tree breeders tried, under the leadership of SCHÖNBACH, to increase frost resistance of the fast-growing Green Douglas-fir. An effort was made in the early 1960s to combine the forst hardiness of *glauca* with the vigor of *viridis* that had already been demonstrated in progeny tests.

Figure 7 shows a series of crosses made by BELLMANN in old trees that resulted in 35 combinations for a progeny test. In 1967, an experiment was established in the Tharandt Forest Range using this plant material. In addition, trees from an imported seedlot were incorporated into the test, the origin was in the Upper Fraser River Valley at 700 m altitude in the interior of British Columbia.

progeny test douglas fir Tharandt — v - viridis, g - glauca

♀ \ ♂	138(g)	84(g)	137(g)	88(v)	3(v)	4(v)	21(v)	23(v)
138(g)		20	19			16	17	18
84(g)			24	23		21		22
137(g)	14	15			10	11	12	13
88(v)		9						36
4(v)	1	2			26		27	28
21(v)	4	5	3		29	30		31
23(v)	7	8	6	35	32	33	34	

progeny number

Figure 7. — Crossing design.

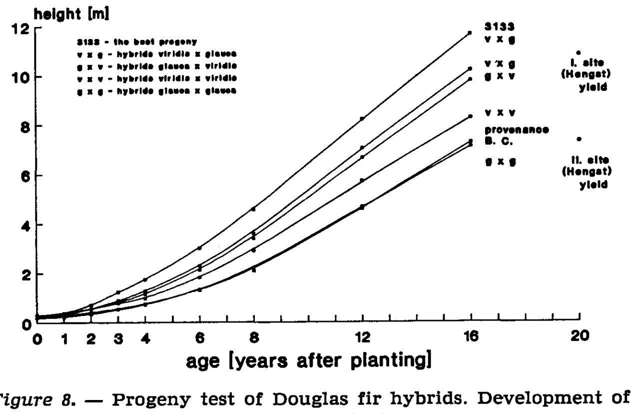


Figure 8. — Progeny test of Douglas fir hybrids. Development of mean tree height.

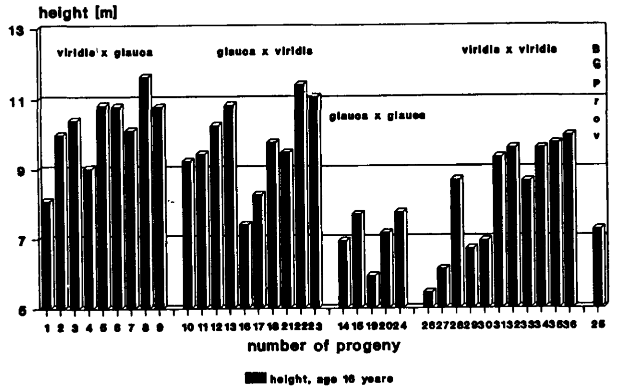


Figure 9. — Progeny test of Douglas fir hybrids. Height growth at age 16 after planting.

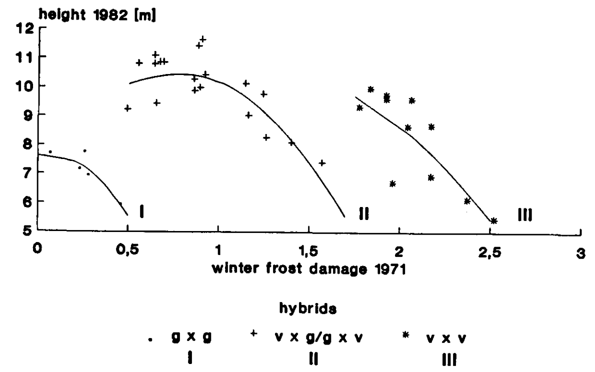


Figure 10. — Progeny test of Douglas fir hybrids. Relationships between tree height and frost hardiness.

3.1. Results of the cultivation test

Over the testing period from 1967 up to autumn 1982 altogether 9 height measurements were made, 1967, prior to outplanting; and each in autumn 1967, 1968, 1969, 1970, 1972, 1974, 1978, and 1982. In addition, frost resistance was measured. The plantation was established on an open-field area, with advance stocking of Norway spruce categorized by WIEDEMANN as "3rd site yield table".

Figure 8 illustrates the course of mean height growth of the progenies, arranged according to groups.

A large part of progenies of crosses between the *viridis* and *glauca* forms of Douglas-fir reaches value lying clearly above a first site quality class according to yield-table of HENGST (1958).

The best progeny from cross-breeding of *viridis* and *glauca* averaged 11.65 m in height 16 years after planting, 60% above the comparative provenance from the Upper Fraser River Valley (Figure 9).

More recent measurements indicate, that the vigorous growth of race hybrids has continued. At age 23 the mean height of progenies v x g and g x v was 16.3 m.

The progenies show distinct differences in frost hardiness. The type of frost damage most dangerous to Douglas-fir, in our region is the damage from winter frost. SCHEUMANN and SCHMIEDEL (1972) and SCHÖNBACH reported this fact, which was also verified by assessment in our experiment. Observations were made on frost damage in the spring of 1968, 1969, and 1971. The pure *glauca* forms

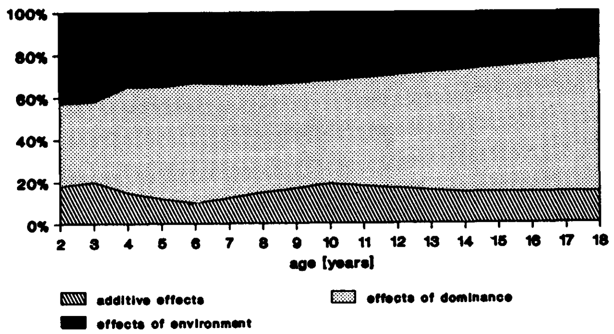


Figure 11. — Progeny test of Douglas fir hybrids — genetic components — tree height.

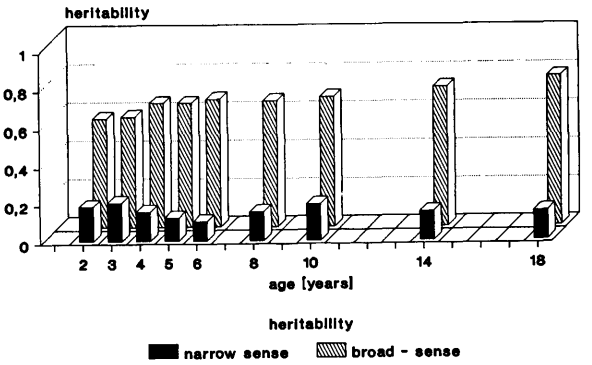


Figure 12. — Development of heritability. Tree height.

were completely frost-hardy. The pure *viridis* progenies were sufficiently damaged to conclude that they were too risky for field planting. The 1971 winter frost had a particularly selective impact.

Figure 10 clearly shows both the different degrees of frost-hazard of the progeny groups and their correlation with vigour (coefficients of determination of the regression curves I, II, III; 66—84%).

3.2. Genetic effects and heritability

A model of cross-classification with unequal or partly missing subclass number was used for estimating the variance components according to Rasch et al. (1981). Genetic analyses of vigour demonstrated the influence of hybrid effects from estimates of dominance effects in the phenotypical total variance (Fig. 11). A distinct dependence of genetic parameters on age is obvious. In all the parameters of tree growth the genetically governed component increased with age and the environmental component decreased proportionately. Moreover, height growth was subject to a stronger genetic control than diameter and basic density (not discussed in the report).

Figure 12 includes narrow- and broad-sense heritability values for tree height.

3.3. Propagation scheme for hybrids

The desirable properties of hybrids progenies include juvenile vigour, high rate of increment of the individual tree, excellent vitality and a high degree of frost hardiness. It would be desirable to transfer breeding results into forestry practice. Modes of implementing this are indicated in Figure 13.

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, save, and effective method and, in fact, presently the sole method of reproducing the hybrids. An increase of the existing plant material by mass vegetative propagation would be feasible.

3.4. New breeding experiments

In consideration of earlier results of interracial hybridization, we intensified this type of breeding during the period from 1985 to 1989. The objectives were (1) to test a large number of trees by using the tester principle via the topcross procedure, and (2) extend the work with interracial hybridization. Figure 14 shows our recent system for crossing.

In addition to these activities, a breeding program was started within the hybrids, as illustrated by Figure 15.

These experiments are designed to test the performance of outstanding F1 hybrids in the second generation, to determine whether the vigorous growth continues in association with the other characteristics described. A percentage of the material derived from these two breeding programs was sown in 1990. First observations are available (Fig. 16).

Figure 16 again demonstrates that vigour in interracial hybrids is often linked with a low susceptibility to frost in comparison with trees from the provenances of Ashford and Darrington. So far, the two progenies of the second generation of cross breeding that are included also have very desirable characteristics.

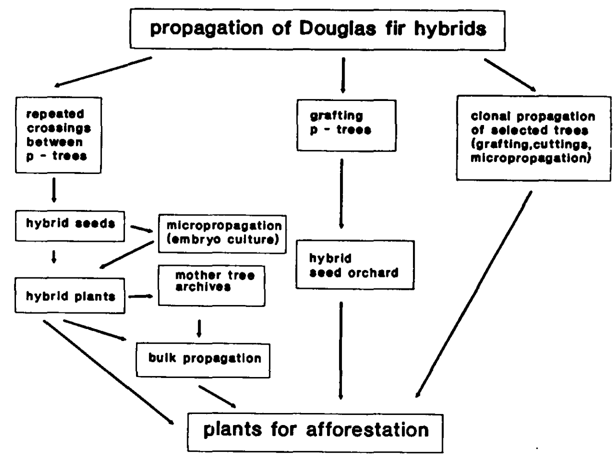


Figure 13.

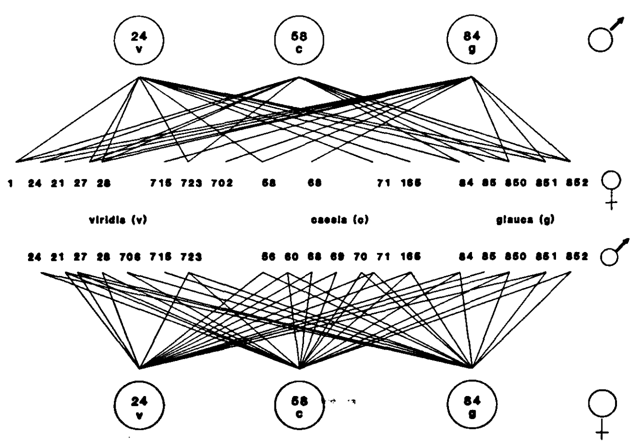


Figure 14. — Plan of cross-breeding in Douglas-fir.

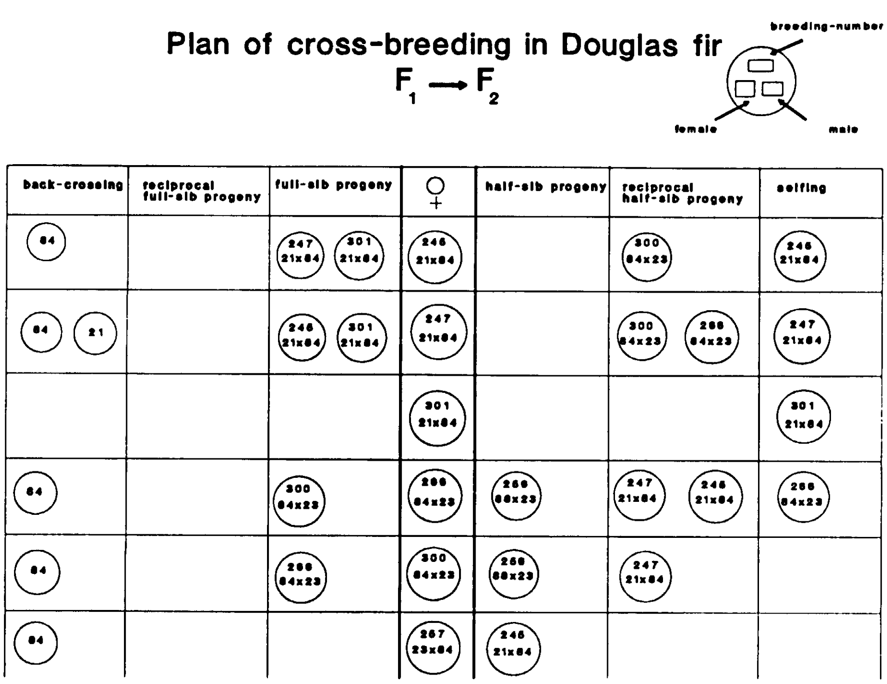


Figure 15.

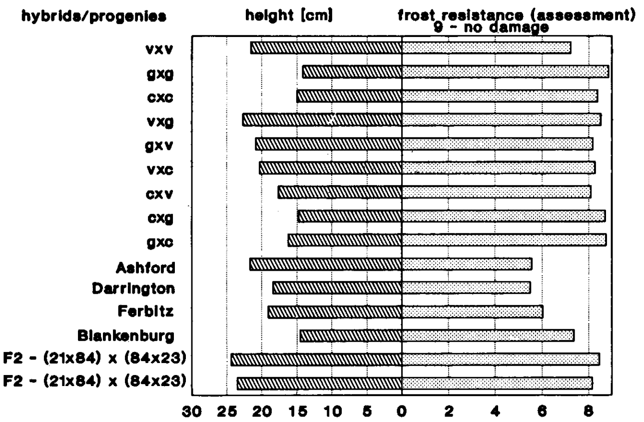


Figure 16. — Progeny test of Douglas fir hybrids. Age 1/1.

In summary, it can be stated that the breeding-oriented activities at Graupa that have been described, ranging from provenance research to hybrid breeding, may be expected to contribute significantly to the intensive culture of Douglas-fir.

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