FBVA - BERICHTE

Nr. 21 Schriftenreihe der Forstlichen Bundesversuchsanstalt 1987

PROCEEDINGS OF THE IUFRO WORKING PARTY ON BREEDING STRATEGY FOR DOUGLAS-FIR AS AN INTRODUCED SPECIES

WORKING PARTY: S. 2.02.05
VIENNA, AUSTRIA
JUNE 1985

W. Ruetz (Co-chairman)
J. Nather (Local coordinator)
Editors

Herstellung und Druck

Forstliche Bundesversuchsanstalt
A-1131 WIEN

Printed in Austria

TABLE OF CONTENTS PAGE

FOREWORD

The IUFRO 22 Working Group on Provenance Research implemented a program for provenance seed collection at their Pont a Mousson, France meeting in September 1965. The collection intended to provide the much needed authenticated material for provenance research mainly from the west coast of North America.

The collection was organized by Helmut Barner from the Danish State Forestry Tree Improvement Station, Humlebaek, financially assisted by the Carlsberg Foundation and the Den Danske Landsmandsbank. The collection commenced by Pseudotsuga menziesii in 1966 and to date 767 kg of seed from 493 sources including Picea sitchensis, Pinus contorta, and Abies grandis have been collected.

The Douglas-fir samples were distributed into 31 countries, and based on the early results, of the most frequently used collection sites were modified and substituted with more suitable origins.

The present meeting from June 10 - 15, 1985, in Vienna - 20 years after the conception of the project - discussed the "Breeding Strategy for Douglas-fir as an Introduced Species", and not only refined collection zones for introduction, but realized the existence of large variation within provenances. New collections in the future, more than likely, will emphasize the family identity within the provenance and consequently will give another dimension to understand intra-specific variation of Douglas-fir. The papers presented are a testimony of the foresight and interest in this species.

The meeting was hosted by the Austrian Federal Research Station Institute for Silviculture. The accommodation provided and test sites visited enhanced the success of the meeting. Finally I would like to express sincere appreciation to Dipl.Ing. J. Nather for his contribution which made this meeting a "moveable feast" one to each of the participants.

Oscar Sziklai
Chairman
Working Group
S2.02.05

LIST OF PARTICIPANTS

D ADAMS, Dr. W. T.
Department of Forest Science
Oregon State University
Corvallis, Or 97331, USA

D BENTZ, Dr. Felix
Bezirksbauernkammer Schärding OÖ
Austria

F BENTZER, Dr. Bengt
Hilleshög Forestry AB, P.O. Box 302
26 123 Landskrona, Sweden

F BERGMANN, Dr. Fritz
Abteilung Forstgenetik und Forstpflanzenzüchtung
Büsgenweg 2
3400 Göttingen - Weende, FRG

F DAOUST, Gaetan
1080 Route du vallon
C.P. 3800 Sainte-Foy (Quebec) Canada G1V 4C7

F DIETRICHSON, Dr. Jon
Norwegian Forest Research Institute
1432 Aas-NLH, Norway

*) O'DRISCOLL, John
Forest & Wildlife Service
Sidmonton Place
Bray Co. Wicklow, Ireland

*) GRACAN, Dr. Joso
Forest Research Institute
Cvijetno Naselje 41
41420 Jastrebarsko, Jugoslavia

GÜNZL, Dipl.Ing. Leopold
Forstliche Bundesversuchsanstalt Mariabrunn
Austria

*) HAGMAN, M.
Department of Forest Genetics
Forest Research Institute
SF-01590 Maisala, Finland

D HEIS, Dipl.Ing. Johann
Landwirtschaftskammer für
Oberösterreich
4021 Linz a.d. Donau
Auf der Gugl 3, Austria

1) D Douglas fir meeting
F Noway spruce meeting
*) announced for both meetings

HOLZER, Dr. Kurt
Fostliche Bundesversuchsanstalt Mariabrunn
Austria

D KING, J.N. Dr.
Department of Forest Science
University of Alberta
Edmonton, Alberta, T6G 2Hl, Canada

*) KLEINSCHMIT, Dr. J.
Nieders. Forstl. Versuchsanstalt
-Abt. Forstpflanzenzüchtung-
D-3513 Escherode, FRG

*) KÖNIG, Dr. Armin
Institut f. Forstgenetik u.
Forstpflanzenzüchtung,
Sieker Landstraße 2
2070 Grosshansdorf 2, FRG

*) KRUTZSCH, Dr. Peter
Skogsstyrelsen
55 183 Jönköping. Sweden

D KUIPER, L.
Department of Silviculture
Agricultural University
Postbus 342 NL-Wageningen
Netherlands

*) LINES, R.
Forestry Commission
Northern Research Station
Roslin, Midlothian, EH25 9SY,
Scotland

D MAGNESEN, S.
Norwegian Forest Research
Institute-Bergen
N-5047 Stend, Norway

D MICHAUD, M.D.
Association Foret Cellulose
9 Av. Garibaldi
F-87 Limoges, France

MÜLLER, Dr. Ferdinand
Forstliche Bundesversuchsanstalt Mariabrunn
Austria

*) NANSON, Dr. A.
Station de Recherches Forestieres
B-1990 Groenendaal-Hoeilaart, Belgium

D NATHER, Dipl.Ing. J.
Forstliche Bundesversuchsanstalt
Wien-Schönbrunn, Austria

D NOSSWITZ, G.
Waldbau-Institut der Universität
Freiburg
Bertoldstr. 17, D-7800 Freiburg i.Br., FRG

D OTTO, Dr. H.J.
Ministerium für Ernährung
Landwirtschaft u. Forsten
Calenberger Str. 2
D-3000 Hannover, FRG

*) PAQUES, L.
Station de Recherches forestieres
B-1990 Gronendaal-Hoeilaart, Belgium

*) PAULE, Dr. Ladislav
Lesnicka fakulta VSLD
960 53 Zvolen, Czechoslovakia

PELEKANOS, Dipl.Ing. Vasilios
Forstliche Bundesversuchsanstalt Mariabrunn
Austria

*) PERSSON, Dr. Anders
SLU - Schwedische Universität
für Agrarwissenschaften
S-77 073 Garpenberg, Sweden

F PRESCHER, Finnvid
Div. of Forest Quality and
Improvement
SLU - Schwedische Universität für
Agrarwissenschaften
S-77 073 Garpenberg, Sweden

D ROMAN-AMAT, B.
I.N.R.A.
Station d'Amelioration des
arbres forestiers
Ardon, F-45160 Olivet, France

*) RAU, H.M.
Hessische Forstliche Versuchsanstalt
Prof. Oelkers Straße 6
3510 Hann. Münden, FRG

D RUETZ, Dr. W.F.
Bayer. Landesanstalt für forstl.
Saat- und Pflanzenzucht
Forstamtsplatz
D-8221 Teisendorf, FRG

SCHULTZE, Dipl.Ing. Ulrich
Forstliche Bundesversuchsanstalt Mariabrunn
Austria

D SZIKLAI, Dr. Oscar
Faculty of Forestry
University of B.C.
Vancouver, B.C. V6T 1W5, Canada

D TOVAL, G.
Centro Forestal de Lourizan
Apartando, 127, Pontevedra, Spain

*) UJVARI, Dr. Eva
Forest Research Institute
Hegyalja u. 10
3232 Matrafüred, Hungary

*) WEISGERBER, Dr. Horst
Hessische Forstliche Versuchsanstalt
Prof. Oelkers Straße 6
3510 Hann. Münden, FRG

*) WERNER, Martin
Institute for Forest Improvement, Ekebo
28 800 Svalöv, Sweden

F WESTCOTT, Dr. R.
Unilever Research Colworth Laboratory
Colworth House, Sharnbrook
Bedford MK 44 1 L Q, England

*) WIDMAIER, T.
Forstliche Versuchs- u. Forschungsanstalt
Abt. Botanik u. Standortskunde
Fasanengarten
7000 Stuttgart 31 Weilimdorf, FRG

F SCHMIDT, Dipl.Ing. Josef
Institut für Landwirtschaft
Österr. Forschungszentrum Seibersdorf
Gesellschaft m.b.H.
Lenaugasse 10
A-1082 Wien, Austria

SESSION I

FIRST RESULTS OF AMERICAN DOUGLAS-FIR PROVENANCE TRIALS IN FRANCE

D.MICHAUD

Association Foret-Cellulose
9, Avenue Garibaldi - 97000 - Limoges - FRANCE

A B S T R A C T

Within the framework of the studying program of the Douglas-Fir (Pseudotsuga menziesii Mirb. Franco) variability, Association Foret Cellulose (A.FO.CEL) planted, from 1977 to 1979 a first series of trials to study the adaptability of 186 provenances covering almost the whole natural area of the species. The first results of a few of these trials are given here.

Growth study, estimated by total height at eight years, shows that the results are very constant from one trial to another. In all cases the most vigorous provenances are coming from the area bounded by the Cascades Range eastward, latitude 50° northward and latitude 44° southward. This area corresponds to the western part of the state of Washington and the northern part of the state of Oregon. Some origins from the south western of British Columbia should also be interesting. Growth decreases when the altitude of the crop-site increases : provenances from lower altitudes are the most vigorous. These results confirm the observations made at the nursery stage (MICHAUD, 1978) on three year transplants. The correlation growth-lateness of flushing is positive and very clear. As regards polycyclism, it is observed that among vigorous provenances some are very polycyclic and others a lot less.

It is pointed out that A.FO.CEL. has also planted, from 1978 to 1981, two other series of trials : one with 82 seed sources from the state of Washington and the other with French artificial seed sources. Cuttings have been taken on the best plants (at three years) of the best provenances, in order to obtain the first polyclonal variety.

I N T R O D U C T I O N

The Association-Foret-Cellulose has begun a research program about the variability of Douglas-fir (Pseudotsuga menziesii Mirb. Franco) since 1975. One of the first preoccupations was to sample as well as possible the whole original area of the species. 186 seed lots were obtained and were used to plant a first series of trials (trials called "PROVDOUG B"). We are going to give here the first results obtained on 7 of these trials. These results are about growth, flushing and polycyclism.

S E E D   S O U R C E S   U S E D

The seed-sources used are described in Table 1 and presented in Figure 1. 75 lots were obtained from IUFRO.

T R I A L S   P R E S E N T A T I O N

The geographic location of the trials and a few site indicators are given in Figure 2. When the 8 years height was measured, the provenance number by trial was the following:

Trials	MAZEROLLAS	ROYERE	BOUISSE	PERRUEL	ST BRISSON	ARUDY	KERPERT
Provenance number	179	136	166	73	80	32	41

Table 2 states precisely what the provenances represented on each trial are. Each provenance is generally represented by 30 plants (single tree lay out). Their planting was realized from 1977 to 1979, and the plants used were one year seedlings raised in containers or 1+2 transplants.

R E S U L T S

Growth

Growth was estimated by measuring the total height at 8 years. First of all, we calculated the correlations between average heights by provenance obtained at MAZEROLLAS and on the other trials. The results are the following (figure 3):

	ROYERE	BOUISSE	PERRUEL	ST BRISSON
MAZEROLLAS	r=0.959***	r=0.873***	r=0.828***	r=0,891***

	ARUDY	KERPERT
MAZEROLLAS	r=0.856***	r=0.792***

These positive and highly significant correlations show that the grading of the provenances is practically the same on the different trials. We notice that the best growth is observed on the MAZEROLLAS trial. On this trial, the average 8 year height of the best provenance-WASHINGTON, SEDRO WOOLLEY (number AFOCEL : 55 and IUFRO : 1051) - is 379 cm.

- Influence of longitude, latitude and altitude of crop-site:

. longitude:

The provenances east of longitude 121 , therefore from the east of the Cascades Range, have weak growth. Figure 4 represents the influence of longitude on growth at MAZEROLLAS. We can see that the most vigorous provenances are from Washington and OREGON. A few provenances from British Columbia also seem interesting; the growth of provenances from California is only low or medium.

. latitude:

We only took into consideration the influence of latitude on the growth of provenances from the western area of the Cascades Range Crest (longitude ⩾ 121°).
Growth increases regularly with latitude as far as 44° , it seems then practically constant as far as the north of Washington and it decreases in British Columbia. These results are illustrated in Figure 5 (MAZEROLLAS trials, height at 8 years).

. altitude:

Altitude has a negative influence on growth. The correlations coefficients between the altitude of the crop site and growth (8 years height) are as follows:

Trials	MAZEROLLAS	ROYERE	BOUISSE	PERRUEL
Cor. Coef.	- 0.670***	- 0.665***	- 0.603***	- 0.470***

Trials	ST BRISSON	ARUDY	KERPERT
Cor. Coef.	-0.580***	- 0.595***	- 0.316***

Figure 6 illustrates the correlation between altitude and growth at MAZEROLLAS. For the state of Washington, we can observe that growth seems practically constant up to 800 m, but the south of this state is not very well sampled.

Flushing

Flushing was studied in the spring of 1980 at MAZEROLLAS, BOUISSE ROYERE and KERPERT, and at MAZEROLLAS and ROYERE in the spring of 1981. Observations were done on the terminal bud. In 1980, we calculated from regular observations, an average flushing note which is all the higher as the provenance is late. In 1981, we simply calculated, at a given date, the percentage of flushed plants for each provenance.

In 1980, the correlations between the results (flushing-note) were very high on the three plots. The coefficients are the following:

	BOUISSE	KERPERT
MAZEROLLAS	r = 0.90***	0.76***

The correlation between flushing at MAZEROLLAS and BOUISSE is illustrated on Figure 7. In 1981, results between MAZEROLLAS and ROYERE were also highly correlated (Figure 8). Observations made at MAZEROLLAS in 1980 and 1981 showed that the grading of the provenances remains the same in time. We observed that there was an important relation between growth and flushing. On the three plots studied on 1981, the correlations between lateness (flushing note) and growth (5 years height) were the following:

MAZEROLLAS	BOUISSE	KERPERT
r = 0.77***	r = 0.52***	r = 0.80***

The MAZEROLLAS results are illustrated in Figure 9.

Polycyclism

Polycyclism notations were done at MAZEROLLAS in 1980 (beginning of the fifth year) and in 1981 at MAZEROLLAS, ROYERE and BOUISSE. 1981 was a bad year for growth and polycyclism was very low on all the trials, so the results are difficult to explain. The MAZEROLLAS 1981 results show that the geographic variability of the polycyclism is not as clear as that of growth and flushing. In Figure 10, we can see that there is no relation between growth and polycyclism at MAZEROLLAS (provenances of longitude $\geqslant 121°$). We will observe that among the most vigorous provenances, some are very polycyclic and some a lot less. Therefore, polycyclism seems a criterion on which selection at provenance level will be effective. But, beforehand, we have to study the consequences of polycyclism, especially on branching.

C O N C L U S I O N S

These first results in planting enable us to determine the part of the natural Douglas-fir area where we will find the most interesting seed sources for French afforestations. This zone is bounded by the Cascade Range eastward (longitude $\geqslant 121°$), by latitude 50° northward and 44° southward. This corresponds to the western part of the state of Washington and the north-western part of Oregon. A few provenances coming from the south-western part of British Columbia should also be interesting. Growth is negatively correlated with the altitude of crop-site. The grading of provenances in terms of lateness of flushing is perfectly permanent in space and in time. Lateness and growth are positively correlated. The variability of polycyclism is difficult enough to appreciate. It seems, that, among the most vigorous provenances, some should be very polycyclic and others a lot less. A selection on this criterion, at provenance level, should be effective.

On this first series of trials we have again to precise the results on growth and to study some criteria like branching.

We must point out that we have also planted two other series of trials: 6 trials have been planted with 82 seed sources from the state of Washington and 4 trials with artificial French seed sources.

In order to produce a first polyclonal variety, cuttings have been taken from the best plants of the best provenances in the nursery, before planting. These clones are now studied in clonal-tests and we keep studying the cutting-technique.

R E F E R E N C E S

Birot Y., Burzynski G. 1981: Analyse comparee d'un test de provenances de Douglas installe en France et en Pologne. Revue Forestiere Francaise XXXIII, 1, pp. 116-126

Ching, K.K. and P. Hinz: Cooperative provenance study of Douglas-fir in the Pacific northwest. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978, pp. 229-233

de Vecchi, E.: IUFRO Douglas-fir plantation in Turin, Italy. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas- Fir provenances, Vancouver (Canada) 1978, pp. 347-349

Griffin, A.R. and A.C. Matheson: Early height growth of some provenances from the IUFRO Douglas-fir collection in nine Australian field trials. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978, pp. 217-228

Illingworth, K.: Douglas-fir provenance trials in coastal British Columbia. Results to six years after planting. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978, pp. 411-426

Kleinschmit, J.: Douglas-fir in Germany. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978, pp. 317-333

Kleinschmit J., Svolba J., Weisgerber H., Jestaedt M., Dimpflmeier R., Ruetz W., Dietrich H. 1979: Ergebnisse aus dem internationalen Douglasien-Herkunftsversuch von 1970 in der Bundesrepublik Deutschland; II: Ergebnisse der Feldversuche im Alter 6. Silvae Genetica 28, 5-6, 1979

Kriek, W.: Further development of Douglas-fir IUFRO provenances in the Netherlands 1966/67 series. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978, pp. 241-255

Lines, R.: The IUFRO experiments with Douglas-fir in Scotland. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978, pp. 297-303

Magnesen, S.: Preliminary report on the international short term Douglas-Fir provenance experiment in West Norway. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978, pp. 257-264

Michaud D., 1978: Résultats en pépiniere de 184 provenances de Douglas. Annales de Recherches Sylvicules de l'AFOCEL, pp. 41-87

Michaud D., 1980: Etude du débourrement de 181 provenances de Douglas. Annales de Recherches Sylvicoles de l'AFOCEL, pp. 153-192

Nanson, A.: Belgian provenance experiments with Douglas-fir, Grand fir and Sitka spruce. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978, pp. 335-349

O'Driscoll, J.: Six-year phenological study of thirty-two IUFRO provenances of Douglas-fir. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978, pp. 265-295

Pearce, M.L.: The IUFRO experiments with Douglas-Fir in England and Wales. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978, pp. 381-388

Reck, S.G.: Height growth and frost resistance in Douglas-Fir provenances tested in the northern part of Germany. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978, pp. 175-188

Weisgerber, H.: Height growth development and damage by spring frost of the IUFRO Douglas-Fir provenance trial of 1970 in Hesse, Federal Republic of German. Proceedings, Joint IUFRO Meeting, S2-02-05 Douglas-Fir provenances, Vancouver (Canada) 1978 pp. 305-316

TABLE 1

IDENTIFICATION OF THE PROVENANCES

AFOCEL NUMBER	IUFRO NUMBER	PROVENANCE	LAT.	LONG.	ALT.	SEED SUPPLIER
1		USA Californie San Diego	33°3	116°8	1524	F.T.S.C. *
2		USA Californie San Bernardino	34°	116°9	-	"
3		USA Californie Los Angeles	34°3	117°7	1315	"
4		USA Arizona Apache	34°	109°5	2745	"
5		USA Idaho Boise	44°	115°6	1829	"
6		USA New Mexico Otero	32°9	105°7	2682	"
7		USA Oregon Lane	44°8	122°1	914	"
9		USA New Mexico Colfax	36°	106°	2667	"
10		USA Arizona Coconino	35°3	111°6	2560	"
11		USA Arizona Apache	33°9	109°3	2550	"
12		USA Oregon Klamath	43°2	121°5	1200	"
13		USA Oregon	43°5	121°5	1050	"
14		USA Washington	47°6	121°7	600	"
15		USA Washington Snohomish/King	47°2	121°8	450	"
16		USA Oregon Tillamook	45°3	123°8	300	"
17		USA Oregon	43°5	121°5	150	"
18		USA Oregon Josephine	42°4	123°7	300	"
19		USA Oregon Jackson	42°5	122°5	1200	"
20		USA Washington Clallam	47°9	123°2	600	"
21		USA Washington Clallam	47°9	123°2	300	"
22		USA Oregon Hood River	45°5	121°7	1350	"
23		USA Oregon Clackamas	45°	122°4	450	"
24		USA Washington Skagit	48°3	121°9	750	"
25		USA Washington Skagit	48°3	121°9	450	"
26		USA Oregon Union	45°9	117°9	1200	"
27		USA Oregon Grant	44°3	118°9	1500	"
28		USA Oregon Klamath	43°2	121°8	1500	"
29		USA Oregon Union	45°	117°9	1050	"
30		USA Oregon Klamath	43°3	121°8	1650	"
31		USA Washington Chelan	47°5	120°4	750	"
32		USA Oregon Hood River	45°3	121°6	1050	"
33		USA Washington Arlington	48°2	122°1	130	S.C. *
34		USA Washington Darrington	48°5	121°7	180	"
35		USA Washington Granite Falls	48°1	121°9	150	"
36	1007	CAN British Columbia Clearwater	51°6	120°	500	IUFRO
37	1008	CAN British Columbia Golden	51°4	117°	1000	"
38	1010	CAN British Columbia Barriere	51°2	120°1	500	"
39	1013	CAN British Columbia Revelstock	51°	118°	600	"
40	1016	CAN British Columbia White Lake	50°	119°	550	"
41	1019	CAN British Columbia Monte Creek	50°6	119°9	700	"
42	1024	CAN British Columbia Oul Creek	50°3	122°7	230	"
43	1030	CAN British Columbia Squamish	49°8	123°1	20	"
44	1032	CAN British Columbia Courtenay	49°7	125°	70	"
45	1034	CAN British Columbia Sechelt	49°5	123°9	200	"
46	1035	CAN British Columbia Nelson	49°5	117°3	900	"
47	1036	CAN British Columbia Alberni	49°3	124°8	150	"
48	1037	CAN British Columbia Franklin River	49°1	124°8	160	"
49	1038	CAN British Columbia Chilliwack	49°1	121°7	915	"
50	1041	CAN British Columbia Cayeuse	48°9	124°4	230	"

* F.T.S.C. : Forest Tree Seed Center (Macon, USA)
* S.C. : Silvaseed Company
* C.F.S. : Canadian Forestry Service

AFOCEL NUMBER	IUFRO NUMBER	PROVENANCE	Lat.	Long.	Alt. (m)	Seed supplier
51	1045	CAN British Columbia Sooke	48°4	123°7	50	IUFRO
52	1046	USA Washington Whatcom/Diable Dam	48°7	121°1	450	"
53	1048	USA Washington Ferry/Republic	48°6	118°7	800	"
54	1049	USA Washington Bacon Point	48°6	121°4	600	"
55	1051	USA Washington Skagit Sedro Woolley	48°5	122°3	60	"
56	1052	USA Washington Okanogan/Twisp	48°4	120°4	900	"
57	1055	USA Washington Pendoreille/Newport	48°2	117°	800	"
58	1056	USA Washington Snohomish/Sloancreek	48°1	121°3	800	"
59	1059	USA Washington Snohomish/Perry Creek	48°0	121°5	650	"
60	1067	USA Washington King	47°7	121°3	300	"
61	1068	USA Washington Chelan/Chiwaukum	47°7	120°7	600	"
63	1072	USA Washington King/Chestermorse Lake	47°4	121°7	700	"
64	1078	USA Washington Kittitas Cle Elum	47°2	121°1	700	"
65	1079	USA Washington Pierce/Parkway	47°0	121°6	800	"
66	1082	USA Washington Yakima/Rimrock	46°7	121°0	800	"
67	1083	USA Washington Lewis Packwood	46°6	121°7	700	"
68	1084	USA Washington Lewis Packwood	46°6	121°7	300	"
69	1088	USA Washington Cawlitz Castle Rock	46°3	122°9	150	"
70	1093	USA Washington Skamania Willard	45°8	121°7	550	"
71	1112	CAN British Columbia Clinton	51°1	121°5	1100	"
72	1113	USA Oregon Marion Mill City	44°8	122°7	120	"
73	1114	USA Oregon Marion Detroit	44°7	122°2	500	"
74	1115	USA Oregon Benton Corvallis	44°7	123°2	80	"
75	1116	USA Oregon Lincoln Burntwood	44°6	123°7	350	"
76	1117	USA Oregon Marion Forks	44°5	122°0	1200	"
77	1119	USA Oregon Lane Eugene	44°0	123°4	230	"
78	1120	USA Oregon Lane Oakridge	43°9	122°4	950	"
79	1121	Oregon Douglas Steamboat	43°4	122°5	1700	"
80	1123	USA Oregon Douglas Roseburg	43°3	123°5	300	"
81	1124	USA Oregon Josephine Wolfcreek	42°7	123°4	430	"
82	1125	USA Oregon Josephine Cave Junction	42°2	123°7	430	"
83	1126	USA Oregon Jackson Ashland	42°1	122°7	1600	"
84	1127	USA California Siskiyou Happy Camp	41°9	123°5	1100	"
85	1129	USA California Siskiyou Sead Valley	41°8	123°0	850	"
86	1130	USA California Siskiyou Hawkinsville	41°8	123°7	1150	"
87	1131	USA California Siskiyou Scott Bar	41°7	123°1	1100	"
88	1132	USA California Siskiyou Fort Jones	41°7	122°8	1300	"
89	1133	USA California Siskiyou Happy Camp	41°6	123°5	1400	"
90	1134	USA California Siskiyou Sawyers Bar	41°3	123°1	1300	"
91	1135	USA California Siskiyou Sawyers Bar	41°3	123°1	1600	"
92	1136	USA California Siskiyou Dunsmuir	41°2	122°3	1100	"
93	1137	USA California Shasta Burney	41°1	121°6	1100	"
94	1138	USA California Humbolt Arcata	40°9	123°8	550	"
95	1139	USA California Trinity Weaversville	40°9	122°7	1200	"
96	1140	USA California Humboldt Arcata	40°9	123°8	950	"
97	1141	USA California Trinity Big Bar	40°8	123°2	1500	"
98	1142	USA California Trinity Big Bar	40°7	123°3	1050	"
99	1143	USA California Shasta Wildwood	40°4	123°0	1300	"
100	1144	USA California Mendocino Covelo	39°9	123°3	1000	"

AFOCEL NUMBER	IUFRO NUMBER	PROVENANCE	Lat.	Long.	Alt. (m)	Seed supplier
101	1145	USA California Glenn	39°8	122°9	1700	IUFRO
102	1146	USA California Alder Springs	39°6	122°7	1500	"
103	1148	USA California Mendocino Willits	39°2	123°4	600	"
104	1149	USA California Lake Lower Lake	38°8	122°7	1030	"
105	1153	MEX Tlaxca	19°7	98°1	2600	"
106	1157	USA Colorado Fremont Coaldale Hayden Creek	38°3	105°8	2800	"
107	1164	USA Arizona Coconino San Francisco Peak	35°3	111°7	3000	"
108	1169	USA New Mexico Otero N of James Carvc	32°9	105°5	2600	"
109	1175	USA Idaho Benewah Chatealets	47°3	116°5	700	"
110	1176	USA Idaho Clearwater St Joe NF	46°8	116°1	1050	"
111		USA Arizona Coconino San Francisco Peak	35°3	111°7	3000	"
112		CAN British Columbia Cininia Quesnel	53°2	122°5	800	C.F.S *
113		CAN Vancouver Isld Strathcona Epk valley	49°7	125°8	915	"
114		CAN E.C. Hwy 16,30 miles Est de Prince George	53°9	122°0	760	"
115		CAN British Columbia Pinetan	50°7	119°8	900	"
116		CAN British Columbia Shuswap	50°8	119°3	610	"
117		CAN British Columbia Fort St James	50°2	124°0	900	"
118		CAN Vancouver Isld Malakat Summit	48°8	123°6	630	"
119		CAN British Columbia Adams Lake	51°4	119°5	600	"
120		CAN British Columbia Hat Creek	50°8	121°5	305	"
121		CAN British Columbia Johnson Lake	51°2	119°7	1070	"
122		CAN British Columbia Golden	51°4	117°0	900	"
123		CAN British Columbia Upper Arrowlake Nakusp	50°2	117°8	460	"
124		USA Oregon Willamette Valley	44°2	123°5	150	Versepuy
125		USA Oregon Lane Leaburg	44°2	122°7	450	"
126		USA Oregon Clackamas Estacada	45°1	122°0	150	"
127		USA Washington King Snoqualmie	47°3	121°7	450	"
128		USA Oregon Willamette Valley Benton	43°7	123°5	150	"
129		USA Oregon Linn Cascadia	44°6	122°5	300	"
130		USA Oregon Grant	45°	119°0	1800	F.I.S.C.
131		USA Oregon Deschutes	44°	122°	1500	"
132		USA Oregon Wasco	45°	121°5	1200	"
133		USA Oregon Wasco	45°	121°5	900	"
134		USA Oregon Hood River	45°5	121°5	1650	"
135		USA Washington Okanogan	49°	120°	750	"
136		USA Washington Okanogan	49°	119°	1200	"
137		USA Washington Yakima	47°	121°	750	"
138		USA Washington Okanogan	49°	119°3	900	"
139		USA Oregon Grant	44°5	119°	1350	"
140		USA Oregon Hood River	45°	121°5	900	"
141		USA Washington Okanogan	48°5	119°	1050	"
142		USA Washington Okanogan	48°5	119°	1050	"
143		USA Oregon Clackamas	45°	122°	1200	"
144		USA Oregon Grant	44°5	119°	1500	"
145		USA Oregon Grant	44°5	119°	1500	"
146		USA Oregon Grant	44°5	119°	1650	"
147		USA Oregon Harney	44°	118°5	1800	"
148		USA Washington Yakima	46°5	121°3	1050	"
149		USA Washington King	47°5	122°	750	"
150		USA Washington Jefferson	47°7	123°	300	"

AFOCEL NUMBER	IUFRO NUMBER	PROVENANCE	Lat.	Long.	Alt. (m)	Seed supplier
151		USA Washington Jefferson	47°5	124°	600	F.T.S.C.
152		USA Oregon Lane	44°3	122°4	900	"
153		USA Oregon Marion	44°6	122°2	1200	"
154		USA Oregon Lane	44°4	121°8	1500	"
155		USA Oregon Lane	44°2	122°3	1350	"
156		USA Oregon Jackson	42°7	122°5	1050	"
157		USA Washington Skamania	46°	122°	1200	"
158		USA Oregon Lincoln	45°[illegible]	123°8	450	"
159		USA Oregon Lincoln	45°	123°	150	"
160		USA Oregon Lane	43°[illegible]	123°	750	"
161		USA Oregon Lane	44°	124°	450	"
162		USA Oregon Lane	44°2	122°2	600	"
163		USA Washington Jefferson	47°7	123°	450	"
164		USA Washington Skagit	48°4	121°8	450	"
165		USA Oregon Jackson	42.6	122°8	900	"
166		USA Oregon Jackson	42°[illegible]	122°5	1200	"
167		USA Washington Whatcom	48°6	121°5	450	"
168		USA Washington Whatcom	48°8	121°5	750	"
169		USA Oregon Wasco	45°5	121°7	1500	"
170		USA Oregon Wasco	45°	121°	1050	"
171		USA Oregon Wasco	45°	121°	1350	"
172		USA Washington Snohomish/Skagit	48°5	121°5	600	"
173		USA Oregon Wasco	45°	121°	600	"
174		USA Oregon Douglas	43°	123°	1050	"
175		USA Oregon Hood River	45°5	121°5	1200	"
176		USA Oregon Hood River	45°5	121°5	750	"
177		USA Oregon Lane	44°	122°	900	"
178		USA Oregon Lane	44°	124°	600	"
179		USA Washington Skamania	46°	122°	450	"
180		USA Washington Clallam	47°9	123°8	300	"
181		USA Washington Jefferson	47°7	123°	600	"
182		USA Oregon Clackamas	45°	122°4	750	"
183		USA Oregon Clackamas	45°	122°	1000	"
184		USA Oregon Clackamas	45°	122°	900	"
185		USA Oregon Linn	44°5	122°	1350	"
186		USA Oregon Lane	43°8	122°5	1250	"

FIGURE 1

PROVENANCES OF "PROVDOUG B" PROGRAM

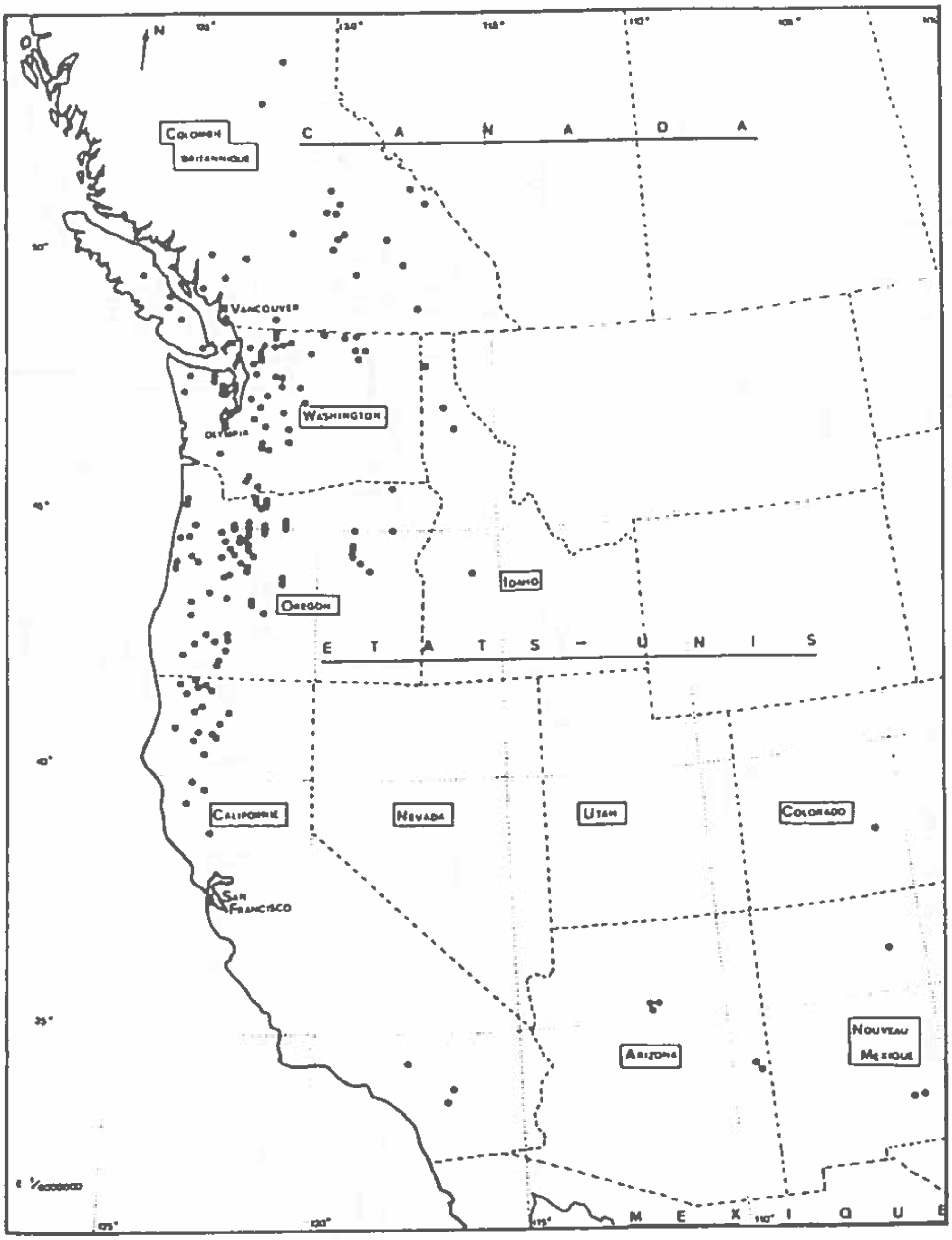


FIGURE 2 : GEOGRAPHIC LOCATION AND SITE DESCRIPTION OF THE TRIALS

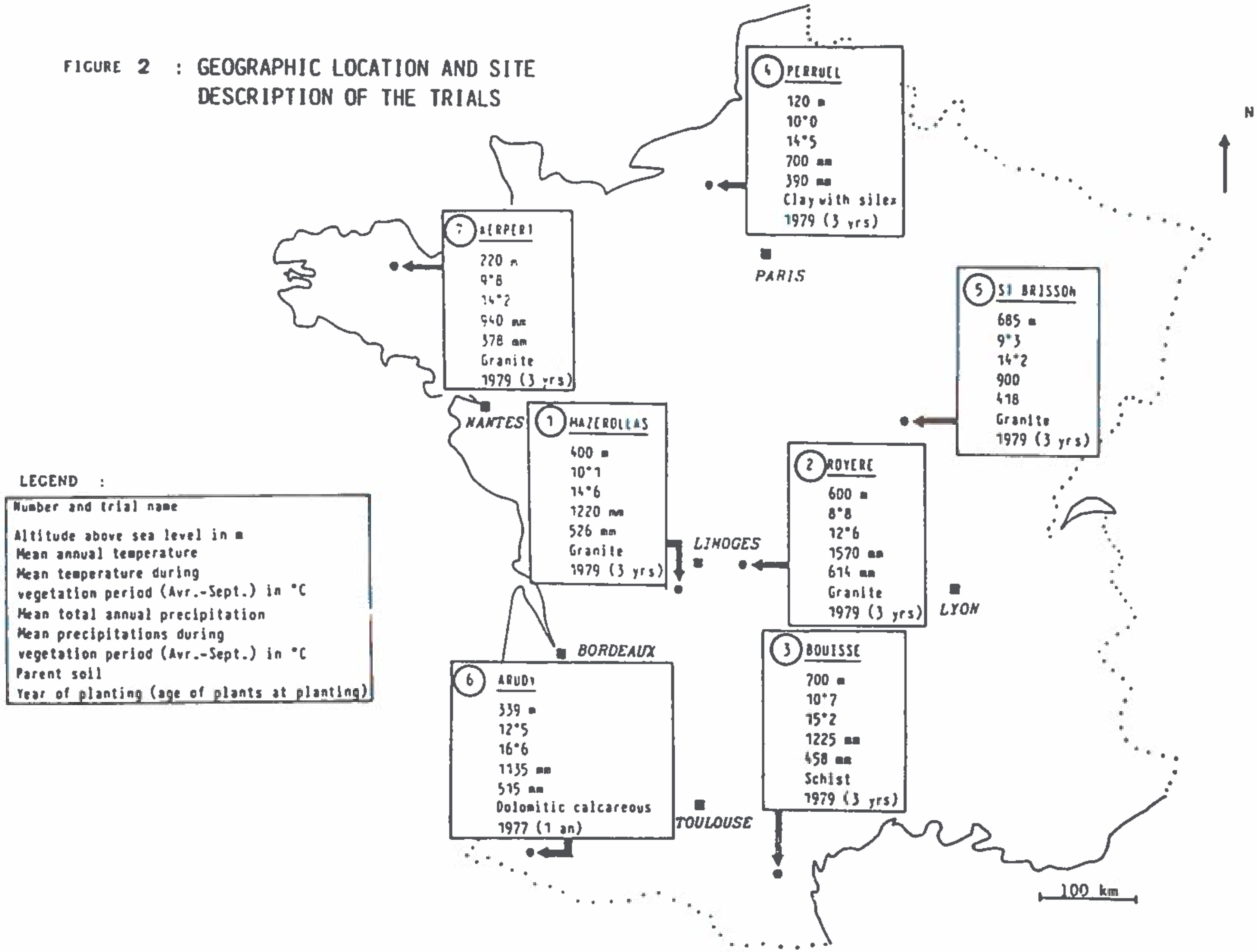


TABLE 2

PROVENANCES DISTRIBUTION IN THE TRIALS

II \ I	1	2	3	4	5	6	7
1							
2							
3	●						
4	●	●	●		●		
5	●						
6	●	●	●				
7							
8							
9	●	●	●		●		
10	●	●	●				
11	●	●	●		●		
12	●	●	●				
13	●	●	●		●		
14	●	●	●		●	●	
15	●	●	●		●		
16	●	●	●				
17	●	●	●		●	●	
18	●	●	●				
19	●	●	●				
20	●	●			●		
21	●				●		
22	●		●				
23	●	●	●			●	
24	●	●	●		●		
25	●	●	●		●		
26	●						
27	●		●				
28	●	●	●				
29	●		●		●		
30	●	●					
31	●	●	●		●	●	

II \ I	1	2	3	4	5	6	7
32	●	●	●				
33	●	●	●	●	●		●
34	●	●	●	●	●		●
35	●	●	●	●	●	●	●
36	●	●	●				●
37	●	●	●				●
38	●	●	●	●	●		●
39	●	●	●				●
40	●		●		●		●
41	●	●	●				●
42	●	●	●	●			●
43	●	●	●	●			●
44	●	●	●	●	●		●
45	●	●	●	●			●
46	●	●	●				
47	●	●	●	●			●
48	●	●	●	●			●
49	●	●	●	●		●	●
50	●	●	●	●			●
51	●		●	●			
52	●	●	●	●			
53	●		●	●			
54	●		●	●		●	●
55	●	●	●	●		●	●
56	●		●	●			
57	●	●	●	●			
58	●	●	●	●		●	
59	●	●	●	●	●		●
60	●	●	●	●		●	●
61	●		●	●			●
62							

II \ I	1	2	3	4	5	6	7
63	●	●	●	●			
64	●	●	●			●	
65	●	●	●	●	●	●	
66	●	●	●		●		
67	●	●	●	●			
68	●		●	●	●	●	
69	●		●			●	
70	●	●	●	●			
71	●		●				
72	●		●			●	
73	●	●	●	●	●	●	
74	●	●	●	●	●		
75	●	●	●		●	●	
76	●	●	●	●			
77	●	●	●			●	
78	●	●	●	●	●		
79	●	●	●	●			
80	●	●	●	●	●		
81	●	●	●	●			
82	●	●	●	●		●	
83	●	●	●				
84	●	●	●	●			
85	●		●	●	●		
86	●	●	●	●	●		●
87	●	●	●	●			
88	●	●	●		●		
89	●	●	●	●	●		
90	●		●	●	●		
91	●		●	●			
92	●		●	●			
93	●		●		●		

II \ I	1	2	3	4	5	6	7
94	●	●	●	●			
95	●	●	●	●	●		●
96	●	●	●	●			●
97	●	●	●	●	●		●
98	●		●	●			●
99	●	●	●	●			●
100	●	●	●	●	●		●
101	●		●	●			●
102	●	●	●	●	●		●
103	●		●			●	
104	●		●	●			●
105	●						
106	●	●	●	●			
107	●	●	●				
108	●	●	●	●			
109	●	●	●	●			
110	●	●	●				
111	●	●	●			●	
112	●						
113	●		●				
114	●		●				
115	●						
116	●					●	
117							
118	●		●				
119	●		●			●	
120	●		●				
121							
122	●						
123	●		●		●	●	
124	●	●	●	●	●		●

II \ I	1	2	3	4	5	6	7
125	●	●	●	●	●	●	●
126	●	●	●	●			●
127	●	●	●	●			●
128	●	●	●	●	●		●
129	●	●	●	●	●	●	●
130	●		●				
131	●	●	●		●		
132	●	●	●	●	●		●
133	●	●	●	●			●
134	●	●		●	●		●
135	●	●	●		●	●	
136	●	●	●				
137	●	●	●		●		
138	●	●	●				
139	●	●	●				
140	●	●	●		●	●	
141	●		●				
142	●		●				
143	●	●	●		●		
144	●						
145	●	●	●				
146	●		●				
147	●		●				
148	●	●	●		●		
149	●	●	●		●		
150	●	●	●		●		
151	●	●	●		●		
152	●	●	●				
153	●	●	●	●	●		
154	●	●	●	●	●		
155	●	●	●		●		

II \ I	1	2	3	4	5	6	7
156	●	●	●		●		
157	●	●	●		●		
158	●	●	●	●	●		
159	●	●	●			●	
160	●	●	●		●		
161	●	●	●		●		
162	●	●	●				
163	●	●	●		●		
164	●	●	●	●	●		
165	●	●	●		●		
166	●	●	●		●	●	
167	●	●	●	●	●		
168	●	●	●	●	●	●	
169	●	●	●		●		
170	●	●	●				
171	●	●	●		●		
172	●	●	●				
173	●	●	●		●		
174	●	●	●		●		
175	●	●	●		●		
176	●	●	●		●		
177	●	●	●		●	●	
178	●	●	●				
179	●	●	●		●		
180	●		●		●		
181	●	●	●	●			
182	●	●	●				
183	●	●	●		●		
184	●	●	●		●	●	
185	●	●	●		●		
186	●	●	●				

I : trial number ; 1 : MAZEROLLAS ; 2 : ROYERE ; 3 : BOUISSE ; 4 : PERRUEL ; 5 : ST BRISSON ; 6 : ARUDY ; 7 : KERPERT

II : provenance number (AFOCEL number)

FIGURE 3 : CORRELATIONS BETWEEN MAZEROLLAS AND THE OTHER TRIALS

HEIGHT AT 8 YEARS

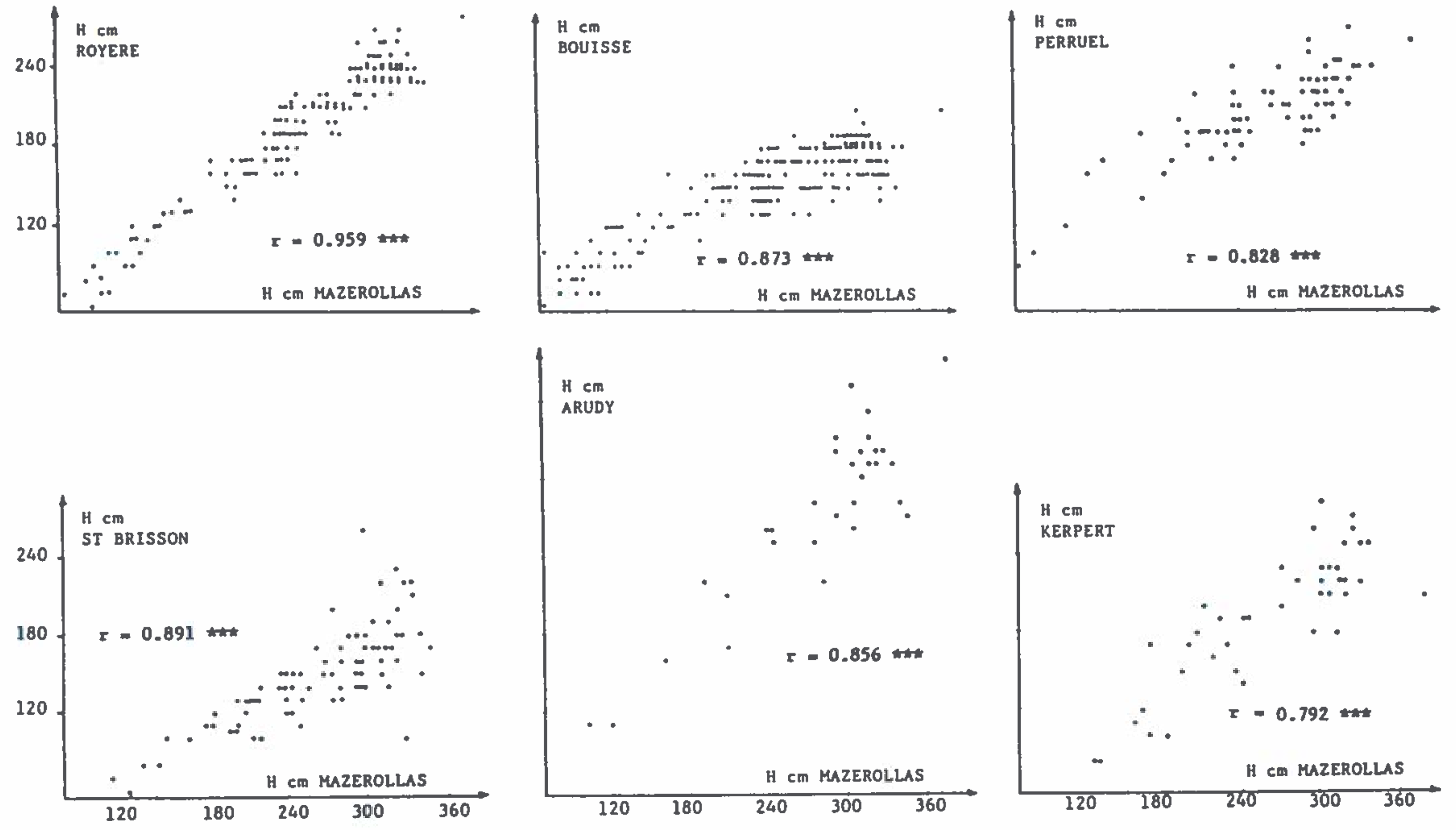


FIGURE 4

INFLUENCE OF PROVENANCES LONGITUDE ON THEIR GROWTH

MAZEROLLAS, HEIGHT AT 8 YEARS

All provenances

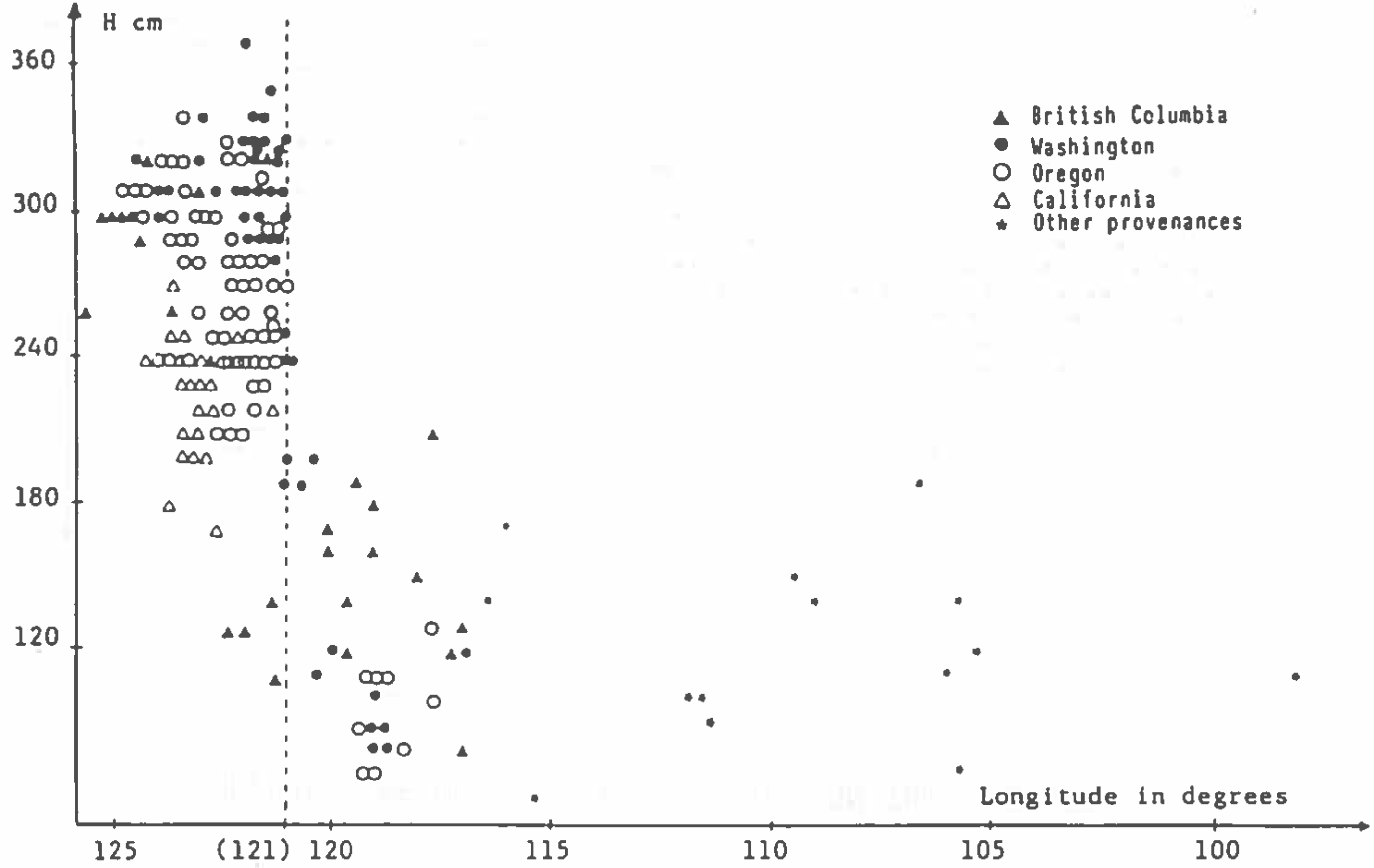


FIGURE 5

INFLUENCE OF PROVENANCES LATITUDE ON THEIR GROWTH

MAZEROLLAS, HEIGHT AT 8 YEARS

Provenances of longitude ⩾ 121°

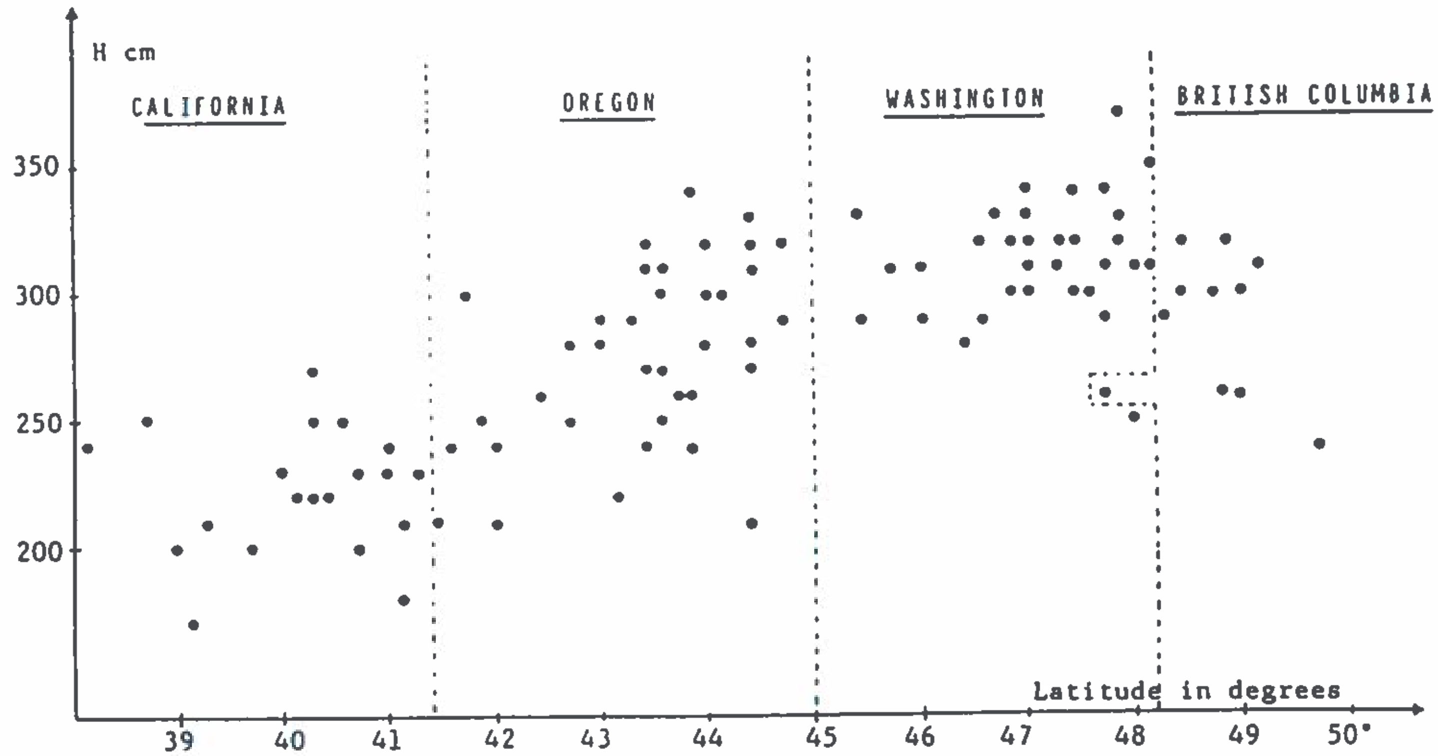


FIGURE 6 **MAZEROLLAS : INFLUENCE OF PROVENANCES ALTITUDE ON THEIR GROWTH**

HEIGHT AT 8 YEARS

Provenances of longitude ≥ 121°

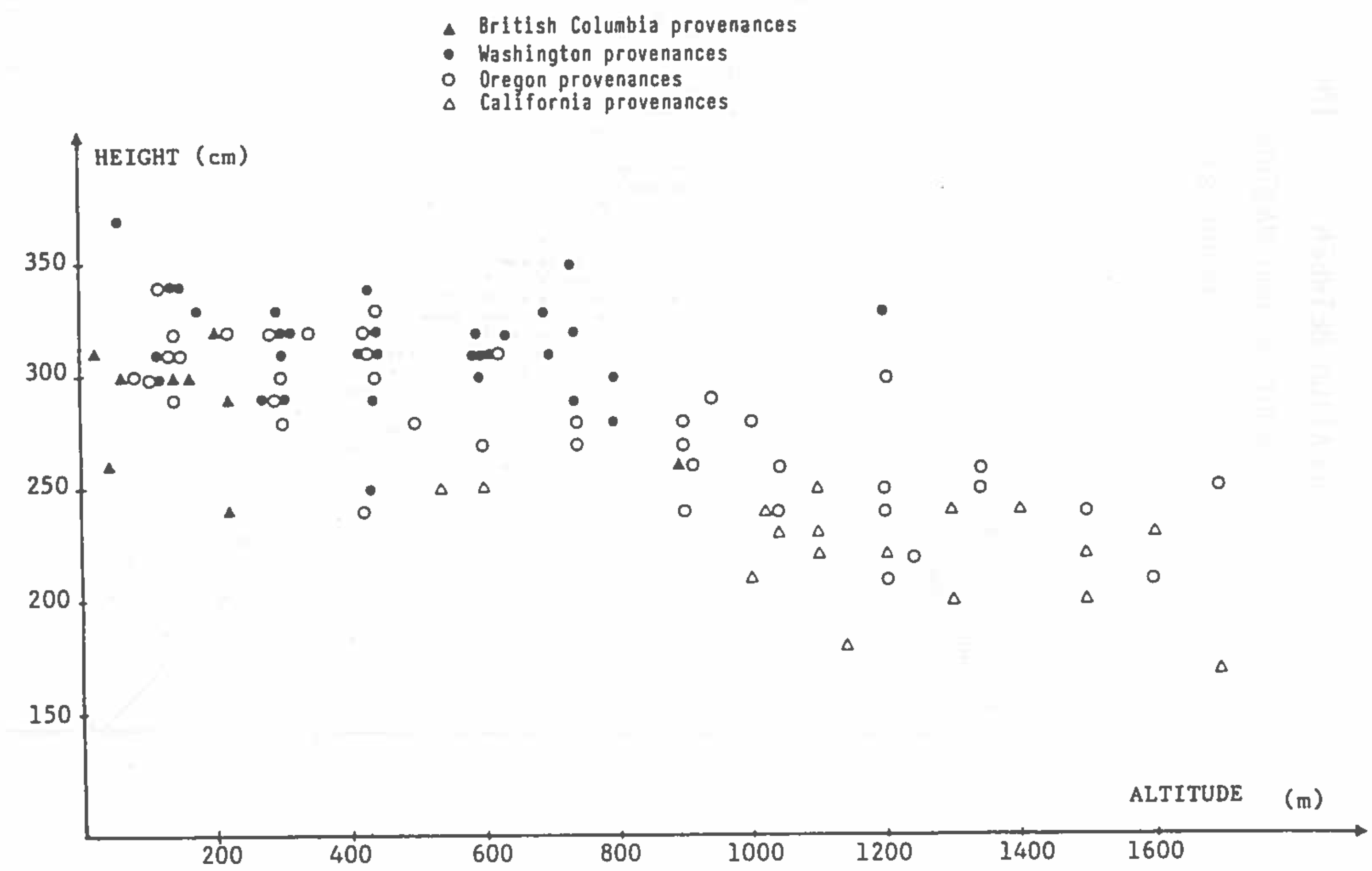


FIGURE 7

RELATION BETWEEN FLUSHING
AT BOUISSE AND MAZEROLLAS
(174 provenances)

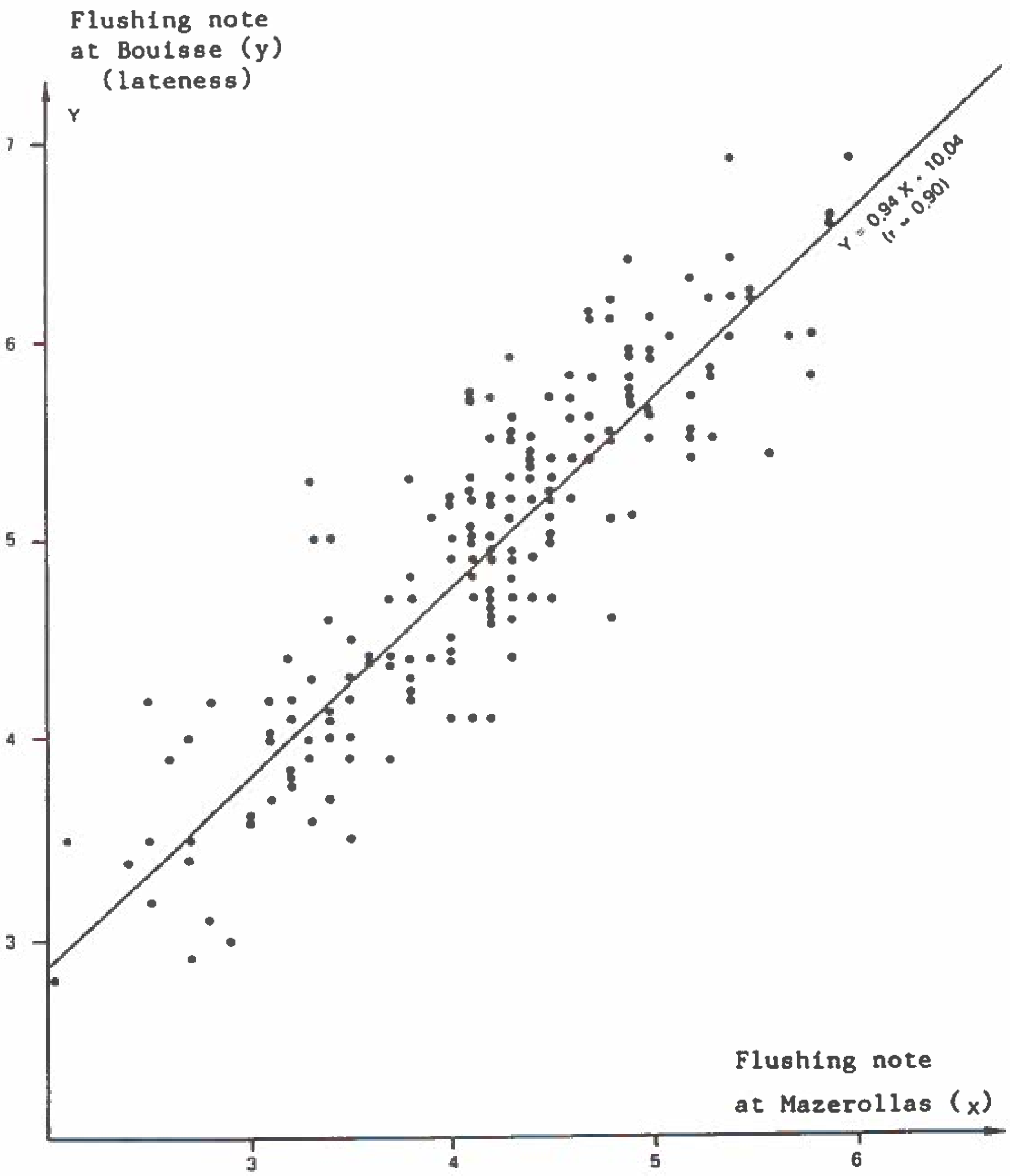


FIGURE 8 RELATION BETWEEN FLUSHING AT MAZEROLLAS AND ROYERE

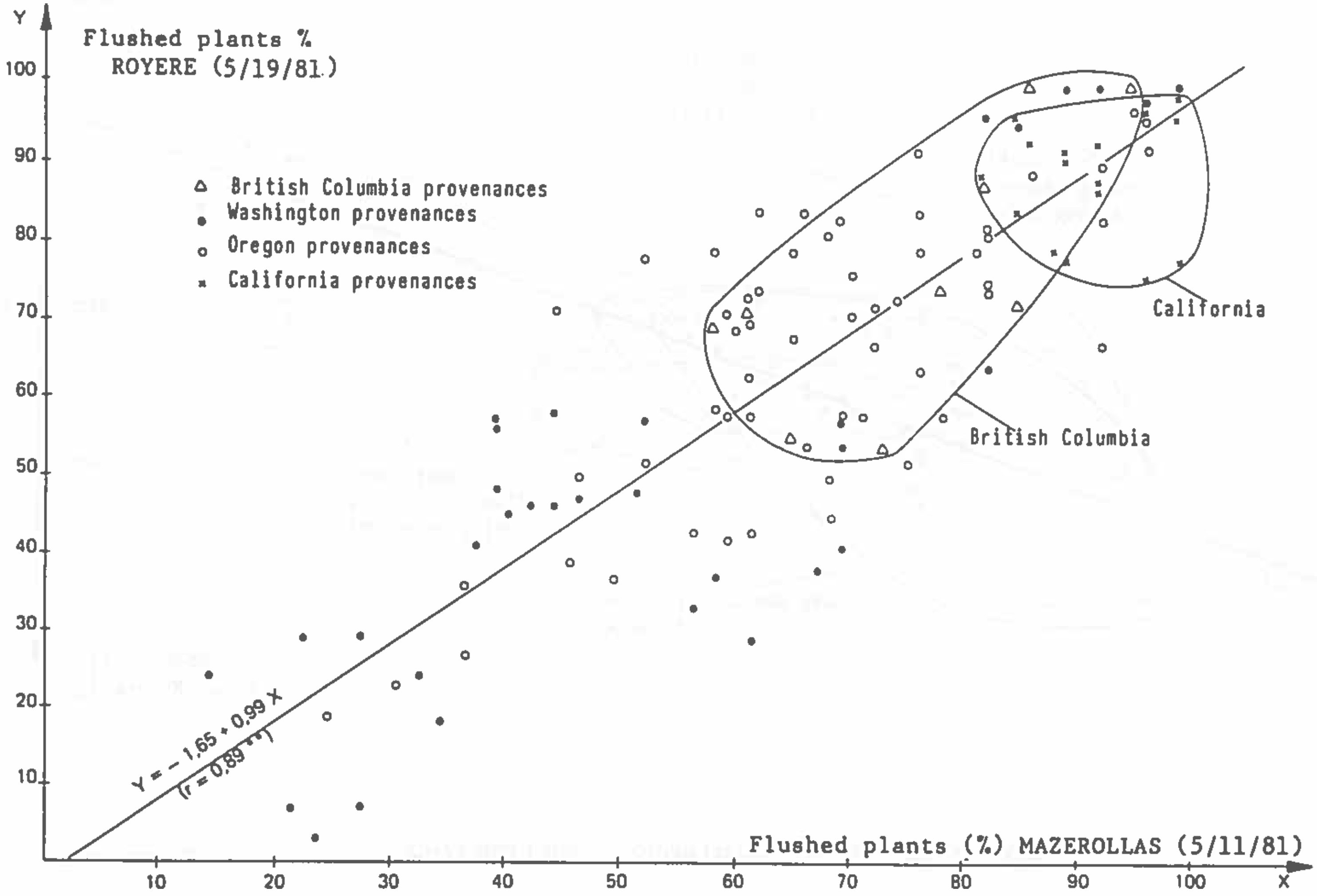


FIGURE 9 MAZEROLLAS : GROWTH-FLUSHING RELATION

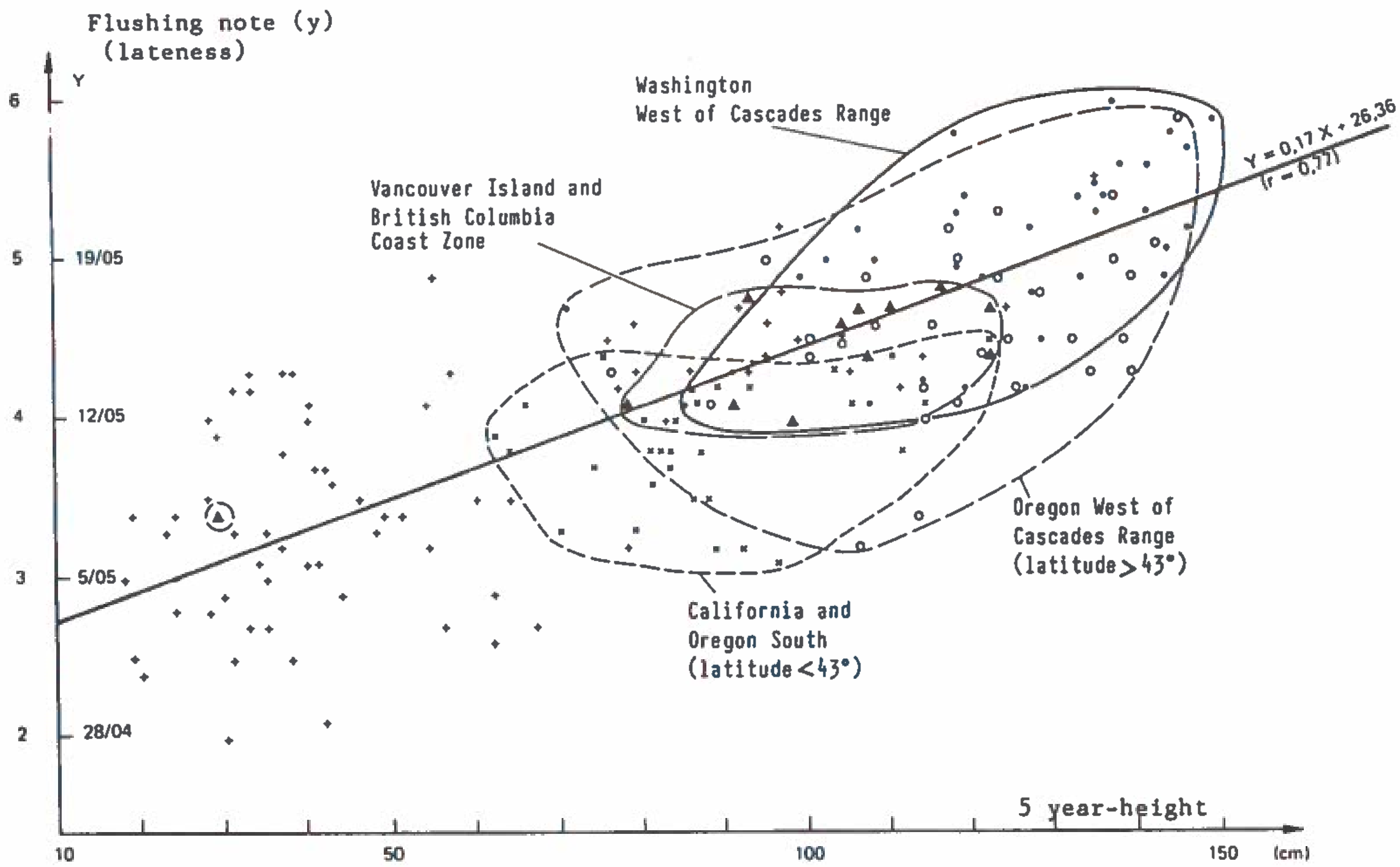
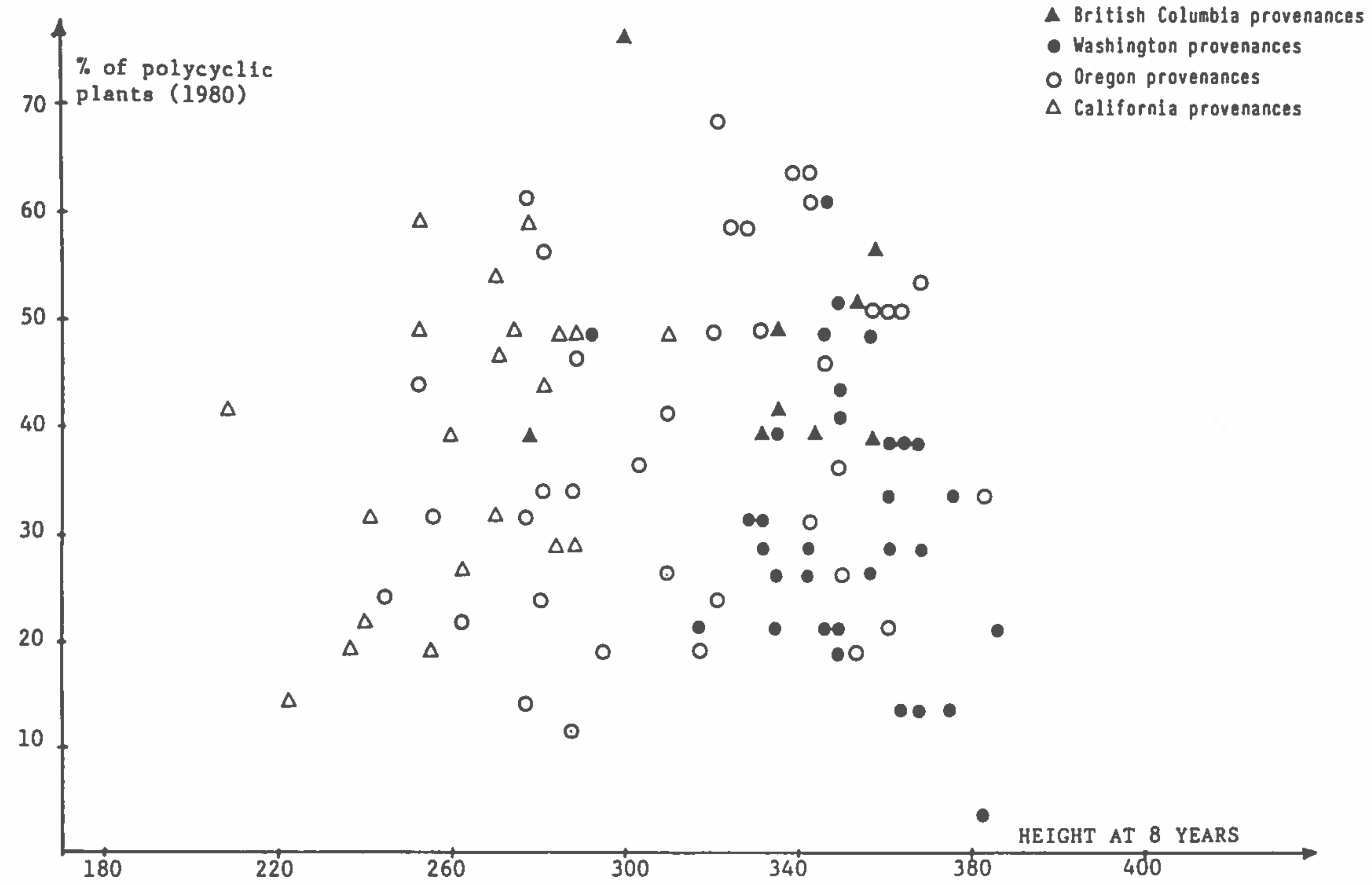


FIGURE 10

MAZEROLLAS : POLYCYCLISM-GROWTH RELATION

Provenances of longitude > 121°



THE INTERNATIONAL SHORT TERM DOUGLAS FIR (PSEUDOTSUGA MENZIESII) PROVENANCE EXPERIMENT IN WEST NORWAY

Stein Magnesen

Norwegian Forest Research Institute-Bergen
N-5047 Stend
Norway

S U M M A R Y

Fifty-one seed origins of Douglas fir have been included in the IUFRO provenance experiment in West Norway. Criteria assessed at age 13 years were survival, height growth and number of trees with wavy stems and broad crowns. The main result is that coast origins are more vigorous than those from the interior. However, survival in interior provenances was distinctly higher than in the coastal group and the coast origins also had a larger proportion of trees with wavy stems and broad crowns. It appears that wavy stems and broad crowns are associated with vigour. The results indicate that the most interesting areas for further provenance research are the interior British Columbia, the Coast Mountains of B.C. and the Cascade Range in Washington and northern Oregon.

Keywords: Douglas fir. Provenances. West Norway

I N T R O D U C T I O N

The Norwegian Forest Research Institute-Bergen obtained 51 Douglas fir seed lots from the IUFRO collections of 1966 and 1968. The Institute also agreed to participate in an international short term provenance trial. The present paper is a brief report on this experiment in West Norway.

The purpose of the Norwegian provenance trial is mainly to select those areas in North America in which provenances of interest to West Norway can be found. All provenances considered possible to grow under the climatic conditions of West Norway were included in the experiment. The selected provenances are listed with their geographical data in Table 1. Seed lots no. 1002 to 1102 (40 provenances) belong to those collected in 1966, and lots no. 1105 to 1126 (11 provenances) form a part of the second collection in 1968.

In Douglas fir geographical varieties are recognized, and in the present report the dividing line between coast provenances and interior provenances is based on climatic zones as defined by HADDOCK and SZIKLAI (1966) for British Columbia, and by WESTERN FOREST TREE SEED COUNCIL (1966) for Washington and Oregon.

E X P E R I M E N T A L   M E T H O D S

In Spring 1969 seeds of the 51 selected provenances were sawn in Ulvik Forest Tree Nursery in Hardanger. Two years later, in spring 1971, the field trial was established in Mobergslien Research Area in Os, employing 2+0 seedlings. The research area is situated about 16 miles south of the City of Bergen, at 60° 10′ latitude north, 5° 27′ longitude east, approximately 100 meters above sea level.

The location is on a slope facing southeast, and ground conditions are generally favourable. Annual precipitation is 1800 to 2000 mm and the mean monthly temperature for May - August is about 13° C. Growth rates in the area are very good. However, the experimental area is somewhat exposed to wind, and the soil is generally rather shallow, which means that growth conditions are below optimum for the district.

In accordance with the recommendations given by IUFRO Working Party S2.02.05., the provenance trial is a randomised block experiment consisting of 30 blocks and single-tree plots.

R E S U L T S   A N D   D I S C U S S I O N

S u r v i v a l

The percentage of living trees in autumn 1981 is given for each provenance in Table 2. More than 60 % of the total losses occurred during the first winter (1971/72). This was an exceptional, severe winter with little or no snow cover. As expected, the heaviest losses were sustained by the coastal provenances, in which group only 34 % of the trees are still alive today. In the inland provenance group the number of living trees average 48 % (Table 3). These findings go well with the results of earlier experiments (HAGEM 1931, ROBAK 1968), and with observations of growth cessation and climatic damage at the nursery stage of the present trial (MAGNESEN 1973). The highest degree of survival was found in provenances from interior British Columbia (Table 4).

G r o w t h

Table 2 shows the mean height of the various provenances at age 13 years from seed. Analysis of variance indicated that there were highly significant differences between origins.
There is little to suggest a clear pattern of latitude or elevation as being primarily responsible for differences in growth vigour. The main result is that coast provenances are more vigorous than interior provenances (Table 3). A breakdown into regional groups (Table 4) shows that the Vancouver Island group was the most vigorous while the poorest growth was achieved by the Washington inland group.

A rather crude assessment on stem form and crown form was attempted in 1982. The number of trees with wavy stems and broad crowns were recorded (Table 2). Both items were significantly positively correlated with vigour and the proportion of trees with wavy stems and broad crowns was larger in coast provenances than in interior provenances, the difference being highly significant

(Table 3.)

P R O V E N A N C E S   F O R   W E S T   N O R W A Y

The best performers in terms of both height growth and hardiness appear to be found along the dividing line between coast provenances and interior provenances in the Coast Mountains of British Columbia and the Cascade Range in Washington and northern Oregon.

Better than average are also two provenances from Vancouver Island, but the results seem to indicate that provenances from this area are not sufficiently hardy for West Norway.

It is worth noting that survival in the interior B.C. group was distinctly higher than in any other group and that the populations from interior B.C. had small proportions of trees with wavy stems and broad crowns (Table 4). These provenances, although slower growing than coastal origins, may be the best choices for Norway after all.

The present experiment has shown that the most important areas for seed collection for further provenance research and forestry practice in Norway are the interior British Columbia north of 50° - 51° N, the Coast Mountains of B.C. and the Cascade Range in Washington and northern Oregon.

L I T E R A T U R E   C I T E D

Haddock, P.G. and Sziklai, O., 1966: Seed collection Zones for Douglas-Fir in Canada. Proceedings of the Sixth World Forestry Congress, Madrid 1966. vol. 2, pp. 1467-1473.

Hagem, O., 1931: Forsøk med vestamerikanske traeslag. Meddel. Vestlandets forstlige forsøksstasjon, vol. 4, no. 12, pp. 1-217.

Magnesen, S., 1973: Preliminary Report on the international short term Douglas fir (Pseudotsuga menziesii) provenance experiment in West Norway. Results in the nursery. Paper presented at IUFRO S2.02.05 Working Party Meeting on Douglas Fir Provenances in Göttingen Sept. 1973. pp. 126-139.

Robak, H., 1968: Overvintring og produksjonssikkerhet hos Douglas i planteskolene i Vest-Agder og Vestlandsfylkene, bedomt etter saningene 1930-66. Årskrift 1967 for Norske Skogplanteskoler, pp. 35-53.

Western Forest Tree Seed Council, 1966: Tree seed zone maps for Washington and Oregon, Portland, Oregon 1966.

Table 1. The geographical data for the provenances.

Marked No.	IUFRO No.		Name	Lat. North		Long. West		Altitude feet
1*	1002	B.C.	Dean	52	48	126	58	20
2*	1004	"	Stuie	52	22	126		750
3	1006	"	Tatla	51	44	124	44	2900
4	1008	"	Golden	51	23	117		2700-3000
5*	1009	"	Klina Klini	51	14	125	35	2000
6*	1011	"	Klina Klini	51	8	125	36	500
7*	1012	"	Klina Klini	51	7	125	36	10
8	1013	"	Revelstoke	51		118	12	2000
9	1017	"	Squilax	50	50	119	34	1900
10	1018	"	Salmon Arm	50	44	119	13	1400-1700
11	1020	"	Pillar Lake	50	35	119	38	3000
12*	1024	"	Owl Creek	50	20	122	44	700
13*	1025	"	Nimkish	50	19	126	53	300
14*	1027	"	Alta	50	12	122	53	2100
15	1028	"	Merritt	50	4	120	51	2700-3000
16*	1029	"	Thasis	49	48	126	38	50
17*	1031	"	Gold River	49	45	126	4	300
18*	1032	"	Courtenay	49	42	125	4	220
19*	1033	"	Forbidden Plat.	49	40	125	9	2000
20	1035	"	Nelson	49	30	117	16	2500-2900
21*	1037	"	Franklin River	49	6	124	46	500
22*	1038	"	Chilliwack	49	6	121	42	3000
23*	1039	"	Chilliwack	49	4	121	48	550
24*	1041	"	Caycuse	48	55	124	26	700
25*	1042	"	Duncan	48	45	123	45	200
26	1048	Wash.	Republic	48	36	118	44	2400
27	1052	"	Twisp	48	23	120	24	2400-2800
28*	1053	"	Darrington	48	16	121	38	500
29*	1056	"	Sloan Creek	48	5	121	18	2000-2300
30*	1061	"	Louella Guard St.	48		123	5	1500
31	1065	"	Spokane	47	47	117	12	1800-2200
32	1066	"	Scenic	47	43	121	8	2900-3300
33	1071	"	Keechelus Lake	47	23	121	22	2600
34	1078	"	Cle Elum	47	13	121	7	2100
35*	1079	"	Parkway	47	2	121	34	2400
36	1082	"	Rimrock	46	40	121	2	2500
37*	1083	"	Packwood	46	34	121	40	1900-2400
38*	1096	Ore.	Sandy	45	23	122	18	900
39*	1099	"	Pine Grove	45	6	121	23	2400
40*	1102	"	Upper Soda	44	23	122	12	3000-3500
41	1105	B.C.	McLeod Lake	54	42	122	53	2500
42	1106	"	Fort St. James	54	29	124	15	2800
43	1107	"	Babine Lake	54	27	125	27	2700
44	1108	"	Wansa Lake	53	46	122	6	2900
45	1111	"	Horsefly	52	18	121	19	2700
46	1112	"	Clinton	51	9	121	30	3400
47*	1117	Ore.	Marion Forks	44	30	122		3500
48*	1118	"	Marys Peak	44	30	123	34	3200-3300
49*	1120	"	Oakridge	43	54	122	22	2900
50*	1121	"	Steamboat	43	22	122	31	5250
51*	1126	"	Ashland	42	5	122	39	4900

*Coast provenances.

Table 2. Mean height, survival and proportion of trees with wavy stems and broad crowns at age 13 years. Provenances arranged in order of decreasing mean height.

IUFRO No.	Provenance	Mean height cm	Survival %	Wavy stems %	Broad crowns %
*1039	Chilliwack	488	33	56	44
*1004	Stuie	471	33	40	80
*1033	Forbidden Plat.	463	27	43	43
*1025	Nimkish	458	40	58	43
*1037	Franklin River	434	20	50	75
*1012	Klina Klini	428	37	33	67
*1032	Courtenay	421	33	37	25
*1029	Thasis	407	33	29	57
1078	Cle Elum	400	43	18	18
*1102	Upper Soda	399	33	44	44
*1038	Chilliwack	392	37	75	62
*1066	Scenic	384	37	0	20
*1118	Marys Peak	382	23	40	60
*1053	Darrington	380	27	29	43
*1041	Caycuse	378	37	62	62
*1083	Packwood	376	40	56	56
*1031	Gold River	376	47	20	30
*1009	Klina Klini	371	33	17	50
*1099	Pine Grove	368	50	17	25
1071	Keechelus Lake	359	47	27	27
*1042	Duncan	358	10	33	0
*1079	Parkway	358	40	27	27
*1024	Owl Creek	357	47	43	43
*1117	Maron Forks	353	43	17	8
*1002	Dean	345	40	50	67
1018	Salmon Arm	345	37	43	29
*1027	Alta	331	43	33	56
*1011	Klina Klini	327	43	37	37
*1121	Steamboat	321	33	0	11
*1126	Ashland	318	10	0	50
*1120	Oakridge	311	30	20	40
*1096	Sandy	304	20	20	20
*1061	Louella Guard St.	299	20	0	50
1105	McLeod Lake	285	63	9	0
*1056	Sloan Creek	283	47	9	9
1035	Nelson	261	27	29	29
1013	Revelstoke	261	40	30	0
1106	Fort St. James	260	73	19	6
1082	Rimrock	259	50	0	8
1017	Squilax	250	43	43	14
1006	Tatla	234	63	27	0
1107	Babine Lake	219	37	0	0
1008	Golden	218	63	7	7
1111	Horsefly	216	57	0	0
1020	Pillar Lake	211	67	13	13
1065	Spokane	208	47	10	20
1028	Merritt	206	53	9	0
1108	Wansa Lake	204	30	0	0
1052	Twisp	176	57	9	0
1112	Clinton	159	53	0	0
1048	Republic	129	23	0	17

*Coast provenances

Table 3. Mean height, survival and proportion of trees with wavy stems and broad crowns in coastal and interior provenances.

	Coast	Interior	T-value
Mean height	375 cm	250 cm	7.17***
Survival	34 %	48 %	4.28***
Wavy stems	33 %	14 %	3.92***
Broad crowns	43 %	10 %	6.74***

Table 4. Mean height, survival and proportion of trees with wavy stems and broad crowns in regional groups. Groups arranged in order of decreasing mean height.

Regional group	Mean height cm	Sur-vival %	Wavy stems %	Broad crowns %
Vancouver Island	412	31	41	42
B.C. Coast and Coast Mountain	390	38	43	56
Washington Coast and Cascades	344	39	18	29
Oregon Coast and Cascades	344	30	20	32
B.C. Inland	238	50	16	7
Washington Inland	171	42	6	12

RESULTS OF THE IUFRO DOUGLAS FIR EXPERIMENTS IN BRITAIN AT 10 YEARS

Roger Lines and C J A Samuel

Forestry Commission, Northern Research Station, Roslin, Midlothian, EH25 9Sy, Scotlad, UK

A B S T R A C T

The main purpose of this report is to present the data on height and diameter growth at 10 years from planting for up to 45 seed origins of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) on five sites in England Scotland and Wales and an analysis of seed origin by site interaction for 31 of these origins.

Greatest vigour for both height and diameter was shown by origins from the Pacific coast and foothills of the Olympic and W. Cascade Mountains of Washington. Some low elevation Oregon coastal sources also grew well. Vancouver Island origins had moderate growth rates. Those from latitudes above 50° N or below 43° N grew poorly, as did those from above 800 m elevation. Origin x site interaction while significant was found to be less easily explained than in Sitka spruce.

I N T R O D U C T I O N

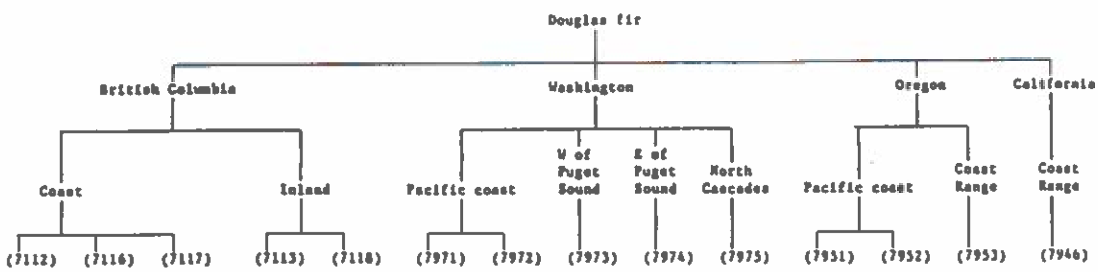
Earlier reports from this series of experiments have covered the seed collection of 180 seed origins in North America (Fletcher and Barner, 1980), the nursery phase (Lines and Mitchell, 1970; Pearce, 1980) and the results up to 6 years after planting in the forest (Lines, 1980; Pearce, 1980). This paper brings together results from all the British experiments, except those at Inchnacardoch and Rosarie, which have too few seedlots for useful comparison. Two nursery experiments sown in 1968 in Scotland produced 1+1 transplants which were established in 1970 at Culloden Forest, 20 miles east of Inverness, and at Craigvinean (Dunkeld Forest), 15 miles north west of Perth. At each site 20 seed origins were planted in a Partially Balanced Incomplete Block design with five replicates of 36 plant plots. At Craigvinean 17 origins were planted in an adjacent experiment with a Triple Lattice design with three replicates of 144 plant plots. In 1972, seven additional seed origins were planted at Craigvinean with two commercial seedlots from Elma, Washington. The Culloden experiment suffered repeated frosts and Pine weevil (*Hylobius*) attacks and despite replacement of failures it eventually had to be abandoned.

The English nursery experiments sown in 1968 produced such variable growth and poor survival that it was decided to re-sow in 1970 at Wareham nursery (Pearce, 1980). The plants from Wareham were used to establish experiments at five sites: Bodmin Forest, Cornwall; Charmouth Forest, Devon; Quantock Forest, Somerset; Forest of Dean, Gloucester; and Radnor Forest, Powys. The Quantock experiment had to be closed after the 6 year assessment due to a variety of adverse factors. At Bodmin three experiments were planted on even slopes with different aspects facing east, north and south. Plot size is 2 x 2 trees. At the other southern sites plot size is 25 plants and a Partially Balanced Lattice design was used. At each site there are also one or two replicates of "extensive" plots of 196 plants. Each experiment covers 3.3 to 6.7 ha and this large area poses problems for assessment and general silvicultural management. Site details for each experiment are shown in Table 1.

SELECTION AND GROUPING OF SEED ORIGINS

When the list of IUFRO seed sources was issued in 1967, the broad pattern of seed origin variation for Douglas fir was known from trials in North America (eg Munger and Morris, 1936; Ching and Bever, 1960). Some information was also available about the most promising sources for use in Britain (Leslie, 1922; Peace, 1948; Wood, 1955; Edwards, 1957; and Lines and Mitchell, 1968). Selection from the 180 sources was concentrated on the coastal or var. viridis. Because of their poor performance in Britain, all seed origins from the Rocky Mountains var. glauca were excluded, though a few from the interior of British Columbia, probably var. caesia, are included.

Whenever the seed origin variation of a species with a wide natural range is being studied, it helps understanding if the seed sources can be grouped into regions with geographical or climatic coherence. This enables tests to be made by partitioning the variance between and within such groups. Such a pattern of geographical regions has been established by the Western Forest Tree Seed Council and the British Columbia Forest Service. Unfortunately, the regions are relatively small, and thus when the IUFRO seedlots are allocated to these regions, the 31 main origins fall into 25 regions (too many to show "within region" variation). We have therefore used the Forestry Commission Seed Regions (Forestry Commission, 1965) which results in 12 regions, of which only three contain a single origin. This is shown in the following extract from the Experiment Plan:



D A T A   O R G A N I S A T I O N

Data were available from 45 seed origins from measurements at 10 - 12 years. Plant shortages meant that not all seed origins could be included at each site, and their distribution is shown in Table 2. It should be noted that because the Craigvinean experiment was planted and assessed 2 years earlier than the others, the seed origins there have not been subjected to the same annual climatic variation as those in the southern experiments. Due to management difficulties the Charmouth experiment was assessed at 12 years and the Dean and Bodmin experiments at 11 years. To enable a comparison to be made across all sites using height at 10 years, it was necessary to adjust the data for these three sites. Since annual increment between 6 and 10 years on these sites in fairly stable, the adjustment was made as follows:

Adjusted height at 10 years =

$$\text{height at 6 years} + \frac{(\text{height at p years} - \text{height at 6 years}) \times 4}{n}$$

where n = 5 and p = 11 for Bodmin and Dean (6 - 11 years)
n = 6 and p = 12 for Charmouth (6 - 12 years)

The adjustment was applied to the data for each plot. The results presented are from the small plots, except at Craigvinean, where data from the "extensive" plots was used in the few cases where a seed origin was not represented in the small plot section. For a comparison across sites it was necessary to reduce the number of seed origins from 45 to 31, including the two "standard" origins from commercial seed sources (Elma and Hoodsport).

R E S U L T S

Height

Table 2 shows the unadjusted mean height for each seed origin at 10, 11 or 12 years expressed as the percentage of the overall mean for each experiment. This gives an estimate of relative performance for each seed origin, but should be used with caution, since with the known strong interaction between seed origin and site for this species, good (or poor) performance on one or two sites could be misleading. By plotting the rank order based on these percentages (Figure 1) it will be apparent that the mainland seed origins from north of the 50th parallel of latitude have grown poorly and similarly those from south of 43°N were poor except for those from a low elevation on the coastal fringe of California. Seed origins from south west Washington, the Olympic Peninsula and the western foothills of the Washington Cascades were the tallest, while Vancouver Island sources were only moderately vigorous. A comparison with rank at 6 years, based on the data of Pearce (1980) shows remarkably little change. Exceptions were 1051 Sedro Woolley which was markedly lower in rank at 10 years, and 1147 Fort Bragg, which rose considerably in rank at 10 years.

The main set of 31 origins, which are present on seven sites, was given detailed statistical analysis. As a first step, mean height at 11 years in the three small-plot experiments at Bodmin was analysed for each experiment separately and then an analysis across all three experiments was carried out. Seed origin differences in each experiment were very highly significant, but there were no significant differences between the experiment means, nor was there a significant experiment x origin interaction. Thus it appeared logical to regard these three experiments as a single site with nine replicates in subsequent analysis across all sites.
The experiments at Charmouth, Dean, Radnor and Craigvinean were also analysed individually and in each case very highly significant variation was found between seed origins. A large part of the variation was accounted for by that between the regions (on all sites this was significant at $p < 0.001$). However, the within region variation was markedly different on different sites. Within the Vancouver Island region (7116) variation was very small at all sites. The same applied to regions (7972) S. Coast of Washington and (7951) N. Coast of Oregon. By contrast, there were no significant differences within region (7974) N. Cascades of Washington at Bodmin and Charmouth, but very highly significant differences in the Radnor experiment. Regions (7975) S. Cascades of Washington and (7953) N. Cascades of Oregon were similarly erratic. Only region (7118) S. Interior of BC showed highly significant variation (due to the consistently greater vigour of 1014, Eagle Bay) on all sites.

A C R O S S   S I T E S   A N A L Y S I S

As noted above, the height data for all sites was adjusted (where necessary) to that at 10 years and an analysis of variance for 31 seed origins across the five sites was carried out. Significance testing showed that variation between origin means, between and within regions and origin x site interactions were all very highly significant. Table 3 shows the adjusted heights for each origin at each site and their overall means. It is interesting to note the trend for increasing height growth from the poorest site at Craigvinean in Scotland, down to Bodmin in the south west tip of England. Climate would seem to play a stronger part in this effect than soil, since the Craigvinean experiment is on a deep, free-draining brown earth and adjacent to a stand of Abies grandis which has a General Yield Class (GYC), defined as the maximum mean annual increment per hectare in m3, of about 34. The Craigvinean site is on the same latitude as Wrangell, Alaska, much further north than this species extends in British Columbia. The tallest seed origin at Bodmin (Cathlamet, 1089) was equivalent to GYC 25 (using the Mean Height/Top Height graph and the Height/Age curves in Everard, 1974). The shortest origin at Bodmin (Tatla, 1006) had an equivalent GYC of 14. By contrast, at Craigvinean, Cathlamet was equivalent to GYC 17 and Tatla to GYC 15.
From Table 3 it will be seen that for individual seed origins, the tallest were: Cathlamet, Enumclaw, Elma and Naselle. The significance of the differences can be seen best from Table 4 (Duncan's Multiple Range Test). This table also brings out the markedly inferior growth of those origins from the northern end of the range and from the Californian Coast Range. Table 5 shows the heights grouped by region means. The regions showing

greatest vigour were: (7972) S. Coast Washington, (7971) N. Coast Washington, (7973) Puget Sound and (7952) S. Coast Oregon.

The effect of elevation at the seed origin on performance in Britain is not straightforward, since increase in elevation may be accompanied by a change from Coastal to interior climate. For example, within the (7117) S. Coast BC region, Squamish (15 m) comes from a site very close to the sea, while Alta, at 640 m, is close to the border with the interior and may well be influenced by gene-flow from inland populations. Klina Klini is from a shoreline site, at the head of the Knight Inlet, though with towering mountains on every side. Stuie comes in the (7112) N. Coast BC region and, while from only 230 m, it is somewhat removed from coastal influence. Within the (7118) S. Interior of BC region there does seem to be a depressing influence of elevation on the growth of the three seed origins. However, in Washington, while elevation could account for the relatively poor growth of Sloan Creek (655 m) in region (7974), and Alder Lake (427 m) and Packwood (655 m) in region (7975), it cannot explain the poor growth of Sedro Woolley (61 m) in region (7974). It appears rather likely that the poor growth of Alder Springs (1372 m) from the Californian Coast Range was influenced by its high elevation, since the much lower elevation origins Fort Bragg (61 m) and Willits (549 m) grew well at Bodmin and Radnor respectively. Thus elevation within the mainly coastal part of the range represented here, cannot account for much of the variation in growth. Yet it is worth noting that of the 17 tallest seed origins (Table 4), none came from more than 305 m above sea level.

As well as testing the significance of the overall differences among seed origins and between and within the regions, the analysis of variance applied to these combined data also considered differences among sites and the significance of seed origin x site interactions.

Analysis of the data was extended to consider the regression across sites of individual seed origins on site means using the method developed by Finlay and Wilkinson (1963). For each seed origin this analysis provides, in addition to an overall mean, a regression coefficient showing its response to increases or decreases in site potential, where this is measured as the mean performance of all origins at a site. The relationship between overall mean and regression coefficient (shown here as a scatter diagram, Figure 2), provides a useful basis for the interpretation of seed origin performance at different sites and for the selection of origins for general use or for specific sites.

The regression analysis allows consideration of the performance of each seed origin under the following aspects:

1. The overall mean across all sites indicates the origin's general level of vigour;

2. the size of the regression coefficient from the regression of origin performance on site mean (greater or less than the expected mean of 1.0) describes the way in which an origin responds to increase or decrease in site potential. This, in combination with the overall mean, indicates

the type of site to which the origin may be best adapted;

3. the significance of any residual deviations about an origin's regression determines the stability of any prediction of its response to environmental change using the regression.

Note that due to the small number of sites, this analysis should be interpreted with caution. Table 6 summarises the regression analysis of the 31 origins across 5 sites. Only 4 origins differed significantly from the average response (1.0), ie Stuie, Gold Bar, Grand Ronde and Waldport. Stuie was significantly below average, showing that its relative performance was better on the poorer sites, while the others were significantly above 1.0, indicating better than average performance on the better sites. It should be noted that Tatla, Revelstoke and Eagle Bay all showed low or very low regression coefficients. None was significant at the 5 % level, and two of them showed significant negative residuals.

There was no marked trend for the northern origins to perform best on the poorer sites and vice versa for the southern origins, which were such striking feature of the IUFRO collection of Sitka spruce seed origins (Lines and Samuel, in press). Instead, this regression analysis confirms that those origins with the largest overall mean height show no serious departure from average response, and would thus be suitable for general use across a range of sites. In addition, the analysis highlights other individual origins (Gold Bar, Grand Ronde and Waldport) whose overall mean is seriously depressed by much worse than average height growth at Craigvinean (the poorest site), but whose regression coefficient indicates a superior position for use in less demanding southern areas.

Diameter

This was assessed only at Bodmin, Charmouth and Dean at the same time as height, hence at 11, 12 and 10 years respectively (see Table 7). With no previous measurement, it is not possible to adjust these data to a common age. Each of the Bodmin experiments was first analysed separately and then an across-sites analysis was carried out. This showed no significant differences between sites. A regression analysis of individual origin means on site means showed little response to site, so the data have been pooled.

The variation in diameter between the seed origin groups was very highly significant at all three sites.

A comparison of overall rank for diameter with overall rank for height shows that these are closely correlated. Examination of those origins which do not fit with this generalisation points to the lower socking of origins which have unusually high diameters for their heights. For example, Waldport ranked 13th for height at Dean, but 7th for diameter. The survival was only 63 % at 11 years compared with an average for the experiment of 86 %. Similary, Tatla ranked 30th for height at Charmouth but 23rd for diameter. Its survival was only 49 %.

DISCUSSION AND CONCLUSIONS

Previous Douglas fir seed origin experiments in Britain (Lines and Mitchell, 1968; 1977) sampled only the middle part of the range in Washington and North Oregon. Despite good experiment design and layout, significant height differences were found at few of the sites although sources from the (7972), (7973) and (7971) regions were usually tallest. The height data shown in Table 2 clearly reveal a pattern of poor growth north of the 50th parallel of latitude, while high elevation sources below 43° N were almost as poor in height. Performance of Vancouver Island seed origins was only moderate. The areas of better growth were mainly on fairly low elevation sites in a "U" shaped zone from Arlington down the west side of the Washington Cascades to the Columbia River and thence up to Forks in the Olympic Peninsula. Some coastal sources in Oregon also grew well.

Douglas fir showed much less interaction between origin and site than Sitka spruce, so that the selection of different seed origins for different parts of Britain is likely to be less important. Although overall origin difference was statistically highly significant, Table 4 shows that the top ten origins differed by only 0,5 m, which means that for practical forestry there is a range of acceptable seed origins for wide-scale use. It seems likely that factors other than optimum vigour may be of equal importance. For example, poor stem form is a common fault with Douglas fir and this character has not yet been fully assessed in these experiments. Early survival of this species is often poor in Britain. Tabbush (unpublished) found that, in the spring, root regeneration potential of Douglas fir was half that of Sitka spruce. Jenkinson (1984) tested 51 seed sources of Douglas fir at the Humboldt nursery and found that survival and growth when spring planted strongly depended on when the seedlings were lifted and put in cold-storage. Depending on seed source, the "lifting window" ranged from 7 - 18 weeks in early November to late March. Leaf-cast diseases, eg Rhabdocline only appear to be important in Britain on the Northern Interior sources, which are undesirable for other reasons. Seed origins from the southernmost part of the coastal range are potentially at risk from frost or winter-blast injury.

ACKNOWLEDGEMENTS

The planning and earlier conduct of the experiments in England and Wales was carried out by my colleagues M.L. Pearce and A.F. Mitchell. Subsequent assessments involved a team of skilled Research Foresters whose ideas and suggestions have been incorporated in this paper.

LITERATURE CITED

Ching, K. K. and Bever, D., 1960: Provenance study of Douglas fir in the Pacific Northwest region. I. Nursery performance. Silvae Genetica 9 pp 11-17.

Edwards, M. V., 1957: Douglas fir. In: Exotic Forest Trees in Great Britain. Ed. J. Macdonald. Bull. For. Commn. Number 30. London, pp 118-126.

Everard, J. E., 1974: Fertilisers in the establishment of conifers in Wales and southern England. Booklet For. Commn. Number 41. London.

Finlay, K. W., and Wilkinson, G. N., 1963: The analysis of adaptation in a plant-breeding programme. Aust. J. Agric. Res. 14, 742-754.

Fletcher, A. M. and Barner, H., 1980: The procurement of seed for provenance research with particular reference to collections in NW America. Proceedings of the IUFRO Joint Meeting of Working Parties, Vancouver, Canada, 1978. Vol. 1, pp 141-154. Ministry of Forests, British Columbia.

Forestry Commission, 1965: Seed Identification Numbers. Research Branch Paper Number 29 (Departmental Circulation).

Jenkinson, J. L., 1984: Seed source lifting windows improve plantation establishment of Pacific Slope Douglas fir. In: Duryea, M. L. and Brown, G. N. (eds.). Seedling physiology and reforestation success. Martinus Nyhoff, Dordrecht. pp 115-141.

Lines, R. and Mitchell, A. F., 1968: Provenance: Douglas fir. Rep. For. Res. For. Commn. 1968. London. pp 71-73.

Lines, R. and Mitchell, A. F., 1970: Provenance: Douglas fir. Rep. For. Res. For. Commn. 1970. London. pp 63-64.

Lines, R., 1977: Seed Origin: Douglas fir. Rep. For. Res. For. Commn. 1977. London. p 17.

Lines, R., 1980: The IUFRO experiments with Douglas fir in Scotland. Proceedings of the IUFRO Joint Meeting of Working Parties, Vancouver, Canada, 1978. Vol. 1, pp 297-303. Ministry of Forests, British Columbia.

Leslie, P., 1922: Studies of Douglas fir. Trans. Roy. Scot. Arbor. Soc. XXXVI (1), pp 113-34.

Munger, T. T. and Morris, W. G., 1936: Growth of Douglas fir trees of known seed source. Tech. Bull. 537 US Dept. Agric. pp 40.

Peace, T. R., 1948: The variations of Douglas fir in its native habitat. Forestry 22 (1), pp 45-61.

Pearce, M. L., 1980: The IUFRO experiments with Douglas fir in England and Wales. Proceedings of the IUFRO Joint Meeting of Working Parties, Vancouver, Canada, 1978. Vol 1, pp 381-388. Ministry of Forests, British Columbia.

Troll, N., 1965: Seasonal Climates of the Earth. In: World Maps of Climatology. Eds: E. Rodenwaldt and H. J. Jusatz.

Wood, R. R., 1955: Studies of north-west American forests in relation to silviculture in Great Britain. Bull. For. Commn. Number 25. London. 43pp.

Table 1. Site factors at each experiment

	Bodmin	Charmouth	Dean	Radnor	Craigvinean
Grid reference	SX100670	SY333985	SO535139	SO307627	NN993458
Latitude °N	50° 28'	50° 46'	51° 49'	52° 15'	56° 35'
Longitude °W	4° 40'	2° 57'	2° 40'	3° 01'	3° 39'
Elevation m	84-100	138	60	226	138
Aspect	East-North-South	North-east	North-west	South-east	East
Exposure	Sheltered	Moderate	Moderate	Sheltered	Fairly sheltered
Slope	Very steep	Variable	Moderately steep	Moderate	Moderate to steep
Geology	Middle Devonian slates	Clay with flints/ Greensand	Lower Old Red Sandstone	Silurian grits	Dalradian mica-schists
Soil	Brown earth, very free drainage	Surface water gley/ peaty gley	Brown earth	Well drained brown earth	Well drained brown earth
Rainfall mm	1400, frequent mists	1050	1000	1000	1000
Oceanicity*	Hyper/Euoceanic	Euoceanic	Hemioceanic	Hemioceanic	Hemioceanic
Vegetation	Rubus/Digitalis	Broadleaved spp/ Juncus	Rubus/Pteridium/ grasses	Pteridium/ Rubus	Grasses/Pteridium/ Rubus
Previous land use	Oak coppice	Oak with scrub	Old Oak/Beech	Originally Oak then L. decidua	L. decidua

*Troll (1965)

Table 2. Unadjusted height as a percentage of site mean at 10-12 years for 45 seed origins on all sites

IUFRO Number	Origin	Bodmin			Charmouth	Dean	Radnor	Craigvinean		Mean
		East	North	South				Intensive	Extensive	
1106	Fort St James					75				75
1109	Dunster				60		78			69
1002	Dean	74	94	94						87
1004	Stuie	93	86	74	83	97	95	101	90	90
1005	Williams Lake	34	45	32			61			43
1006	Tatla	49	55	54	50	75	80		96	66
1012	Klina Klini	93	100	94	112	95	98		93	98
1013	Revelstoke	67	88	74	64		80	87	95	79
1014	Eagle Bay	66	72	89	83	100	100			85
1023	Jeune Landing	99	105	104	104	97	94	99	102	100
1027	Alta	89	95	81	100	88	88	83	81	88
1029	Thasis		117	117	113	96	95			106
1030	Squamish	113	102	103	118	102	103			107
1031	Gold River	97	94	100				99	98	98
1043	San Juan				106	103	92	111		103
1050	Marblemount	110	112	99	97	108			109	106
1051	Sedro Woolley				96	105	101		98	100
1053	Darrington	104	108	103	104	103	112			106
1054	Arlington	123	110	111	115	102	101			110
1056	Sloan Creek	97	100	109	101	85	95	98	85	96
1062	Forks	113	120	110	126	102	108	110	114	113
1063	Gold Bar	110	117	124	106	110	113	91	95	108
1075	Enumclaw	134	117	104	115	110	112	115		115
1081	Alder Lake	104	98	106	99	107	107	93		102
1083	Packwood	101	103	104	114	107	106	96	123	107
1086	Naselle	119	112	111	129	112	103	113		114
1089	Cathlamet	133	129	123	104	113	114	117		119
1094	Vernonia	110	111	100	106	107	105	108		107
1098	Hebo				110	100	105	99	106	104
1100	Grand Ronde Agency	110	111	107	104	103	107	87	105	104
1101	Waldport	121	103	120	115	105	110	90	107	109
1118	Mary's Peak					98				98
1103	Coquille				129	112	120	110		118
1124	Wolf Creek	83	89	96			96			91
1104	Brookings					113	109	93		105
1126	Ashland	87	89	101	78					89
1130	Hawkinsville				82		69			76
1135	Sawyers Bar				76	80				78
1144	Covelo	80	86	93		98				89
1146	Alder Springs	79	91	81	83	78				84
1147	Fort Bragg	119	102	110						110
1148	Willits						113			113
1150	St Helena Mt	87	105	101						98
(7973)2	Hoodsport	120	106	114	114	103	99			109
(7975)8R	Elma	126	112	120	108	117	108			115
Experiment mean height, m		7.00	6.50	7.00	7.20	6.00	5.29	3.82	3.54	
Age when measured, years		11	11	11	12	11	10	10	10	

Table 3. Adjusted mean height at 10 years for the 31 origins common to all 5 sites, metres

Region	IUFRO Number	Origin	Bodmin	Charmouth	Dean	Radnor	Craigvinean	Mean
(7112)	1004	Stuie	5.058	4.589	5.080	4.997	3.844	4.728
(7116)	1023	Jeune Landing	6.172	5.867	4.997	4.977	3.712	5.288
	1029	Thasis	6.896	5.334	4.943	5.083	3.953	5.561
	1043	San Juan	6.211	5.802	5.377	4.847	4.248	5.444
(7117)	1012	Klina Klini	5.708	6.183	4.907	5.183	3.288	5.071
	1027	Alta	5.280	5.503	4.610	4.657	3.262	4.702
	1030	Squamish	6.401	6.447	5.350	5.433	4.011	5.624
(7118)	1006	Tatla	3.152	2.837	3.893	4.227	3.448	3.412
	1013	Revelstoke	4.494	3.590	2.995	4.257	3.358	3.903
	1014	Eagle Bay	4.497	4.592	5.140	5.303	2.825	4.335
(7971	1062	Forks	6.849	7.003	5.250	5.730	4.168	5.932
(7974)	1050	Marblemount	6.438	5.513	5.643	5.633	3.858	5.548
	1051	Sedro Woolley	6.109	5.393	5.467	5.330	3.412	5.244
	1053	Darrington	6.308	5.803	5.423	5.947	3.961	5.569
	1054	Arlington	6.894	6.319	5.253	5.323	4.183	5.811
	1056	Sloan Creek	6.104	5.653	4.443	5.037	3.670	5.160
	1063	Gold Bar	7.083	5.970	5.793	5.970	3.406	5.825
(7975)	1075	Enumclaw	7.121	6.354	5.743	5.943	4.428	6.102
	1081	Alder Lake	5.884	5.493	5.573	5.680	3.748	5.302
	1083	Packwood	6.120	6.213	5.607	5.623	3.622	5.457
		Elma	7.212	6.030	5.903	5.707	4.438	6.088
(7973)		Hoodsport	6.820	6.390	5.490	5.253	4.185	5.813
(7972)	1086	Naselle	6.840	7.100	5.833	5.457	4.294	6.009
	1089	Cathlamet	7.704	5.830	5.903	6.037	4.444	6.299
(7953)	1094	Vernonia	6.451	5.867	5.593	5.557	4.294	5.677
	1100	Grand Ronde	6.540	5.860	5.430	5.667	3.300	5.488
(7951)	1098	Hebo	6.204	6.137	5.220	5.573	3.656	5.431
	1101	Waldport	7.010	6.400	5.390	5.820	3.460	5.792
(7952)	1103	Coquille	6.477	7.109	5.867	6.367	4.172	5.964
	1104	Brookings	6.269	6.037	5.937	5.783	3.624	5.557
(7946)	1146	Alder Springs	4.917	4.613	4.093	3.341	2.566	4.053
				Standard error for means across all sites				0.515

Least significant differences 1.43 $p<0.05$
1.88 $p<0.01$
2.39 $p<0.001$

Table 4. Duncan's multiple range test applied to overall origin means for adjusted height at 10 years, metres

FC Region	Mean	IUFRO Number	Name	5%	1%
(7972)	6.299	1089	Cathlamet		
(7975)	6.102	1075	Enumclaw		
(7975)	6.088		Elma		
(7972)	6.009	1086	Naselle		
(7952)	5.964	1103	Coquille		
(7971)	5.932	1062	Forks		
(7974)	5.825	1063	Gold Bar		
(7973)	5.813		Hoodsport		
(7974)	5.811	1054	Arlington		
(7951)	5.792	1101	Waldport		
(7953)	5.677	1094	Vernonia		
(7117)	5.624	1030	Squamish		
(7974)	5.569	1053	Darrington		
(7116)	5.561	1029	Thasis		
(7952)	5.557	1104	Brookings		
(7974)	5.548	1050	Marblemount		
(7953)	5.488	1100	Grand Ronde		
(7975)	5.457	1083	Packwood		
(7116)	5.444	1043	San Juan		
(7951)	5.431	1098	Hebo		
(7975)	5.302	1081	Alder Lake		
(7116)	5.288	1023	Jeune Landing		
(7974)	5.244	1051	Sedro Woolley		
(7974)	5.160	1056	Sloan Creek		
(7117)	5.071	1012	Klina Klini		
(7112)	4.728	1004	Stuie		
(7117)	4.702	1027	Alta		
(7118)	4.335	1014	Eagle Bay		
(7946)	4.053	1146	Alder Springs		
(7118)	3.903	1013	Revelstoke		
(7118)	3.412	1006	Tatla		

Treatment means which have no line in common are significantly different at the given probability level. Treatment means which have a common line are not significantly different at the given probability level.

Table 5. Adjusted mean height at 10 years for the 31 origins common to all 5 sites, region means, metres

Region	Origin	Bodmin	Charmouth	Dean	Radnor	Craigvinean	Mean	Significant differences within regions
(7112)	North Coast, BC	5.058	4.589	5.080	4.997	3.844	4.728	-
(7116)	Vancouver Island	6.426	5.668	5.106	4.969	3.971	5.431	ns
(7117)	South Coast, BC	5.796	6.044	4.956	5.091	3.520	5.132	***
(7118)	Southern Interior, BC	4.048	3.673	4.009	4.596	3.210	3.883	***
(7971)	North Coast, Washington	6.849	7.003	5.250	5.730	4.168	5.932	-
(7974)	North Cascades, Washington	6.489	5.775	5.337	5.540	3.748	5.526	***
(7975)	South Cascades, Washington	6.584	6.023	5.707	5.738	4.059	5.737	***
(7973)	Puget Sound, Washington	6.820	6.390	5.490	5.253	4.185	5.813	-
(7972)	South Coast, Washington	7.272	6.465	5.868	5.747	4.369	6.154	ns
(7953)	North Cascades, Oregon	6.496	5.863	5.512	5.612	3.797	5.583	ns
(7951)	North Coast, Oregon	6.607	6.268	5.305	5.697	3.558	5.611	ns
(7952)	South Coast, Oregon	6.373	6.573	5.902	6.075	3.898	5.761	*
(7946)	Coast Range, California	4.917	4.613	4.093	3.341	2.566	4.053	-
Overall Mean		6.169	5.737	5.231	5.346	3.769	5.361	

*p = <0.05
**p = <0.01
***p = <0.001
ns = non significant
- = single origin only in region

Table 6. Regression analysis of 31 origins across 5 sites

Seed Origin			Overall mean height (m)	Regression coefficient (b)	t value for test of b ≠ 1.0
7112	1004	Stuie	4.728	0.480	-3.66*
7116	1023	Jeune Landing	5.288	1.039	0.42
	1029	Thasis	5.561	1.183	0.67
	1043	San Juan	5.444	0.818	1.26
7117	1012	Klina Klini	5.071	1.059	0.31
	1027	Alta	4.702	0.873	1.05
	1030	Squamish	5.624	1.027	0.23
7118	1006	Tatla	3.412	-0.160	-4.49
	1013	Revelstoke	3.903	0.453	2.10
	1014	Eagle Bay	4.335	0.690	0.85
7971	1062	Forks	5.932	1.167	0.85
7974	1050	Marblemount	5.548	1.043	0.37
	1051	Sedro Woolley	5.244	1.101	0.93
	1053	Darrington	5.569	0.972	0.29
	1050	Arlington	5.811	1.138	0.83
	1056	Sloan Creek	5.160	1.029	0.19
	1063	Gold Bar	5.825	1.502	+4.49*
7975	1075	Enumclaw	6.102	1.113	1.26
	1018	Alder Lake	5.302	0.878	0.83
	1083	Packwood	5.457	1.063	0.44
		Elma	6.088	1.122	0.72
7973		Hoodsport	5.813	1.108	0.73
7972	1086	Naselle	6.009	1.105	0.53
	1089	Cathlamet	6.299	1.295	1.05
7953	1094	Vernonia	5.677	0.888	2.31
	1100	Grand Ronde	5.488	1.341	+5.33*
7951	1098	Hebo	5.431	1.084	0.94
	1101	Waldport	5.792	1.486	+9.37**
7952	1103	Coquille	5.964	1.015	0.06
	1104	Brookings	5.557	1.101	0.63
7946	1146	Alder Springs	4.053	0.987	0.08

Significance at: $p<0.05$*
$p<0.01$**

Table 7. Mean diameter at 10-12 years of 31 origins on 3 sites, cm

Region	IUFRO No	Origin	Bodmin 11 years	Charmouth 12 years	Dean 10 years	Mean
(7112)	1004	Stuie	8.47	7.80	7.83	8.03
(7116)	1023	Jeune Landing	9.54	9.67	7.30	8.84
	1029	Thasis	10.26	9.54	7.40	9.07
	1043	San Juan	-	9.91	8.40	9.15
(7117)	1012	Klina Klini	8.77	10.10	7.60	8.82
	1027	Alta	7.68	8.67	7.10	7.82
	1030	Squamish	9.84	10.57	7.97	9.46
(7118)	1006	Tatla	3.63	9.44	6.10	6.39
	1013	Revelstoke	5.83	5.54	-	5.69
	1014	Eagle Bay	6.17	8.26	7.83	7.42
(7971)	1062	Forks	10.38	11.90	7.40	9.90
(7974)	1050	Marblemount	11.20	10.07	8.37	9.88
	1051	Sedro Woolley	-	8.13	7.67	7.90
	1053	Darrington	10.17	9.53	7.67	9.12
	1054	Arlington	10.81	11.09	7.80	9.90
	1056	Sloan Creek	10.01	9.37	6.83	8.74
	1063	Gold Bar	11.23	11.23	8.23	10.23
(7975)	1075	Enumclaw	11.51	10.24	8.80	10.18
	1081	Alder Lake	10.02	10.07	8.63	9.57
	1083	Packwood	8.96	10.27	8.53	9.25
	(7975)8R	Elma	10.86	10.73	8.67	10.08
(7973)	(7973)2	Hoodsport	10.54	10.97	8.23	9.92
(7972)	1086	Naselle	10.79	11.70	8.47	10.32
	1089	Cathlamet	11.66	10.67	8.97	10.43
(7953)	1094	Vernonia	10.92	10.30	8.90	10.04
	1100	Grand Ronde	10.76	10.03	9.23	10.01
(7951)	1098	Hebo	-	10.93	8.53	9.73
	1101	Waldport	11.63	10.47	8.70	10.30
(7952)	1103	Coquille	-	11.44	9.33	10.39
	1104	Brookings	-	-	9.53	9.53
(7946)	1146	Alder Springs	7.64	8.50	8.08	8.08

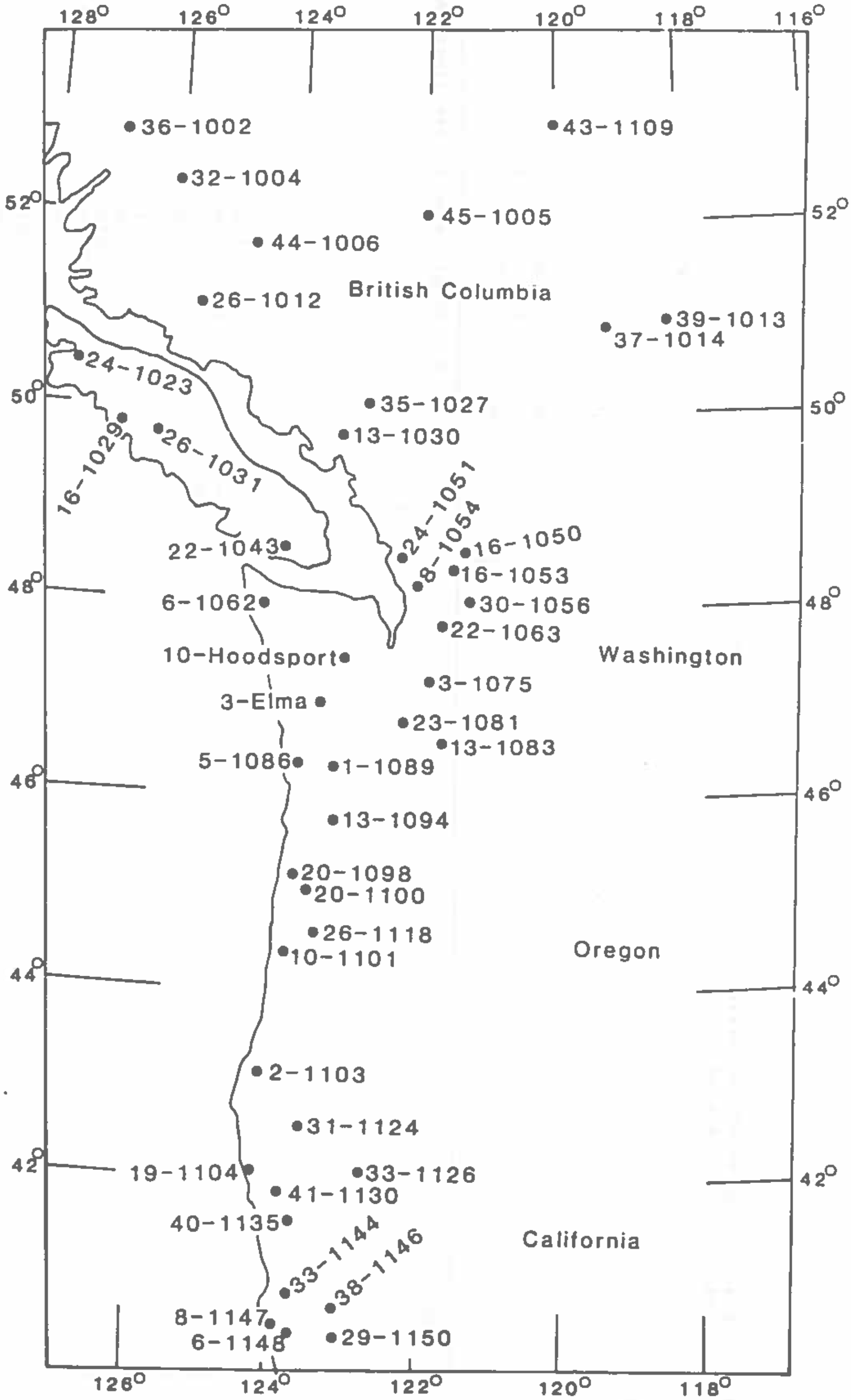
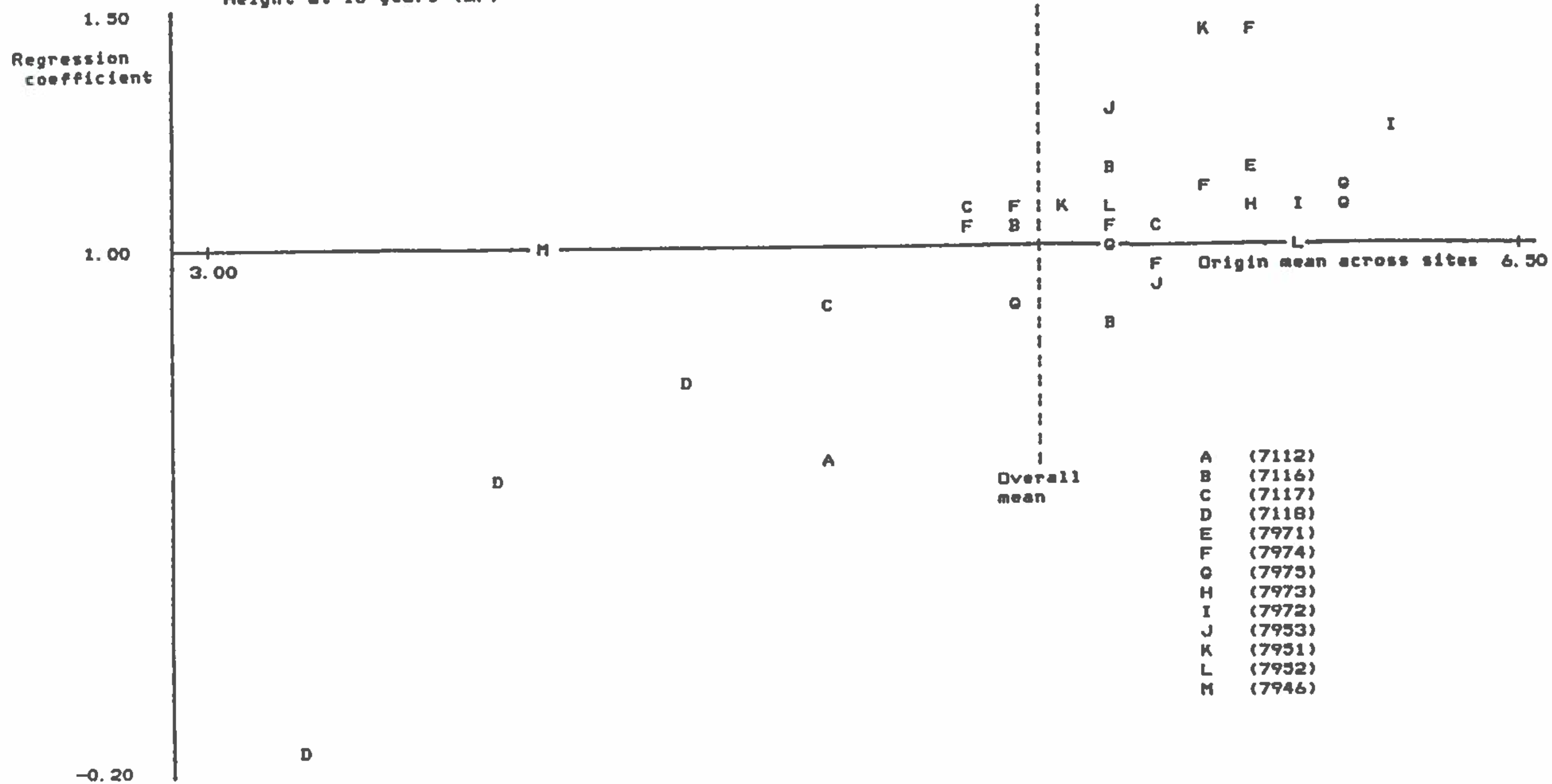


Figure 1. Rank of 45 seed origins based on overall height shown in Table 2

Figure 2. Scatter diagram of regression coefficient vs. origin mean. Height at 10 years (m.)



RESULTS IN TWO TEST SITES OF PROVENANCES OF THE IUFRO COLLECTION OF PSEUDOTSUGA MENZIESII (MIRB) FRANCO IN GALICIA

G. Toval

Departamento de Investigación Forestal de Lourizan. Conselleria de Agricultura, Pesca y Alimentacion. Xunta de Galicia. Apartado 127. 36080 Pontevedra. España

SUMMARY

Since 1977 we have been working with 87 provenances of Pseudotsuga menziesii (Mirb) Franco from the IUFRO collection, a species with a promising future in the North of Spain. In this paper are presented the results of two test sites in Galicia (NW Spain) at 800 and 1.400 m height, both representative of the principal mountain ranges in Galicia.

After five years growth, the most promising origins are those found between South Washington and North Oregon, and between the coastal mountains and the Cascades. Although growth in the test site of lesser altitude is greater than that of the higher zone, the survival percentage of both sites is nevertheless similar.

INTRODUCTION

Since 1977, we have been testing 87 provenances of Pseudotsuga menziesii (Mirb) Franco in the North of Spain in 18 different sites.

During the first five years, the work was undertaken within a research project of a Spanish U.S. cooperation agreement, and at present by means of project no 1603/82 of the Assessory Committee of Scientific and Technical Research (CAICYT). Here are presented the results from two test sites situated in the principal moutain ranges of Galicia, and which include the 87 provenances mentioned.

There are, in Galicia, some 300,000 ha of mountains above 800 m, covered by scrub which could, from the climatic and topographic point of views, be forested. At present, in the upper heights of the mountains the species most used is Pinus sylvestris L., of which there are some 50,000 ha (ICONA 1972); Pseudotsuga menziesii (Mirb) Franco, could be an important alternative in this area.

MATERIAL AND METHODS

The seed used in this study comes from the IUFRO collection, collected in its area of origin in 1966, 1967 and 1968, with the exception of the Mexican origins, collected in 1961 and 1965.

They were received in 1967, 1968 and 1969 and stored in refrigerated rooms at -30ºC until the date of sowing.

The sowing took place in March, June and July of 1977; after 1 month stratification in wet sand in a fridge at 4ºC.

The sowing was done in boxes whose substrate was formed of 1/3 river sand, 1/3 peat and 1/3 soil previously sterilized with Vapam (50 % metam - sodium).

In January and February of 1978 the seedlings were transplanted to polythene bags of 1 litre capacity, whose substrate was formed by ground pine bark and fertilized with Plantosan 4-D (20 % of amidic nitrogen, 10 % P_2O_5, 15 % K_2O, 3,6 % Mg, 0.045 % B, 0.112 % Mn, 0.05 % Cu and 0.0085 Mo) in the proportions of 2.5 Kg of fertilizer to 1 m^3 of bark (TOVAL, 1983).

In March 1978 a test site was installed in Sierra del Eje (S1) and in November of the same year in La Hermida (S2).

In both cases, the experimental design was in randomized complete blocks, with 3 blocks, 87 provenances, 25 plants for each block and provenance with a spacing of 3 m x 3 m.

In the Sierra del Eje (S1) the ground was prepared by ploughing, to a depth of 60 cm, and in La Hermida the terracing was done with a stripper and bulldozer (ICONA, 1975).

Tabel 1 shows the geographical data and Table 2 the climatological data of both sites; a fuller description can be found in TOVAL et al (1982).

TABLE 1. - GEOGRAPHICAL DATA OF TEST SITES

	SIERRA DEL EJE (S1)	LA HERMIDA (S2)
Latitude	42º 17' N	42º 31' N
Longitude	6º 58' W	8º 17' W
Altitude	1.360 m	700 m
Aspect	SW	N
Average slope	10 %	30 %

TABLE 2. - CLIMATIC DATA OF TEST SITES

S I E R R A   D E L   E J E

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
Temperatures	1.6	1.9	3.7	4.8	7.0	12.2	15.0	15.6	15.1	8.8	5.7	2.2	7.8
Precipitation	95	141	94	76	94	45	29	33	52	140	83	205	1087

L A   H E R M I D A   (S_2)

	J	F	M	A	M	J	J	A	S	O	N	D	YEAR
Temperatures	6.8	7.5	9.6	11.6	14.3	17.3	19.8	19.1	17.2	13.9	9.4	6.8	12.8
Precipitation	228	179	178	111	106	61	25	35	70	131	181	178	1482

The geographic localization of the 87 origins tested are presented in Table 3.

Five years after planting in the test site the total height of all the plants have been measured as well as the survival percentage according to the following mathematical model of the variance analysis:

$$X_{ijkl} = \mu + P_i + S_j + B_{k(j)} + PS_{ij} + PB_{ik(j)} + \varepsilon_{l(ijk)}$$

where P_i = provenances, S_j = test sites, $B_{x(j)}$ = blocks, and the corresponding interactions.

The comparison of means was done with the Duncan-Bonner test at 5 %.

At the same time, regression analyses were done between height and survival data of the different provenances in each of the test sites, as well as geographical localization of the provenances.

TABLE 3.- GEOGRAPHIC LOCALITY OF THE PROVENANCES TESTED.

B. COLUMBIA (CANADA)

	Latitud	Longitud	Altitud m.
1.003	52°41' 30"	122°26' 00"	630 - 800
1.014	50°56' 00"	119°13' 00"	430 - 530
1.024	50°20' 00"	122°43' 30"	233
1.031	49°43' 00"	126°04' 00"	100
1.032	49°41' 45"	125°03' 30"	74
1.034	49°30' 40"	123°32' 35"	200
1.039	49°04' 24"	121°48' 00"	174
1.040	49°03' 30"	123°57' 00"	217
1.045	48°24' 00"	123°44' 00"	50

WASHINGTON (U.S.A.)

	Latitud	Longitud	Altitud m.
1.048	48°36'	118°44'	800
1.050	48°35'	121°24'	130
1.051	48°32'	122°19'	65
1.053	48°16'	121°38'	165
1.054	48°13	122°04	100
1.058	48°04'	124°00'	330
1.059	48°03'	121°28'	630-700
1.060	48°02'	123°02'	30-100
1.061	48°00'	123°05'	500
1.062	47°59'	124°24'	100
1.063	47°51'	121°39	130
1.064	47°48'	123°58'	265
1.065	47°47'	117°12'	600-730

OREGON (U.S.A.)

	Latitud	Longitud	Altitud m.
1.101	44° 24'	123° 52'	30 - 100
1.102	44° 23'	122° 12'	1.000 - 1.165
1.103	43° 12'	124° 10'	30 - 130
1.104	42° 07'	124° 12'	265 - 400
1.113	44° 48'	122° 42'	180
1.114	44° 44'	122° 10'	330
1.115	44° 42'	123° 13'	80
1.116	44° 36'	123° 42'	365
1.118	44° 30'	123° 34'	1.065 - 1.100
1.119	44° 01'	123° 23'	230
1.120	43° 54'	122° 22'	965
1.121	43° 22'	122° 31'	1.750
1.122	43° 20'	122° 42'	565
1.123	43° 19'	123° 30'	265 - 330
1.124	42° 41'	123° 23'	465
1.125	42° 11'	123° 40'	430 - 500
1.126	42° 05'	122° 39'	1.630

CALIFORNIA (U.S.A.)

	Latitud	Longitud	Altitud m.
1.127	41° 57'	123° 30'	1.065
1.128	41° 51'	123° 59'	130
1.129	41° 48'	123° 00'	800 - 930
1.130	41° 47'	122° 40'	1.165
1.131	41° 44'	123° 06'	1.065 - 1.130
1.133	41° 39'	123° 31'	1.365

WASHINGTON (U.S.A.)

	Latitud	Longitud	Altitud m.
1.068	47° 41'	120° 44'	600
1.072	47° 22'	121° 40'	600 - 730
1.073	47° 19'	123° 54'	150
1.075	47° 16'	121° 56'	265
1.076	47° 15'	123° 25'	130
1.077	47° 15'	123° 12'	100
1.078	47° 13'	121° 07'	700
1.080	47° 01	122° 44'	65
1.082	46° 40'	121° 02'	830
1.084	46° 34'	121° 42'	330
1.085	46° 33'	122° 03'	365
1.086	46° 22'	123° 44'	30 - 65
1.088	46° 19'	122° 52'	165
1.089	46° 18'	123° 16'	165 - 265
1.091	46° 00'	122° 22'	130
1.092	46° 00'	121° 10'	530
1.093	45° 48'	121° 41'	500 - 600
1.095	45° 37'	122° 08'	500

OREGON (U.S.A.)

	Latitud	Longitud	Altitud m.
1.094	45° 46'	123° 13'	330
1.096	45° 23'	122° 18'	300
1.097	45° 19'	122° 08'	665 - 800
1.098	45° 13'	123° 51'	130 - 200
1.099	45° 06'	121° 23'	800
1.100	45° 06'	123° 36'	165 - 230

CALIFORNIA (U.S.A.)

	Latitud	Longitud	Altitud m.
1.134	41° 17'	123° 08'	1.230 - 1.300
1.135	41° 16'	123° 09'	1.565 - 1.600
1.136	41° 12'	122° 18'	1.100
1.137	41° 05'	121° 39'	1.115
1.138	40° 55'	123° 50'	500 - 565
1.139	40° 54'	122° 44'	1.200 - 1.300
1.140	40° 54'	123° 46'	965
1.141	40° 47'	123° 12'	1.365 - 1.500
1.142	40° 43'	123° 18'	1.080
1.143	40° 23'	123° 00'	1.300
1.144	39° 55'	123° 10'	1.000
1.145	39° 48'	122° 56'	1.700
1.147	39° 30'	123° 43'	65
1.148	39° 23'	123° 25'	600
1.149	38° 50'	122° 42'	1.030
1.150	38° 40'	122° 36'	730-830

MEXICO

	Latitud	Longitud	Altitud m.
1.151	25° 17'	100° 35'	2.750 Pseudotsuga flahaulti
1.152	19° 36'	98° 03'	2.730 Pseudotsuga macrolepis

RESULTS

Height

In Table 4 the results are given of the variance of total heights, from which one can conclude the superiority of the La Hermida site over Sierra del Eje, with a total mean growth of 69.22 cm in the former as against 39.13 cm in the latter.

Blocks 5 and 6 of La Hermida, with a mean height of 73.1 and 72.3 respectively are superior to no 4 of the same site, where mean height reaches 62.0 cm, but all are superior to the blocks in Sa del Eje, where 2 and 3 reach a height of 41.7 and 41.3 cm respectively, differing significantly to 1 where the plants only reached 34.0 cm.

The provenance x site interaction is significant and qualitative, at least for some origins. In Table 5 are given results of total heights reached by the different provenances in both sites, classified in established groups according to the Duncan-Bonner test with 5 % probability.

Survival

In Table 6 the analysis data is given for the variance for survival percentage, from which it can be concluded that there are no significant differences between the test sites, and there is no site x provenance interaction. In Table 7 the survival results of the different provenances can be seen.

The differences between blocks, although significant, are slight, varying between 77.5 % in block 3 of Sierra del Eje, and 71.03% in block 2 of the same site.

Correlations

The correlations of mean height reached by each provenance, as well as the survival percentage, with the latitude, longitude and altitude of the provenances in each of the test sites (Table 8) produces the following results.

In both sites the growth in height correlates negatively with altitude of the origin of the seed, while there is no correlation either with latitude or longitude.

In the Sierra del Eje (S1) the survival percentage correlates inversely with the longitude, that is to say, the more coastal the provenance, the lower the survival percentage, while in La Hermida, (S2) survival correlates with altitude.

On the other hand, the existing correlations between survival percentages and total heights for each provenance in each test site, and the correlations of each one of these results in both sites (Table 9) shows us that there is a linear correlation between the survival percentages and increases in height, being more pronounced in La Hermida than in Sierra del Eje.

Thus there exists a linear correlation between heights and survival percentages in both test sites.

TABLE 4.- ANALYSIS OF VARIANCE OF TOTAL HEIGHTS

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	ESTIMATE MEAN SQUARES	F
Provenance (P)	86	995,855.95	11,579.72	$\sigma^2 + 108\sigma^2_P$	3.35***
Site (S)	1	2,174,194.72	2,174,194.72	$\sigma^2 + 4.698\sigma^2_S$	47.90**
Block (B)	4	181,565'98	45,391.50	$\sigma^2 + 1.566\sigma^2_B$	82.95***
P x S	86	287,596'76	3,344.15	$\sigma^2 + 54\sigma^2_{PS}$	6.11***
P x B	344	1,190,800.86	3,461.63	$\sigma^2 + 18\sigma^2_{PB}$	6.33***
Residual	8,874	4,855,956.23	547.21	σ^2	
Total	9,395	9,685,970.50			

TABLE 6.- ANALYSIS OF VARIANCE OF SURVIVAL PERCENTAGE

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	ESTIMATE MEAN SQUARES	F
Provenance (P)	86	39,447.08	458.69	$\sigma^2 + 12\sigma^2_P$	1.94***
Site (S)	1	315.77	315.77	$\sigma^2 + 522\sigma^2_S$	1.34
Block (B)	4	2,736.89	684.22	$\sigma^2 + 87\sigma^2_B$	2.90*
P x S	86	22,648.89	263.36	$\sigma^2 + 6\sigma^2_{PB}$	1.11
P x B	344	81,257.78	236.21	σ^2	
Total	521	146,406.41			

TABLE 8.- CORRELATION COEFFICIENTS BETWEEN HEIGHTS AND SURVIVAL PERCENTAGES WITH THE GEOGRAPHICAL COORDINATES IN EACH TEST SITE.

	Latitude	Longitude	Altitude
Total heights in S_1	0.10	0.21	-0.32**
Survival % S_1	0.06	-0.23*	0.12
Total heights S_2	0.13	0.10	-0.46***
Survival % S_2	-0.02	-0.11	0.22**

*** Significant to 0.01

** Significant to 0.1

* Significant to 0.5

TABLE 5.- MEAN HEIGHTS OF THE PROVENANCES IN EACH TEST SITE. DUNCAN-BONNOR TEST 5%.

SIERRA DEL EJE (S_1)									
CLASS 1		CLASS 2		CLASS 3		CLASS 4		CLASS 5	
Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm
1113	60.03	1098	49.45	1128	37.89	1003	26.28	1048	13.76
1063	58.78	1149	49.41	1095	37.87	1099	26.24		
1118	58.61	1124	49.25	1059	37.51	1088	26.21		
1115	53.86	1058	49.14	1032	37.28	1151	26.15		
1064	53.13	1053	48.00	1136	36.67	1065	26.13		
1080	53.05	1101	46.56	1034	36.45	1137	26.12		
1089	52.25	1094	45.98	1097	36.29	1061	25.92		
1072	51.31	1131	45.85	1139	36.17	1127	25.61		
1084	49.92	1125	45.10	1140	36.17	1130	16.93		
		1073	44.83	1086	36.06				
		1062	44.15	1039	35.93				
		1024	44.00	1148	35.58				
		1092	43.65	1077	35.06				
		1060	43.60	1104	35.05				
		1050	45.57	1152	34.84				
		1114	42.84	1147	34.55				
		1102	42.26	1142	34.36				
		1040	41.97	1068	33.91				
		1122	41.96	1121	33.70				
		1085	41.93	1129	33.58				
		1103	41.67	1150	32.44				
		1093	41.33	1134	32.24				
		1135	41.16	1141	31.83				
		1145	40.95	1082	31.57				
		1116	40.95	1120	30.88				
		1075	40.92	1133	30.38				
		1091	40.88	1014	30.23				
		1119	40.87	1100	29.46				
		1045	40.60	1076	29.35				
		1138	40.39	1126	29.25				
		1143	40.24	1031	28.40				
		1123	39.74	1144	27.80				
		1078	39.11						
		1096	39.03						
		1051	38.46						
		1054	38.38						

LA HERMIDA (S_2)													
CLASS 1		CLASS 2		CLASS 3		CLASS 4		CLASS 5		CLASS 6		CLASS 7	
Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm
1091	106.08	1073	95.38	1040	84.19	1064	72.44	1031	60.88	1048	48.94	1003	33.64
1077	100.25	11051	93.15	1095	83.49	1143	72.28	1050	60.57	1099	48.40		
1113	97.13	1072	92.70	1045	83.46	1122	71.49	1145	59.65	1065	46.90		
		1032	92.61	1104	82.31	1097	71.47	1098	58.85	1130	45.72		
		1089	89.30	1136	80.78	1094	71.37	1135	57.88	1014	44.17		
		1096	88.61	1062	79.85	1140	71.15	1129	57.79	1133	40.78		
		1053	86.20	1088	78.95	1119	71.03	1118	57.19				
		1115	85.28	1101	78.64	1152	69.05	1142	56.92				
				1100	77.93	1123	68.96	1075	55.95				
				1063	76.41	1084	68.69	1114	55.53				
				1147	75.83	1080	68.22	1103	55.43				
				1114	74.74	1138	68.00	1127	54.83				
				1076	74.62	1085	67.71	1131	54.79				
				1116	74.14	1093	67.59	1141	54.28				
				1054	74.07	1102	67.59	1149	54.16				
						1059	67.21	1082	53.50				
						1086	67.19	1120	53.45				
						1125	66.98	1137	53.07				
						1124	66.85	1126	52.77				
						1039	66.75	1024	52.49				
						1060	66.71	1121	52.32				
						1128	66.61	1068	52.30				
						1061	64.28						
						1058	63.70						
						1092	63.58						
						1151	63.18						
						1150	66.13						
						1034	62.84						
						1144	62.59						
						1148	62.41						
						1078	62.29						
						1139	61.75						

TABLE 7.- MEAN PERCENTAGES OF SURVIVAL OF DIFFERENT PROVENANCES TESTED. DUNCAN-BONNOR TEST 5%.

Class a)				Class b)		Class c)	
PVNCE nº	SURV. %	PVNCE nº	SURV. %	PVNCE nº	SURV. %	PVNCE nº	SURV. %
1115	92.0	1031	76.7	1131	68.7	1048	40.0
1098	88.0	1054	76.7	1050	68.0		
1024	86.8	1097	76.7	1088	68.0		
1096	86.7	1100	76.7	1032	67.3		
1113	86.0	1144	76.7	1059	67.3		
1040	84.7	1051	76.0	1133	67.3		
1073	84.7	1060	76.0	1062	66.7		
1089	84.7	1063	76.0	1064	66.7		
1053	84.0	1101	76.0	1152	66.7		
1140	84.0	1136	76.0	1099	64.0		
1095	83.3	1072	75.3	1103	64.0		
1125	83.2	1116	75.3	1014	61.3		
1141	83.2	1119	74.7	1137	61.3		
1094	82.7	1121	74.7	1068	60.0		
1091	82.0	1135	74.7	1142	60.0		
1129	82.0	1078	74.0	1130	58.7		
1143	82.0	1085	74.0	1065	51.3		
1039	81.3	1034	73.3	1003	48.7		
1114	80.7	1139	73.3				
1124	80.7	1093	72.7				
1148	80.7	1118	72.7				
1080	80.0	1122	72.7				
1104	80.0	1126	72.7				
1147	80.0	1086	72.0				
1058	79.3	1151	72.0				
1082	79.3	1128	71.3				
1123	78.7	1138	71.3				
1092	78.0	1149	71.3				
1077	78.0	1061	70.7				
1150	78.0	1075	70.7				
1102	77.3	1127	70.7				
1145	77.3	1084	70.0				
		1134	70.0				
		1076	69.8				
		1045	69.3				
		1120	69.3				

TABLE 9.- CORRELATION COEFFICIENTS BETWEEN TOTAL HEIGHTS, SURVIVAL PERCENTAGES AMONG THEMSELVES, AND IN EACH TEST SITE.

	Heights in S_2	% Survival in S_1
Heights in S_1	0.4***	0.36***
% Survival S_2	0.70***	0.29**

DISCUSSION AND CONCLUSIONS

The superiority of the test site of La Hermida (S2) is obvious, and reflects more favourable climatic conditions than in Sierra del Eje, as can be seen in Table 2, affecting th growth of all the provenances.

Survival, however, does not differ significantly from one site to the other, from which we can argue that conditions of Sierra del Eje are not completely adverse for the majority of the provenances.

The differences in survival as in growth appear between the blocks on the same site, reflect the importance of the microsite such as soil, vegetative competition, edaphic humidity, etc.

The provenance x site interaction, in growth as well as height, implies the necessity to select the most adequate provenance for each environment, and the possibility of determining which provenances with acceptable growth can be adapted to different environments (BIROT 1982).

The existing correlation between survival and growth in height helps in this selection, given that those provenances with less growth implies a lack of adaptation.

In Fig. 1 is represented the height reached by the best provenances in each site, where the interaction previously mentioned, can be seen, and the existence of origins which adapt themselves in an acceptable manner in the two different sites.

Provenances 1113, 1072, 1089 and 1115 are the most outstanding.

The lack of correlation between the latitude and longitude of the origin of seeds with growth and survival, make it impossible to define areas of superior behaviour; altitude (greater growth in provenances of lower altitude) being the only variable which correlates with the behaviour of the plants. This result ties in with other tests (KRIEK, 1974; O'DRISCOLL, 1978; CAMPBELL and FRANKLIN, 1981).

In Figs. 2 to 7 are shown, for each provenance, the values of the class of growth (1 to 7) ans survival (a, b and c); the following tendencies are noticeable:

- The most easterly origins (1014, 1048, 1065) can be excluded, given that their adaptation, in respect both to height as well as survival, is poor.
- The Canadian and Mexican provenances, independent of their geographic locality, present a low adaptation to the test sites.
- The origins from South-Washington and North-Oregon found between the coastal ranges and the Cascades and of low altitude are those which show the best behaviour in La Hermida (1091, 1077, 1113).
- This tendency is less clear in Sierra del Eje where, together with origins of the above cited area (1113, 1118, 1115, 1063, 1080, 1072, 1085) there are some coastal provenances from Washington, Oregon and California which are very promising (1064, 1089).

B I B L I O G R A P H Y

Birot, Y., 1982. Genetics of Douglas-Fir. Reun. Tecn. Principios de Introduccion de Especies. INIA-IUFRO. Lourizan. Pontevedra.

Campbell, R.K.; Franklin, J.F., 1981. A comparison of habitat type and elevation for seed zone classification of Douglas fir in western Oregon. For. Sci. Vol., 27, no 1, 49-61.

ICONA, 1982. Inventario Forestal Nacional. Provincias de La Coruna, Lugo, Orense y Pontevedra. Mo de Agricultura. Madrid.

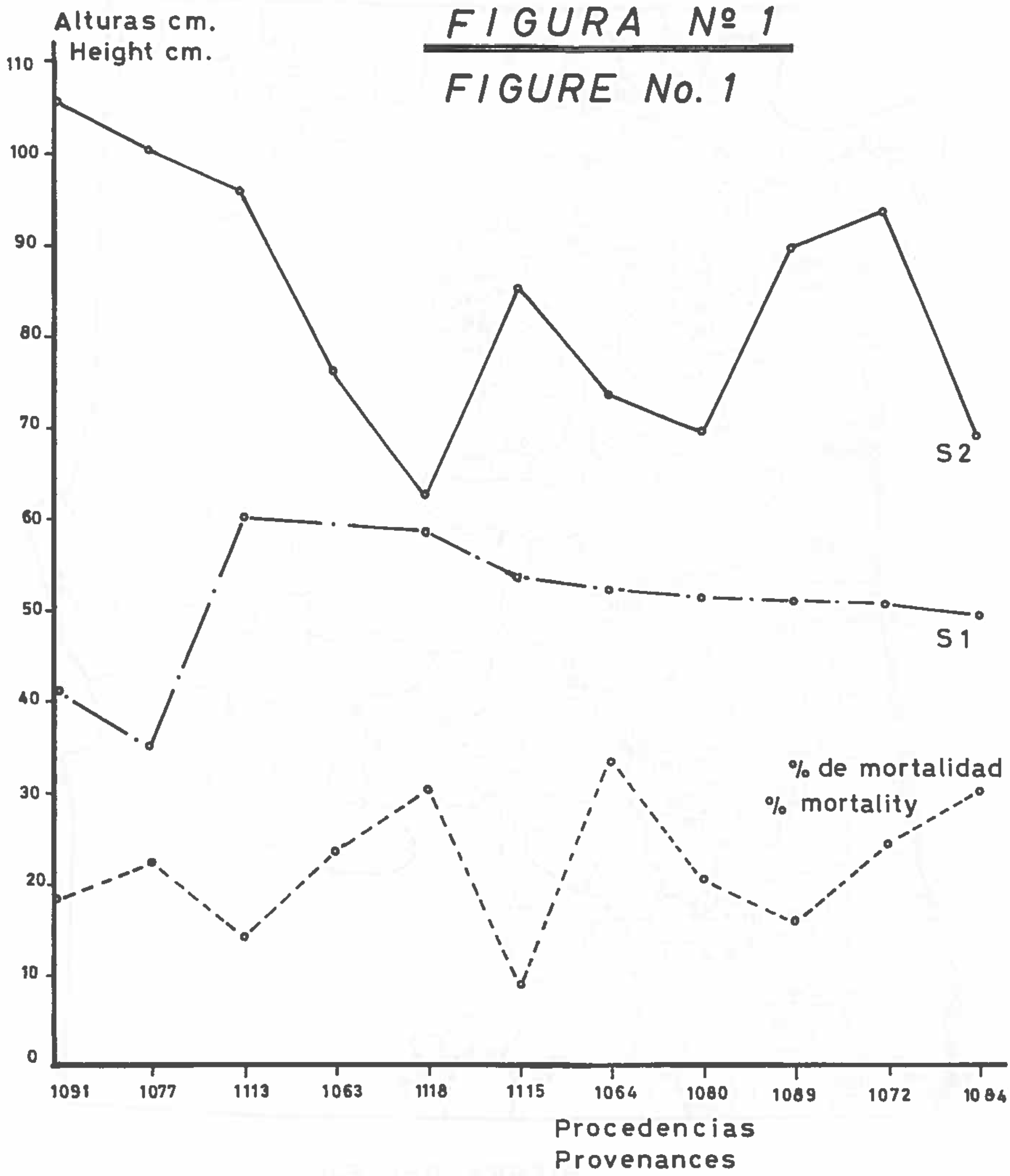
ICONA, 1975. Tecnicas de Forestacion, 1975. Mo de Agricultura. Madrid.

Kriek, W., 1974. Douglas fir IUFRO provenances in the Netherlands, 1966-67. Series Ned. Bosb. Tijdsch. 46 (1), 1-14

O'Driscoll, J., 1978. Six year phenological study of thirty-two IUFRO provenances of Douglas fir. Proc. of the IUFRO Joint Meeting of Working Parties. Vancouver, 265-297.

Toval, G., 1983. Utilizacion de la corteza de pinos como substrato en viveros, An. INIA. Serie Forestal, no 7. Madrid 67-81.

Toval, G.; Vega, G.; Puerto, G.; Fernandez, J., 1982. Ensayo de procedencias de *Pseudotsuga menziesii* en Galicia (Espana). Reun. Tecn. Princip. Introd. Especies. INIA-IUFRO. Lourizan. Pontevedra.



INTERACCION SITIO X PROCEDENCIAS. ALTURA MEDIA ALCANZADA POR LOS ORÍGENES MÁS PROMETEDORES Y PORCENTAJE DE MORTALIDAD.

SITE X PROVENANCE INTERACTION. MEAN HEIGHT REACHED BY THE MOST PROMISING ORIGENS AND PERCENTAGE OF MORTALITY

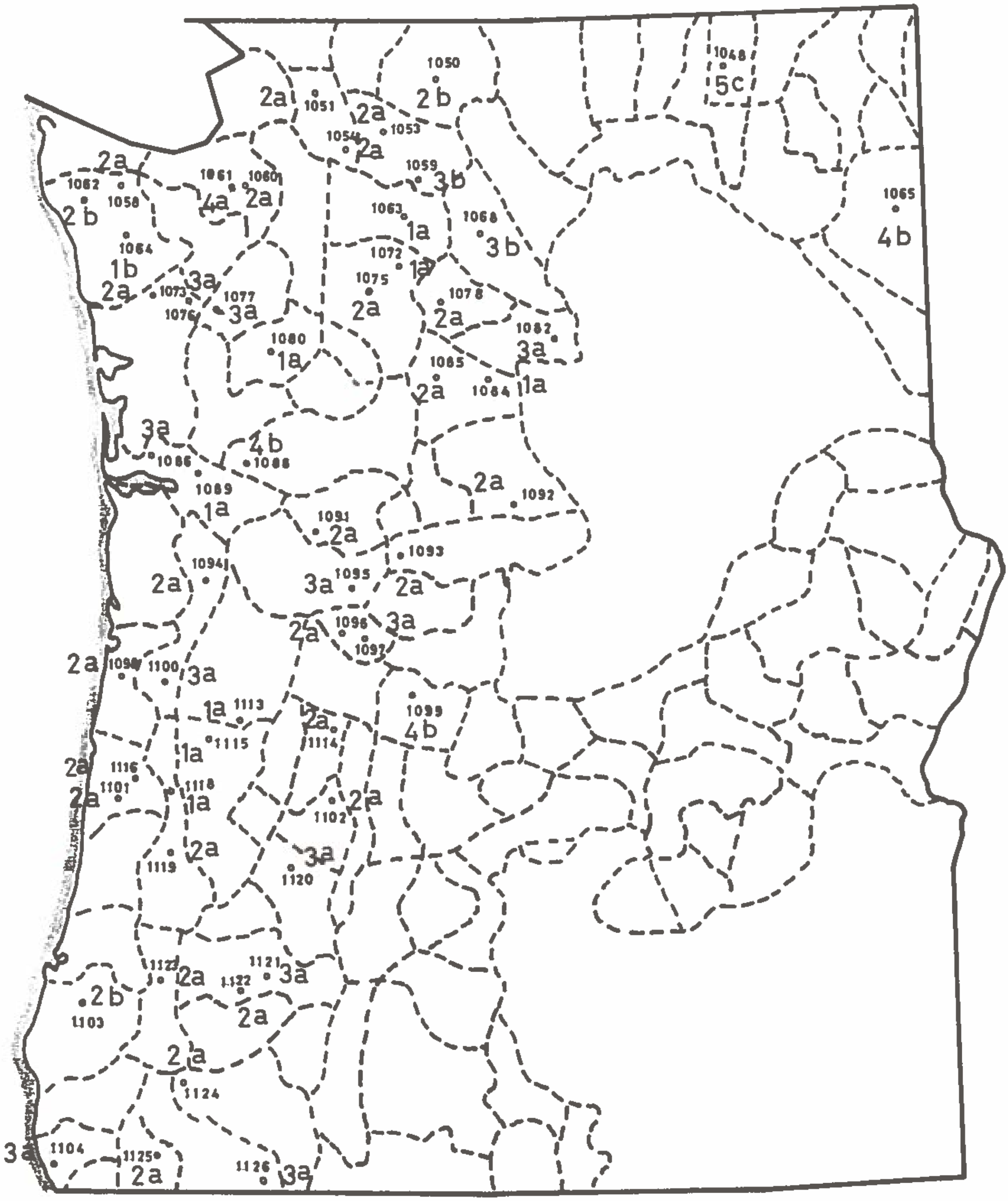


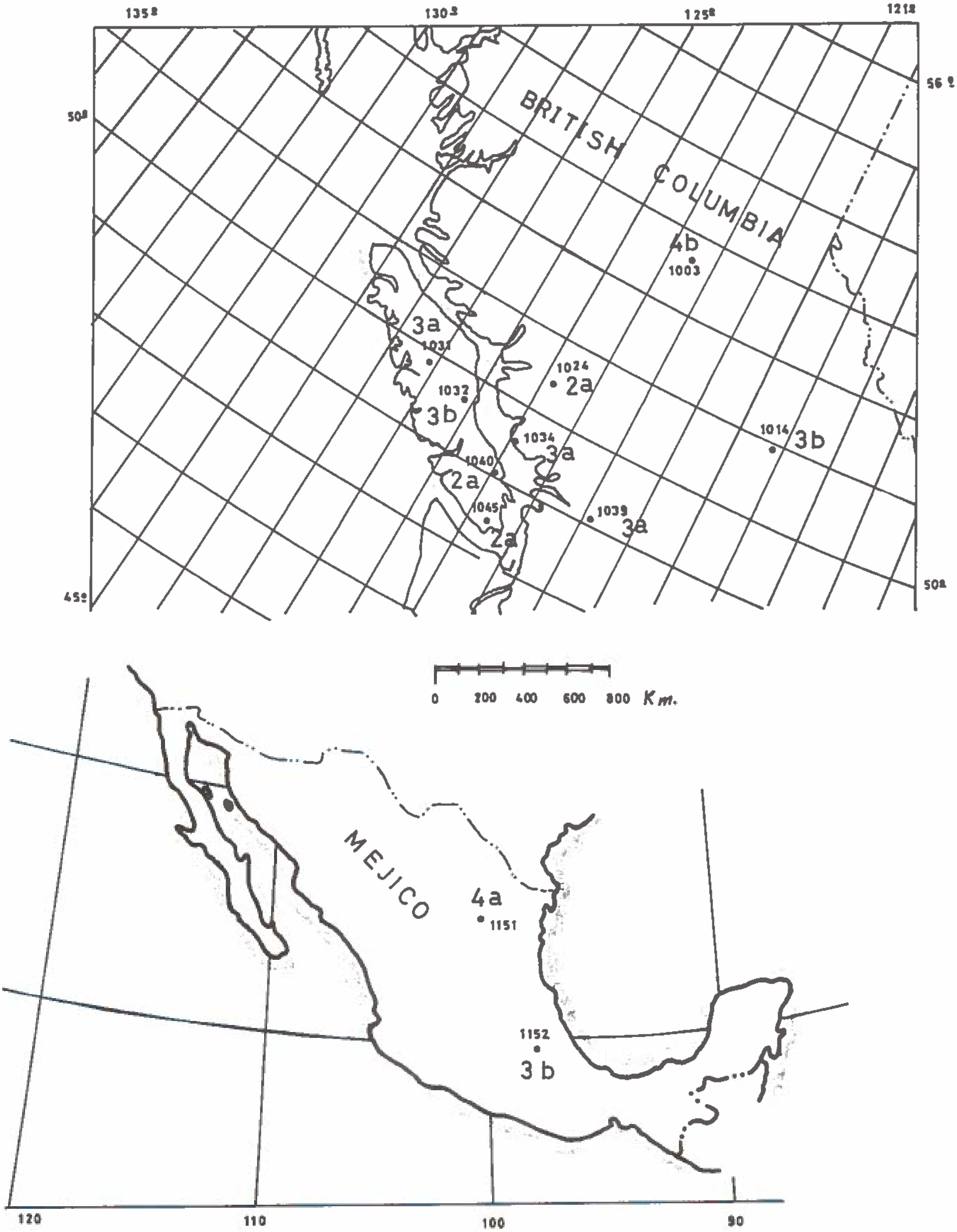
FIG. 2 CLASES DE ALTURA Y SUPERVIVENCIA DE LAS PROCEDENCIAS

CLASS OF HEIGHT AND SURVIVAL OF THE PROVENANCES

SIERRA DEL EJE

FIG. 3 CLASES DE ALTURA Y SUPERVIVENCIA DE LAS PROCEDENCIAS

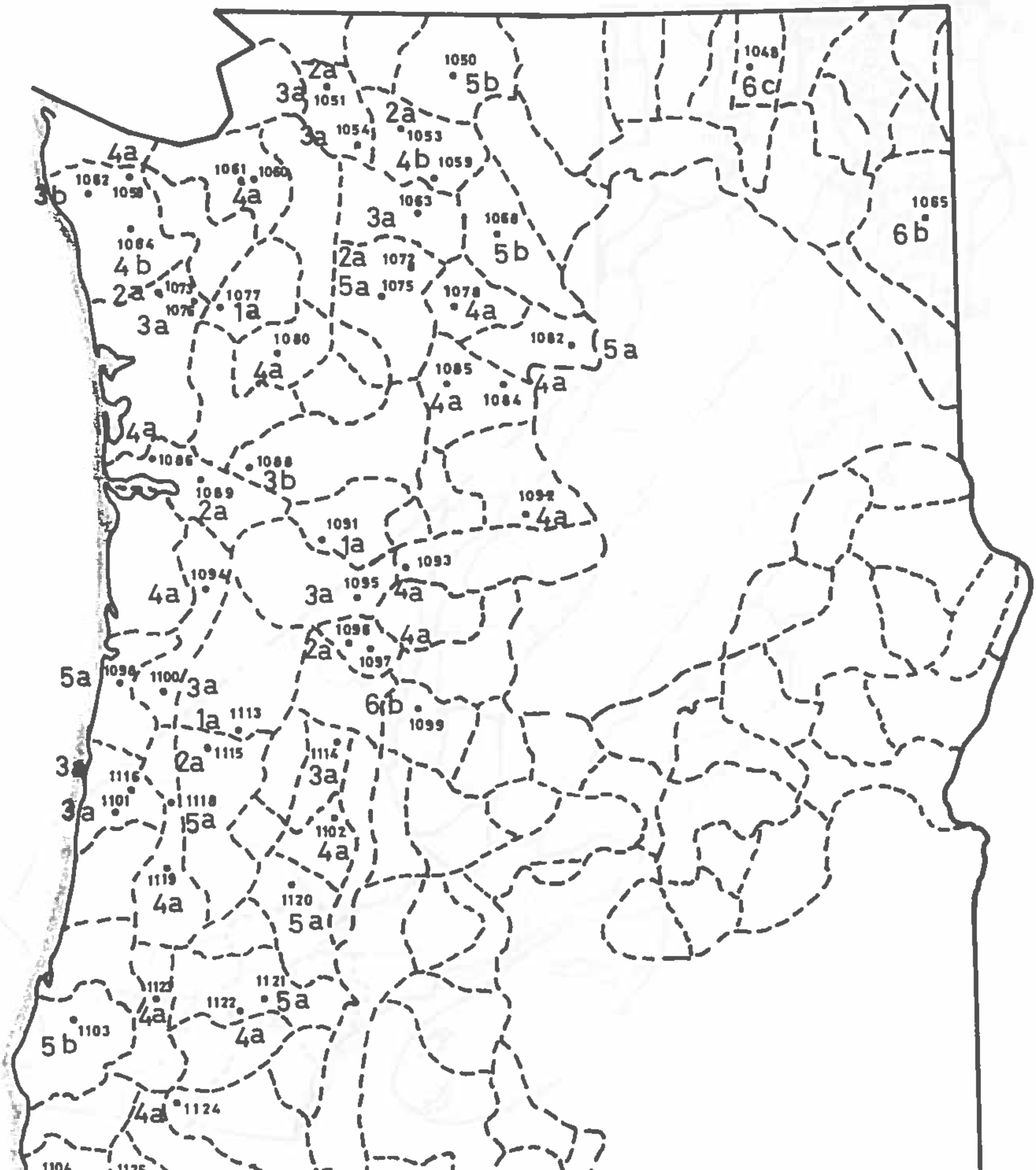
CLASSES OF HEIGHT AND SURVIVAL OF PROVENANCES.



SIERRA DEL EJE

FIG. 4 CLASES DE ALTURA Y SUPERVIVENCIA DE LAS PROCEDENCIAS

CLASSES OF HEIGHT AND SURVIVAL OF PROVENANCES



LA HERMIDA

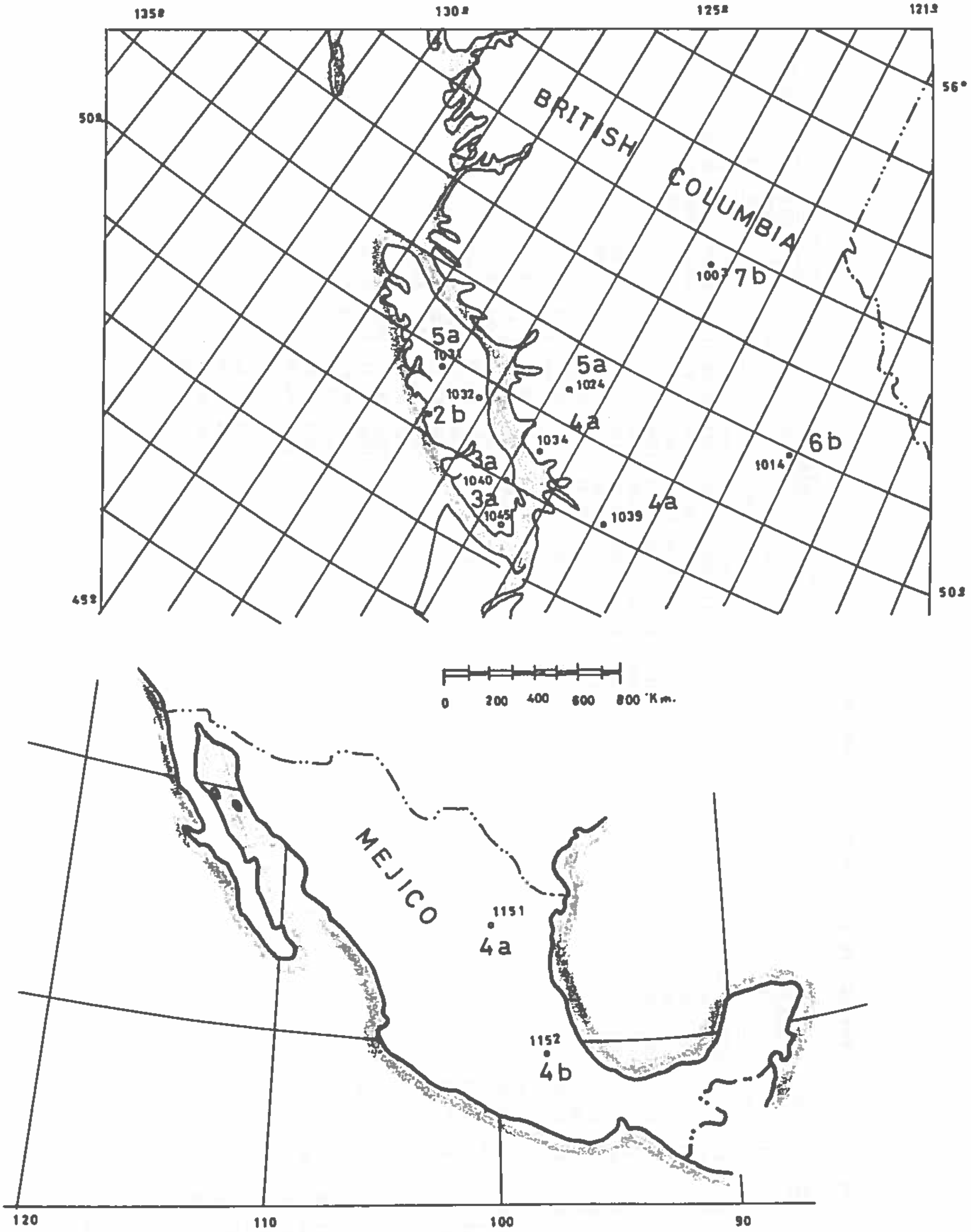
FIG. 5 CLASES DE ALTURA Y SUPERVIVENCIA DE LAS PROCEDENCIAS

CLASS OF HEIGHT AND SURVIVAL OF PROVENANCES

LA HERMIDA

FIG. 6 CLASES DE ALTURA Y SUPERVIVENCIA DE LAS PROCEDENCIAS

CLASSES OF HEIGHT AND SURVIVAL OF PROVENANCES



LA HERMIDA

FIG. 7 CLASES DE ALTURA Y SUPERVIVENCIA DE LAS PROCEDENCIAS
CLASSES OF HEIGHT AND SURVIVAL OF PROVENANCES

TABLE 5.- MEAN HEIGHTS OF THE PROVENANCES IN EACH TEST SITE. DUNCAN-BONNOR TEST 5%.

SIERRA DEL EJE (S_1)									
CLASS 1		CLASS 2		CLASS 3		CLASS 4		CLASS 5	
Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm
1113	60.03	1098	49.45	1128	37.89	1003	26.28	1048	13.76
1063	58.78	1149	49.41	1095	37.87	1099	26.24		
1118	58.61	1124	49.25	1059	37.51	1088	26.21		
1115	53.86	1058	49.14	1032	37.28	1151	26.15		
1064	53.13	1053	48.00	1136	36.67	1065	26.13		
1080	53.05	1101	46.56	1034	36.45	1137	26.12		
1089	52.25	1094	45.98	1097	36.29	1061	25.92		
1072	51.31	1131	45.85	1139	36.17	1127	25.61		
1084	49.92	1125	45.10	1140	36.17	1130	16.93		
		1073	44.83	1086	36.06				
		1062	44.15	1039	35.93				
		1024	44.00	1148	35.58				
		1092	43.65	1077	35.06				
		1060	43.60	1104	35.05				
		1050	45.57	1152	34.84				
		1114	42.84	1147	34.55				
		1102	42.26	1142	34.36				
		1040	41.97	1068	33.91				
		1122	41.96	1121	33.70				
		1085	41.93	1129	33.58				
		1103	41.67	1150	32.44				
		1093	41.33	1134	32.24				
		1135	41.16	1141	31.83				
		1145	40.95	1082	31.57				
		1116	40.95	1120	30.88				
		1075	40.92	1133	30.38				
		1091	40.88	1014	30.23				
		1119	40.87	1100	29.46				
		1045	40.60	1076	29.35				
		1138	40.39	1126	29.25				
		1143	40.24	1031	28.40				
		1123	39.74	1144	27.80				
		1078	39.11						
		1096	39.03						
		1051	38.46						
		1054	38.38						

LA HERMIDA (S_2)													
CLASS 1		CLASS 2		CLASS 3		CLASS 4		CLASS 5		CLASS 6		CLASS 7	
Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm	Pvnc nº	ht. cm
1091	106.08	1073	95.38	1040	84.19	1064	72.44	1031	60.88	1048	48.94	1003	33.64
1077	100.25	11051	93.15	1095	83.49	1143	72.28	1050	60.57	1099	48.40		
1113	97.13	1072	92.70	1045	83.46	1122	71.49	1145	59.65	1065	46.90		
		1032	92.61	1104	82.31	1097	71.47	1098	58.85	1130	45.72		
		1089	89.30	1136	80.78	1094	71.37	1135	57.88	1014	44.17		
		1096	88.61	1062	79.85	1140	71.15	1129	57.79	1133	40.78		
		1053	86.20	1088	78.95	1119	71.03	1118	57.19				
		1115	85.28	1101	78.64	1152	69.05	1142	56.92				
				1100	77.93	1123	68.96	1075	55.95				
				1063	76.41	1084	68.69	1114	55.53				
				1147	75.83	1080	68.22	1103	55.43				
				1114	74.74	1138	68.00	1127	54.83				
				1076	74.62	1085	67.71	1131	54.79				
				1116	74.14	1093	67.59	1141	54.28				
				1054	74.07	1102	67.59	1149	54.16				
						1059	67.21	1082	53.50				
						1086	67.19	1120	53.45				
						1125	66.98	1137	53.07				
						1124	66.85	1126	52.77				
						1039	66.75	1024	52.49				
						1060	66.71	1121	52.32				
						1128	66.61	1068	52.30				
						1061	64.28						
						1058	63.70						
						1092	63.58						
						1151	63.18						
						1150	66.13						
						1034	62.84						
						1144	62.59						
						1148	62.41						
						1078	62.29						
						1139	61.75						

RESULTS OF THE IUFRO DOUGLAS-FIR PROVENANCE EXPERIMENT IN THE FEDERAL REPUBLIC OF GERMANY AT AGE 14

by

J. Kleinschmit 1), J. Svolba 1), H. Weisgerber 2), R. Dimpflmeier 3), W. Ruetz 3), and Th. Widmaier 4)

Presented at the Meeting of the IUFRO Working Party S2.02.05
"Douglas-Fir Provenances"
Vienna, Austria, June 10 - 14, 1985

1) Lower Saxony Forest Research Institute, Department of Forest Tree Breeding, 3513 Staufenberg/Escherode

2) Hessian Forest Research Institute, Institute of Forest Tree Breeding, 3510 Hann.-München

3) Bavarian Federal Station of Forest Seed and Plant Breeding, 8221 Teisendorf

4) Forest Research Institute of Baden-Württemberg, Department of Botany and Forest Ecology, 7000 Stuttgart-Weilimdorf

SUMMARY

The growth and development of 123 Douglas fir provenances was followed up to an age of 14 years on 6 field experiments in the Federal Republic of Germany. Based on height growth and survival provenances from the Olympic Peninsula and from the North Washington Cascades performed best. There are some provenances from South Washington, North Oregon, Vancouver Island and the Interior of British Columbia which are of interest as well. In these regions the exact location of origin is however of extreme importance for the success of the plantation.

Low elevation provenances near Puget Sound have extremely high losses and poor performance. The same is true for provenances from near the Columbia river. The 4 German provenances included had high losses but good growth (118 % of overall mean). The comparison with earlier measurements shows, that height growth was quite stable after age 10. Bud set and length of vegetation period in the nursery are significantly correlated with height at age 14.

ZUSAMMENFASSUNG

Wachstum und Entwicklung von 123 Douglasienherkünften wurden bis zum Alter von 14 Jahren auf 6 Versuchsflächen in der Bundesrepublik Deutschland verfolgt.

Bei zusammengefaßter Betrachtung von Höhenwachstum und Überleben schneiden die Herkünfte von der Olympic Halbinsel und von den Kaskaden Nord-Washingtons am besten ab. Aber auch einige Herkünfte von Süd-Washington, Nord-Oregon und aus dem Interior von British Columbien zeigen befriedigende Leistungen. In diesen Gebieten ist jedoch die exakte Lokalisierung des Herkunftsortes von größter Bedeutung für den Anbauerfolg.

Tieflagenherkünfte nahe des Puget Sound zeigen extrem hohe Ausfälle und geringes Wachstum. Das gleiche gilt für Herkünfte aus dem Columbia-River Gebiet. Die 4 beteiligten deutschen Bestandesabsaaten zeigten hohe Ausfälle, aber gutes Wachstum (118% des Gesamtmittels).

Der Vergleich mit früheren Aufnahmen der gleichen Versuche zeigt, daß sich im Höhenwachstum ab Alter 10 kaum noch Rangänderungen ergeben. Vegetationsabschluß und Länge der Vegetationszeit in der Baumschule (Alter 2) zeigen gesicherte Korrelation mit der Höhe im Alter 14.

1. INTRODUCTION

Douglas fir is by far the most important introduced tree in the Federal Republic of Germany. It is expected to cover 10 - 20 % of the woodland area in Germany.

Douglas fir has been grown in Germany for more than 100 years. The productivity of Douglas fir is superior to all indigenous species and surpasses Norway spruce by about 30 %. Furthermore it is of interest due to its broad adaptability to a wide range of sites, its health, its silvicultural behaviour and the high wood quality.

There have been problems in the past due to choice of the wrong seed origin. Therefore provenance research has high priority with Douglas fir. This is especially true since the majority of the seed has to be imported in the near future.

The first provenance experiments were established by SCHWAPPACH (1910) and MÜNCH (1912); the next series was established by WIEDEMANN (1932/1933). The results of both sets of experiments have been published by MÜNCH (1923; 1928); BOISELLE (1953), KANZOW (1937), SCHOBER (1954; 1955) and others.

In the year 1954/1958 SCHOBER established a provenance experiment on 7 sites, the results were published by DONG (1970).

In 1958 SCHOBER initiated another experiment with 39 provenances, which was planted on 15 sites and the results of this experiment were published in 1983/1984 (SCHOBER et al.).

Since Douglas fir became more and more important additional provenance experiments have been established by different institutions, these trials have been summarized by KLEINSCHMIT (1978). The most important set was the IUFRO collection.

2. MATERIAL AND METHODS

The tree breeding institutes of the states Baden-Württemberg, Bavaria, Hessia and Lower Saxony planned a joint experiment with 111 IUFRO provenances and 9 additional provenances from British Columbia.

The experiment was sown in two stages:
In the first stage all provenances were sown out in 1970 with the aim to establish short term field experiments of about 20 years duration.

The second stage includes only about 1/3 of all provenances. These were selected at the end of the nursery phase according to growth, vigour and frost hardiness; they were sown in 1973. These experiments were established for a mean observation time of about 40 years. The results of nursery performance and 6 year field performance were published in Silvae Genetica (KLEINSCHMIT et al. 1974; 1979) where further details of the experiments are given. JESTAEDT (1979) published the results of all experiments of this collection in the state of Hessia. In this paper the results of 14 year field height growth and mortality on 6 test sites are presented.

The test sites are described in Table 1. The sites cover the Federal Republic of Germany quite well (Figure 1).

Elevation ranges from 22 m to 600 m above sea level, mean annual temperature from 6°C to 8,5°C and annual precipitation from 667 mm to 1.000 mm. The soil is mostly poor to medium in nutritional level, which is the soil type on which Douglas fir is to be planted in Germany. Due to losses in the nursery not all provenances could be included in all field experiments. The representation of the provenances in the different field tests can be seen from Table 2.

To get maximum information from this incomplete design, calculations of stability parameters, analysis of variance etc. have been calculated stepwise for different sets of provenances and different numbers of field tests. In addition comparisons with earlier measurements of the material have been carried out using regressions. To calculate overall means the 29 provenances, represented in all tests, have been used as a base for comparison.

Every provenance mean of the respective experiment has been expressed in % of this overall mean. In this way the linear differences between the experiments could be eliminated. The provenance overall mean is then calculated as the mean relative performance of the provenance on the different sites where it was represented. This value had to be corrected due to the deviation of the total mean from 100 %.

3. RESULTS

3.1 Survival

Survival was assessed in 1983 11 years after field tests were established. Overall survival calculated on the basis of experimental means was 70.5 % which corresponds quite well to the general silvicultural experience with Douglas fir in Germany. There were considerable differences between the different field tests, ranging from 87,2 % in Hilders (500 m elevation) to 54,5% in Neumünster (45 m elevation). There is however no clear trend in survival between the 6 field experiments, neither with elevation nor with region (Table 3).

Provenances differ considerably in survival within location as well as overall. Mean figures for provenances within one location differ as much as 6.3 % to 91.7 %, or between 12.5% and 91 % as a mean over all locations.

From the analysis of variance it becomes clear that provenances explain 22 %, planting sites 28 % and interaction location x provenance 50 % of the total variation in survival.

Provenances with few overall losses were Pend Oreille (Wash.), Clearwater (B.C.), Barriere (B.C.), Merrit (B.C.) and Tatla (B.C.). High losses were observed in Siskiyou (Calif.), Brookings (Oregon), Alder Lake (Wash.), Hebo (Oregon) and Willard (Wash.). The regional distribution of losses in the field experiments up to age 14 is given in Figure 2. From this figure it becomes apparent, that provenances with high losses originate from coastal British Columbia from Puget Sound and low elevation in southern Washington, from coastal Oregon and California. There is a clear trend for lower losses moving north and moving east.

As a mean over all provenances losses reach 36.3 %. This value is higher than the mean calculated on the base of the mean of the different field tests, due to the fact that the more sensitive provenances were not represented in all field experiments. The mean survival was highest for provenances from British Columbia (68,4 %) followed by
Washington (63.4 %)
Oregon (61.1 %)
California (12.5 %)

Within these states, there was an obvious differentation in survival due to specific provenance origin.

In British Columbia losses were higher in the coastal part. Vancouver Island provenances had losses of 43.8 % (n = 13); the Shuswap Lake region on the contrary only had losses of 23,2 % (n = 13). Provenances from Southern Vancouver Island were expecially poor in survival. In Washington the most obvious differentation was to be found between the provenances west and east of the ridge of Cascades up to the eastern border of the state. For the interior provenance the losses were only 29.3 % (n = 13), on the other hand the low elevation provenances near Puget Sound, down to Southern Washington and the Columbia River region, the losses reached more than 51 % (n = 11). The Olympic peninsula provenances and the provenances from the Washington Cascades were very similar with 36.8 % (n = 8) and 35.7 % (n = 16) mortality which was slightly better than the overall mean.

There is a clear trend to extreme mortality among provenances from Southern Oregon (75.5 %) and in the only provenance form California (87.5 %).

3.2 Height

Height growth at age 14 of the different field experiments ranges from 415 cm (Bremervörde) to 532 cm (Katzenelnbogen) with an overall mean of 448 cm. The mean values are given in Table 3.

Within the single field tests there is a considerable variation between provenance means (Table 2). The range of variation for the single experiments and the result of the analysis of variance are given in Table 4. In all experiments provenance variation is highly significant, explaining roughly 60 % of the total variation.

In addition 5 different sets of data have been analysed to estimate the provenance and location influence.

Table 5: Analyses of variance for different sets of provenances common for a certain number of field tests.

Number of location	Number of provenances	components of variance % provenances	locations	interaction
6	29	39.6***	28.9***	31.5
5	41	43.7***	24.4***	31.8
4	59	49.0***	24.0***	27.0
3	59	60.0***	1.9*	38.0
2	105	73.3***	1.4*	25.3

Depending on the number of provenances and locations included, the respective components of variance increase or decrease. Here again provenance influences are in all cases highly significant (0.1 % level) and explain between 40 % - 73 % of the total variation. The interaction components is more or less constant with about 30 % of the total variation.

Height growth does not follow a clinal trend in a similar way as was observed with survival. Only 28.6 % of total variation in 14 years height could be explained by latitude, elevation and longitude of location, longitude not contributing at all to explain height growth in the multiple regression. This corresponds with a multiple correlation coefficient of 0.53***. For 2 year height the respective values have been r = 0.86** and r2 = 0.74.

The simple linear correlations for the variables included are given in

Table 6:

	latitude	longitude	elevation	height 1983
latitude	1.00			
longitude	-0.09	1.00		
elevation	0.38**	-0.50**	1.00	
height 1983	-0.44**	0.28	-0.45**	1.00

Height growth is negatively correlated with latitude and elevation of the location of seed origin. However looking at Figure 3 it is obvious, that maximum height growth is formed in provenances from the state of Washington and it decreases as well to the north as to the south.

Looking to the relative height values of the states represented we observe the following sequence:

British Columbia	96.5 %
Washington	104.5 %
Oregon	99.0 %
California	50.7 %

There is however considerable variation between the different regions of the states in height growth as well: In British Columbia the Shuswap Lake region has a mean performance of 96.6 % with single provenance means of 86 % (Pillar Lake) to 110 % (Eagle Bay). Vancouver Island has a mean performance of 103 % with single provenance means between 86 % (Franklin River) and 119 % (Duncan).

Even more pronounced are the growth differences between the regions in Washington. The interior provenances reach only 90 % of the overall mean, provenances west of the Cascade ridge 115 % excluding those south of Puget Sound who reach only 80 %.

The best overall provenances at age 14 have been the following ones, all from the state of Washington:

1050	Skagit, Marblemount	140 %
1059	Snohomish, Perry Creek	135 %
1064	Jefferson, Hoh River	133 %
1072	King, Chester Morse Lake	125 %
1076	Mason, Matlock	125 %
1073	Grays Harbor, Humptulips	125 %
1090	Cowlitz, Cougar	122 %

From Figure 3 it is obvious, that the Olympic Peninsula and the Northern Cascades in Washington are those regions from which the most vigorous provenances originate.

Central and northern Oregon have a mean performance of 103 %, southern Oregon only 80 %. The different stability parameters calculated show, that most of the provenances west of the Cascade ridge are quite stable. Matlock, Humptulips and Shelton rank best, with northern Oregon provenances ranking quite well also.

The interior Washington provenances are most variable in performance. The most vigorous interior British Columbia provenances are quite stable (Blind Bay, Eagle Bay and Salmon arm). The provenances with very variable performance on different sites like Ferry, Republic (Wash.); Mc Leod Lake (B.C.), Babine Lake (B.C.); Yakima, Rimrock (Wash.); Okanogan Twisp (Wash.) and Williams Lake (B.C.) have very poor overall growth also.

3.3 Correlation of characters

It is of interest to observe how far the earlier measurements and observations fit in with the most recent measurements.

In the nursery we observed flushing, bud set, length of growing season and height at age 3. Additional height measurements of the field tests were taken at age 6 and age 10.

The correlation-matrix is given in Table 7. From this table it is apparent that bud set and length of growing season are closely correlated and that these phenological characteristics influence height growth considerably. This is not true with flushing.

All height measurements show significant correlation, however between height at age 3 (1972) and at age 14 (1983) considerable rank changes occurred. Only 37 % of the variation in height at age 14 can be explained from the height variation at age 3. Between age 10 and age 14 very limited rank changes were observed. This is in good agreement with results found in Norway spruce, that provenance height can be judged quite well at age 10.

It is of interest to note, that height at age 14 is more closely correlated with bud set than with length of vegetation period.

Losses show no significant correlation with any of the other characters.

4. DISCUSSION

The result of the IUFRO Douglas fir provenance experiment after 14 years growth confirm the general results of earlier experiments in Germany. They allow however a more detailed interpretation.

The provenance experiments of SCHOBER gave basically the same information at age 21. The best provenance regions were the Olympic peninsula and Washington Cascades also, however we have gained additional information from the IUFRO experiment:

1. Low elevation provenances from the Puget Sound area and from near the Columbia river have high losses and comparatively poor growth.

2. Only the south-eastern Vancouver Island provenances are poor in survival and growth.
   There are some regions which have provenances with good survival and growth (e.g. 1041 Caycuse, 1036 Alberni, 1026 Stella Lake).

3. In the Shuswap Lake region survival is excellent but only few provenances have relatively good growth (e.g. Blind Bay, Eagle Bay and Salmon Arm).

4. Survival and height growth is very variable in South Washington and North Oregon from one provenance to the other. Some excellent provenances can be found in this region also (e.g. 1090 Cowlitz Cougar. 1097 Clackamas Cherryville, 1099 Wasco Pine Grove).

5. Provenances from east of the ridge of the Cascades in Washington have good survival but poor growth.

6. Coastal British Columbia provenances were poor in survival and had only poor to average growth.

7. South Oregon and California provenances are not of interest for the Federal Republic of Germany.

LITERATURE

BOISELLE, R. (1954): Die Snoqualmie Douglasie, die Douglasie der Zukunft. Allgemeine Forst- und Jagdzeitung 125, pp. 61 - 69.

DONG, Ph. H. (1970): Wuchsleistung und biologisch-waldbauliches Verhalten der Douglasie in Kulturversuchen der Niedersächsischen Forstlichen Versuchsanstalt. Dissertation der Forstlichen Fakultät der Universität Göttingen. 213 p.

JESTAEDT, M. (1979): Untersuchungen über die Jugendentwicklung von Douglasienprovenienzen in Hessen und mögliche züchterische Folgerungen. Dissertation an der Forstwissenschaftlichen Fakultät der Ludwig-Maximilian Universität in München. 142 p.

KANZOW, H. (1937): Die Douglasie. Zeitschrift für Forst- und Jagdwesen. Pp. 65, 113, 241.

KLEINSCHMIT, J., J. RACZ; H. WEISGERBER; W. DIETZE; H. DIETRICH und R. DIMPFLMEIER (1974): Ergebnisse aus dem internationalen Douglasien-Herkunftsversuch von 1970 in der Bundesrepublik Deutschland. Silvae Genetica 23, p. 167 - 176.

KLEINSCHMIT, J. (1978): Douglas fir in Germany. Proceedings of the IUFRO joint meeting, Vancouver, Canada, pp. 317 - 333.

KLEINSCHMIT, J.; J. SVOLBA; H. WEISGERBER, M. JESTAEDT; R. DIMPLMEIER; W. RUETZ und H. DIETRICH (1979): Ergebnisse aus dem internationalen Douglasien-Herkunftsversuch von 1970 in der Bundesrepublik Deutschland. Silvae Genetica 28, p. 226 - 244.

MÜNCH, E. (1923): Anbauversuche mit Douglasfichten verschiedener Herkunft und anderen Nadelholzarten. Mitteilungen der Deutschen Dendrologischen Gesellschaft, p. 61.

MÜNCH, E. (1923): Klimarassen der Douglasie. Centralblatt für das gesamte Forstwesen, p. 254.

SCHOBER, R. (1954): Douglasien-Provenienzversuche I. Allgemeine Forst- und Jagdzeitung 125, p. 160.

SCHOBER, R. und H. MEYER (1955): Douglasien Provenienzversuche II. Allgemeine Forst- und Jagdzeitung 126, pp. 221 - 243.

SCHOBER, R.; J. KLEINSCHMIT und J. SVOLBA (1983, 1984): Ergebnisse des Douglasien-Provenienzversuchs von 1958 in Nordwestdeutschland. Teil I und Teil II. Allgemeine Forst- und Jagdzeitung, 154 pp. 209 - 236 und 155 pp. 53 - 80.

Table 1: Description of Test Sites

Forest District	Elevation above sea level	Temperature annual	Temperature May - Sept.	Precipitation annual	Precipitation May - Sept.	Geolog. Substrate	Soil type
Bremervörde	22 m	8.o ^{o}C	14.3 ^{o}C	752 mm	356 mm	loamy sand mean silicate content	podsolic brown soil
Neumünster	45 m	8.1 ^{o}C	14.4 ^{o}C	75o mm	363 mm	Sander-sand of Saale glaciation	podsolic sand in 1,2m glacier loam
Katzenelnbogen	34o m	8.5 ^{o}C	13.9 ^{o}C	667 mm	311 mm	River gravel deposits	base poor brown soil
Frankenberg	6oo m	6.o ^{o}C	12.5 ^{o}C	1.ooo mm	4oo mm	Kulm Lydites (shist)	brown soil
Hilders	5oo m	6.4 ^{o}C	13.1 ^{o}C	8oo mm	38o mm	Red sand stone with loam	podsolic brown soil
Heigenbrücken	3oo m	7.5 ^{o}C	14.2 ^{o}C	1.ooo mm	39o mm	Red sand stone	base poor brown soil

Table 2

DOUGLAS-FIR IUFRO PROVENANCE EXPERIMENT

DOUGLASIEN - PROVENIENZVERSUCH 1.STUFE

*** HÖHE 1983 ***

Height age 14 dm

!!! = PROVENANCE NR.

!!!! = IUFRO-NR.

!----NAME---------!

N A M E O F F I E L D E X P E R I M E N T

HÖHE 1983 IN DM

!!!	!!!!	NAME	HEIGENBRÜCKEN	BREMERVÖRDE	KATZENELNBOGEN	NEUMÜNSTER	HILDERS	FRANKENBERG
1	1001	BC-STONER	39.63	42.31	50.55	46.32	40.00	41.21
2	1003	BC-ALEXANDRIA	43.87	42.75	49.76	51.94	48.00	39.68
3	1004	BC-STUIE	39.50	41.94				
4	1005	BC-WILLIAMS LAKE	31.11	37.97	43.46	42.59	34.21	34.90
5	1006	BC-TATLA	35.43	39.59	49.00	43.71	51.67	41.92
6	1007	BC-CLEARWATER	40.54	36.09	58.51	50.43	52.34	47.70
7	1008	BC-GOLDEN	37.58	36.44	49.45	41.92	33.85	37.89
8	1010	BC-BARRIERE	39.73	42.32	51.31	48.00	44.60	39.93
9	1013	BC-REVELSTOKE	39.87	43.46	53.34	42.56	35.52	40.91
10	1014	BC-EAGLE BAY	51.61	40.62	58.14	44.64	50.34	
11	1015	BC-BLIND BAY	46.65	43.15	60.44	45.71	54.37	
12	1016	BC-WHITE LAKE	40.06	42.38	54.84	50.31	48.05	45.00
13	1017	BC-SQUILAX	40.97	46.90	60.51	41.04	47.74	44.11
14	1018	BC-SALMON ARM	41.24	51.17	58.35	50.60	43.88	38.09
15	1019	BC-MONTE CREEK	39.10	36.41	44.95	43.96	47.82	47.41
16	1020	BC-PILLAR LAKE	39.30	41.30	42.96	42.73	33.44	28.75
17	1021	BC-D'ARCY	42.31	48.59			41.53	
18	1022	BC-FLY HILL	39.31	40.75	54.72	40.83	31.55	37.79
19	1023	BC-JEUNE LANDING	41.97	48.21	43.62	42.80		
20	1024	BC-OWL CREEK	39.49	37.77	42.25	40.29		
21	1025	BC-NIMKISH	44.73	41.71				
22	1026	BC-STELLA LAKE	50.34	45.06	57.11	51.43		46.52
23	1027	BC-ALTA	43.39	37.58				39.39
24	1028	BC-MERRITT	33.28	33.42	51.56	43.85	50.02	43.96
25	1030	BC-SQUAMISH	33.75	37.67			36.29	44.03
27	1032	BC-COURTENAY	40.35	51.37	54.40	47.69	43.96	
28	1033	BC-FORBIDDEN PLA	52.39	37.33	48.27	42.54		
29	1034	BC-SECHELT	26.33	48.32	61.61	43.58	44.27	43.25
30	1035	BC-NELSON	41.57	30.87	55.37	40.29	47.52	
31	1036	BC-ALBERNI	44.31	45.87			44.63	
32	1037	BC-FRANKLIN RIVE		38.47			37.22	
33	1038	BC-CHILLIWACK	43.57	48.84			50.29	
34	1040	BC-CASSIDY	37.27	27.95			38.96	
35	1041	BC-CAYCUSE	45.51	40.37	61.31	46.94	47.80	
36	1042	BC-DUNCAN	39.71	29.89	57.93			
37	1043	BC-SAN JUAN	48.09	45.19	60.89	55.00		42.40
38	1045	BC-SOOKE	40.14	40.26	64.61	43.00		
39	1046	W-WHATCOM DIABLO	38.43	48.82	47.90	33.74		33.89
40	1047	W-WHATCOM CONCRE	45.36	40.93	58.84		45.00	
41	1048	W-FERRY REPUBLIC	22.70	27.52	35.66	33.61	35.12	33.60
42	1049	W-SKAGIT BACON P	48.09	55.31	58.66	44.93		44.78
43	1050	W-SKAGIT MARBLE	53.97	59.91				
44	1051	W-SKAGIT SEDRO W	40.55	42.52	58.39	60.47		
45	1052	W-OKANOGAN TWISP	29.76	30.24	43.67	36.76	42.60	38.37
46	1054	W-SNOHOMISH ARLI	53.65	46.43				47.92
47	1055	W-PEND OREILLE N	38.60	41.36	46.31	47.97	36.86	41.89
48	1056	W-SNOHOMISH SLOA	42.65	37.83	48.71	24.00	46.55	
49	1058	W-CLALLAM LAKE C	41.26	61.24			45.69	
50	1059	W-SNOHOMISH PERR	53.90	56.48				
51	1060	W-CLALLAM SEQUIM	42.15	35.62	52.07	26.62		

52	1061	W-CLALLAM LOWELL	44.03	52.00	57.87	45.39	42.55	
53	1063	W-SNOHOMISH GOLD	58.33	55.77	63.45	37.73		45.48
54	1064	W-JEFFERSON HOH	59.97	54.03	67.95	57.54		
55	1065	W-SPOKANE SPOKAN	39.18	45.50	47.59	48.60	31.95	36.38
56	1066	W-KING SCENIC	40.62	40.90				
57	1067	W-KING SKYKOMISH	48.69	36.11			41.77	
58	1068	W-CHELAN CHIWAUK	36.22	42.93	52.35	47.25		
59	1070	W-KING DENNY CRE	57.34	49.84	59.47	51.46		47.83
60	1071	W-KITTITAS KEECH	48.50	44.92				38.52
61	1072	W-KING CHESTER M	53.23	55.52	59.39	56.67		
62	1073	W-GRAYS HARBOR H	52.47	61.14	66.77	51.90	54.85	47.43
63	1074	W-MASON MATLOCK	50.97	46.24	59.32	58.42	52.52	
64	1075	W-KING ENUMCLAW	54.93	51.73	59.50	39.67		46.44
65	1076	W-MASON MATLOCK	58.22	64.26	55.69	50.27	50.26	
66	1077	W-MASON SHELTON	57.57	41.82	56.45	51.00	51.75	45.30
67	1078	W-KITTITAS CLE E	42.07	44.21				40.33
68	1079	W-PIERCE PARKWAY	44.85	41.55			32.90	42.62
69	1080	W-THURSTON YELM	48.10	34.40			35.13	
70	1081	W-PIERCE ALDER L		28.90				
71	1082	W-YAKIMA RIMROCK	37.87	30.81			33.10	
72	1083	W-LEWIS PACKWOOD	47.65	19.83				41.56
73	1084	W-LEWIS PACKWOOD	52.85	31.00				41.44
74	1085	W-LEWIS RANDLE	40.00					41.16
76	1088	W-COWLITZ CASTLE	51.37	48.32			33.30	42.97
77	1089	W-WAHKIAKUM CATH		43.11	58.57	54.14		41.94
78	1090	W-COWLITZ COUGAR	52.75	52.12				47.13
79	1092	W-KLICKITAT GLEN	44.13	36.06				37.84
80	1093	W-SKAMANIA WILLA	42.40	35.87				
81	1094	O-COLUMBIA VERNO	46.58	42.82				45.25
82	1095	W-SKAMANIA PRIND	41.67	43.63				42.72
83	1097	O-CLACKAMAS CHER	57.30	50.26			52.49	40.75
84	1098	O-TILLAMOOK HEBO	36.00	34.27				
85	1099	O-WASCO PINE GRO	43.46	50.52			50.04	
86	1100	O-YAMHILL GRAND	49.82	50.94			44.24	43.65
87	1101	O-LINCOLN WALDPO	57.20	34.22				43.81
88	1102	O-LINN UPPER SOD	42.52	49.95				42.81
89	1103	O-COOS COQUILLE	42.58	30.87				
90	1104	O-CURRY BROOKING	37.00	23.64				
91	1105	BC-MC LEOD LAKE	33.47	30.97			34.08	
92	1106	BC-FORT ST. JAME	38.28	33.79	37.30	39.55	41.12	
93	1107	BC-BABINE LAKE	30.70	30.72			38.62	
94	1108	BC-WANSA LAKE	38.83	35.17				
95	1109	BC-DUNSTER	40.31	29.86	50.56	41.90	40.45	
96	1110	BC-CLEMINA	43.92	35.60	48.95	46.50	41.43	41.09
97	1111	BC-HORSEFLY	42.11	42.32	56.22	47.78	44.59	44.29
98	1112	BC-CLINTON	41.02	34.80			38.28	39.24
100	1114	O-MARION DETROIT		37.38				
101	1115	O-BENTON CORVALL	37.44	35.57				
103	1117	O-MARION MARION	43.84	38.37				
111	1134	CA-SISKIYOU SAWY		22.17				
113		BRD-EIFEL - STAN	53.27	41.21				
114		BC-PINETAN	35.61	31.21	46.31	40.12	46.31	43.57
115		BC-TURTLE VALLEY	40.42	37.49	47.66	50.67	48.41	42.70
116		BRD-NIEDERSACHSE	50.91	39.75				
117		BC-SALMON RIVER	38.19	34.63	42.71	40.64	48.31	43.22
118		BRD-PFALZER WALD	44.47	60.39				
119		BC-HEFFLEY LAKE	40.60	34.13	46.77	43.61	38.41	40.91
120		BC-CAMPBELL RIVE	47.23	48.97	57.35	48.00		
121		BC-PILLAR LAKE	38.30	30.07	41.59	42.26	40.90	42.55
122		BRD-STANDARD SOD	47.75	47.97	70.14	50.13		
123		ORIGIN CEDAR		49.87				
124		BC-BEAR CREEK	45.23	30.42	39.76	42.87	46.11	
125		VANCOUVER ISLAND		49.50				

Table 3: Mean performance of the 6 field experiments.

Forest District	Mean survival	Mean overall height age 14
Bremervörde	6o.5 %	415 cm
Neumünster	54.5 %	453 cm
Katzenelnbogen	77.5 %	532 cm
Frankenberg	84.2 %	419 cm
Hilders	87.2 %	431 cm
Heigenbrücken	59.4 %	435 cm

Table 4: Range of variation and variance components for height at age 14.

Forest District	Range of variation of provenance mean	components of variance %			
		provenances	repetitions	blocks	residual
Bremervörde	2o3 - 64o cm	58.5	2.9	11.4	27.2
Neumünster	238 - 599 cm	54.1	o.6	8.3	37.o
Katzenelnbogen	362 - 726 cm	63.o	o.6	12.8	23.6
Frankenberg	289 - 478 cm	53.6	3.6	8.2	34.6
Hilders	246 - 56o cm	62.1	4.7	8.8	24.3
Heigenbrücken	229 - 6o8 cm	55.8	8.6	7.3	28.3

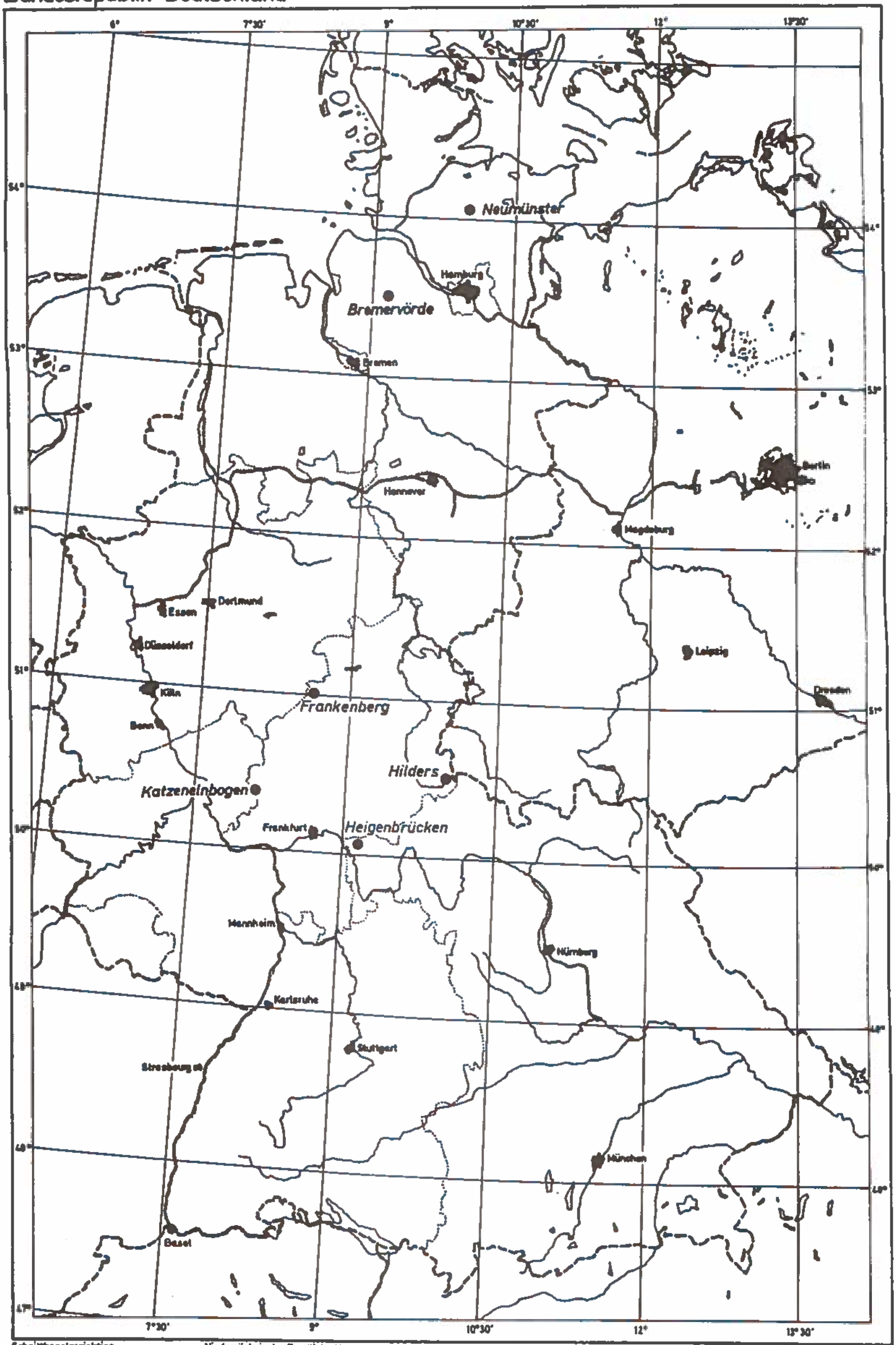
Table 7

CORRELATIONMATRIX

		1	2	3	4	5	6	7	8
1	bud burst	1.oo							
2	bud set	-.13	1.oo						
3	period of growth	-.63**	.85**	1.oo					
4	height age 3	.o1	.52**	.41*	1.oo				
5	height age 6	.o6	.59**	.42*	.81**	1.oo			
6	height age 1o	-.o1	.61**	.49**	.65**	.85**	1.oo		
7	height age 14	-.o1	.54**	.43**	.61**	.8o**	.97**	1.oo	
8	mortality up to age 14	.1o	.o2	-.o4	.13	.14	-.1o	-.13	1.oo

Figure 1

Bundesrepublik Deutschland



Schnittkegelprojektion

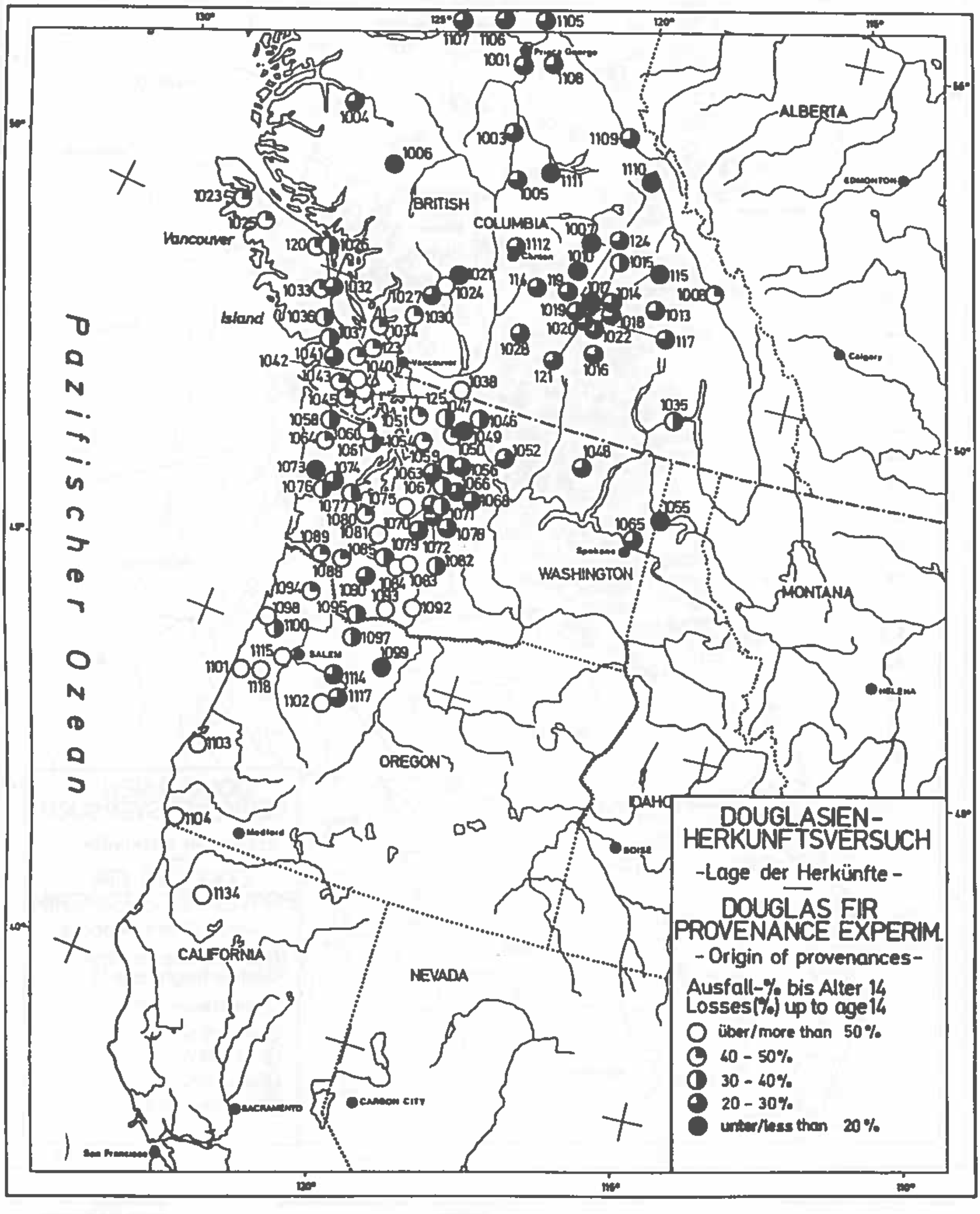
Niedersächsische Forstliche Versuchsanstalt - Abt. Forstpflanzenzüchtung Escherode

0 20 40 60 80 100 Kilometer 200

Quellenangabe: Knaurs Großer Weltatlas John Bartholomew & Son Ltd, Edinburgh Tafel 62, Maßstab 1:2500000; 1971

Figure 2

Nordamerikanische Westküste



Lamberts Konforme Kegelprojektion

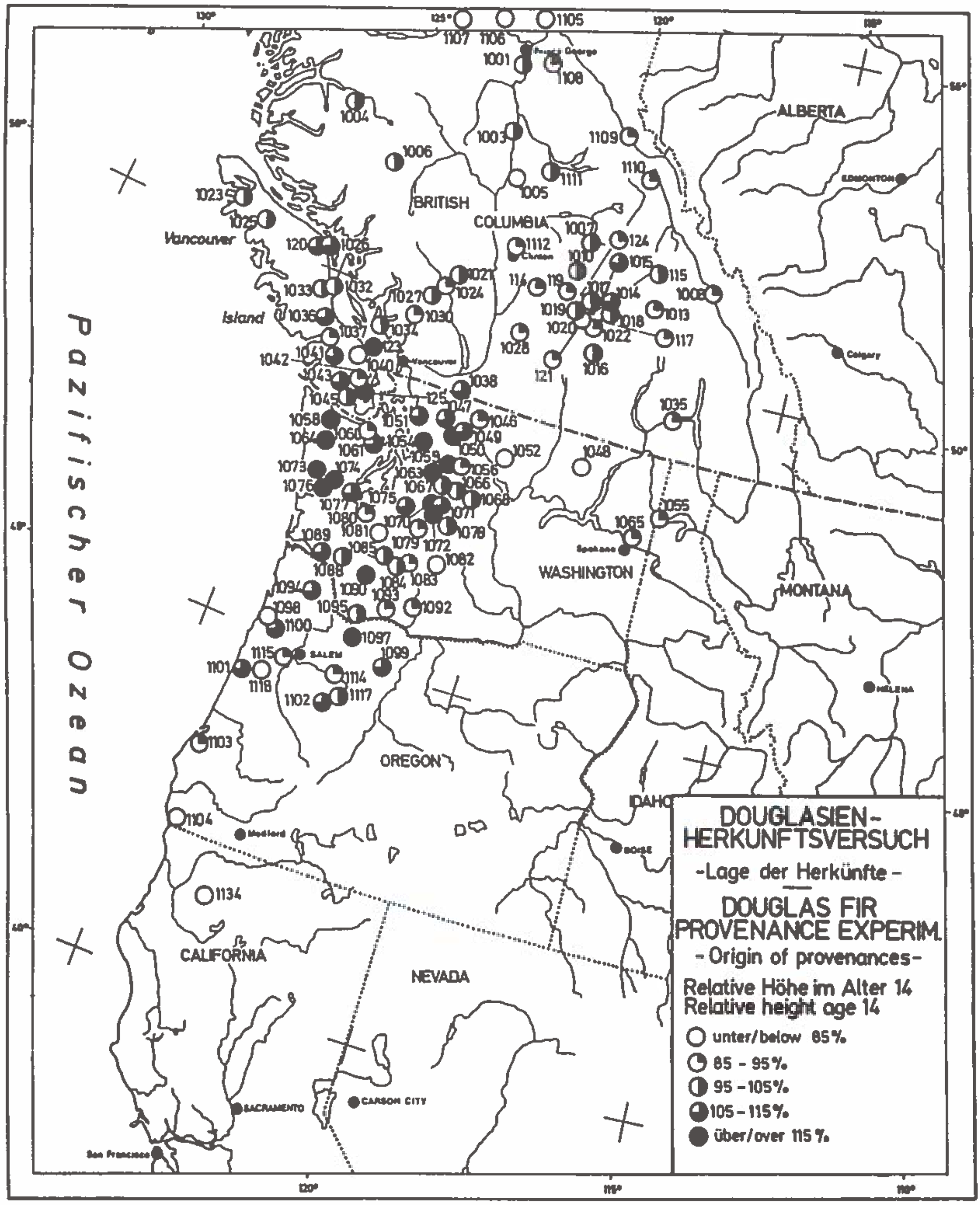
Niedersächsische Forstliche Versuchsanstalt - Abt. Forstpflanzenzüchtung
Escherode
Kilometer 50 0 50 100 150
Maßstab 1 : 6 000 000

Quellenangabe: Rand Mc Nally
Imperial Map of Canada
Maßstab 1 : 6 000 000
C 5282000 - 21 - 5 - 6 - 7 - 8

R

Figure 3

Nordamerikanische Westküste



Lamberts Konforme Kegelprojektion

Niedersächsische Forstliche Versuchsanstalt - Abt. Forstpflanzenzüchtung
Escherode

Kilometer 50 0 50 100 150

Maßstab 1 : 6 000 000

Quellenangabe: Rand Mc Nally
Imperial Map of Canada
Maßstab 1 : 6 000 000
C 5202000 - 21 - 5 - 6 - 7 - 8

COMPARATIVE RESEARCH WITH GERMAN AND AMERICAN DOUGLAS FIR PROVENANCES

H.M. RAU

Hessian Forest Research Station, Institute of Forest Tree Breeding, Hann.Münden, Federal Republic of Germany (FRG)

ABSTRACT

Douglas-fir has become the most important foreign tree species in the Federal Republic of Germany. Silvicultural success depends on the decision for the right provenance. According to the results of provenance research the interest in Central Europe concentrates on provenances of a quite restricted area of the natural range. The investigations presented here, shall render us information, whether it will be possible to meet the future demand of Douglas-fir seeds from German stands without too great disadvantages.

Douglas-fir provenances from the Odenwald, Southern Vogelsberg and the Eifel investigated in two series of Hessian provenance trials (age 23 and 13) give us reason to hope that they grow similar or even better than the best of the American and Canadian provenances.

To secure the future demand of Douglas-fir seeds, it is therefore recommended to admit these stands, if not yet done, for seed collection and to utilize in future even small crops. In addition further German stands should be investigated in new provenance tests.

UNTERSUCHUNGEN ZUM VERGLEICH DEUTSCHER UND AMERIKANISCHER DOUGLASIENHERKÜNFTE

H.-M. RAU

Hessische Forstliche Versuchsanstalt, Institut für Forstpflanzenzüchtung, Hann. Münden, Bundesrepublik Deutschland

ZUSAMMENFASSUNG

Die Douglasie hat sich zur wichtigsten Fremdbaumart in der Bundesrepublik Deutschland entwickelt. Über den Anbauerfolg entscheidet die Wahl der richtigen Herkunft. Aufgrund der Ergebnisse der Herkunftsforschung konzentriert sich das Interesse in Mitteleuropa auf Herkünfte aus ganz bestimmten Regionen des Ursprungsgebietes. Die vorgestellten Untersuchungen sollen die Frage klären helfen, ob in Zukunft zur Deckung des Saatgutbedarfes auch deutsche Bestände stärker herangezogen werden können, ohne daß dadurch zu große Nachteile entstehen. In 2 hessischen Versuchsreihen (Alter 23 bzw. 13 Jahre) untersuchte Douglasienherkünfte unter anderem aus dem Odenwald, dem südlichen Vogelsberg und der Eifel geben Anlaß zur Hoffnung, daß sie den bestwüchsigen Provenienzen aus Kanada und USA nicht nachstehen oder sie sogar übertreffen. Zur Sicherung des künftigen Saatgutbedarfes bei Douglasie wird unter anderem empfohlen, diese Bestände, soweit noch nicht geschehen, zur Beerntung zuzulassen und künftig auch bei geringen Masten zu beernten. Außerdem sollten weitere deutsche Bestände in Prüfungen einbezogen werden.

DIE HEUTIGE BEDEUTUNG DER DOUGLASIE

Mehr als 100 Jahre sind vergangen, seitdem die ersten Douglasien in Deutschland angebaut wurden. Inzwischen kann die Douglasie für den Bereich der Bundesrepublik als wichtigste Fremdbaumart angesehen werden. Sie wird wegen ihrer Wüchsigkeit bei gleichzeitig relativ geringen Ansprüchen an die Nährstoff- und Wasserversorgung des Standortes waldbaulich sehr geschätzt, was sich in den zunehmenden Bestockungsanteilen ausdrückt und am Beispiel des Staatswaldes Hessen belegt werden soll (JESTAEDT 1979, Jahresbericht 1983).

Douglasie	1970	1978	1985 (geschätzt)
Bestockungsanteil in %	0,7	1,2	1,5
Bestockungsanteil in Hektar	2200	3800	4800

Seit zirka 15 Jahren liegt der Anteil an der Neukulturfläche (ohne Saat und Naturverjüngung) bei über 10 %. Bei den anderen Waldbesitzarten Hessens sowie auch bei anderen Bundesländern z.B. Rheinland-Pfalz, ist die Douglasie bereits deutlich stärker vertreten. Baden-Württemberg will den Douglasienanteil in seinem öffentlichen Wald von derzeit 2,3 auf 8 % ausdehnen (KENK, HRADETZKY 1984).

Nach heutiger Auffassung werden der Douglasie insbesondere mäßig frische, mesotrophe Standorte zugewiesen, wo sie Kiefern, Fichten, Buchen und Eichen ersetzen kann, vorausgesetzt die Klimatönung geht nicht zu sehr ins Kontinentale und die Wasserspeicherkapazität der Böden reicht aus, um Trockenperioden zu überwinden (RIEBELING 1979).

Auch die Holzeigenschaften der Douglasie verdienen Anerkennung. Auch wenn zwischen dem Holz aus Primärbeständen und Holz aus Pflanzbeständen ein deutlicher Qualitätsabfall besteht (ANONYMUS 1985), kann Holz aus deutschen Beständen doch als gutes Bau- und Tischlerholz bezeichnet werden (GROSSER 1982).

Trotz der Wertschätzung der Douglasie aus waldbaulicher und verwertungstechnischer Sicht müssen spezifische Probleme beim Douglasienanbau beachtet werden. So ist die Douglasie beispielsweise im Kulturerfolg der Fichte deutlich unterlegen. Ausfälle von 25 % der Pflanzenzahl sind immer noch keine Seltenheit. Dabei spielen Pflanzenqualität, Pflanzverfahren und -termin eine wichtige Rolle. Der Gesamterfolg beim Douglasienanbau wird jedoch entscheidend durch die Wahl der richtigen Herkunft geprägt. Dank der Herkunftsforschung sind wir heute in der Lage, vorläufige Empfehlungen zu geben, die zumindest helfen, Fehler zu vermeiden, die für die Jugendphase und damit auch für den späteren Erfolg so entscheidend sind. Aufgrund der Ergebnisse der Herkunftsforschung konzentriert sich das Interesse in Mitteleuropa auf Vermehrungsgut aus ganz bestimmten Regionen des Ursprungsgebietes (JESTAEDT 1979, KLEINSCHMIT et al. 1979, RECK 1984). Dadurch und durch den zunehmenden Eigenbedarf in den

USA und Kanada als Folge der Abholzung der Urbestände wird es in Zukunft immer schwieriger werden, geeignetes Vermehrungsgut in ausreichender Menge nach Europa zu importieren. Es stellt sich daher die Frage, inwieweit heimische Bestände geeignet sind, als Ausgangsmaterial für die Saatgutgewinnung zu dienen.

Im folgenden soll von 2 hessischen Provenienzversuchen berichtet werden, die Hinweise für einen Vergleich zwischen Herkünften aus dem Ursprungsgebiet und Herkünften aus Deutschland liefern können:

1. Der Douglasienprovenienzversuch von 1958 in Hessen

Über den Kern dieses Versuches hat einer der Mit-Initiatoren, SCHOBER, 1983 und 1984 unter Beteiligung anderer berichtet. Mit einem Großteil der von Schober untersuchten Herkünfte sind 1961 auch in Hessen Versuchsflächen angelegt worden (vgl. Tabelle 1 und 2). Der gesamte Versuch bestand ursprünglich aus 15 Flächen verteilt auf 7 Forstämter. Wegen der großen Parzellen (0,1 ha) mußte auf Wiederholungen am gleichen Ort verzichtet, einzelne Wiederholungen sogar auf verschiedene Orte verteilt werden. Zum Ausgleich für die dadurch bedingten Nachteile bemühte man sich, standörtlich möglichst ähnliche Flächen für die 3 Grundversuche zu finden. Wie Tabelle 2 zeigt, konzentrieren sich die Versuchsorte auf 3 Schwerpunktregionen in Hessen, die wichtige Douglasienanbaugebiete repräsentieren.

Nach Übernahme des Versuches in die Zuständigkeit des Institutes für Forstpflanzenzüchtung sind die Flächen 1980 und 1981 nach Stammzahl, Wuchsleistung (Höhe, Durchmesser), Form und Fruktifikation aufgenommen worden. Abbildung 1 zeigt die mittleren Höhen der Herkünfte auf den einzelnen Versuchsflächen und das Mittel über alle Versuchsflächen in Beziehung zum jeweiligen Flächendurchschnitt im Alter von 23 Jahren. Auf den ersten Blick fällt das gute Abschneiden der deutschen Herkünfte im Gesamtvergleich auf. Im Vergleich dazu liegen die Herkünfte aus dem Innern British Columbias deutlich unter dem Durchschnitt; die Herkunft Fraser River erreicht auf keiner Fläche mehr als durchschnittliche Werte. Schlechte bis allenfalls mittlere Leistungen zeigen auch die Herkünfte von Vancouver Island, überdurchschnittliche Leistungen hingegen weist die Grafik für die Provenienzen aus dem Raum Darrington auf. Eine differenzierte Betrachtung erfordern die Prüfglieder von der Olympic Halbinsel. Während Joyce und Louella vom küstennahen Raum nordöstlich

der Olympic Mountains leicht unterdurchschnittlich abschneiden, erreicht das südlich gelegene Humptulips den besten Gesamtmittelwert aller amerikanischen Herkünfte. Die Herkünfte der Regionen Puget Sound, Kaskaden in Süd-Washington, Puget-Senke und Küstengebirge in Oregon bleiben insgesamt im Bereich des Gesamtmittels,wohingegen die Westkaskadenherkünfte aus Oregon enttäuschen.
Da die Vollkluppung für die Leistungsrangfolge der Herkünfte im Durchmesserzuwachs keine wesentlich anderen Ergebnisse erbrachte, soll darauf hier nicht näher eingegangen werden.
Hinsichtlich des Formverhaltens gab es keine grundlegenden Unterschiede zwischen deutschen und amerikanischen Herkünften. Zwischen der Wuchsleistung und dem Anteil gerader Stämme bestand eher ein negativer Zusammenhang (z.B. Humptulips, Neustadt).
Fruktifikation gab es in größerem Umfang nur auf den Flächen im Nördlichen Hessischen Schiefergebirge. Am stärksten fruktifizierten dort die deutschen Herkünfte und die Herkunft Fraser River (ca. 25 % schwacher bis mittlerer Behang, zusätzlich 5 % starker Behang).
Wegen der guten Leistungen der deutschen Herkünfte haben wir uns bemüht, im nachhinein herauszufinden, wo genau ihr Ausgangsmaterial zu suchen ist. Dabei ergab sich, daß zumindest ein Teil der Prüfglieder sehr wahrscheinlich von Beerntungen verschiedener, für Plantagenbegründung ausgewählter Plusbäume aus den Bereichen Odenwald und südlicher Vogelsberg, stammt. Im einzelnen wird darüber vom Verfasser 1985 berichtet.

2. Der Douglasienprovenienz- und Einzelstammabsaatenversuch von 1970/71

Der Provenienzteil dieses Versuches enthält in Hessen 115 Herkünfte aus den IUFRO-Ernten 1966, 67, 68 ergänzt durch 9 aus dem Handel bezogene Herkünfte. Von den 12 mit diesem Material angelegten Flächen (vgl. Tabelle 3 und 4) werden 9 jeweils durch einen parallel angelegten Versuchsteil ergänzt, der insgesamt 91 Einzelstammabsaaten von 6 in der Eifel liegenden Beständen enthält, die 1968 bei der Beerntung zwischen 32 und 86 Jahre alt waren. Pro Bestand sind ähnlich wie bei den IUFRO-Provenienzen 8 - 20 Bäume beerntet worden, wegen der geringen Mast allerdings vorwiegend an den Bestandesrändern. Die Bestände sind dadurch nicht gut repräsentiert. 1983/1984 haben wir die 8 noch vorhandenen Versuchsflächen hinsichtlich Ausfällen, Höhenwuchsleistung und Geradschaftigkeit aufgenommen.

Abbildung 2 enthält die Ergebnisse der Höhenmessungen im Alter von 13 bzw. 14 Jahren, links die Höhen der 6 Eifelherkünfte, in der Mitte die Höhen der verschiedenen meist parallel vorhandenen amerikanischen Provenienzen zusammengefaßt nach Regionen, wobei die Zusammensetzung innerhalb der Regionen nicht auf allen Flächen die gleiche ist (Tabelle 5). Die Regionen sind nach durchschnittlicher Wüchigskeit ihrer Prüfglieder angeordnet. Auf der rechten Seite sind die Flächenmittel der jeweiligen Provenienz- und Einzelstammabsaatenversuche aufgeführt. Die Darstellung zeigt, daß die Eifeldouglasien auf dem Leistungsniveau der besten Provenienzen (WNK, WOL, WST) liegen und sich untereinander nur relativ wenig unterscheiden.

Die Ausfälle (s. Abbildung 3), das heißt die Zahl der bei der Aufnahme vorgefundenen Fehlstellen, waren bei den Einzelstammabsaaten außer in Frankenberg etwas höher als bei den Provenienzen. Die extremen Ausfälle der Fläche Bad Sooden-Allendorf resultieren aus der Extremlage des Versuchsstandortes. Auch bei den Ausfällen liegen die Regionen WNK und WOL besonders günstig.

Abbildung 4 gibt den Anteil der geraden Stämme wieder. Danach besteht zwischen der Wuchsleistung und der Form eine gewisse Gegenläufigkeit. Die geringwüchsigen Douglasien aus dem Binnenland und aus dem Norden treten hier nach vorne, die wüchsigen Herkunftsgebiete erscheinen frühestens im Mittelfeld. Bei den Einzelstammabsaaten sind die Formunterschiede relativ gering ($\pm$ 10 %), der Anteil gerader Stämme liegt meist ziemlich niedrig.

DISKUSSION

Die vorgestellten Ergebnisse belegen, daß es sich lohnt, dem genetischen Potential unserer heimischen Douglasien mehr Aufmerksamkeit zu widmen. Diese Aussage wird auch durch andere Versuchsansteller gestützt. So berichten KENK und THREN (1984) von im allgemeinen guten bis sehr guten Wuchsleistungen von 4 süddeutschen Herkünften, die im Rahmen des baden-württembergischen Teiles des oben genannten Provenienzversuches von 1958 beobachtet wurden. Zwar erwiesen sie sich als nicht sehr kultursicher, blieben jedoch später von größeren Schäden verschont. Auch mit Hilfe anderer älterer Douglasienprovenienzversuche, die einzelne süddeutsche Herkünfte enthalten, belegen KENK und THREN, daß die geprüften heimischen Herkünfte in der Regel vom Wuchs her gute bis sehr gute Leistungen zeigen, ausgenommen die Herkunft Kandern. Die Herkunft Kandern ist es auch, die in jungen österreichischen Versuchen im Vergleich zu autochthonem Material im Wuchsverhalten relativ schlecht abschneidet (GÜNZL, RASCHKA 1984). Sehr gute Leistungen dagegen erbrachte in den östereichischen Versuchen die deutsche Sonderherkunft Südbaden. KLEINSCHMIT et al. berichten 1974, daß Nachkommenschaften deutscher Bestände in dem IUFRO-Versuch von 1970 bis zum Ende der Anzuchtphase sehr gut abgeschnitten haben. Bei der Herkunft Kandern hat er 1973 erhöhte Frostempfindlichkeit nachgewiesen, möglicherweise die Ursache für ihr schlechtes Abschneiden auch in anderen Versuchen.

Wie bereits dargelegt, ist in Zukunft mit Schwierigkeiten bei der Versorgung mit geeignetem Douglasienvermehrungsgut zu rechnen. Deshalb muß und kann das Potential der heimischen Bestände verstärkt genutzt werden. Ein Großteil der von uns geprüften Herkünfte ist bisher nicht für die Saatgutgewinnung zugelassen. Das sollte schnellstens geändert werden, auch wenn es sich, wie es leider häufig der Fall ist, nur um kleine Vorkommen unbekannten Ursprungs handelt. Zur Zeit sind in der Bundesrepublik Deutschland zirka 1400 ha Douglasie zur Beerntung zugelassen. Die meisten zugelassenen Bestände liegen in Baden-Württemberg und Rheinland-Pfalz. Angesichts der geringen Fruktifikation reicht diese Fläche bei weitem nicht aus, den künftigen Bedarf zu decken. Die Ausdehnung auf weitere, auch ungeprüfte Bestände, die nur nach ihrem äußeren Erscheinungsbild ausgewählt werden, dürfte trotz der damit verbundenen Problematik vermutlich für einige Jahrzehnte nicht zu umgehen sein. Parallel dazu haben wir in Hessen 1984 und 1985 mit 5 vielfach geprüften und bewährten Herkünften gezielt künftige Saatguterntebestände angelegt, die isoliert von anderen Douglasien herkunftsrein aufwachsen und später vorrangig der Saatgutproduktion dienen sollen.

Von Seiten einiger gewerblicher Baumschulen besteht eine gewisse Ablehnung gegenüber deutschen Douglasien-Vermehrungsgut, die mit Problemen während der Anzucht begründet wird (Auflaufergebnis schlechter, Frostanfälligkeit, ...). Bei allem Verständnis für solche Vorbehalte können jedoch für die Forstwirtschaft nur langfristig wirksame Beurteilungskriterien wie Produktionsleistung und Betriebssicherheit (vgl. KLEINSCHMIT 1973) ausschlaggebend sein. Vermehrungsgut mit nachweislich guter Veranlagung wie bei den meisten der hier untersuchten Herkünfte darf nicht außer acht gelassen werden. Der Verdacht, daß die Vorbehalte auch auf ganz anderen

Überlegungen beruhen (höhere Erntekosten, schärfere Erntekontrolle), ist sicher nicht ganz abwegig. Die Waldbesitzer, insbesondere die Staatsforstverwaltungen sind aufgefordert, die vorhandenen älteren Douglasienbestände verstärkt zur Saatgutgewinnung heranzuziehen. Dazu bedarf es ...

nicht nur der problematischen Ausdehnung der Zulassung auf weitere auch ungeprüfte Bestände, sondern auch

- der schnellen Zulassung in Prüfungen bewährter Douglasienbestände
- des Aufbaus künftiger Saatguterntebestände mit geprüftem Vermehrungsgut
- der verstärkten Beerntung auch bei geringen Masten
- der Einleitung der Prüfung weiterer heimischer nicht zu alter Douglasienbestände.

LITERATUR

Anonymus, 1985: Oregon Pine (Douglasie). Holz-Zentralblatt, Bd. 139, S. 806-807.

Grosser, D., 1982: Douglasie. Informationsdienst Holz, Nr. 10, Herausgeber Arbeitsgemeinschaft Holz e. V. und Centrale Marketinggesellschaft der deutschen Agrarwirtschaft.

Günzl, L.; Raschka, D., 1984: Ergebnisse aus Douglasien-Herkunftsversuchen der FBVA. Internationaler Holzmarkt, Nr. 18.

Jahresbericht 1983. Herausgeber Hessische Landesforstverwaltung.

Jestaedt, M., 1979: Untersuchungen über die Jugendentwicklung von Douglasienprovenienzen in Hessen und mögliche züchterische Folgerungen. Diss. München.

Kenk, G.; Hradetzky, H., 1984: Behandlung und Wachstum der Douglasien in Baden-Württemberg. Mitteilungen Baden Württembergische Versuchs- und Forschungsanstalt, Nr. 113.

Kenk, G.; Thren, M., 1984: Ergebnisse verschiedener Douglasien-Provenienzversuche in Baden-Württemberg. I. Teil Allgemeine Forst- und Jagdzeitung, Bd. 155, S. 165-184, II. Teil Allgemeine Forst- und Jagdzeitung, Bd. 155, S. 221-240.

Kleinschmit, J., 1973: Zur Herkunftsfrage bei der Douglasie. Forst- und Holzwirt, Bd. 28, S. 209-213.

Kleinschmit, J.; Racz, J.; Weisgerber, H.; Dietze, W.; Dieterich, H. und Dimpflmeier, R., 1974: Ergebnisse aus dem Internationalen Douglasien-Herkunftsversuch von 1970 in der Bundesrepublik Deutschland. Silvae Genetica, Bd. 23, S. 167-176.

Kleinschmit, J.; Svolba, J.; Weisgerber, H.; Jestaedt, M.; Dimpflmeier, R.; Ruetz, W. und Dieterich, H., 1979: Ergebnisse aus dem Internationalen Douglasien-Herkunftsversuch von 1970 in der Bundesrepublik Deutschland. Silvae Genetica, Bd. 28, S. 226-244.

Rau, H.-M., 1985: Der Douglasien-Provenienzversuch von 1958 in Hessen. Allgemeine Forst- und Jagdzeitung, Bd. 156, S. 72-79.

Reck, S., 1984: Eignung und Verfügbarkeit von Samenherkünften der Douglasie. Mitteilungen Bundesforschungsanstalt für Forst- und Holzwirtschaft Hamburg, Nr. 146, S. 29-36.

Riebeling, R., 1979: Standortskundliche, ertragskundliche und betriebswirtschaftliche Überlegungen zum Anbau schnellwachsender Baumarten insbesondere der Douglasie. Forst- und Holzwirt, Bd. 34, S. 177-184.

Schober, R.; Kleinschmit, J. und Svolba, J., 1983 u. 84: Ergebnisse des Douglasien-Provenienzversuches von 1958 in Nordwestdeutschland. I. Teil Allgemeine Forst- und Jagdzeitung Bd. 154, S. 209-236, II. Teil Allgemeine Forst- und Jagdzeitung Bd. 155, S. 53-80.

Tabelle 1: Versuchsmaterial
List of the provenances

Nr.	Provenienz		geographische Lage n. Br. , w. L.	Höhenlage m ü. NN	Nr. der Nieders. Forstl.Versuchsanst.
1	A	Neustadt	-	-	-
2	B	Büdingen	-	-	-
3	C	Obernburg	-	-	-
4	D	Michelstadt	-	-	-
5	E	Birkenau	-	-	-
6	F	Wald-Michelbach	-	-	-
7	202	Alder	46° 48' , 122° 15'	320 - 380	65
8	204	Ashford	46° 48' , 122° 00'	460	67
9	209	Baker	46° 20' , 122° 35'	290 - 305	71
10	301	Breightenbush	44° 45' , 122° 05'	700 - 775	75
11	28	Cameron Lake	49° 15' , 124° 40'	210	45
12	217	Carson	45° 42' , 121° 40'	270 - 290	87
13	100	Coombs	49° 20' , 124° 25'	80	61
14	24	Darrington Gold Hill	48° 20' , 121° 30'	150	83
15	26	Darrington Conrad Creek	48° 15' , 121° 30'	260 - 300	43
16	305	Detroit	44° 40' , 122° 10'	500 - 550	76
17	200	Joyce	48° 10' , 123° 35'	85	64
18	206	Humptulips	47° 12' , 123° 55'	45 - 62	68
19	201	Louella	48° 08' , 123° 10'	85	86
20	306	Marion Creek	44° 35' , 121° 55'	840 - 900	77
21	203	Mineral	46° 42' , 122° 11'	470	66
22	300	Molalla	45° 15' , 122° 25'	230 - 290	74
23	207	Orting	47° 05' , 122° 14'	120 - 135	69
24	33	Duncan Paldi	48° 45' , 123° 50'	230 - 290	40 / 60
25	2	Pamelia Creek	44° 40' , 121° 50'	750	44
26	31	Salmon Arm	50° 50' , 119° 10'	650	46
27	3	Santiam River	44° 40' , 121° 58'	600 - 1000	42 / 58
28	208	Sequest	46° 20' , 122° 45'	140	70
29	219	Silver Lake	46° 20' , 122° 48'	310 - 395	73
30	34	Tenas Creek	48° 20' , 121° 30'	465 - 525	47
31	32	Timber	45° 48' , 123° 23'	230 - 270	41 / 59
32	213	Vader	46° 25 , 123° 00'	90 - 120	72
33	101	South Wellington	49° 07' , 123° 55'	55 - 60	62
34	I	Fraser River	52° 30' , 121° 30'	750	88(1)
35	II	Darrington	-	-	84 oder 85(1)
36	III	Stella	46° 13' , 123° 10'	100	78(1)

(1) die Identität der Nummern 34 - 36 mit den genannten Nummern der Nieders. Forstl. Versuchsanstalt wird vermutet

<u>Tabelle 2:</u> Übersicht über die Versuchsflächen mit Standortbeschreibung und Zusammenstellung der wichtigsten absoluten Wuchsleistungsdaten
Description of the field experiments with site classification and compilation of the most important absolute data about growth performance

F l ä c h e		Wuchsgebiet/-bezirk	Wuchszone	Klimafeuchte	Wasserhaushalt	Trophie	ca. m ü. NN	Expo- sition	Zahl der Herk.	durchschnittliche Zahl Dgl./ha	durchschnittliche Höhe m	durchschnittliche BHD cm
1.1 Beerfelden	21 D				frisch	mesotroph	415	S	24	970	15,2	13,6
1.2 Beerfelden	40 1	Odenwald / Südwestl.Buntsandstein-Odenwald					345	SW	2	1170	14,3	16,0
1.3 Wald-Michelbach	501 A 2		Ob.Bu-Mischwaldz.	st.subatl.					18	550	7,8	7,6
1.4 Wald-Michelbach	177 A 3				mäßig frisch	oligotroph	470	W	18	630	9,2	9,0
1.5 Wald-Michelbach	204 A 1								35	720	9,7	9,0
2.1 Grebenau	10	Vogelsberg / Schlitzer Bergland		schw.subatl.	mäßig frisch		400	W	12	1020	9,8	11,2
2.2 Grebenau	76 B				wechselfeucht	oligotroph	360	WSW	17	560	8,3	10,0
2.3 Rauschenberg	629	Nordwesthess. Bergland / Neustädter Gebiet	Ob.Bu-Mischwaldz.	schw.subk.	frisch		315	SW	36	490	9,5	9,7
2.4 Neukirchen	125 B	Nordosthess. Bergland /					315	NNW	18	810	11,5	11,8
2.5 Neukirchen	229 B	Schwalm Bergland		mäßig subk.	frisch	mesotroph	280	SW	17	430	8,5	8,2
3.1 Hatzfeld	129 A		Unt.Bu-Zone				520	SO-N	35	900	10,8	13,4
3.2 Frankenberg	247 B	Nördl.hess.Schiefergebirge/			mäßig frisch	mesotroph	460	SSO	29	920	11,7	15,4
3.3 Frankenberg	409	Östl.Rothaargebirgsausläufer	Ob.Bu-Mischwaldz.	schw.subatl.			420	eben	6	740	11,4	15,5
3.4 Hatzfeld	310 A					mesotroph			30	990	11,6	13,7
3.5 Hatzfeld	308 B		Unt.Bu-Zone		mäßig trocken	schw.mesotroph	490	SSO	5	1140	11,4	14,9

Tab. 3: Douglasien-Provenienz- und -Einzelstammabsaatenversuch von 1970/71 - Standortsdaten der Versuchsflächen

Forstamt	Abt.	Höhe ü. NN	Durchschnittl. Temperatur		Durchschnittl. Niederschlag		Bodenwasser-haushalt	Trophie	Bodentyp	Versuchs-typ *
			Jahr	Vegper.	Jahr	Vegper.				
Bad Homburg	14 A	400 - 405	7,5	14,0	850	340	mäßig frisch / mäßig trocken	oligotroph	podsolierte Braunerde	P
	49 A	630 - 650	6,4	12,8	900	460	mäßig frisch	oligotroph	podsolierte Braunerde	E
Bad Sooden-Allendorf	375	750	5,0	12,4	1000	560	frisch	mesotroph	Braunerde	P
Bensheim	147 B	95	9,9	16,5	600	300	frisch / mäßig frisch	schwach mesotroph	Podsol-Braunerde bis Gley-Braunerde	E
Frankenberg	513	580 - 610	6,0	12,5	1000	400	mäßig frisch	mesotroph	Braunerde	E, P
Gahrenberg	63 A	160 - 180	8,0	14,7	730	350	mäßig frisch	mesotroph	schwach podsolierte Braunerde	P
Hilders	140	490 - 520	6,4	13,1	800	380	mäßig frisch / frisch	gut oligotroph	Podsol-Braunerde	E, P
Hirschhorn	503	230 - 280	8,3	15,1	995	430	mäßig frisch / frisch	gut oligotroph	Podsol-Braunerde	E, P
Rotenburg	539	230 - 310	7,8	14,6	640	312	mäßig frisch / mäßig trocken	mesotroph	podsolierte Braunerde	E, P
Waldsolms	121	340 - 370	7,4	14,2	750	340	mäßig frisch / mäßig trocken	gut mesotroph	Braunerde bis Parabraunerde	E, P

* E = Einzelstammabsaatenversuch

P = Provenienzversuch

Tab. 4: Douglasien-Einzelstammabsaatenversuch von 1970
- Angaben zu den Erntebeständen

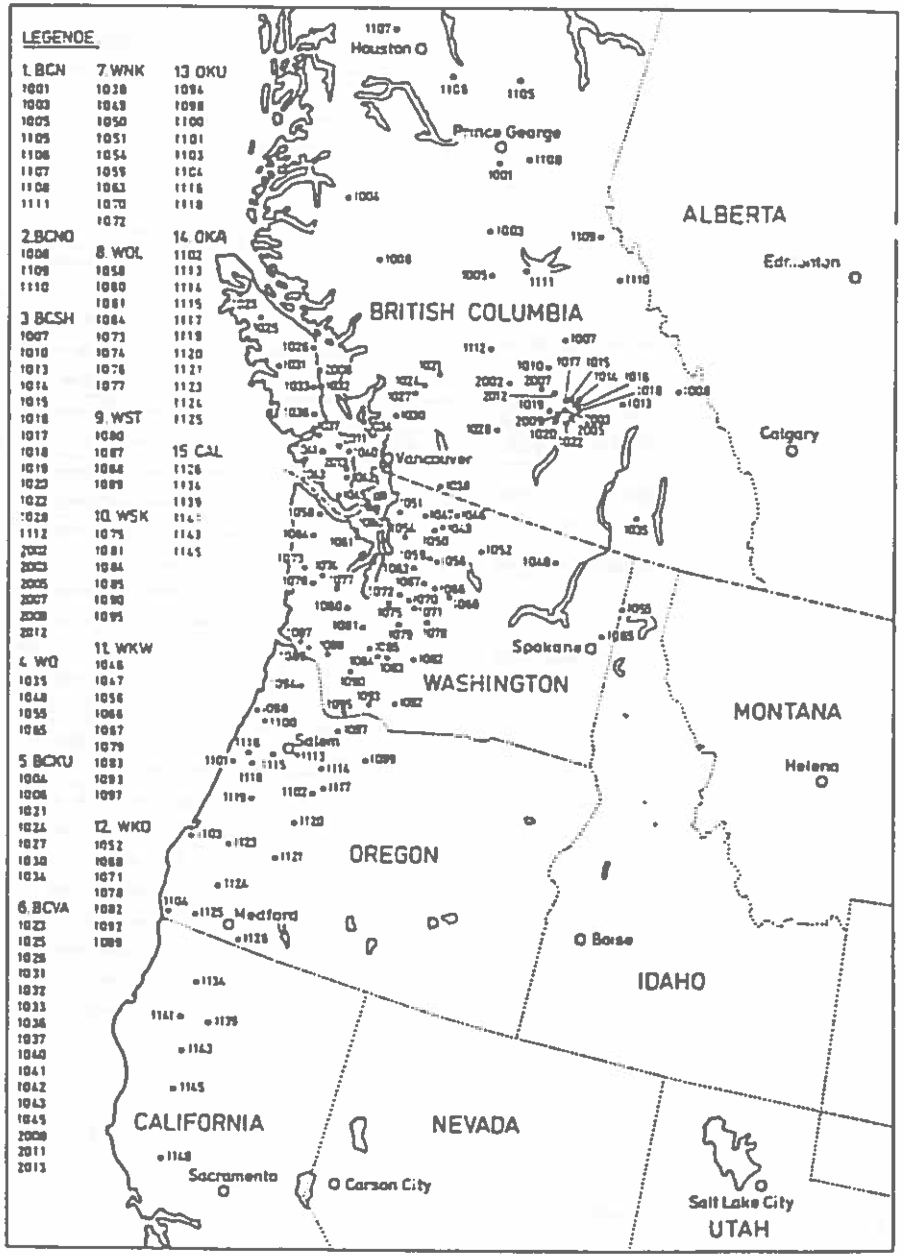
Nr.	Forstamt	Abt.	Alter b. Ernte	Fläche (ha)	Bestockungs-anteil (%)	Bonität *	Höhe ü.NN	Zahl der beernteten Bäume
1	Wittlich-West Gemeinde Bergweiler	16	38	5,0	50	II.5	230	18
2	Wittlich-West Gemeinde Bruch	3 b	38	4,7	85	II.0	230	20
3	Manderscheid	36 b	86	0,6	100	I.0	400	15
4	Daun-Ost	39 a	39	6,4	40	I.5	520	15
5	Daun-Ost	46 c 1	32	0,5	100	I.5	500	15
6	Prüm-Süd	79 c	57	0,5	100	I.0	380	8

* nach Wiedemann/Schober

Abbildungen

<u>Tab. 5:</u> Erläuterung der Abkürzungen für die Herku...tsgebiete

1. BCN nördlicher Teil des Verbreitungsgebietes in British Columbia (8 Herkünfte)
2. BCNO nord-östlicher Teil des Verbreitungsgebietes in British Columbia (3 Herkünfte)
3. BSCH Shuswap-Lake-Gebiet (19 Herkünfte)
4. WO Ostteil von Washington und Süd-Osten von British Columbia (4 Herkünfte)
5. BCKU Küstenbereich von British Columbia (7 Herkünfte)
6. BCVA Vancouver Island (16 Herkünfte)
7. WNK Bereich zwischen Küste und Kaskaden (einschließlich der westlichen Teile) im nördlichen Washington und süd-westlichen British Columbia (bis zum Frazer River) (9 Herkünfte)
8. WOL Olympic Peninsula (8 Herkünfte)
9. WST Tieflagen im südlichen Washington (4 Herkünfte)
10. WSK untere Lagen der westlichen Kaskaden in Süd-Washington (6 Herkünfte)
11. WKW mittlere und obere Lagen im Westteil der Kaskaden (bis zur Wasserscheide) in Washington und Oregon (nördlich des 45. Breitengrades) (9 Herkünfte)
12. WKO Ostteil der Kaskaden in Washington und Oregon (nördlich des 45. Breitengrades) (7 Herkünfte)
13. OKU Küstenbereich von Oregon (bis zur Wasserscheide der Coast Range) (8 Herkünfte)
14. OKA östliche Teile der Coast Range und westliche Teile der Kaskaden in Oregon. (Es wurde darauf verzichtet, für die Herkünfte vom Ostteil der Coast Range eine eigene Gruppe auszuscheiden, da von diesen 5 Herkünften nur eine auf einer einzigen Fläche vertreten ist.)
15. CAL Kalifornien sowie eine Herkunft aus dem Süden von Oregon (7 Herkünfte)



Ursprungsorte der Herkünfte

Abb. 1

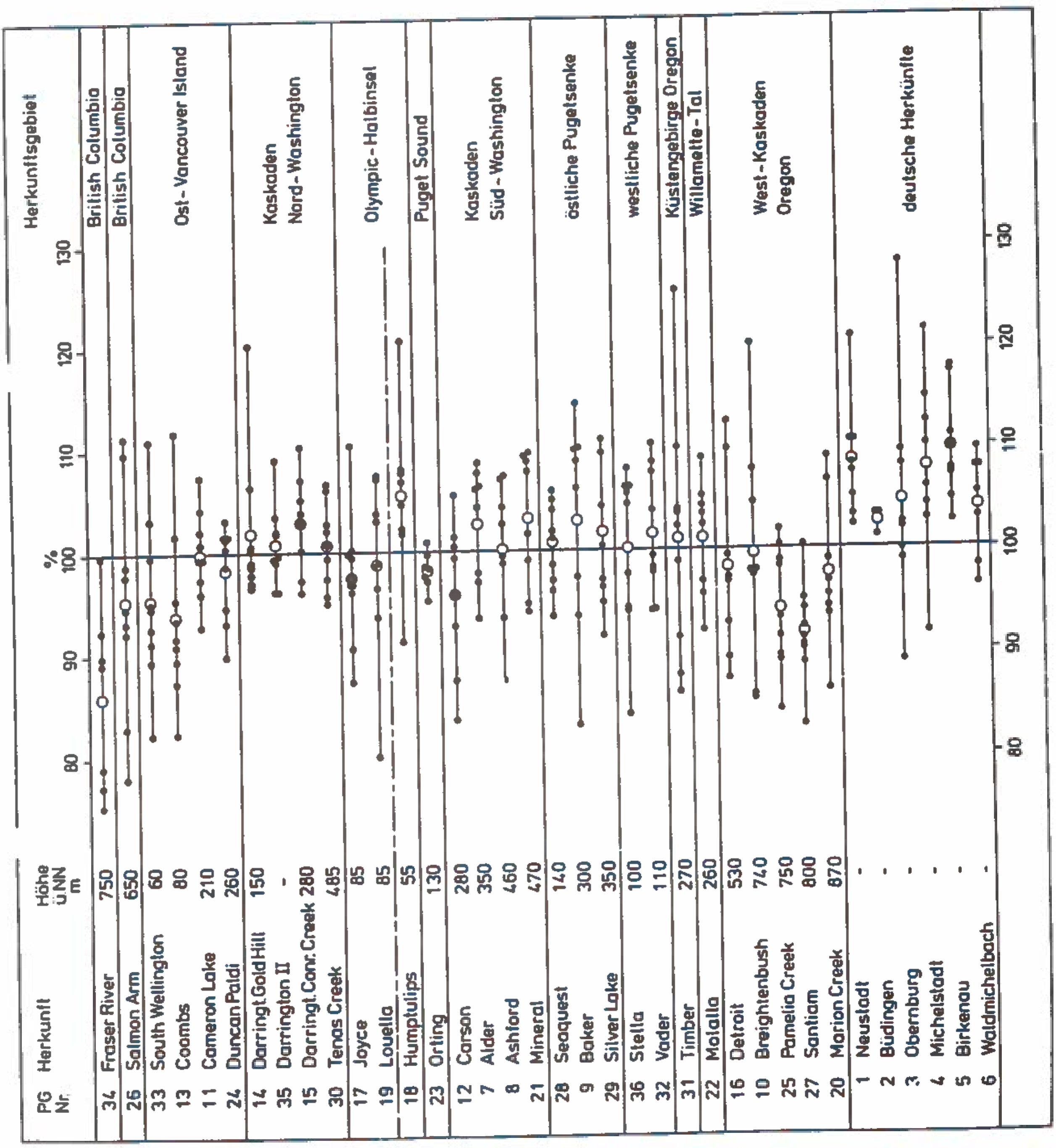

PG Nr.
Herkunft
Höhe ü.NN m
%
Herkunftsgebiet
34 Fraser River 750
26 Salmon Arm 650
33 South Wellington 60
13 Coombs 80
11 Cameron Lake 210
24 Duncan Paldi 260
14 Darringt. Gold Hill 150
35 Darrington II -
15 Darringt. Conr. Creek 280
30 Tenas Creek 485
17 Joyce 85
19 Louella 85
18 Humptulips 55
23 Orting 130
12 Carson 280
7 Alder 350
8 Ashford 460
21 Mineral 470
28 Seaquest 140
9 Baker 300
29 Silver Lake 350
36 Stella 100
32 Vader 110
31 Timber 270
22 Molalla 260
16 Detroit 530
10 Breightenbush 740
25 Pamelia Creek 750
27 Santiam 800
20 Marion Creek 870
1 Neustadt -
2 Büdingen -
3 Obernburg -
4 Michelstadt -
5 Birkenau -
6 Waldmichelbach -
80
90
100
110
120
130
British Columbia
British Columbia
Ost-Vancouver Island
Kaskaden
Nord-Washington
Olympic-Halbinsel
Puget Sound
Kaskaden
Süd-Washington
östliche Pugetsenke
westliche Pugetsenke
Küstengebirge Oregon
Willamette-Tal
West-Kaskaden
Oregon
deutsche Herkünfte

Abb. 2

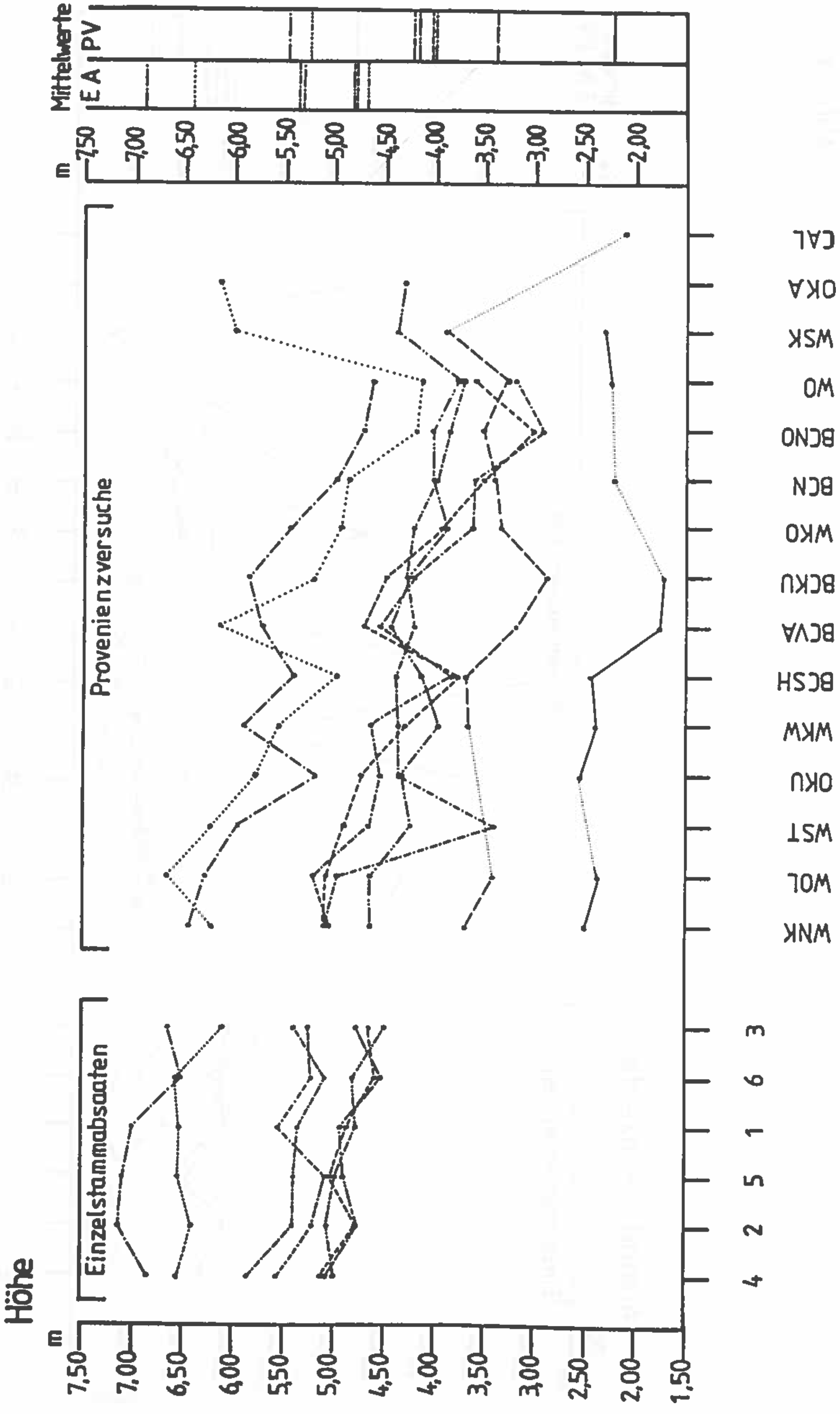

Höhe
m
7,50
7,00
6,50
6,00
5,50
5,00
4,50
4,00
3,50
3,00
2,50
2,00
1,50
Einzelstammabsaaten
4
2
5
1
6
3
Provenienzversuche
WNK
WOL
WST
OKU
WKW
BCSH
BCVA
BCKU
WKO
BCN
BCNO
WO
WSK
OKA
CAL
Mittelwerte
E A
PV
m
7,50
7,00
6,50
6,00
5,50
5,00
4,50
4,00
3,50
3,00
2,50
2,00

Abb. 3

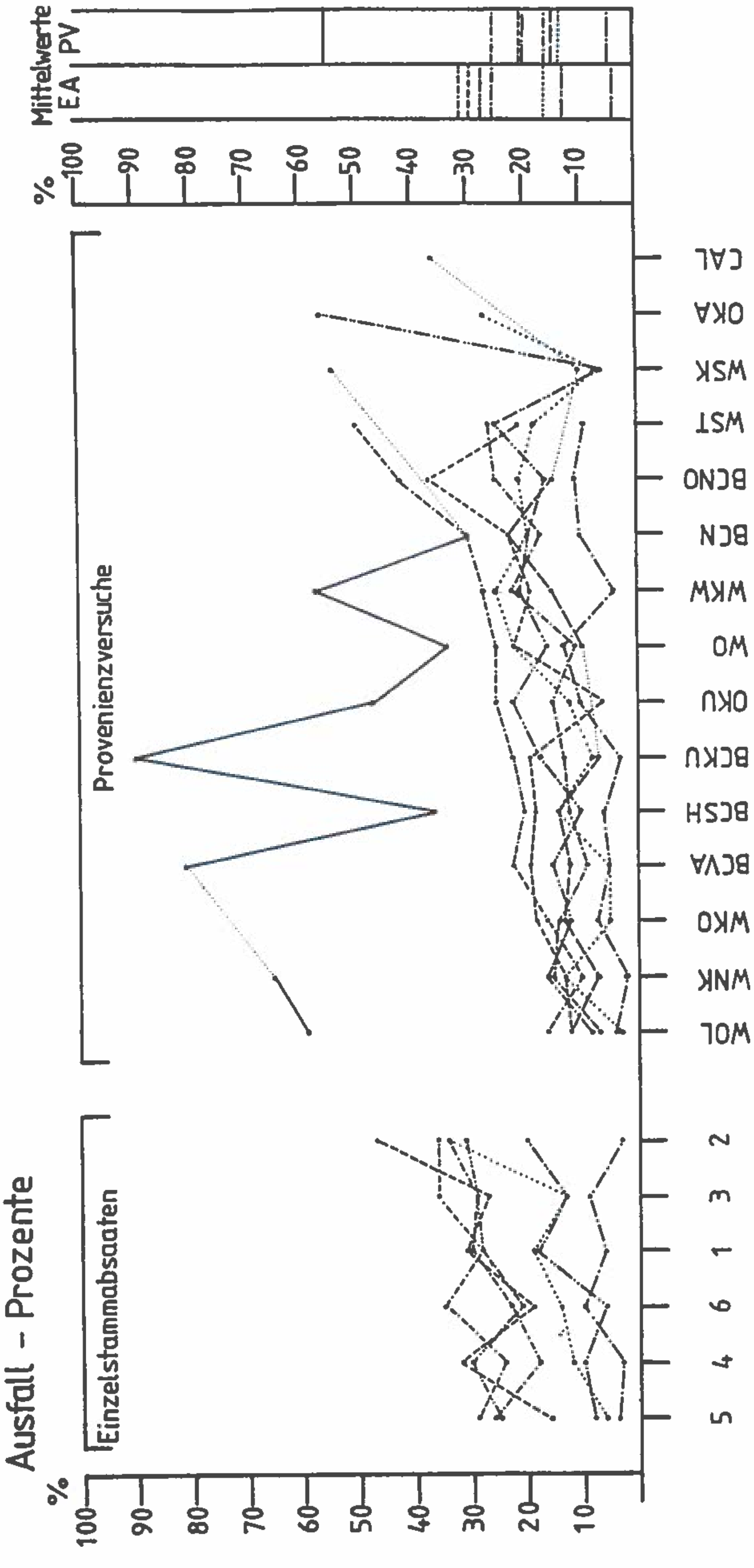
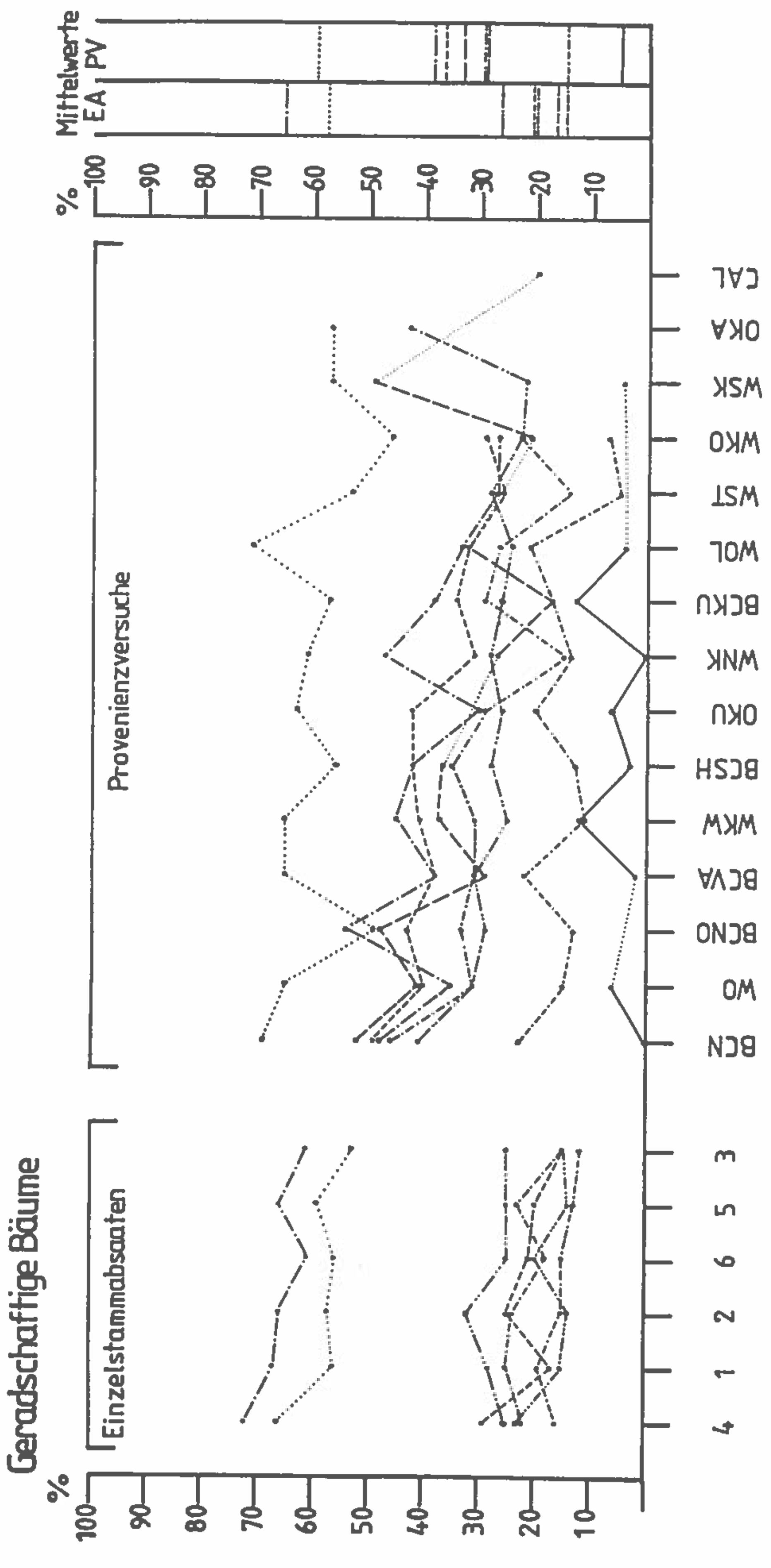

Ausfall - Prozente
Einzelstammabsaaten
Provenienzversuche
Mittelwerte
EA
PV
%
100
90
80
70
60
50
40
30
20
10
5
4
6
1
3
2
WOL
WNK
WKO
BCVA
BCSH
BCKU
OKU
WO
WKW
BCN
BCNO
WST
WSK
OKA
CAL

Abb. 4


Geradschaftige Bäume
Einzelstammabsaaten
Provenienzversuche
Mittelwerte
EA
PV
%
100
90
80
70
60
50
40
30
20
10
4
1
2
6
5
3
BCN
WO
BCNO
BCVA
WKW
BCSH
OKU
WNK
BCKU
WOL
WST
WKO
WSK
OKA
CAL

LAMMAS SHOOTS AND HEIGHT-GROWTH OF DOUGLAS-FIR

WIDMAIER, TH.; DAGENBACH, H.; HAUFF, U.
Forstliche Versuchs- und Forschungsanstalt,
Baden-Württemberg

I. INTRODUCTION

From many experiments with Douglas-fir we know that there are great differences in the frequency of Lammas shoots between provenances, between individuals, between sites and from year to year (1). In these experiments it appears that individuals with Lammas shoots have better height-growth (2). To test this hypothesis we carried out the following experiment.

II. MATERIAL AND METHODS

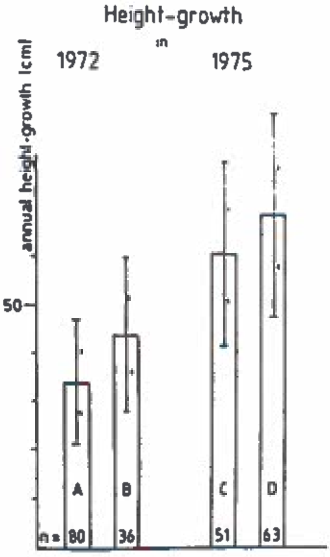
In 1972 we started measuring height and observing Lammas shoots in a 6 years old plantation of Douglas-fir. The provenance used was from South-Baden/Germany. Measurements and observations were repeated annually till age 13 in the autumn of 1978. In 1972 and 1975 we had a sufficient number of Lammas shoots for statistical analysis.

III. RESULTS

In Figure 1 one sees the mean annual height-growth of the plants with, respectively without Lammas shoots. It appears that the plants with Lammas shoots have better annual height-growth. The difference is significant.

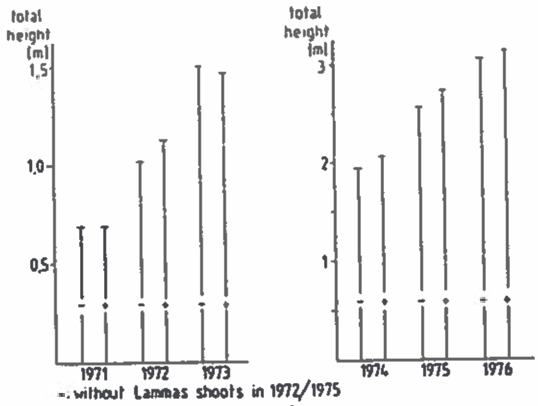
However if we test the mean total height-growth after 13 years (Figure 2) and correlate this to the intensity of Lammas shoots there is no significant difference between plants which had Lammas shoots or plants which had one, two, three etc. Lammas shoots.

To find the reason for this result we added up the mean annual height-growth in the year after growing Lammas shoots of the same collectives, which had Lammas shoots respectively which had no Lammas shoots in the year before (Figure 3). The plants which had Lammas shoots in 1972 resp. 1975 had a significant lower height-growth in 1973 resp. 1976.



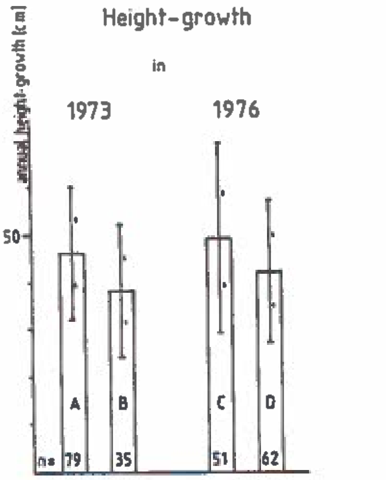
A,C: plants without Lammas shoots
B,D: plants with Lammas shoots

Figure 1



-: without Lammas shoots in 1972/1975
•: with Lammas shoots in 1972/1975

Figure 2



A,C: plants without Lammas shoots in the last year
B,D: plants with Lammas shoots in the last year

Figure 3

IV. DISCUSSION

The growing of Lammas shoots had a positive effect on the individual annual height-growth. But the same plants have lower height-growth in the following year. This may be the reason for the result that plants with a high frequency of Lammas shoots have no better total height-growth than the other.

We can say that Lammas shoots of Douglas-fir are Prolepsis in the original meaning of this word. In consequence to this fact it is difficult for example to realize a sorting experiment with Douglas-fir individuals in years with high intensity of Lammas shoots, because in a population with many Lammas shoots one will choose not the fast growing individuals but the individuals with Lammas shoots. Already in the next year they may grow slowly and the difference between a high and low collective may be lost.

V. SUMMARY

In a planting test with Douglas-fir correlations between intensity of Lammas shoots and total height-growth were analysed. In consequence to these results we point out the difficulties of sorting Douglas-fir on the basis of height.

VI. LITERATURE

JESTAEDT, M. Untersuchungen über die Jugendentwicklung von Douglasienprovenienzen in Hessen.Mitt. der Hess. Landesforstverwaltung. Band 16, 1980.

MARCET, E. Bemerkungen und Beobachtungen über den August-Trieb.Schweiz.Zeitschr.f.Forstwesen, 126.Jg., Nr.3, März 1975.

VARIATION OF CONE SCALE AND SEED MORPHOLOGY IN DOUGLAS-FIR. (PSEUDOTSUGA MENZIESII).

R.K. Scagel[1], R. Davidson[2], Y.A. El-Kassaby[2,3], O. Sziklai[2]

[1] Dept. of Botany, University of British Columbia, Vancouver, B.C., Canada, V6T-2B1.

[2] Faculty of Forestry, University of British Columbia, Vancouver, B.C., Canada, V6T-1W5.

[3] C.I.P. Forest Products Inc., Tahsis Pacific Region, 8067 E. Saanich Rd., R.R. #1, Saanichton, B.C., Canada, V0S-1M0.

ABSTRACT

The nature of variation of 10 variables describing seed and cone morphology of Douglas-fir was examined using multivariate analyses. This variation was related to geography for 89 populations in primarily the western range of the species. There was significant differentiation for population centroids, within-population variation, and within-population variable inter-correlations. Only population centroids could be shown to be related to geography. Varietal distinction was less pronounced than intra-population variation. Seed source differentiation was shown to account for a larger proportion of the total variation than varietal variation but it was still smaller than that attributed to individual populations. These observations argue for revised, or at least expanded, approaches to the study of variation in Douglas-fir and the derivation of recommendations concerning the utilization of such variation.

Keywords: Pseudotsuga menziesii, morphology, population differentiation, canonical correlations.

INTRODUCTION

Geographic variation of Douglas-fir (*Pseudotsuga menziesii*) has been a source of both interest and frustration to foresters (Larsen 1937; Langlet 1962, 1963). Hypotheses have been tendered concerning subspecific and population differentiation with respect to geography and climate. Additional hypotheses have been tendered for smaller, more local scales of population differentiation. The consensus of numerous studies using different variables and experiments is that the majority of variation is of an intra-population nature (Chen *et al*. 1985; Sorensen and Miles 1978; Campbell and Franklin 1981; Campbell and Sorensen 1978; Rehfeldt 1983; El-Kassaby and Sziklai 1982).

We wish to examine the nature of geographic variation of populations and varieties for seed and cone scale morphology, as well as instances where there is a demonstrated lack of co-incidence. We are thus concerned with more than central tendencies of groups of trees, but also the nature of variation within these groups as it relates to *all* hypothesized levels of variability (Silen 1978; Adams 1981). For practical purposes we are interested in those factors, geographic *or* otherwise, which explain most of the variation in the data (Campbell and Franklin 1981; Daniels 1984).

MATERIALS AND METHODS

Materials and variables

89 populations (Fig. 1) of the 1966/ 67 IUFRO collection of Douglas-fir were measured for 10 variables on a total of 15 trees per population (Yao 1971). Sampling was concentrated in the coastal area of the range, primarily in southern British Columbia and Washington. The morphological variables measured are illustrated in Fig. 2 and, where available, the values are averaged based on 3 scales per tree. Repeatability estimates (Falconer, 1981) are given in Table 1. The average repeatability of the variables for which intra-individual variation could be measured was % 76, an estimate comparable to others reported for conifers (Khalil 1974; Chen *et al*. 1985). The repeatability for A1L is particularly low, however more than half the variability is attributable to inter-tree differences. Thousand seed weight (TSW), seed length (SL), seed width (SW), wing length (WL), and wing width (WW) are based on a single value per tree and thus repeatability estimates could not calculated. Repeatability estimates were calculated without respect to any circumscribing level of organization in the data besides the individual trees. As such, the variables measured

can be regarded as an estimate of genetic differences. This does not mean they are the only variables that could be used in such a study, merely convenient given the sampling constraints and lack of space available for raising families. There are no selective advantages hypothesized for any of these variables - simply that they be shown to vary more between trees than within trees. In this manner, any patterns of variation above the level of the individual tree are allowed to be emergent rather than being imposed *a priori*. Other, more detailed aspects concerning sampling can be found in Yao (1971). More detailed discussion of such selection of morphological variables can be found in Scagel (1984).

In describing geography we have used the longitude, latitude, and elevation of the populations. These variables can be considered to roughly approximate climate. This does not perclude considering other, more local scales of variation, or non-linear relationships (Campbell and Franklin 1981; Campbell and Sorensen 1978) but serves as a convenient general scale for the examination of the nature of variation (Falkenhagen 1982).

Statistical analyses

The data gathered form a multivariate sample and require a multivariate analysis that addresses variable means and correlations. Further, the analysis selected should be able to examine the differences in centroids and correlation structure of any hypothesized grouping. Above the level of individual we examined the variation at the level of:

i) population (89 populations)
ii) varieties (*menziesii*, *glauca*)
iii) glacial history (glaciated, non-glaciated)
iv) seed source.

As the primary interest is in morphological variation associated with geographic variation, the appropriate multivariate technique is canonical correlation analysis (CCA; details in Gittins 1979; example in Falkenhagen and Nash 1978). CCA is an eigenvector-eigenvalue extraction technique that maximizes the dispersion amongst individual samples on the basis of two sets of variables: cone scale and seed morphology *vs*. geography. As such CCA can be viewed as the multivariate extension of the more familiar product-moment correlation. The sample size available was adequate for the dimensionality of the data and the stabilization of the various matrices involved in CCA (Scagel *et al*. 1985). We have elaborated upon the results of CCA by utilizing ANOVA of canonical variates scores for morphology. Based on ANOVA, variation was expressed as a percentage of the total sums of squares, prorated by the intra-set redundancy for morphology, and summed over all canonical variates (Scagel and Maze 1984). Intra-set redundancy for morphology is the percent of the total morphological variation attributed to a specific correlation between two sets of variables. Such an examination of CCA by ANOVA provides canonical variate specific interpretations for the results in addition to the weighting of the individual variables used in the CCA.

All ANOVAs were conducted according to the completely nested model:

Y = VARIETY + GLACIATION/V + POPULATION/ GV + E.

ANOVA of seed source was based on the nested model:

Y = SEED SOURCE + POPULATION/ SS + E.

The assignment of samples on the basis of glacial history follows the results of Clague (1981) and its inclusion is based on the results of Chen et al. (1985) that indicate there may be a significant latitudinal trend to differentiation. The comparison of seed sources focuses on the issue of how well the classification of Haddock and Sziklai (1966) is co-incident with the actual geographic variation of Douglas-fir.

Preliminary studies based on multivariate analysis of variance (MANOVA; Cooley and Lohnes 1971; Chatfield and Collins 1980) indicated that the within-population covariation and correlation matrices were not equal (Box's test, Morrison 1976). Thus in addition to examining the relation of the central tendencies of the populations to geography through CCA, we examind the relation of population covariation and correlation to geography as well as the co-incidence with population centroids. To make such comparisons, determinants of the population covariance and correlation matrices were correlated with the scores for the morphological vectors from CCA and geography. Such use of determinants has been previously illustrated by Phillips et al. (1973). The determinant of the covariance matrix ($|S|$) ranges from 0 to ∞ and reflects differences in variable variance and covariance. The determinant of the correlation matrix ($|R|$) ranges from 0 to 1 and reflects differences in variable inter-correlations. (For further discussion of the nature of determinants see Green (1976)). If population differentiation that is associated with geography is co-incident with change in determinants, then it can be inferred that geography is somehow associated with both population differentiation of centroids and covariances. If population differentiation is only related to change in covariance and not correlation structure, then population differentiation may be ascribed to basically change in size and variability rather than covariability. These analyses address the relation of population central tendency, variation about the centroid, and the nature of that variation.

RESULTS

The general form of the relation between cone scale morphology and geography is illustrated in Fig. 3. It should be remembered that each point represents centroids for 45 individual scales collected from 15 trees and that only inter-individual variation was used in the CCA. In other words, the 25 % of the total variation associated with intra-individual variation (Table 1) was excluded from analysis. This ordination represents the two vectors of the first canonical variate (Table 2) and has a canonical correlation (Rc) of .63 accounting for 55% of the total variation shared in common by morphology and this scale of geography. However, on the basis of intra-set redundancy for morphology this ordination only accounts for 24% of the total inter-tree variation of cone scale morphology. Over all three canoncial variates (I, II, III Table 2) that were extracted, only 50% of the total morphological variation was shared in common with this scale of geography. For brevity we will detail only the major source of variation: the first canoncial variate.

The trend shown in Fig. 3 is significantly correlated with the latitude of the population and, based on component correlations, emphasizes the variables WW, SL, SCW, and A2L (Table 2). The individuals with larger values for these variables are found at lower latitudes. The populations with the largest scores for the geographic vector are those of populations in southern and eastern Oregon, they seem to represent outliers from the general trend associated with latitude. The interior populations that appear to cluster with the coastal populations are those in the immediate rainshadow of the Cascades in eastern Washington (Fig. 1). The latitudinal trend shown in Fig. 3 is further emphasized in Fig. 4 with the smallest values being found towards the northern interior. Notice also the apparent discontinuity of samples and sample scores suggesting that some of the differentiation may be attributable to sampling inadequacies (i.e. non-random sampling over the geographic range, particularly toward the interior, Fig. 1) rather than actual patterns of variation. In general, the second canonical variate extracted (reflecting TSW) was correlated with longitude and the third canonical variate (reflecting A1L) was correlated with elevation (Table 2).

The independent patterns of morphological variation from the first two canonical variates are presented in Fig. 5. Together the two vectors shown account for only 36% of the total morphological variation in the data and emphasize the differences between coastal and interior varieties. Again, the interior populations that appear to cluster with the coastal populations are those from the rainshadow of the Cascades in eastern Washington. Obscured in this diagram is the largest source of variation - within-population variation (Table 3). It is interesting to note that although the within-population variation for the first canonical vector is homogenous, it is heterogenous for the second vector. Generally populations from the eastern and southern areas were the most variable. Populations in intervening areas between the two varieties did not appear to be more variable. A similar lack of relation for determinants were also observed (Table 4). The relation of $|\underline{S}|$ to geography is much stronger than for $|\underline{R}|$ suggesting that variable inter-correlations are not effected by the same scale of geography as that which influences variable variances and covariance. There is a significant relation between $|\underline{S}|$ and the population centroids suggesting that more southerly and easterly populations have smaller $|\underline{S}|$ (= stronger variable inter-correlations).

Varietal differentiation appears marked in Fig. 3, however when prorated over the three canonical variates by the morphological intra-set redundancy, it accounts for 8 % of the total morphological variation. The hypothesized source dealing with post-glacial history is 60 % smaller than that attributed to varieties. All inter-individual sources of variation were indicated as being significantly different over all three canonical variates. Comparing the partitioning of variation of morphology associated with geography (i.e. from CCA) to total variation of morphology (Table 3) indicates that, for the hypothesized sources of variation, the CCA accounts for nearly 70 % of the total variation attributed to these same sources without respect to geography. This is particularly evident for inter-population sources of variation, suggesting that geography and these hypothesized sources of variation are closely related. The CCA is particularly poor at representing population and intra-population variation.

The hypothesized seed source designations are larger than that attributed to the hypothesized natural historical patterns of differentiation. The smaller the geographic scale of variation hypothesized, the more efficaceous the source is in accounting for variation. Seed source variation does not account for as much variation as that of the population.

DISCUSSION

The results presented here corroborate the general impression from the literature based on a plethora of variables under different experimental conditions that indicates that the majority of variation in Douglas-fir resides within the population (i.e. 67 %). This same generalization can be applied to most other conifers. Whether in fact the trends shown here are co-incident with those exhibited for other variables or under different experimental conditions remains to be seen (Campbell and Sorensen 1978). The lack of information concerning such co-incidence decries the need for more detailed multivariate studies - in fact with the advent of multiple-trait selection programmes it is a necessity.

Numerous hypotheses exist to explain within-population differentiation, however there have been few critical tests of these hypotheses. This is surprising owing to the magnitude of this source of variation. Tendered hypotheses have favoured selectionist explanations and have concentrated on the central tendencies rather than other aspects of variation. The differing inter-correlations exhibited by the variables here, possibly indicating linkage disequilibrium (Mitton et al. 1981), would seem to suggest that additional or alternative explanations for this differentiation should be considered (Lande 1979, 1982). Further, considering what is known of population structure in Douglas-fir (i.e mating, family structure, etc.; Shaw and Allard 1982; Rehfeldt 1978) non-selectionst explanations could be considered equaly feasible. Additionally the nature of ontogeny (Sorensen and Miles 1978; Sorensen 1983; Grafius 1978), as well as the inheritance and linkage of these variables might shed further light on the nature of the differentiation. To address these issues would require a more extensive intra-individual sampling than was conducted here.

Although all of the hypothesized sources of inter-population variation (glacial history, varietal classification) were shown to be significant, the amount of variation attributable to these sources was small, particularly for post-glacial history. Regardless of the small amount of variation attributed to post-glacial history there is still a strong latitudinal cline to the data compared to the longitudinal cline suggested by the hypothesized varieties. This conclusion tends to corroborate the observations of Chen et al. (1985) and Sziklai (1969) concerning the existance of a latitudinal cline, however such a conclusion remains tentative pending a more longitudinally extensive sampling than was used here. Results from such a longitudinally extensive collection may well indicate a more substantial varietal differentiation than was shown here. Additionally, such an extensive sampling could be used to examine the nature of varietal differentiation over the entire range, possibly addressing the plethora of specific segragates recognized by Flous (1934). For example, in the southern portion of the range, is there more varietal differentiation than in the northern portion, and is there indeed evidence of inter-varietal introgression (vonRudloff and Rehfeldt 1980)? Secondly, how might the nature of within-population variation and variable inter-correlations relate to such an expanded geographic sample?

It should be noted that TSW, although previously demonstrated to be highly related to latitudinal differentiation (Sziklai 1981), appears to be most highly related to longitude in this study. Explanation for this disparity could be biological (vagrancies of seed set and maturation in the year of collection) or analytic (multivariate vs. univariate). The results presented in Table 2 suggest that TSW is partially independent of the major pattern of variation of the other variables. Secondly, although the immediate relationship of TSW is to longitude there is also a significant relationship to latitude. We are lead to conclude that the disparity is analytic, and that the latitudinal trend identified here is stronger than that identified based only on TSW. Such a conclusion emphasizes the value and necessity of a multivariate approach to such studies.

The results presented here may also serve as a source of comparison against which patterns of variation based on progeny from populations can be compared. This data presented here enhances our understanding of the naturally occurring patterns of variation and represents additional information about the parent population in the I.U.F.R.O. collections outside of environment and general growth attributes. To incorporate this data into present I.U.F.R.O. programmes would require examining the relationship of these structural variables to physiological and growth variables currently being studied. Such comparisons could facilitate establishment of juvenille-mature relations and, possibly, lead to alternative strategies and criteria for selecting parent trees.

We suggest that the overall weak clinal trend shown here for this scale of variation of Douglas-fir and the degree of intra-population differentiation argue against establishing rigid seed transfer guidelines. Certainly the extremes in the cline are different but precise recommendations concerning transfer between adjacent areas in the cline should be the subject of more local investigations (cf. Rehfeldt 1979, 1982; Campbell and Franklin 1981; Campbell and Sorensen 1978) than are reported here and should employ other variables more suited to the specific objective in transfer and improvement. For example, although the results presented in Figs. 3 to 5 suggest that certain "interior" populations might better be regarded as "coastal" populations, re-assignment of the populations cannot be recommended without reference to additional evidence and more local investigation of patterns of variation. It should be pointed out that the techniques employeed in this study, although dealing with large scale geographic variation of mature trees, could be easily extended and utilized in a study of local variation of juvenile trees. Indeed, statistically removing the effects of geography by CCA could be an important means of exploring such local variation.

The recognized seed sources are indeed more efficaceous than hypothesized taxonomic varieites in accounting for variation. However the seed source still does not account for as much variation as is accounted for by the recognition of individual populations. This would argue for the necessity of conducting local investigations with respect to the validity of seed transfer. Although seed transfer may be a possibility, or even a necessity, more effective screening and investigation of local variability may well be a more appropriate choice. This shifts the emphasis of studies concerned with silvicultural recommendations to more local levels, levels which account for the majority of observed variation. Seed sources and other broad geographic scale transfer guidelines can be revised and altered only on the basis of locally collected data rather than theoretical constructs. Indeed, the attention to local variation and the associated large porportion of variation attributed to this source serves to emphasize the remarks of deCandolle (1880):

> "There will come a day when science will treat the elements of species just as the elements of genera and families, and all these groups will be co-ordinated into a perfectly uniform system."

and directs our academic and technical attention to this basic source of information and application.

ACKNOWLEDGEMENTS

We should like to thank Cheng Yao for the efforts put into collecting the data and Lee Charleson for assisting with the compilation and computation.

LITERATURE CITED

Adams, W.T. 1981. Population genetics and gene conservation in Pacific Northwest conifers. In, Evolution today. Edited by, G.G.E. Scudder and J.L. Reveal. Hunt Inst. Bot. Doc., Carnegie-Mellon U., Pittsburgh. pp. 401-415.

Campbell, R.K. and J.F. Franklin. 1981. A comparison of habitat-type and elevation for seed-zone classification of Douglas-fir in western Oregon. For. Sci. 27: 49-59.

Campbell, R.K. and F.C. Sorensen. 1978. Effect of test environment on expressin of clines and on delimitation of seed zones in Douglas-fir. Theor. Appl. Gen. 51: 233:246.

Campbell, R.K. and F.C. Sorensen. 1984. Genetic implications of nursery practises. In, Forestry manual for productin of bareroot seedlings. Edited by, M.L. Duryea and T.D. Landis. Dr. W. Junk, Boston. pp. 183-191.

Chatfield, C. and A.J. Collins. 1980. Introduction to multivarite analysis. Chapman and Hall, New York.

Chen, Z.-Y., R.K. Scagel, and J. Maze. 1985. A study of morphological variation in Pseudotsuga menziesii in southwestern British Columbia. For. Sci. (submitted).

Clague, J.J. 1981. Late quaternary geology and geochronology of British Columbia. Geol. Surv. Can., Pap. 80-35.

Cooley, W.W. and P.R. Lohnes. 1971. Multivariate data analysis. John Wiley and Sons, New York.

Daniels, J.D. 1984. Role of tree improvement in intensive forest management. For. Ecol. Mmg. 8: 161-195.

DeCandolle, A.L.P.P. 1880. La phytographie. G. Masson, Paris.

El-Kassaby, Y.A. and O. Sziklai. 1982. Genetic variation and quantitative traits in a selected Douglas-fir (Pseudotsga menziesii var. menziesii) population. For. Ecol. Mono. 4: 115-126

Falconer, D.S. 1981. Introduction to quantitative genetics. 2nd Ed., Oliver and Boyd, Edinburgh.

Falkenhagen, E.R. 1982. A discussion of the effect of test environment on expression of clines and on delimitation of seed zones in Douglas-fir. Theor. Appl. Gen. 63: 282.

Falkenhagen, E.R. and S. Nash. 1978. Multivariate classification in provenance research. Silvae Gen. 27: 14-23.

Flous, F. 1934. Revision de Pseudotsuga. Trav. Lab. For. Toulouse 4(2): 1-132.

Gittins, R. 1979. Ecological applications of canonical analysis. In, Multivariate methods in ecological work. Edited by, L. Orloci, C.R. Rao, and W.M. Stiteler. Int. Co-op. Publ. House, Fairland. pp. 309-535.

Grafius, J.E. 1978. Multiple characters and correlated response. Crop Sci. 18: 931-934.

Green, P.E. 1976. Mathematical tools for applied multivariate analysis. Academic Press, New York.

Haddock, P.G. and O. Sziklai. 1966. Seed collection zones for Douglas-fir in Canada. Proc. 6th World For. Congr. 2: 1467-1473.

Khallil, M.A.K. 1974. Genetics of cone morphology in white spruce (Picea glauca). Can. J. Bot. 52: 15-21.

Lande, R. 1979. Quantitative genetic analysis of multivariate evolution applied to brain:body size allometry. Evol. 33: 402-416.

Lande, R. 1982. A quantitative genetic theory of life history evolution. Ecol. 63: 607-615.

Langlet, O. 1962. Ecological variability and taxonomy of forest trees. In, Tree growth. Edited by, T. Kozlowski. Ronald Pressm New York. pp. 357-370.

Langlet, O. 1963. Patterns and terms of intra-specific ecological variability. Nature 200: 347-348.

Larsen, C.S. 1937. Genetics in silviculture. Trans. H.L. Anderson. (1956) Oliver and Boyd, Edinburgh.

Mitton, J.B., Y.B. Linhart, M.L. Davis, and K.B. Sturgeon. 1981. Estimation of outcrossing in ponderosa pine, Pinus ponderosa Laws., from patterns of segregation of protein polymorphisms and from frequencies of albina seedlings. Silvae Gen. 30: 117-121.

Morrison, D.F. 1976. Multivariate statistical methods. 2nd Ed., McGraw-Hill, Toronto.

Phillips, B.F., N.A. Campbell, and B.R. Wilson. 1973. A multivariate study of geographic variatin in the whelk, Dicathius. J. Exp. Mar. Biol. Ecol. 11: 29-63.

Rehfeldt, G.E. 1978. The genetic structure of a population of Douglas-fir (Pseudotsuga menziesii var. glauca) as reflected by its wind-pollinated progenies. Silvae Gen. 27: 49-52.

Rehfeldt, G.E. 1979. Ecological adaptations in Douglas-fir (Pseudotsuga menziesii var. glauca) populations. I. Northern Idaho and northeast Washington. Heredity 43: 383-397.

Rehfeldt, G.E. 1979. Ecological adaptations in Douglas-fir (Pseudotsuga menziesii var. glauca) populations. II. Western Montana. U.S.D.A. F.S. Res. Pap. INT-295.

Rehfeldt, G.E. 1983. Genetic variability within Douglas-fir populations: implications for improvement. Silvae Gen. 32: 9-14.

Scagel, R.K. 1984. Morphological and anatomical variation of Picea in southwestern British Columbia. M.Sc. Thesis, Botany Dept., U.B.C., Vancouver.

Scagel, R.K., Y.A. El-Kassaby, and J. Emanuel. 1985. Assessing sample size and variable number in multivariate data with specific reference to cone morphology variation in a population of Picea sitchensis. Can. J. Bot. 63: 0000-0000.

Scagel, R.K. and J. Maze. 1984. A morphological analysis of local variation in Stipa nelsonii and S. richardsonii (Gramineae). Can. J. Bot. 62: 763-770.

Silen, R. 1978. Genetics of Douglas-fir. U.S.D.A. F.S. Res. Pap. WO-35.

Shaw, D.V. and R.W. Allard. 1982. Estimation of outcrossing rates in Douglas-fir using isozyme markers. Theor. Appl. Gen. 62: 113-120.

Sorensen, F.C. 1983. Geographic variation in seedling Douglas-fir (*Pseudotsuga menziesii*) from the western Siskiyou mountains of Oregon. Ecol. 64: 696-702.

Sorensen, F.C. and R.S. Miles. 1978. Cone and seed weight relationships in Douglas-fir from western and central Oregon. Ecol. 59: 641-644.

Sziklai, O. 1969. Preliminary notes on variation in some cone and seed morphology of Douglas-fir. Second World Conf. For. Tree Breed., Washington. FO-FTB-69-6/ 9:11.

vonRudloff, E. and G.E. Rehfeldt. 1980. Chemosystematic studies in the genus *Pseudotsuga*. IV. Inheritance and geographical variation in the leaf oil terpenes of Douglas-fir from the Pacific Northwest. Can. J. Bot. 58: 546-556.

Yao, C. 1971. Geographic varition in seed weight, some cone scale measurements, and seed germination of Douglas-fir. M.Sc. Thesis, Fac. Forestry, U.B.C., Vancouver.

Table. 1. Repeatability estimates (Falconer 1981) for morphological variables on the basis of 3 values per tree. Abbreviations given in Fig. 2. NA - not applicable due to lack of measurement of intra-individual variation. $\bar{x}$ repeatability based on the five variables that could be have repeatabilities calculated.

Variable	%SS
SCL	89.25
SCW	88.80
BW	80.67
A1L	55.54
A2L	73.49
TSW	NA
WL	NA
WW	NA
SW	NA
SL	NA
$\bar{x}$	75.55

Table 2. Results of CCA. Component correlatins given in body of table between the variable suite and the respective vector. Intra-/ inter-; intra- and inter-set redundancy for each vector of canonical variate. Abbreviations given in text. *, significant @ p $\geq$ 0.01.

	CANONICAL VARIATES		
	I	II	III
% variance	54.89	32.20	12.91
eigenvalue	0.399	0.234	0.094
Rc	0.631	0.484	0.306
MORPHOLOGY			
TSW	.172 *	.866 *	.276 *
WL	.521 *	-.240 *	.265 *
WW	.678 *	-.006	.211 *
SL	.617 *	.409 *	.051
SW	.319 *	.352 *	.294 *
SCW	.646 *	.256 *	.341 *
BW	.075 *	.238 *	-.308 *
SCL	.476 *	.022	.323 *
A1L	.220 *	.274 *	-.636 *
A2L	.640 *	.174 *	-.477 *
intra-/inter-	.2352/.1672	.1331/.0994	.1227/.0146
GEOGRAPHY			
ELEV	-.525 *	.594 *	.610 *
LAT	-.806 *	-.589 *	.058
LONG	-.577 *	-.759 *	.302 *
intra-/inter-	.4194/.0938	.4252/.0311	.1555/.0115

Table 3. Partitioning of morphological variation. All results for morphological vectors of CCA (% TOTAL CCA) prorated by intra-set redundancy and summed over all canonical variates expressed as a percentage of morphological variation accounted by CCA; parenthetic values indicate percentage of total morphological variation accounted for by CCA. Percentage of total values (% TOTAL) based on average variance component over all morphological variables. ANOVA models given in text.

SOURCE	df	% TOTAL CCA	% TOTAL
POST-GLACIAL	1	9.83 (4.81)	6.76
VARIETY	2	16.71 (8.20)	6.89
POPULATION	85	22.21 (10.91)	19.88
RESIDUAL	1220	51.23 (25.15)	67.26
SEED SOURCE	7	21.50 (10.56)	9.29
POPULATION	81	27.56 (13.53)	23.45
RESIDUAL	1220	51.24 (25.15)	67.26

Table 4. Correlation of within-population variation of CV1 and CV2 mor (σ_1^2, σ_2^2) and within population $|\underline{S}|$ and $|\underline{R}|$. CV1, CV2 mor -scores from morphological vector of first and second canonical variate from CCA. Multiple R^2 from multiple linear regression against latitude, longitude, and elevation (E+L+L). *, significant @ $p \geq 0.01$.

SOURCE	$\lvert\underline{S}\rvert$	$\lvert\underline{R}\rvert$	σ_1^2	σ_2^2
ELEV	.056	-.237	-.062	.183
LATITUDE	.449 *	.097	-.011	-.119
LONG	.117	.250	.109	-.166
CV1 mor	-.368 *	-.041	.095	-.099
CV2 mor	-.348 *	-.202	-.161	.362 *
MULTIPLE R^2: E+L+L	.225	.089	.012	.060

Figure 1. Geographic location of populations used in analysis. Open glyphs - coastal; closed glyphs - interior; dashed line - glacial maximum (Clague 1981). 89 populations of 15 trees.

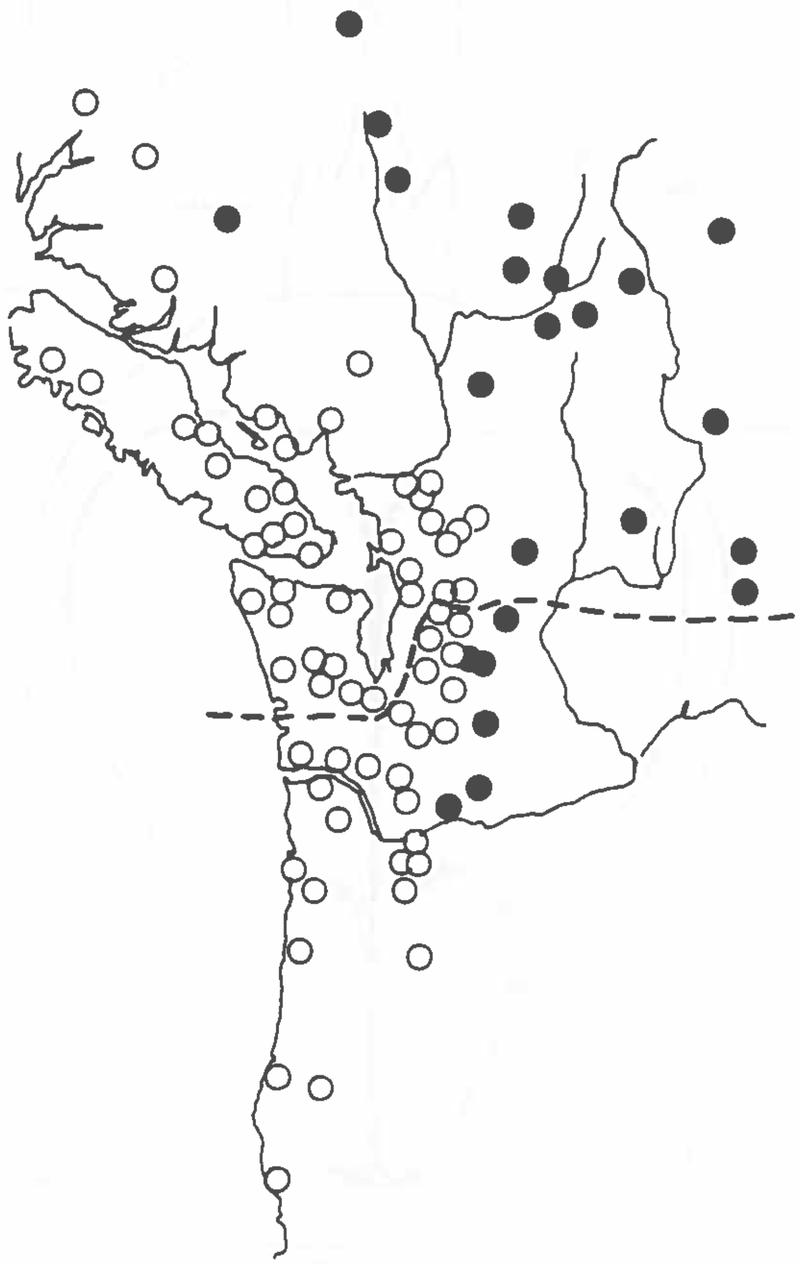


Figure 2. Cone scale morphology variables measured. TSW - thousand seed weight not shown. Abbreviatins explained in text. SCL, SCW, BW, A1L, A2L based on three measures per tree, all other variables based on 1 measure per tree.

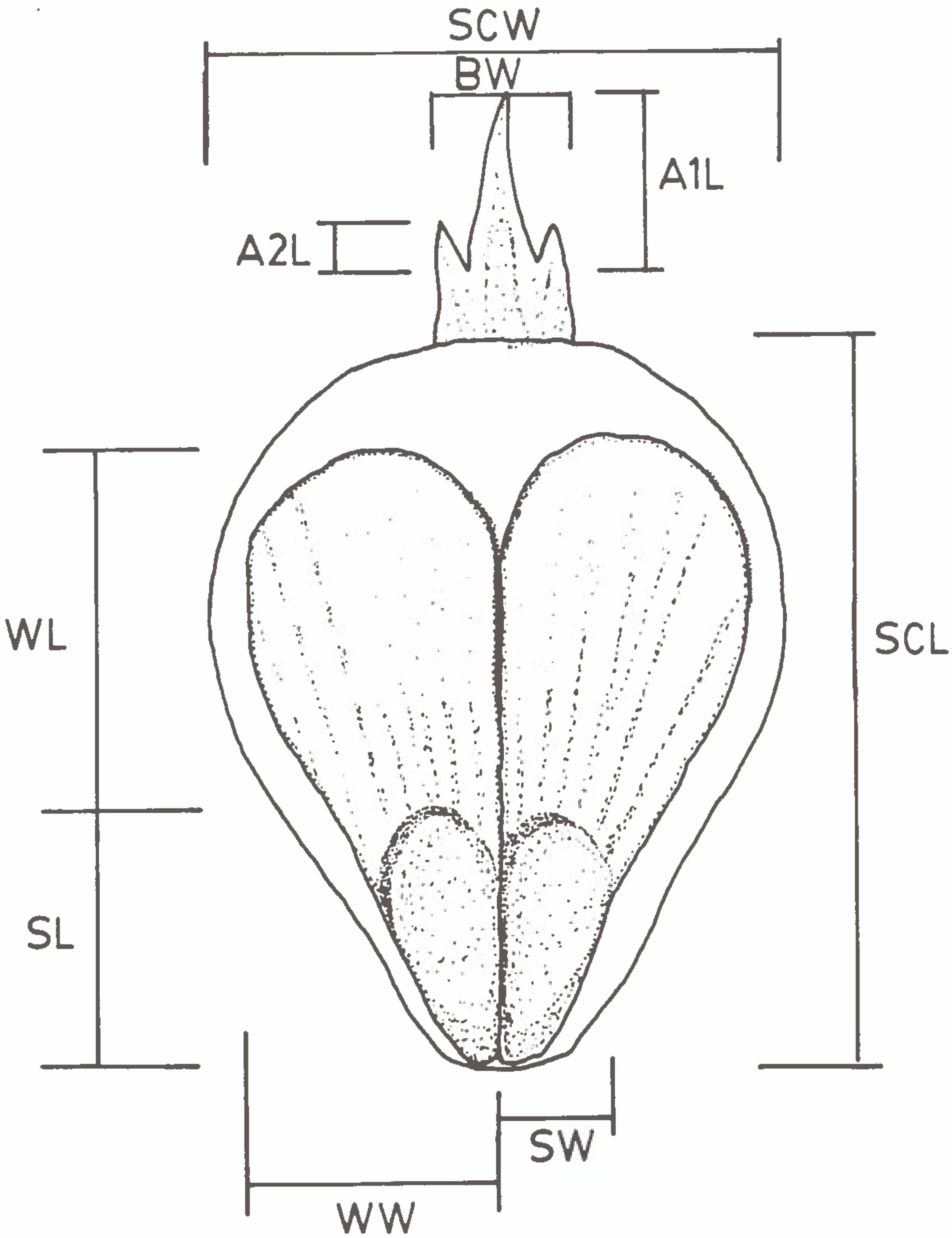


Figure 3. Ordination of centroids of populations for morphological (CV1 mor) and geographic vector (CV1 env) from first canonical variate of CCA. Glyphs as in Fig. 1.

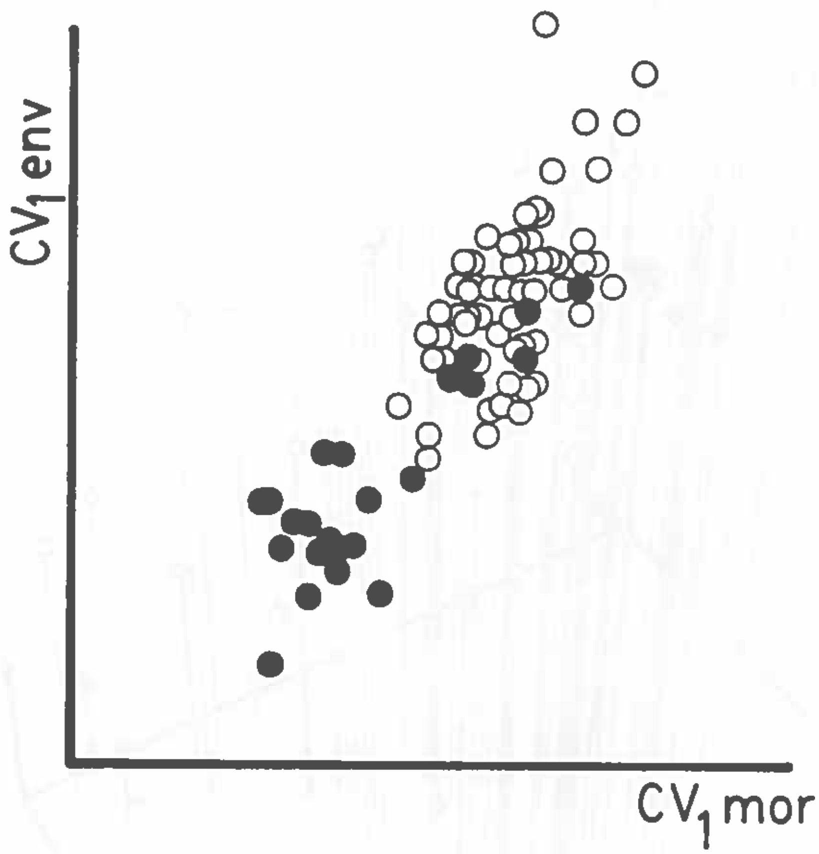


Figure 4. Ordination of centroids of populations for morphological vector (CV1 mor) from first canonical variate against longitude and latitue. Glyphs as in Fig. 1.

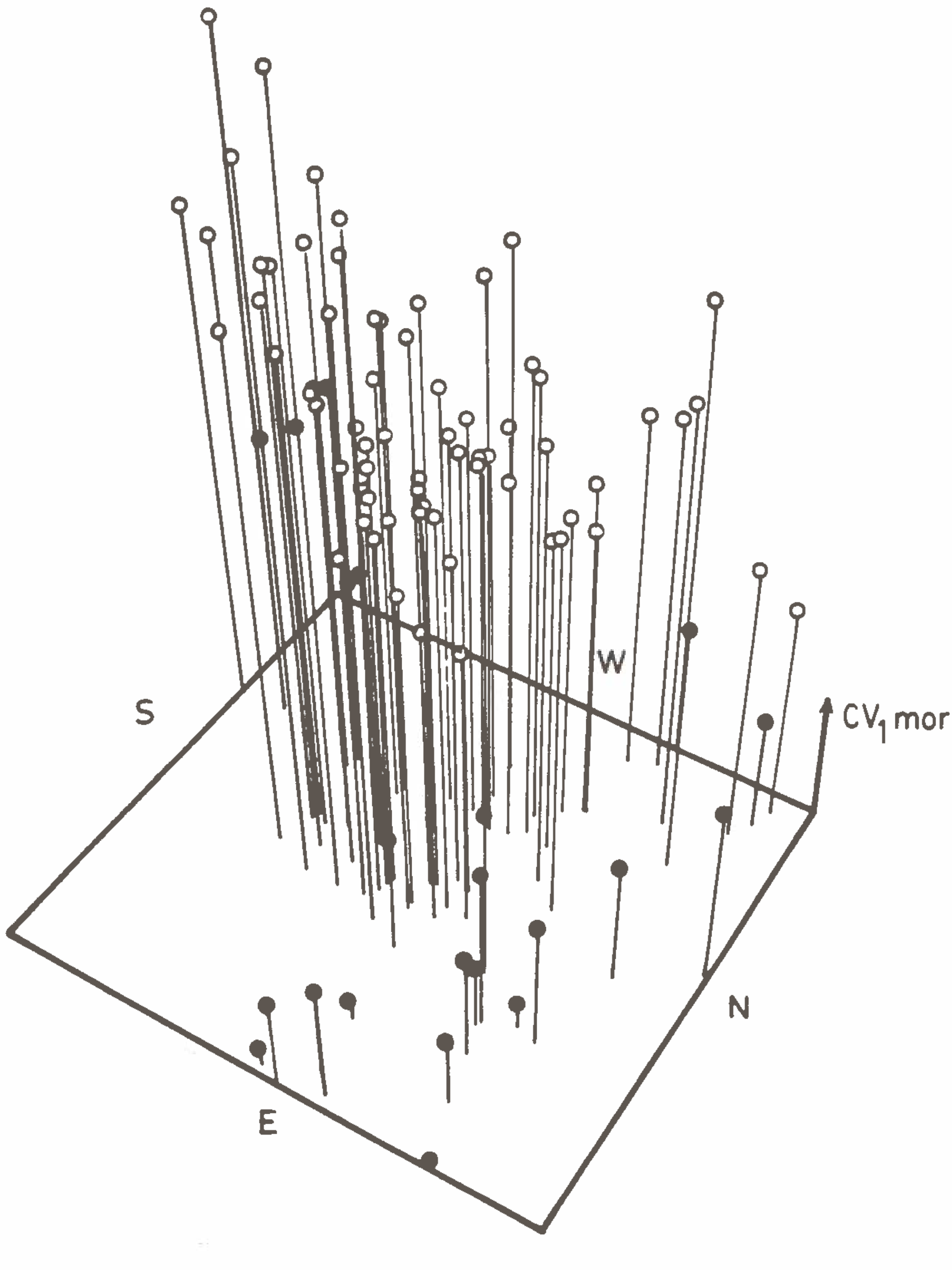
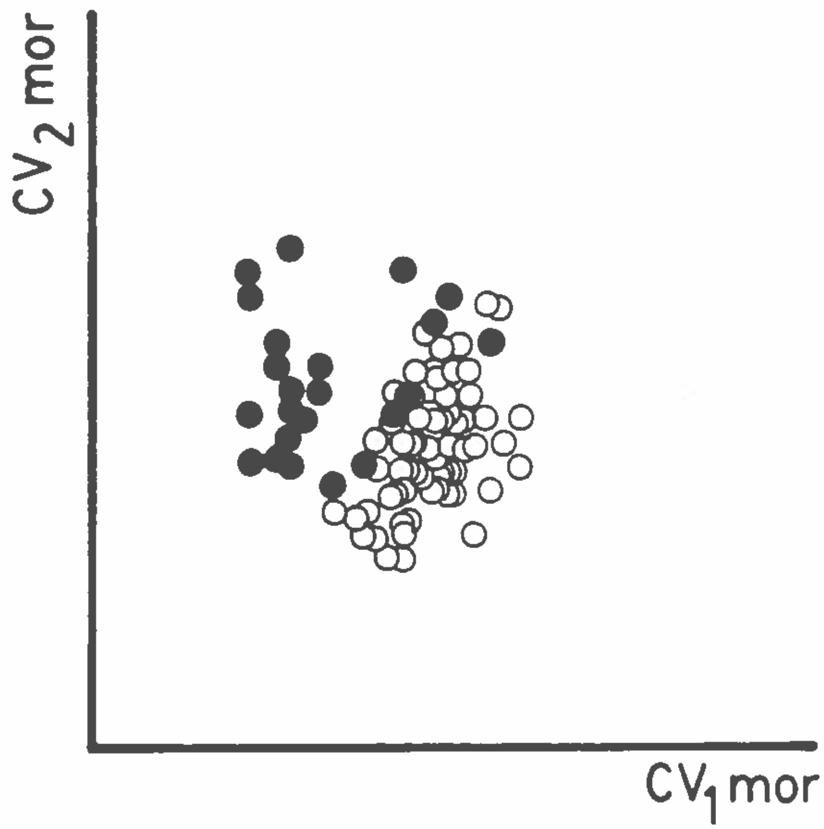


Figure 5. Ordination of centroids of populations for morphological vectors from first two canonical variates of CCA. Glyphs as in Fig. 1.



RELATIONSHIP OF *PSEUDOTSUGA MENZIESII* WITH OTHER *PSEUDOTSUGA* SPECIES INFERRED FROM KARYOTYPE RECONSTRUCTION.

O. Sziklai[1], Y.A. El-Kassaby[1,2], and R.K. Scagel[3]

[1] Faculty of Forestry University of British Columbia, Vancouver, B.C. V6T-1W5.

[2] C.I.P. Forest Products Inc., Tahsis Pacific Region, 8067 E. Saanich Rd., R.R. #1, Saanichton, B.C., V0S-1M0.

[3] Botany Department, University of British Columbia, Vancouver, B.C. V6T-2B1.

ABSTRACT

Evaluation of chromosome morphology for seven of the eight species of *Pseudotsuga* suggests that *Pseudotsuga menziesii* departs strongly from other species in the genus. The karyotype of the two varieties of *P. menziesii*, var. *menziesii* and *glauca*, are shown to be poorly differentiated. Assuming that karyotype differentiation of *P. menziesii* is the result of a misdivision of a metacentric chromosome and the production of stable telocentrics, an ancestral karyotype is hypothesized and reconstructed. The reconstructed karyotype, as well as others, were submitted to multivariate analysis and suggests that *P. menziesii* is more similar to the North American *P. macrocarpa* than to any of the Asiatic species. The results further suggest that karyotypic differentiation amongst the Asiatic species is not as pronounced as might otherwise be expected based upon their present allopatric distribution. Indeed, the karyotypic differentiation amongst the Asiatic species is not as discrete as among the two varieties of *P. menziesii*.

Keywords: *Pseudotsuga*, karyotype, multivariate analysis.

INTRODUCTION

Pseudotsuga menziesii (n=13) and *Pseudolarix amabilis* (n=22) are the only species of the Pinaceae known to exhibit deviations from the basic chromosome number of n=12 (Sax and Sax 1933; Zenke 1953; Mehra and Khoshoo 1956). Of the eight species of *Pseudotsuga*, seven have been karyotyped and, with the exception of *P. menziesii*, all have morphologically similar haploid compliment resembling that of other Pinaceous species (see review in El-Kassaby, *et al*. 1983).

It is generally agreed that the karyotype of *P. menziesii* consists of five metacentrics, six submetacentrics, and two telocentric chromosomes (Fig. 1). These observations refute earlier conclusions that there was a haploid compliment of 12 chromsomes (Langlet 1932; Durrieu-Vabre 1958) or that the telocentrics were infact subtelocentric (Owens 1967; DeVescovi and Sziklai 1975). Observations on the karyotyped Asiatic species (*P. forrestii*, *P. gaussenii*, *P. japonica*, *P. sinensis*, and *P. wilsoniana*) and *P. macrocarpa* indicate that all have six pairs of metacentric and submetacentric chromosomes (Fig. 1).

Explanations for the lack of a pair of metacentric chromosomes compared with other *Pseudotsuga* species and the presence of two telocentric pairs in *P. menziesii* have been suggested by several authors. These explanations have assumed the karyotype of n=12 is pleisiomorphic on the basis of the karyotype of the other *Pseudotsuga* species and the ubiquity of this haploid compliment in other Pinaceous species. Sax and Sax (1933) hypothesized that segmental interchange and duplication through non-disjunction might account for such an increase in chromosome numbers and the morphology of *P. menziesii*. Barner and Christiansen (1962) have suggested that centromere breakage (misdivision) may account for the extra chromosomes. Thomas and Ching (1968) have proposed the most elaborate mechanism involving chromosome translocation - seven consecutive successfull structural mutations in four generations!

The parsimony of Barner and Christiansen's (1962) explanation is appealing in comparison with the convoluted and improbable scenarios tendered by Sax and Sax (1933) and Thomas and Ching (1962). These alternative hypotheses assume that telocentric chromosomes are unstable, thus these proposed explanations had to consider the occurrence of subtelocentric chromosomes rather than telocentrics. Additionally, the known karyotype abnormalities in *P. menziesii* suggest that the type of chromosome abnormalities hypothesized by Sax and Sax (1933) and Thomas and Ching (1968) are either deleterious or results in severe morphological abnormalities and reproductive sterility (Owens 1967; Ching and Doerksen 1971; Hermann 1982).

In this study we have hypothetically reconstructed the precursor karyotype of *P. menziesii* by assuming a single meiotic misdivision, that proposed earlier by Barner and Christiansen (1962), but with a different chromosome breakage. We have compared this hypothesized precursor karyotype to that of the other karyotyped Pseudotsuga species. Such a comparison may indicate here-to-the-fore unreported relationships amongst species of Pseudotsuga. Such relationships may be of value in explaining the phylogeny of the genus.

MATERIALS AND METHODS

Materials and cytological techniques

Root tips and vegetative buds from seven species (P. forrestii (PF), P. gaussenii (PG), P. japonica (PJ), P. macrocarpa (PM), P. sinensis (PS), and P. wilsoniana (PW)), and the two varieties of P. menziesii (menziesii (PMM), and glauca (PMG)) were treated with colchicine, fixed, stained, and spread to examine for chromsomes. Materials were not available for the asiatic P. brevifolia. Separate chromosomes were photographed, arms were measured, and the homology amongst chromosomes inferred by ranking according to relative length and relative position of the centromere (further details in El-Kassaby, et al. 1983).

Reconstruction of ancestral P. menziesii karyotype

The assumptions made in reconstructing the ancestral karyotype to P. menziesii are: n=12 is the pleisiomorphic karyotype in the genus; telocentric chromosomes are the results of misdivision of a metacentric chromosome;and, following misdivision, the overall form of the karyotype has remained relatively unchanged or proceeded uniformly in all species. In the actual reconstruction of the karyotype, the relative size of the telocentric chromosomes suggested that they were the result of a misdivision of a metacentric chromosome in the precursor karyotype. Secondly, the overall size of the telocentrics suggested that the size of the ancestral metacentric was rougly equivalent to chromosomes II, III, and IV of the extant n=12 species (Fig. 1). Thirdly, using the location of secondary constrictions as a source of additional karyotypic information (Stewart 1947), and assuming that the secondary constriction on the long arms of chromsomes II and IV are pleisiomorphic, then, by elimination, the metacentric precursor to the telocentrics must have been homologous to the metacentric chromosome III of the n=12 species. A diagram of the reconstruction and re-arrangement of P. menziesii karyotype is given in Fig. 2.

Statistical analyses

El-Kasssaby *et al*. (1983) performed a stepwise discriminant function analysis (forward-selection) on the measured length of the chromosome arms (Pi and Qi), total length of the chromosome (Pi + Qi), as well as a series of ratios based on these original variables: arm ratio, centromere index, morphological index, and relative length. The number of variables used in their analysis were 91. The number of samples (cells) used per species (callibration group) were 20 for *P. gaussenii* and 40 for all other species and varieties.

In this study two multivariate techniques, principal components analysis (PCA) and canonical variates analysis (CVA) were used in the data analysis. Only two variables per chromosome (Pi and Qi) were used. PCA was employed to identify the major components of variation expressed in the data and to generate summary variables by which the degree of variation expressed between cells within species could be compared among the different species. CVA was performed on PCA axis scores and was used to investigate inter-species relationships. Utilizing PCA for such dimensionality reduction follows suggestions in Gittins (1979) and Chatfield and Collins (1980). This reduction in dimensionality was necessary owing to the dimensional constraints associated with CVA. The calibration groups used in the CVA consisted of dividing the total number of samples (cells) per species into groups of 10 samples. Utilizing such groups in a CVA will aid in detecting the presence of any significant differences among the species by evaluating the CVA scores with a one-way ANOVA.

The use of PCA and CVA in this manner will respect the nature of the data, the caveats of the statistical techniques used, and the nature of the desired comparisons. It avoids the dimensionality, dependancies, lack of validation, and circularity inherent in the stepwise variable selection of El-Kassaby *et al*. (1983).

RESULTS

Original karyotype data

PCA of the original data indicated (Table 1a) that the first component accounted for the largest source of variation in the data (86%). The size and sign of the eigenvector values associated with this component suggested that the lack of a short arm (Q12) and the presence of chromosome 13 in *P. menziesii* strongly influences the bipolar nature of the component.

The scores from the first component of the previous analysis were subjected to a one-way ANOVA and the results (Table 2a) indicate that thirty percent of the variation associated with this component is due to differences amongst the species, primarily *P. menziesii versus* all other species. Prorating the results of this ANOVA by the amount of variation extracted by this component indicates that only 30% of the total karyotypic variation was accounted for (Table 2).

Performing separate PCAs for the n=12 species and the n=13 varieties (Tables 1b,c, 2b,c) removes the convoluting effects created by a highly polar data set that included *P. menziesii*. In both PCAs the first components accounts for the largest source of variation in the data (92% and 97% for n=12 and n=13 respectively) and the relative size of the component coefficients suggest that these components are reflecting primarily size differences among the karyotypes.

The differentiation among the two varieties of *P. menziesii* (Table 1c) is equivalent to that shown among the Asiatic species and *P. macrocarpa* (Table 1b). Further, ANOVA of component scores (Table 2b,c), suggests that the amount of variation due to differences among the six n=12 species is just slightly less than that between the two *P. menziesii* varieties.

CVA based upon component scores was performed. The results are given in Table 3a. The polarity evident in the PCA (Table 1a) is further emphasized (Fig. 3) for the first canonical variate (Table 3a).

Average Mahalanobis' D^2 values among species (Table 4a) and groups of species (Table 5a), suggest that karyotype differentiation amongst the Asiatic species is virtually identical to that of differentiation among the varieties recognized for *P. menziesii*. There appears to be three groups of taxa: the five Asiatic n=12 species, *P. macrocarpa*, and *P. menziesii* (Fig. 3).

Reconstructed karyotype data

PCA utilizing the reconstructed karyotype for *P. menziesii* (Table 1d, 2d) greatly reduces the polarity compared to the orginal data (Table 1a). Generally the data reflects size differences in the karyotypes, *P. menziesii* having smaller chromosomes than the other species (Fig. 1).

CVA based upon component scores from PCA was performed (Table 3b and Fig. 4). Average D^2 values (Tables 4b and 5b), indicate the *P. menziesii* is slightly more similar to *P. macrocarpa* than the Asiatic species. Further, the results suggest that *P. gaussenii* is discrete with respect to the other Asiatic species. Indeed, the overlap of standard deviations around the canoncial variate means for the first component suggests that *P. gaussenii* is, of the Asiatic species, the most similar to *P. menziesii*. The D^2 values amongst Asiatic species further corroborate the impression from the ordination that the karyotype of P. gaussenii is the most discrete of the Asiatic species.

DISCUSSION

Karyotype evolution appears to have been remarkably slow in the Pinaceae. All but two of the 209 species in nine genera of this family have the same chromosome number (n=12) (Stern and Roche 1974). Prager et al. (1976) estimated that the average rate of karyotypic evolution in the Pinaceae has been 0.04 changes in chromosome number per lineage per 10^8 years. Besides being conservative with respect to chromosome number, the Pinaceae are also conservative with respect to chromosome re-arrangements.

The results presented here are clearly at variance with those presented by El-Kassaby et al. (1983). Differences in results are attributed to differences and appropriateness of analytic technique. The n=13 karyotype of P. menziesii is clearly discrete in the genus. P. macrocarpa is shown here to be different from the other species in the genus. The lack of differentiation amongst the Asiatic species is suggestive of the same degree of differentiation seen between the varieties of P. menziesii.

Successfull crossability studies have been conducted between P. menziesii and P. macrocarpa (Ching 1959) but the resultant numbers of fertile seeds produced was small (see also Silen 1978). These "hybrids" were planted and, after 25 years exhibit menziesii characteristics (Ching, pers. comm.) suggesting either menziesii chromosomes have become dominant or casting doubt on the authenticity of the hybridization. Controlled crosses between P. menziesii and P. wilsoniana conducted by Orr-Ewing proved unsuccessfull (Heaman, pers. comm.).

Stebbins (1971) has suggested that the trend in karyotype evolution has been toward increasing asymmetry in chromosome size and number of acrocentric chromosomes relative to metacentrics. If, as postulated here, the n=13 karyotype is derived, then evolution has been accompanied by an increased asymmetry through reduction of the number of metacentric chromosomes and by an increase in the number of acrocentric chromosomes.

The indication that size differences of the karyotype is the major source of differentiation in the genus and that the most recent species, P. menziesii, has the smallest chromosomes suggests that karyotype reduction and fragmentation has been an evolutionary trend in Pseudotsuga. That size differences are indicated as being the major source of variation among the two subspecies of P. menziesii corroborates the earlier findings of DeVescovi and Sziklai (1975). Further, the smaller size of var. menziesii, suggests that it is a more recently derived lineage than var. glauca. Further studies concerned with the assessment of qualitative differences associated with this trend may be revealing concerning karyotype evolution in Pseudotsuga.

Accepting these trends in karyotype evolution, it would appear that the Asiatic species are more pleisiomorphic than the North American species. The nature of the occurrence of secondary constrictions suggests that these features may be independent of overall karyotype diversification.

Darlington (1937) hypothesized that, in conifers, the nucleus-cytoplasm ratio has reached an equilibrium and is, at present, at an upper limit. That is, at a stage when any alterations are deleterious. This may be part of the reason for the rarity of polyploidy in Gymnosperms (Khoshoo 1959). The change in equilibrium by duplication or deficiency results in weak and slow growing individuals. In most cases any observed chromosomal abnormalities (i.e. trisomics; Owens 1967) have been detected in the protected habitats associated with nurseries. The misdivision proposed here for chromosome III did not appear to have upset this equilibrium.

The data presented here suggest that the karyotypic diversification amongst the Asiatic species of Pseudotsuga is equivalent to that shown for the two varieties of P. menziesii. This sugests that diversification amongst these species might not be as pronounced as their geographic distributions suggest, thus corroborating Hermann's (1982) view of morphological diversificiation amongst the Asiatic species. The lack of karyotypic diversification could be explained in that the present distribution is the result of comparatively recent destruction and confinement of the Asiatic species to apparently relictual habitats. If in fact this is the case, the diversity of Asiatic taxa may constitute an important source of variation for breeding programmes associated with Asiatic forestry.

The data presented here represent one source of information concerning taxonomic relationships in the genus. Additionaly, thorough morphological study (Changde 1981) would greatly increase our knowledge of this genus for the purpose of reconstructing its phyllogeny. Prior to any serious revision, there should be a concerted effort made to examine morphological variables. Karyotypic data is necessary but not sufficient in itself as an autonomous arbiter in taxonomic decisions (Stebbins 1950). Controlled breeding amongst the Asiatic species may prove especially rewarding. Further, the nature of the hypothesized relation of the acrocentrics of P. menziesii to metacentric chromsome II in the other species would be ameniable to further karyotypic testing.

The results presented here point to the need to conduct more intensive studies on Pseudotsuga as well as other genera of conifers. Particularly important is the issue of the inter-relationships amongst Asiatic species. Considering this issue brings up whether the taxonomic treatment or evolution in the conifers has been liberal. Similar remarks have been raised with respect to Picea (Wright 1955, LaRoi and Dugle 1968) and Douglas-fir (Langlet 1963) and serves to underscore the necessity for population based studies as an adjunct to any systematic revision.

ACKNOWLEDGEMENTS

The data used here were collected by Anna M. Colangeli for her Masters Thesis and her technical assistance is acknowledged. Thanks are also extended to Zhon-zing Chen for rendering interpretation of the available Chinese literature. We would also like to thank L. Irvine for preparing the figures.

LITERATURE CITED

Barner, H. and H. Christiansen. 1962. The formation of pollen, the pollination mechanism, and the determination of the most favourable time for controlled pollination of in *Pseudotsuga menziesii*. Silvae Gen. 11: 89-102.

Chatfield, C. and A.J. Collins. 1980. Introduction to multivariate analysis. Chapman and Hall, New York.

Changde, C. 1981. A brief introduction to the Chinese species of the genus *Pseudotsuga*. Davidsonia 12: 15-17.

Ching, K.K. 1959. Hybridization between Douglas-fir and bigcone Douglas-fir. For. Sci. 5: 246-254.

Ching, K.K. and A. Doerksen. 1971. A natural chimera of Douglas-fir. Silvae Gen. 20: 209-210.

Darlington, C.D. 1937. Recent advances in cytology. J. & A. Churchill Ltd., London.

DeVescovi, M.A. and O. Sziklai. 1975. Comparative karyotype analysis of Douglas-fir. Silvae Gen. 24: 68-72.

Durrieu-Vabre,A. 1958. Chromosomes de *Pseudotsuga douglasii* Carr. C.R. Hebd. Seances Acad. Sci. 246: 3660-3663.

El-Kassaby, Y.A., A.M. Colangeli, and O. Sziklai. 1968. A numerical analysis of karyotypes in the genus Pseudotsuga. Can. J. Bot. 61: 536-544.

Gittins,R. 1979. Ecological applpication of canonical analysis. In, Multivariate methods in ecological work. Edited by, L. Orloci, C.R. Rao, and W.M. Stiteler. Int. Co-op. Publ. House, Fairland. pp. 309-535.

Hermann,R.K. 1982. The genus Pseudotsuga : historical records and nomenclature. For. Res. Lab., Ore. State U., Special Publ. 20.

Khoshoo,T.N. 1959. Polyploidy in Gymnosperms. Evol. 13: 24-39.

Langlet, O. 1932. Uber chromosomenverhaltnisse und systematik der Ranunculaceae. Sven. Bot. Tidskr. 26: 381-400.

Langlet, O. 1963. Patterns and terms of intra-specific ecological variability. Nature 200: 347-348.

LaRoi, G.H. and J.R. Dugle 1968. A systematic and genecological study of Picea glauca and P. engelmannii using paper chromatograms of needle extracts. Can. J. Bot. 46: 649-687.

Mehra, P.N. and T.N. Khoshoo. 1956. Cytology of conifers. J. Gen. 54: 165-180.

Owens, J.N. 1967. Chromsome aberrations in Douglas-fir. Can. J. Bot. 45: 1910-1913.

Prager, E.M., D.P. Fowler, and A.C. Wilson. 1976. Rates of evolution in conifers (Pinaceae). Evol. 30: 637-649.

Sax, K. and H.J. Sax. 1933. Chromosome number and morphology in the conifers. J. Arn. Arb. 14: 256-274.

Silen, R. 1978. Genetics of Douglas-fir. U.S.D.A. Forest Serv. Res. Pap. WO-35.

Stebbins, G.L. 1950. Variation and evolution in plants. Columbia Univ. Press, New York.

Stebbins, G.L. 1971. Chromosomal evolution in higher plants. Addison-Wesley Publ. Co., Reading.

Stern, K. and L. Roche. 1974. Genetics of forest ecosystems. Springer-Verlag, New York.

Stewart, R.N. 1947. The morphology of somatic chromosomes in Lilium. Amer. J. Bot. 34: 9-26.

Thomas, G. and K.K. Ching. 1968. A comparative karyotype analysis of *Pseudotsuga menziesii* (Mirb.) Franco, and *P. wilsoniana* Hayata. Silvae Gen. 17: 138-143.

Wright, J.W. 1955. Species crossability in spruce in relation to distribution and taxonomy. For. Sci. 1: 319-349.

Zenke, U. 1953. Untersuchungen ueber den Ablauf der meisosis bei *Pseudotsuga taxifolia* Britt. Silvae Gen. 2: 96-102.

Table 1. Results of PCA of karyotypes. Only first component shown.

	a. Original	b. Original (n=12)	c. Original (n=13)	d. Recons.
EIGENVALUE	21.55	22.15	23.19	22.50
% VARIANCE	86.19	92.29	96.63	93.76
VARIABLE		EIGENVECTOR VALUES		
P1	.210	.207	.205	.206
Q1	.211	.206	.206	.206
P2	.210	.206	.205	.206
Q2	.210	.205	.205	.206
P3	.211	.208	.203	.207
Q3	.212	.207	.205	.200
P4	.211	.207	.205	.206
Q4	.212	.206	.205	.206
P5	.212	.208	.205	.207
Q5	.212	.207	.205	.207
P6	.199	.205	.206	.205
Q6	.182	.192	.204	.197
P7	.212	.208	.206	.207
Q7	.208	.202	.204	.203
P8	.211	.206	.205	.206
Q8	.206	.201	.203	.202
P9	.211	.206	.205	.206
Q9	.205	.200	.203	.200
P10	.211	.206	.204	.206
Q10	.207	.201	.201	.202
P11	.210	.206	.203	.206
Q11	.205	.198	.201	.200
P12	.136	.205	.204	.205
Q12	.147	.195	-	.198
P13	-.080	-	.203	-

Table 2. ANOVA of PCA scores for all components with eigenvalues ≥ 1.0 for karyotype data. *, @ $p \leq 0.01$. % of total sums of squares. df - degrees of freedom (among/within taxa).

	a	b	c	d
	ORIGINAL	ORIGINAL (n=12)	ORIGINAL (n=13)	RECONS.
(df	7/292	5/214	1/79	7/292)
SOURCE				
AMONG TAXA	30.44*	9.32*	10.59*	21.14*
WITHIN TAXA	69.56	90.68	89.41	78.86

Table 3. Results of CVA of (a) original and (b) reconstructed karyotype data. R - canonical correlation. Only first canonical variate given.

	a	b
EIGENVALUE	29.67	4.13
R	.98	.90
% VARIANCE	92.04	69.99
PCA AXIS		
I	-.564	.018
II	3.001	2.448
III	.087	-2.666

Table 4. Average Mahalanobis' D^2 values within and among species for (a) original and (b) reconstructed karyotype data. Diagonal elements: average D^2 values amongst random replicates within species. Off-diagonal elements, average D^2 among species.

		PF	PG	PJ	PS	PW	PM	PMM	PMG
	PF	0.3							
	PG	1.9	0.8						
	PJ	1.4	1.7	1.5					
	PS	1.3	1.1	1.0	1.0				
(a)	PW	0.6	2.8	1.4	1.6	0.5			
	PM	16.8	13.9	20.4	18.3	21.6	0.9		
	PMM	120.6	138.9	133.1	133.5	119.3	136.0	0.7	
	PMG	136.8	155.3	148.7	128.6	154.9	154.9	2.1	1.8
	PF	0.5							
	PG	26.5	2.8						
	PJ	7.6	8.5	1.5					
	PS	3.9	12.7	1.6	0.9				
(b)	PW	1.6	18.8	3.5	1.6	0.6			
	PM	34.4	16.4	25.3	26.9	29.9	1.5		
	PMM	11.3	11.5	8.6	8.9	9.9	9.5	0.4	
	PMG	16.3	7.3	8.8	10.2	13.4	6.3	1.7	1.2

Table 5. Average D^2 values within and among groups of species for (a) original and (b) reconstructed karyotypes. Diagonal elements average D^2 values amongst random groups within groups of species. Off-diagonal elements, average D^2 among groups of species.

		ASIATIC	PM	PMM & G
	ASIATIC	1.2		
(a)	PM	1.5	0.9	
	PMM & G	136.4	145.5	1.3
	ASIATIC	6.8		
(b)	PM	26.6	1.5	
	PMM & G	10.6	7.9	1.1

Figure 1. Idiograms of karyotypes of species and varieties of *Pseudotsuga* studied.

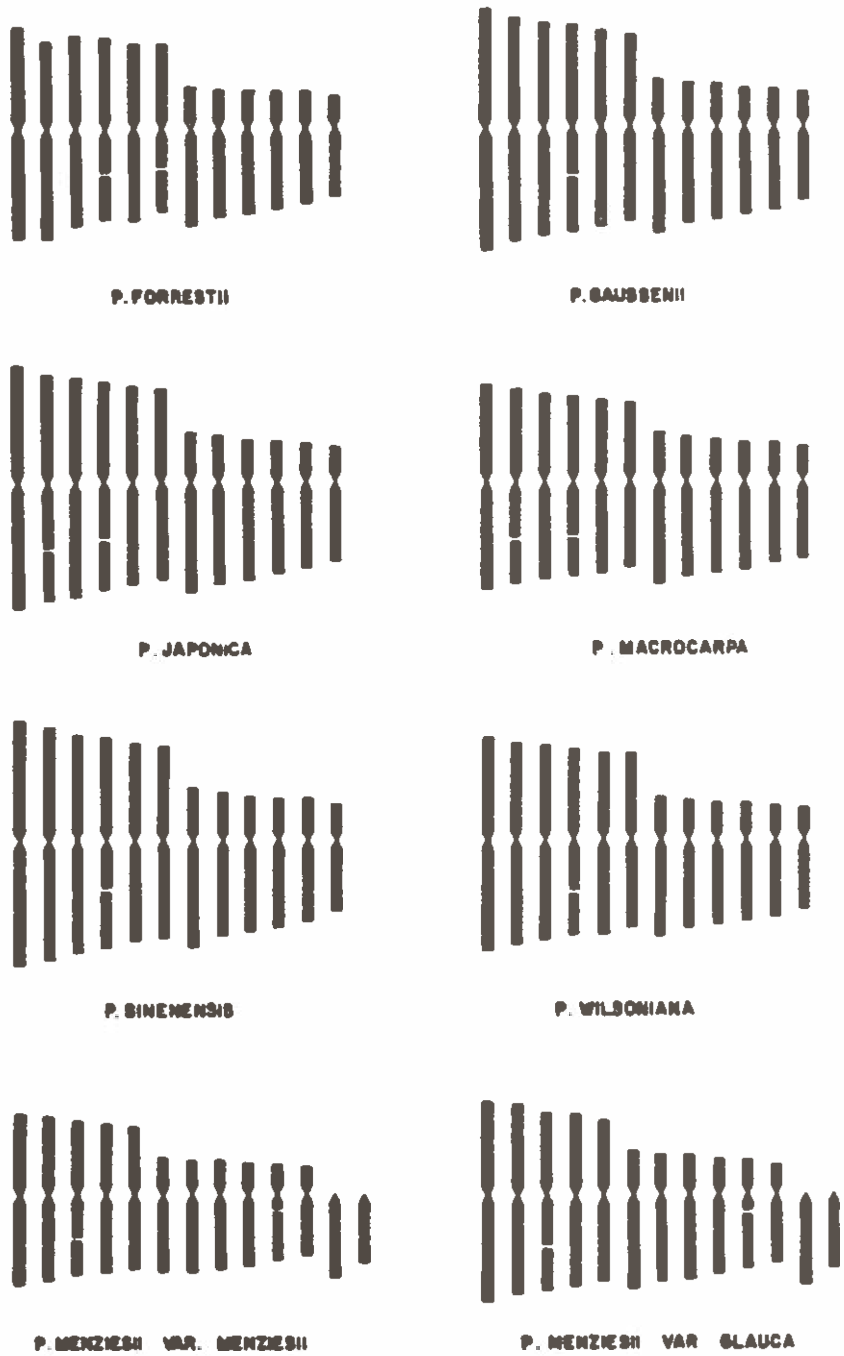
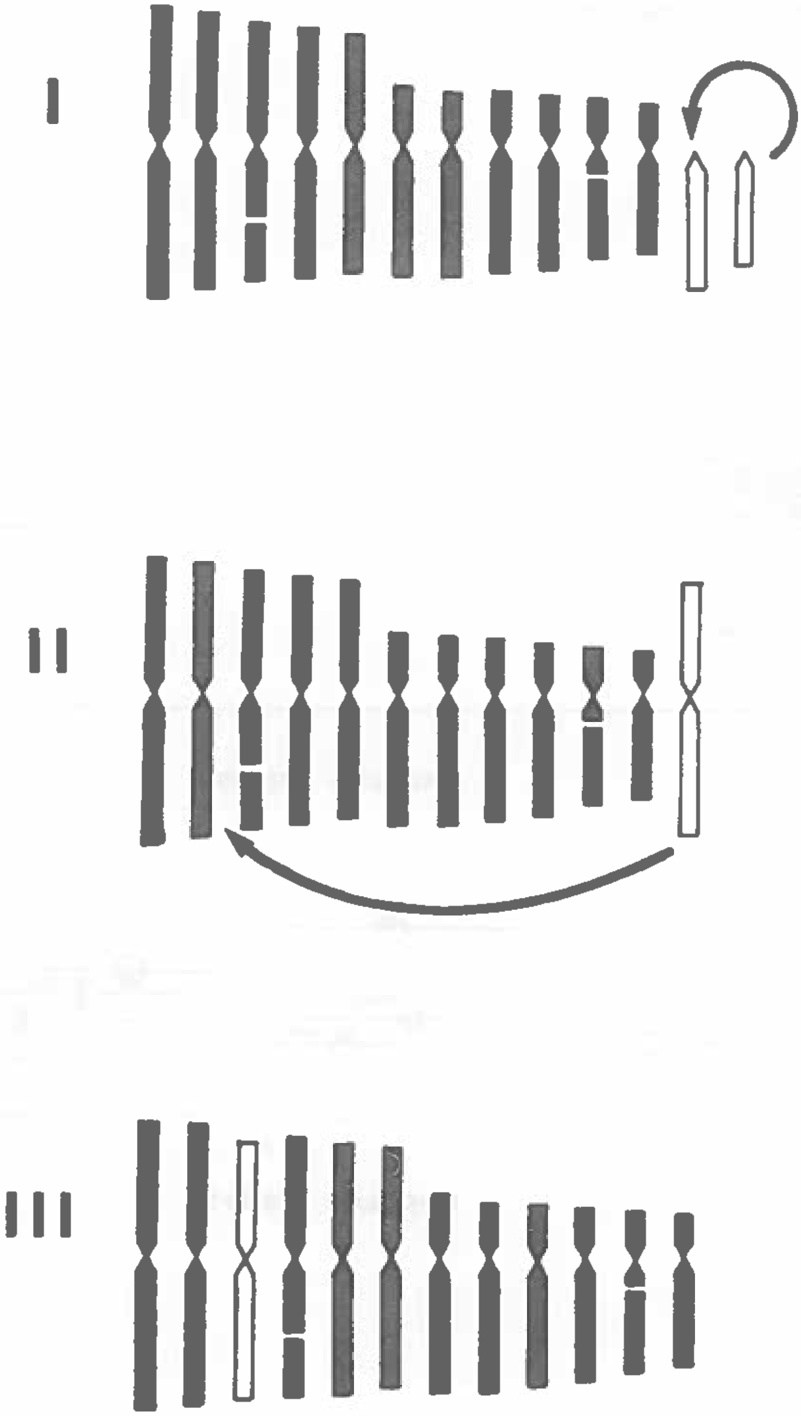
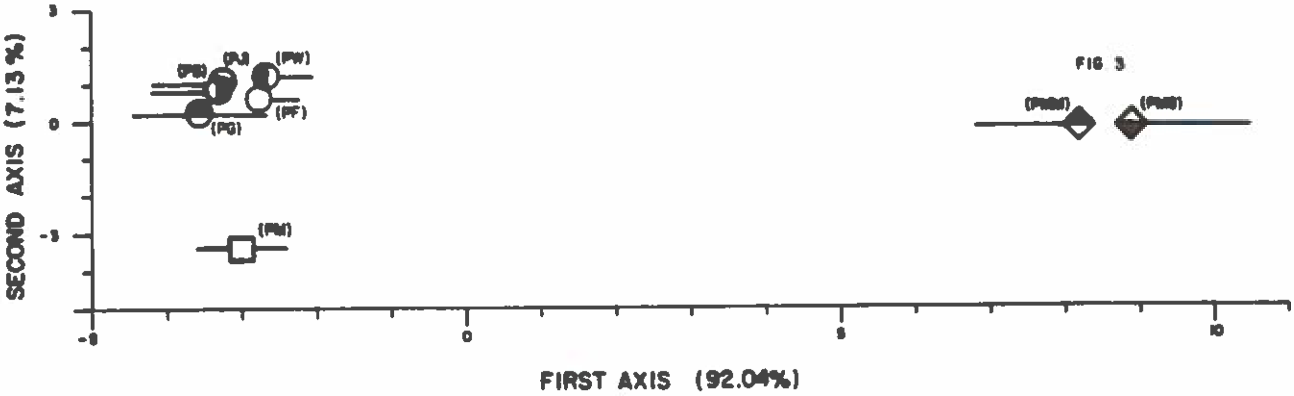
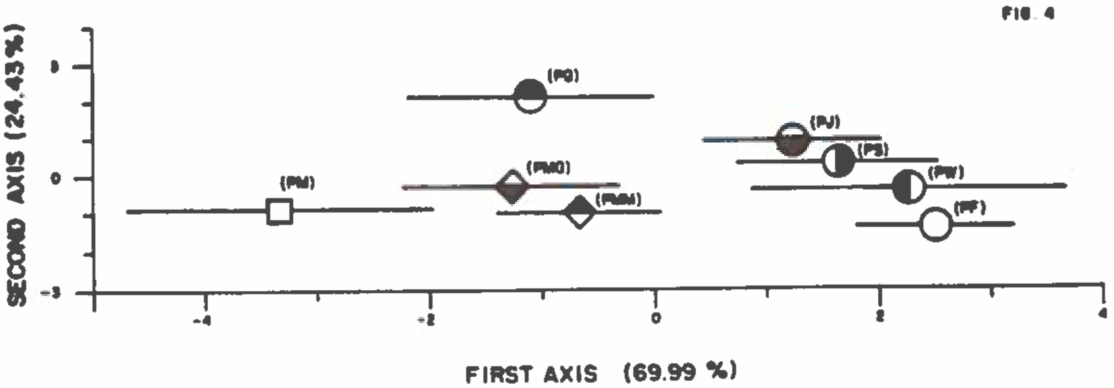


Figure 2. Hypothesized meiotic disjunction and inferred reconstruction of <u>Pseudotsuga menziesii</u>.



Figures 3 and 4. Figure 3. Ordination of first two canonical variates from CVA of original karyotype data for all species. Glyphs represent centroids and standard deviations around centroid. Standard deviations for the second canonical variate smaller than the glyphs. Percentages in brackets indicate amount of variation accounted for by canonical vector. Figure 4. Ordination of first two canonical variates from CVA of reconstructed karyotype data for all species. Glyph as in Fig. 3.





SESSION II

- P O S T E R -

DOUGLAS FIR IN BELGIUM: BREEDING STRATEGY AND THE EVOLVING SEED ORCHARD

PAQUES, L. and NANSON, A.
EEC grant DG XII,
Station de Recherches forestieres et hydrobiologiques
B-1990 Groenendaal-Hoeilaart (Belgium)

ABSTRACT

The breeding strategy of Douglas Fir in Belgium is briefly summarized. It follows the general scheme given by NANSON (1979) and includes furthermore the new concept of the EVOLVING SEED ORCHARD.

Some 8 ha of Douglas Fir Evolving Seed Orchard are presently under establishment in Belgium.

Through a Permanent Evaluation System and regular adjustments (replacement, over-grafting, etc) of its clonal composition, the Evolving Seed Orchard should be a synthesis of the best available genetic material. It is proposed as an alternative to traditional Seed Orchards which, with their fixed number and nature of clones become usually obsolete by the time they produce seed.

A high genetic quality connected with a high number of entries (100 groups of several clones) will make this system a flexible and economical tool for: Breeding and Gene Conservation, Seed Production, and as soon as problems related to vegetative propagation techniques are solved, it could become the source for top-performant Multiclonal Varieties.

Continuous and immediate progress, high flexibility at low cost, genetic diversity and increased resistance-adaptation with nevertheless fair high gain, and possible coupling with multiclonal varieties are some of the advantages presented by this new system. Some drawbacks could be however: decreased seed production, some loss of gain from its possible expected maximum, and increased complexity. To overcome the latter and reduce the former, the developments of computerized systems for Management of the orchard, Permanent Evaluation of its components, and Optimization of its 3 functions are underway.

Literature cited:

NANSON, A. (1979); Optimal combination of provenance research and of individual breeding in Norway Spruce. IUFRO Joint Meet. Romania; Sept. 1979, 13 p.

STEM SINUOSITY MEASUREMENT IN YOUNG DOUGLAS-FIR PROGENY TESTS

W. T. ADAMS and GLENN T. HOWE

Department of Forest Science, Oregon State University
Corvallis, OR 97331

ABSTRACT

Methods of visually assessing stem sinuosity in 12- to 13-year-old families of Douglas-fir [Pseudotsuga menziesii Mirb. (Franco)] were studied by measuring trees in a total of four plantations in two progeny tests. The most efficient method for accurately evaluating families for this trait was the scoring of maximum stem displacement in the interwhorl below the leader. Displacement of the stem varied considerably among families and had a narrow-sense family heritability of 0.59. The potential for genetically improving stem straightness by using information obtained through use of this simple measurement technique seems promising.

INTRODUCTION

Sinuosity, defined as stem crookedness or waviness totally within interwhorl segments, is one of the more noticeable stem form defects in Douglas-fir [*Pseudotsuga menziesii* Mirb. (Franco)]. While sinuosity shows considerable phenotypic variation, heritability of this trait is apparently quite low in natural stands ($h^2 < .10$, Campbell 1965). Nevertheless, moderate to strong genetic control has been observed in progeny tests, suggesting that there is potential for genetically improving stem straightness of Douglas-fir (Birot and Christophe 1983, Orr-Ewing 1967).

The decision whether to include a particular trait in a selection program depends on its genetic control, its cost of measurement, and its impact on the value of the final product. In this paper, we address the first two factors, the genetic control and cost of measurement of stem sinuosity. This research is part of a study conducted by the Pacific Northwest Tree Improvement Research Cooperative[1/] to develop efficient means of measuring growth and stem quality in young Douglas-fir progeny tests.

Although stem sinuosity of young trees is eventually covered up by eccentric cambial growth leaving normal-appearing boles, this "inner" sinuosity increases the size of the knotty central core, reducing the yield of knot-free boards (Campbell 1965, Shelbourne 1970). Furthermore, sinuosity increases the total amount of undesirable compression wood in the stem, resulting in reduced pulp yields (Zobel 1971) and poorer quality lumber and plywood (Shelbourne 1969, 1970). Improved straightness results in greater product quality and quantity, but the ultimate effect on the value of stems is product dependent and can only be determined by conducting milling studies (Blair et al. 1974, Busby 1983, Miller 1975, Zobel and Kellison 1978).

Stem straightness has often been measured using a subjective score (Birot and Christophe 1983, Cooper and Ferguson 1981, Stonecypher et al. 1973, Orr-Ewing 1967, Wilcox et al. 1975), but techniques involving actual measurement of the number and severity of stem displacements from vertical have been described. One of the most elaborate of these quantitative methods involves measuring stem displacements from photographs (Campbell 1965, Shelbourne and Namkoong 1966). While accuracy of subjective scores is questionable (Cooper and Ferguson 1981, Shelbourne 1969), photographic techniques are obviously too expensive for practical application on a large scale. A compromise between a subjective score and detailed measurements is the crook index defined by Goddard and Strickland (1964) as the number of crooks in the first log times the deviation in inches of the most severe crook in the bole. A modification of the crook index was used to measure stem sinuosity in this study.

[1/] This cooperative, centered at Oregon State University, includes members from 14 forestry organizations, including private industries and federal and state agencies in the northwestern United States and Canada.

Measurement techniques were developed using a two-phase approach. In the first phase (Phase I), we intensively measured a limited number of trees in a small Douglas-fir progeny test plantation. This experience helped in developing measurement methods and provided preliminary information on phenotypic and genotypic variation of sinuosity. In Phase II, measurement techniques developed in Phase I were evaluated in a larger genetic test, and estimates of quantitative genetic parameters and costs of measurement were obtained.

PHASE I

Methods

A 13-year-old Douglas-fir progeny test located at the Oregon State University College of Forestry Genetics Nursery near Corvallis, Oregon, was chosen for the Phase I measurements. This test contains 100 full-sib families resulting from factorial matings (NC State Design II) involving 22 female and 4 male parents randomly selected from a breeding population in Coastal British Columbia (Yeh and Heaman 1982). Two-year-old plug seedlings were planted in December 1973 at a 2.44 x 2.44 m spacing in a randomized complete block design with 4-tree, square plots and 4 replications. Survival and growth of trees has been good and their form appears normal in comparison to trees of similar age grown from local seedlots.

Sixty trees from each of three blocks with the highest survival were chosen for detailed measurement. These trees are progeny from factorial crosses between 20 females and 3 males. One tree from each of these 60 (20x3) full-sib families was measured in each block. This "measurement" tree was chosen essentially at random from the four trees present in each plot, with the exception that abnormally slow-growing trees and border trees were avoided. During analyses, the male parentage was ignored and the progeny of the female parents were treated as half-sibs. The statistical design, therefore, was 20 "half-sib" families replicated three times, with family plots made up of three non-contiguous, randomly located trees in each block.

Stem sinuosity of standing trees was assessed visually during the late summer of 1984. The leader (interwhorl 1) and second and third interwhorls from the top of each tree were scored separately by two observers located at approximately right angles to each other around the tree base. The vantage points were chosen in order to give the best overall view of the tree being evaluated. In some cases adjacent trees were climbed because branches obscured vision when the top three interwhorls were viewed from the ground. Two traits, frequency and displacement were recorded for each interwhorl (Figure 1). Frequency is defined as the maximum number of crooks in the interwhorl; and displacement is the largest distance the stem

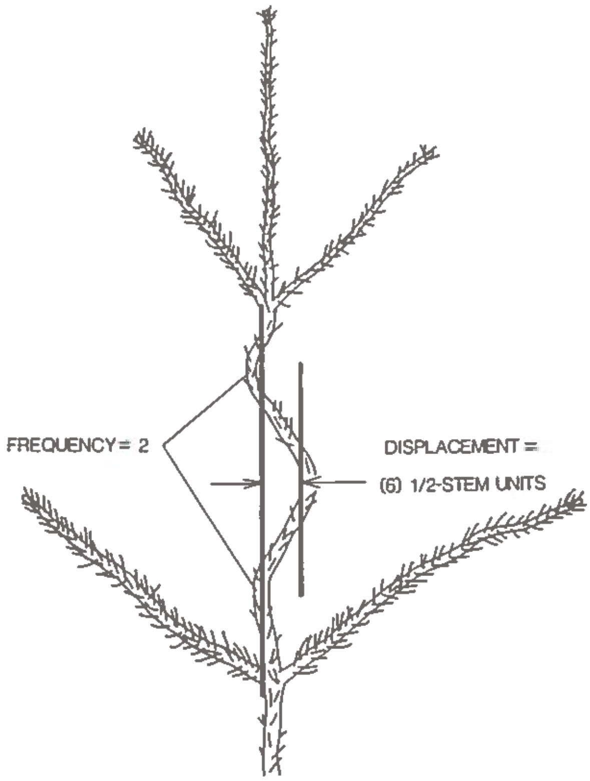


Figure 1.

is offset from the position it would occupy if the stem had no sinuosity. Displacement was measured in units equal to one-half the stem diameter at the point of maximum displacement. In a manner similar to the crook index described by Goddard and Strickland (1964), a sinuosity index (= frequency x displacement) was calculated for each interwhorl. The mean sinuosity index over all three interwhorls was considered _a priori_ to be our "best measure" of stem sinuosity for each tree. "Less intensive", but potentially adequate measures of sinuosity were also calculated from the frequency and displacement scores. Two questions were of primary interest: 1) How is the measurement of stem sinuosity influenced by recording sinuosity index on more than one interwhorl?, and, 2) What is the value of including both frequency and displacement information in the sinuosity index?

Individually observed frequency and displacement scores and derived sinuosity index scores, were averaged over the two observers for each interwhorl. Sinuosity index values often decreased more than tenfold from interwhorl 1 to interwhorl 3, therefore, the "best measure" (mean tree sinuosity index) was calculated as the mean of the standardized sinuosity indices[2/] of the three interwhorls. This gave a total of 10 sinuosity scores per tree; frequency, displacement, and sinuosity index for each of the three interwhorls, and mean tree sinuosity index. Each score was transformed to Ln (score + 1) to normalize the data and plot means of the transformed values were used in all analyses. An analysis of variance for each of the 10 transformed scores was calculated, as well as analyses of covariance of the transformed mean tree sinuosity index with each of the nine transformed scores from individual interwhorls. All statistics and discussion of scores in the remainder of this paper are based on transformed values.

The various measures of sinuosity were evaluated by comparing estimated genetic gain by selection based on the "less intensive" scores relative to that obtainable through selection based on mean tree sinuosity index ("best measure"). Selection based on one of the "less intensive" scores can be considered indirect selection for mean tree sinuosity index. Thus, assuming equal selection intensities, the relative efficiency (RE) of selecting for the "less intensive" measures in order to indirectly obtain gain in mean tree sinuosity is $RE = [h_{fL}/h_{fB}]\ R_A$, where h_{fL} and h_{fB} are the square roots of the family narrow-sense heritabilities for the "less intensive" and "best" measures, respectively, and R_A is the genetic correlation between the two measures (Falconer 1981). Measurement techniques were compared on the basis of their relative efficiency values and ease of application in order to choose the optimal techniques for use in the Phase II portion of the study.

Results

Considerable variation among family means was observed for all sinuosity measures, and as expected, mean tree sinuosity index gave the largest family F-value ($F = 3.82$, $P < .01$) (Table 1). Family means differed significantly for sinuosity index at each interwhorl. In addition, the relative efficiencies of selection for mean tree sinuosity index based on the sinuosity indices of interwhorls 1 or 2, were, respectively, 91 and 94 percent. Thus, it appears that the cost of selection could be reduced, with little loss in selection efficiency, by measuring sinuosity index for a single interwhorl. Although the data indicate that measuring sinuosity index on either interwhorl 1 or 2 would be almost equally effective, we recommend using interwhorl 2 because sinuosity scores, especially displacement, are much higher for interwhorl 1 (Table 1) making measurement of sinuosity index in this interwhorl more difficult and time consuming.

Family F-values for both displacement and frequency scores were lower than for sinuosity index at interwhorl 2, and significant only for displacement ($P < .05$) (Table 2). Nevertheless, selection for total tree sinuosity

---

[2/] Standardized sinuosity index = $(x_i - \bar{x})/s$, where x_i = sinuosity index for ith tree at interwhorl in question, $\bar{x}$ = mean x_i, and s = standard deviation of x.

Table 1. Genetic and phenotypic parameter estimates for sinuosity index (SI) of the top three interwhorls (Phase I progeny test trees) and comparison of individual interwhorl SI values with mean tree sinuosity index.

	Ln(SI + 1)				Comparison with mean tree sinuosity index[c]		
Interwhorl	Test Mean	Range in Family Means	F[a]	h^2[b]	r_p	r_A	RE
1 (leader)	1.28	0.55 - 1.93	2.76**	0.64	0.83	0.98	0.91
2	0.51	0.16 - 1.11	2.82**	0.65	0.81	1.00	0.94
3	0.13	0.02 - 0.35	1.96*	0.49	0.62	0.86	0.70
Mean tree sinuosity index[d]	-0.26	-0.95 -(+)0.56	3.82**	0.74	—	—	—

[a] F = F-value for testing differences in family means (*, ** = significant at the 0.05 and 0.01 levels of probability, respectively, with (19, 38) degrees of freedom).

[b] h^2 = narrow-sense family heritability.

[c] r_p = plot-mean correlation, r_A = genetic correlation, RE = relative efficiency of genetic gain in mean tree sinuosity index based on selection for sinuosity index of the listed interwhorl.

[d] Mean tree sinuosity index is the mean of the standardized sinuosity indices of the three interwhorls.

based only on displacement, was nearly as efficient (RE = .89) as selection based on sinuosity index (RE = .94) at interwhorl 2. These results suggest that displacement alone may be an adequate measure of sinuosity in young Douglas-fir.

Subjective scores used to measure stem sinuosity in young Douglas-fir progeny tests have been based primarily on the degree of maximum displacement of stems from vertical. In order to compare the effectiveness of such a subjective scoring system to that of the sinuosity index, a "subjective" score for each tree was derived from the displacement scores by bulking observations into four classes. Only the largest displacement in interwhorls 2 and 3 was considered, and bulking was carried out in the following manner: "subjective" score (SS) = 1 when maximum displacement (d) = 0.0; SS = 2 when d = 0.5 or 1.0; SS = 3 when d = 2.0 or 3.0; and SS = 4 when $d \geq 4.0$. Although significant variation in mean subjective score was found among families, the relative efficiency of the subjective score in selecting for mean tree sinuosity index was only 77 percent, quite a bit lower than the relative efficiencies of either sinuosity index or displacement of interwhorl 2 (Table 2). We conclude, that since the relative

Table 2. Genetic and phenotypic parameter estimates for sinuosity scores (Phase I progeny test trees) and comparison of the scores with mean tree sinuosity index.

		Ln(score + 1)				Comparison with mean tree sinuosity index[d/]		
Score	Inter-whorl(s)	Test Mean	Range in Family Means	F[b/]	h^2[c/]	r_p	r_A	RE
Frequency	2	0.51	0.17 - 0.78	1.73	0.42	0.78	1.11	0.84
Displacement	2	0.44	0.16 - 0.88	2.30*	0.57	0.78	1.01	0.89
Sinuosity index	2	0.51	0.16 - 1.11	2.82**	0.65	0.81	1.00	0.94
Subjective[a/]	2,3	1.06	0.86 - 1.33	1.93*	0.48	0.79	0.96	0.77

[a/] The subjective score was based on the maximum displacement found in either interwhorl 2 or interwhorl 3.

[b/] F = F-value for testing differences in family means (*, ** = significant at the 0.05 and 0.01 levels of probability, respectively, with (19, 38) degrees of freedom).

[c/] h^2 = narrow-sense half-sib family heritability.

[d/] r_p = plot-mean correlation, r_A = genetic correlation, RE = relative efficiency of genetic gain in mean tree sinuosity index based on selection for listed sinuosity score of the second interwhorl.

efficiencies of subjective scores when actually applied, are likely to be lower than the score derived in this example, the sinuosity index is a superior method of measuring stem sinuosity.

PHASE II

Methods

Three progeny test plantations were selected for use in Phase II. These plantations were established by the Umpqua Tree Improvement Cooperative using wind-pollinated progeny of parent trees located in the Coast Range of central Oregon (Noti Breeding Unit of the Douglas-fir Progressive Tree Improvement Program) (Silen and Wheat 1979). Trees belonging to 90 families common to all three test sites were measured. These families were divided into three sets of 30 families each. The sets were planted as separate randomized complete block design experiments with four replications at each of the three locations. Families within each block are represented by four-tree non-contiguous plots, with the trees in each plot assigned to planting spots at random. The plantations were fenced to exclude large browsing animals and were established with 1-0 plug seedlings at a 3.05 x 3.05 m spacing. Trees in two of the plantations were 12 years old from seed at the time of measurement in November 1984, while the third plantation was 13 years old from seed. Survival of test trees averaged 79 percent. Mortality was replaced for three years after planting, but replacements were not used in the analyses.

The second interwhorl of each tree was scored for frequency and displacement from two vantage points located at right angles to one another, and the sinuosity index for each vantage point was calculated. A single observer scored all trees in a replication and, in contrast to Phase I, made measurements from both vantage points.

Two questions concerning measurement technique were of interest in Phase II: 1) What is the value of including both frequency and displacement information in the sinuosity index?, and 2) What is the value of scoring sinuosity from more than one vantage point? Measurement techniques were evaluated in essentially the same manner as described for Phase I, with the mean sinuosity index from two vantage points considered as the "best measure" of stem sinuosity for each tree. Thus, the "best measure" for Phase II consisted of mean sinuosity index of interwhorl 2, while in Phase I the "best measure" consisted of mean tree sinuosity, because information had been recorded on the top three interwhorls in the more intensive Phase I portion of this study. This gave a total of six sinuosity scores per tree; frequency, displacement and sinuosity index from the first vantage point and the frequency, displacement and sinuosity index averaged over two vantage points. Individual tree scores were transformed [Ln (score + 1)] and plot means of transformed scores were used in all analyses. Analyses of variance and covariance followed the form shown in Table 3. Only five of the 1080 plots were missing because all four trees in a plot had died. For these plots, missing values were estimated using the method described in Steel and Torrie (1960, section 8.5).

The amount of time needed to measure each block in the test was recorded. In many of the blocks, however, traits in addition to sinuosity were measured at the same time in order to see how different traits might be "packaged" most efficiently. Elapsed times were influenced by varying weather conditions, terrain, tree size and personnel, but still provide a guide for estimating the cost of measuring sinuosity.

Results

Results from the three-plantation progeny test confirm our observations from Phase I, and the findings of Birot and Christophe (1983), that stem sinuosity varies considerably among families of young Douglas-fir. F-values for testing family differences were significant at the 0.01 probability level and estimates of family heritabilities were generally high for all scores (Table 4). Selection for mean displacement

Table 3. Sources of variation and degrees of freedom for the Phase II Douglas-fir progeny test analyses of variance and covariance.

Source of variation	Degrees of freedom
Plantations	2
Sets	2
Plantations x Sets	4
Replications (Sets and Plantations)	27
Families (Sets)	87
Plantations x Families (Sets)	174
Error	778[a]

[a]Degrees of freedom were reduced because five plots were missing from the analyses.

scored from two vantage points appears to be as efficient for improving mean sinuosity index (interwhorl 2), as selection for mean sinuosity index itself (RE = 1.02). Furthermore, indirect selection for mean sinuosity index based on displacement scored from one vantage point, is nearly as efficient (RE = .98). Indirect selection based on frequency scores alone, however, have much lower relative efficiencies.

Costs of measuring stem sinuosity can be estimated from the elapsed time recorded by the crews in the Phase II plantations. Scoring mean sinuosity index, for example, took less than half the time required to measure tree heights with a telescoping measuring pole (64 trees/man-hour vs. 27 trees/man-hour, respectively). Of course, the man-hours needed to measure stem sinuosity would be further reduced if displacement was scored from a single vantage point. Stem sinuosity, however, can be scored conveniently with other bole traits such as degree of forking and ramicorn branching in combination with tree height measurement. When all four of these traits were recorded simultaneously, only 28 percent more time was needed as compared to measuring tree height alone (21 trees/man-hour vs. 27 trees/man-hour, respectively).

Table 4. Genetic and phenotypic parameter estimates for sinuosity scores of the second interwhorl (Phase II progeny test trees) and comparison of the scores with the mean sinuosity index.

Score (No. of vantage points)	Ln(score + 1)				Comparison with mean sinuosity index of second interwhorl[d/]		
	Test Mean	Range in Family Means[a/]	F[b/]	h^2[c/]	r_P	r_A	RE
Frequency (1)	0.57	0.36 - 0.70	1.56**	0.36	0.83	1.04	0.84
Frequency (2)	0.59	0.35 - 0.73	1.92**	0.48	0.89	0.97	0.90
Displacement (1)	0.56	0.28 - 0.90	2.20**	0.55	0.90	0.99	0.98
Displacement (2)	0.58	0.26 - 0.92	2.44**	0.59	0.95	0.99	1.02
Sinuosity index (1)	0.67	0.31 - 1.06	1.95**	0.49	0.96	1.01	0.94
Sinuosity index (2) (mean sinuosity index)	0.70	0.32 - 1.11	2.25**	0.56	--	--	--

[a/] Largest range in family means among the three 30-family sets.

[b/] F = F-value for testing differences among family means (** = significant at the 0.01 level of probability, with (87, 174) degrees of freedom).

[c/] h^2 = narrow-sense family heritability.

[d/] r_P = plot-mean correlation, r_A = genetic correlation, RE = relative efficiency of genetic gain in mean sinuosity index based on selection for listed sinuosity score of the second interwhorl.

CONCLUSIONS

1. There is a large amount of variation in stem sinuosity among 12- to 13-year-old families of Douglas-fir. Relatively high family heritability estimates for this trait indicate that stem straightness can be readily improved through selection and breeding programs which include progeny testing.

2. Visual scoring of sinuosity in the upper portion of young Douglas-fir trees appears to be very effective for assessing family differences in stem straightness. The most efficient measurement technique

in this study consisted of scoring the maximum stem displacement in the interwhorl below the leader. Displacement distance units of one-half the stem diameter at the point of maximum displacement can be estimated without difficulty from the ground, and are recommended. Use of larger stem displacement units, or large "subjective" classes, will most likely result in reduced gain without making the measurement of displacement substantially easier. Selection based on displacement scored from two separate vantage points around the tree will likely result in somewhat more gain than selection based on scores from a single vantage point. A decision whether to use one, or two vantage points, however, should be based on a comparison of increased gain versus the increased cost of taking measurements from two vantage points.

3. Stem sinuosity is substantially less costly to measure than tree height, but is probably most efficiently measured in combination with other traits where the marginal cost of adding sinuosity may be minimal. Of course, the final decision on whether to include sinuosity in a selection program will depend on an assessment of its impact on the value of the final product.

4. Evaluation of a wide range of sinuosity scores in this study points out that genetic parameter estimates will vary with choice of measurement technique, in addition to the more obvious factors of test design quality and genetic structure of the test population. This will be true for any trait where measurement technique varies among researchers and measurement involves a degree of subjectivity or visual estimation. We recommend that uniformity of measurement technique be a goal of tree breeders in order to make comparisons of results among researchers more valid.

ACKNOWLEDGEMENTS

The authors wish to thank Robert Campbell, USFS Pacific Northwest For. and Range Expt. Sta., Corvallis, OR; Donald Lester, Crown Zellerbach Corp, Wilsonville, OR; and Jeffrey Madsen, Champion International Corp., Eugene, OR for their review of this manuscript.

REFERENCES

Birot, Y., and C. Christophe. 1983. Genetic structures and expected genetic gains from multitrait selection in wild populations of Douglas-fir and Sitka spruce. 1. Genetic variation between and within populations. Silvae Genet. 32:141-151.

Blair, R. L., B. J. Zobel, E. C. Franklin, A. C. Djerf, and J. M. Mendel. 1974. The effect of tree form and rust infection on wood and pulp properties of loblolly pine. TAPPI 57:46-50.

Busby, C. L. 1983. Crown-quality assessment and relative economic importance of growth and crown characters in mature loblolly pine. Proc. 17th South. Forest Tree Improv. Conf., Athens, GA. pp. 121-130.

Campbell, R. K. 1965. Phenotypic variation and repeatability of stem sinuosity in Douglas-fir. Northwest Sci. 39:47-59.

Cooper, D. T., and R. B. Ferguson. 1981. Evaluation of bole straightness in cottonwood using visual scores. USDA Forest Service Res. Note SO-277. 3 p.

Falconer, D. S. 1981. Introduction to Quantitative Genetics (Second ed.). Longman Inc., New York. 340 p.

Goddard, R. E., and R. K. Strickland. 1964. Crooked stem form in loblolly pine. Silvae Genet. 13:155-157.

Miller, R. G. 1975. Visual assessment of stem straightness in radiata pine. Aust. For. Res. 7:45-46.

Orr-Ewing, A. L. 1967. A progeny test of Douglas-fir to demonstrate the importance of selection in forest practice. British Columbia For. Serv. Res. Notes No. 43. 23 p.

Shelbourne, C. J. A. 1969. Breeding for stem straightness in conifers. Proc. 2nd World Consult. For. Tree Breed., IUFRO, FO-FTB-69-3/4:8 p.

Shelbourne, C. J. A. 1970. Genetic improvement in different tree characteristics of radiata pine and the consequences for silviculture and utilization. Paper presented to FRI Symp. No. 12, Forest Res. Inst., Rotorua, New Zealand. 18 p.

Shelbourne, C. J. A., and G. Namkoong. 1966. Photogrammetric technique for measuring bole straightness. Proc. 18th South. Conf. For. Tree Improv. pp. 131-136.

Silen, R. R., and J. G. Wheat. 1979. Progressive tree improvement program in coastal Douglas-fir. J. For. 77:78-83.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York. 481 p.

Stonecypher, R. W., B. J. Zobel, and R. Blair. 1973. Inheritance patterns of loblolly pines from a nonselected natural population. North Carolina Exp. Sta. Tech. Bull. No. 220. 60 p.

Wilcox, M., A. Firth, C. B. Low, and D. L. McConchie. 1975. First assessment of the Pinus radiata open-pollinated progeny test of the "268" series parents. Stage 2: Re-ranking of best 120 families based on volume, straightness, branch quality and wood density. Stage 3: Among and within family index selection of 100 new plus trees from progeny test. Intern. Rep. No. 78. New Zealand For. Serv., F. R. I., Rotorua. 50 p.

Yeh, F. C., and C. Heaman. 1982. Heritabilities and genetic and phenotypic correlations for height and diameter in coastal Douglas-fir. Can. J. Forest Res. 12:181-185.

Zobel, B. 1971. Genetic manipulation of wood of the southern pines including chemical characteristics. Wood Science and Tech. 5:255-271.

Zobel, B. J., and R. C. Kellison. 1978. The rate of growth syndrome. Silvae Genet. 27:123-124.

SELECTION OF TRAITS FOR GROWTH, FORM, AND WOOD DENSITY IN DOUGLAS-FIR PROGENY

John N. King, Bruce P. Dancik
Department of Forest Science,
University of Alberta,
Edmonton, Alberta,
CANADA

J. Chris Heaman, Francis C.H. Yeh
British Columbia Ministry of Forests,
Research Branch,
1450 Government Street,
Victoria, B.C.
CANADA

SUMMARY

Tree improvement programs are increasingly emphasizing traits of quality as well as yield. Detailed assessments of stem, crown, and juvenile growth features, and specific gravity were made on full-sib progeny trials of the British Columbia Forest Service. The results indicate that significant sources of additive genetic variance exist for key traits of quality and yield. Genetic variation for all traits was mainly attributable to additive gene sources although SCA effects were significant for some of the branch form traits. Genotype x environment interactions were not significant for any trait for the limited range of sites tested. Our results demonstrate that multiple-trait selection that include quality traits should be effective in the genetic improvement of coastal Douglas-fir.

INTRODUCTION

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is the most important commercial species of the Pacific Northwest where it is valued for both its growth potential and timber quality. Timber quality relies on characteristics of wood quality and form. In terms of wood quality, specific gravity (SG) is considered the single most important clearwood characteristic affecting the quality of a softwood raw-material resource for pulp, lumber and plywood (Kellog 1982). In fast growing plantation forestry it is important to maintain the density to the quality found in the indigenous resource (Zobel and Kellison 1978) and breed for a uniform product (Zobel *et al*. 1982). The form characteristics of Douglas-fir and its relative freedom from major defects of forks, crooks, sweeps, and branchiness are important in reducing knots and compression wood and increasing the value of the clearwood timber quality. However considerable phenotypic variation can exist for bole and crown form characters (Campbell 1961, 1963, 1965) and the ameliorated environment of plantation forestry may promote detrimental growth form features in juvenile Douglas-fir (Carter *et al*. 1985). The potential for significant improvement for quality traits has been demonstrated in Douglas-fir (form: Orr-Ewing 1967, Jarret 1976 and Birot and Christophe 1983; SG: McKimmy 1966).

The tree improvement program for coastal Douglas-fir has been active in British Columbia since 1957 when phenotypic mass selections were begun (Orr-Ewing 1969). Form features were included in the first stage selection criteria (Heaman 1967). A major breeding program was initiated in 1973 and quality traits will be important in the recurrent selections. The present study began as a desire to find out what traits are likely to be important and how they can be effectively measured on large scale progeny trials, to estimate genetic parameters for the traits, and to establish models for multiple trait selection stategies. Using older full-sib progeny trials outwith the breeding program as research material it is hoped that guidelines can be given that are useful in the breeding program of coastal Douglas-fir in British Columbia. In this paper we present preliminary information on the significance of genetic and non-genetic sources of variation.

MATERIAL AND METHODS

The experimental population for this study is from a 1971 controlled pollination cross of coastal Douglas-fir (E.P. 707 B.C. Ministry of Forests; Yeh and Heaman 1982). The cross-pollination involved 26 trees randomly selected from the 360 tree breeding population of low elevation coastal Douglas-fir. The breeding followed a North Carolina II (factorial) four pollen tester mating design, where 22 trees, serving as seed parents (F), were crossed with 4 trees, serving as pollen parents (M). Progeny families were planted in a randomized block design with three replications (R) of nine tree plots on two sites (S); Cowichan Lake Experimental Station (CLES-elev. 165m) and the Greater Victoria Watershed (GVWS-elev. 488m).

Growth form measures were taken at 11 years (summer 1983) and specific gravity measures were taken after the 11th growing season (winter 1984). The details of the measures that were taken and the justification for using them as indicators of traits are discussed in manuscripts in preparation. In this paper we wish to present preliminary information on 8 key traits;

YIELD..............................	Height 10 years	HT10
....	Diameter at 10 years	DM10
FORM	Branch thickness	BTT
....	Branch angle	BA
....	Branch length	BLT
....	Forking	FORK
....	Sinuosity	SIN
WOOD QUALITY......................	Specific Gravity	SG

The analysis of variance was completed for the model;

$$Y_{ijklm}=\upsilon+S_i+R_{j(i)}+M_k+F_l+SM_{ik}+SF_{il}+RM_{jk}+RF_{jl}+MF_{kl}+SMF_{ikl}+RMF_{jkl}+E_{m(ijkl)}$$

except for SG which was measured at only one site (CLES).

In the random effects models we are interested in testing the following hypothesis for genetic and non-genetic sources of variation:

$$H_0: \sigma^2 = 0.$$

Hypotheses are tested with *F* statistics from analysis of variance tables. Where appropriate mean square ratios were not availabe the Satterthwaite (1946) approximation was used.

The variance components from our analyses are used in predictions for the response to selection (Namkoong *et al*. 1966). The important sources of variation in these predictions are;

1)σ^2(females) the variance due to differences between female half-sib families estimates additive genetic variance (=1/4Va),
2)σ^2(males) the variance due to differences between male half-sib families estimates additive genetic variance but sampling error of too few parents make it less reliable as an estimate,
3)σ^2(cross) the variance due to the differences between full-sib crosses estimates dominance genetic variance (=1/4Vd),
4)σ^2(S*F) the variance due to the differences between site by female interactions estimates a genotype-macrosite error variance,
5)σ^2(R*M*F) the variance due to the differences between plots is the error variance caused by the full-sib family plots behaving differently between replications
3)σ^2(WITHIN) the variance due to the differences of trees within a plot has both the error variance caused by microsite differences and the remaining genetic variability among individuals within plot.

RESULTS AND DISCUSSION

TABLE 1 Degrees of Freedom and significance of F test for null hypothesis

	(d.f.)	HT10	DM10	BTT	BA	BLT	SIN	FORK	SG
FEMALE	(21)	**	**	***	***	***	***	***	***
CROSS	(63)	NS	NS	**	*	NS	NS	NS	NS
S*F	(21)	NS	NS	NS	NS	NS	NS	NS	NA
R*M*F	(126)	***	***	***	***	***	***	***	***

*, **, *** = significant at .05, .01, .001 levels of probability

NS = non-significant; NA = not available

Sources of variation for additive genetic variance were significant (P<.01) for all traits and were highly significant for quality traits (P<.001). Additive genetic variation was consistently the most significant source of genetic variation. Specific combining ability determined from the source of variation of the full-sib cross was significant (P<.05) for branch angle and branch thickness but was not significant for other traits. Standard seed orchard practices that use tested parents to capture GCA would therefore be the most useful for the improvement of these economically important traits.

No trait showed a significant variance component for the source of variation attributable to genotype x environment interaction. However this source of variation may be important where a wider range of environments are tested.

Our results indicate that both quality and yield traits provide a significant source of variation for additive genetic variance and can be profitably exploited by multiple trait breeding. The high significance of sources of additive genetic variance for quality traits demonstrates that emphasis may be placed on these traits once selections for geographic sources, emphasizing yield, have been made. For Douglas-fir as an introduced species, once provenance data provides the desired selections for "the adapted ecotype which can realize the biomass-potential of the local environment, in addition, the breeder may have some opportunity to exploit the potential of his species for improved partition (between stem and branch) and wood quality (straightness and density)" (Simmonds 1978).

LITERATURE CITED

Birot Y., and Christophe C., 1985: Genetic structures and expected genetic gains from multitrait selection in wild populations of Douglas-fir and sitka spruce. 1. Genetic variation between and within populations. Silvae Genet. 32:141-151.

Campbell, R.K., 1961: Phenotypic variation and some estimates of repeatability in branching characteristics of Douglas-fir. Silvae Genet. 10:109-118.

Campbell, R.K., 1963: Phenotypic correlation among branch and upper-crown stem attributes in Douglas-fir. For. Sci. 9:444-451.

Campbell, R.K., 1965: Phenotypic variation and repeatability of stem sinuosity in Douglas-fir. Northwest Science 39:47-59.

Carter, R.E, Weber C.D. and Hoyer G., 1985: Factors affecting stem form in immature Douglas-fir. Stand management for the future. Proc. conf. Coll. For. Res. Univ. of Washington. (In Press)

Heaman, C., 1967: A review of the plus-tree selection program for Douglas-fir in coastal British Columbia. B.C. For. Serv. Res. Note 44. 27 p.

Jarret, M.P., 1978: Variabilite genetique des caracteres de forme (tronc et branchaison) et de quelques caracteres auxometriques et phenologiques chez le Douglas. Memoire de Stage de 3e annee de l'E.N.I.T.E.F. Doc. interne No 78/2 77p.

Kellogg, R.M., 1982: Coming to grips with wood quality. Forestry Chronicle 5:254-257.

McKimmy, M.D., 1966: A variation and heritability study of wood specific gravity in 46-year-old Douglas-fir from known seed source. Tappi 49:542-549.

Namkoong, G., Snyder E.B. and Stonecypher, R.W., 1966: Heritability and gain concepts for evaluating breeding systems such as seedling seed orchards. Silvae Genet. 15:76-84.

Orr-Ewing, A.L., 1967: A progeny test of Douglas-fir to demonstrate the importance of selection in forest practice. B.C. For. Serv. Res. Note 43, 29p.

Orr-Ewing, A.L., 1969: The development of a program for the genetic improvement of Douglas-fir in British Columbia. Forestry Chronicle 45:395-399.

Satterthwaite, F.E., 1946: An approximate distribution of estimates of variance components. Biometrics Bulletin 2:110-114.

Simmonds, N.W., 1979: Principles of crop improvement. London; New York: Longman, 408p.

Yeh, F. and Heaman C., 1982: Heritabilities and genetic and phenotypic correlations for height and diameter in coastal Douglas-fir. Can. J. For. Res. 12:181-185.

Zobel, B.J. and Kellison, R.C., 1978: The growth rate syndrome. Silvae Genet. 27:123-124.

Zobel, B.J., Campinhos, E. and Ikemori, Y., 1982: Selecting and breeding for wood uniformity. Tappi Res. Devel. Conf. proc. 159-167.

NATURAL VARIABILITY OF SOME WOOD QUALITY TRAITS OF COASTAL DOUGLAS FIR IN A FRENCH PROGENY TEST.

IMPLICATIONS ON BREEDING STRATEGY

PAPER PRESENTED AT THE IUFRO S2.02.05-W.P.
MEETING IN VIENNA; AUSTRIA, JUNE 1985.

J.Ch. BASTIEN *, B. ROMAN-AMAT *, G. VONNET +**

- ABSTRACT -

On increment cores taken on 14-year-old Douglas-fir trees belonging to a provenance-progeny test located in southern France, several densitometric traits and their correlations with growth, flushing date and Pilodyn-needle depth penetration were assessed. Block, provenance and family-level variability of these traits was analyzed. Family-level variability was found preponderant for wood quality traits. Heritabilities, additive genetic correlations and expected genetic gains estimates were presented. The genetic correlations between wood density and total height, flushing and wood heterogeneity, were found strongly unfavourable. On the other hand, the correlation between height and wood heterogeneity was in most cases either neutral or favourable. Potential gains, or losses, on wood quality traits were small and ranged, with 10% of the trees being selected, from 7 to 16%. The Pilodyn-penetrometer was not effective for selection purpose. Breeding implications of these results are briefly discussed.

* INRA, Station d'Amélioration des Arbres forestiers - ARDON, 45160 OLIVET, (France).

** CTFT : Centre Technique Forestier Tropical, 48, Avenue de la Belle Gabrielle, 94140 NOGENT-SUR-MARNE (France).

Densitometric measurements were made at : INRA, Station de Recherches sur la Qualité des Bois, CHAMPENOUX, 54280 SEICHAMPS (France).

INTRODUCTION

For the last 20 years, the French Douglas-fir breeding program has been focused on such conspicuous traits as phenology, growth and morphology. Some internal traits of wood may also be worth working on in order to produce a more valuable timber. Among conifers, for example, the bending-strength generally increases with wood specific gravity and intra-ring homogeneity is considered a determining factor in the production of wood for high precision joinery and veneer (5).

However, studies of the variability of wood quality traits require that two kinds of conditions be brought together. First an appropriate plant material is needed which is well-known and genetically variable. Second, a quick, nondestructive and precise method is necessary in order to measure wood characteristics at the intra-ring level. These requirements were met in a joint study recently conducted in France by G. VONNET working with the Douglas-fir breeding team in Orleans and the wood quality station in Nancy (9).

MATERIAL AND METHODS

*** Plant material**

Trees included in the study were from a field progeny test which comprised 26 IUFRO provenances, from Washington, U.S.A. Each provenance was represented by 10 to 15 half-sib (open pollinated) families.

The trees were grown for 4 years from seed in a nursery and then planted during the fall of 1971 at Cendrieux (Dordogne) (latitude : 45°02'N; longitude : 0°50'E; altitude : 220m; mean annual rainfall : 850mm). The experimental layout was incomplete blocks with single tree plots. At the end of 1979, the average number of trees per family was 23 and a branch pruning was made up to the height of 2.5m.

Ten fast-growing provenances were selected for this study, six of them being late flushing and four early flushing. Eight provenances came from the west piedmont of the northern Cascades.(see Annex 1). As a rule ten trees per family were chosen for each provenance, in blocks showing good growth. Increment cores (5mm diameter) through the tree and centered on the pith were taken out of these trees at breast height during the spring of 1982 (age 14). A total of 1433 increment-cores were analyzed. The study thus concerned juvenile wood, since COWN (2) considers that Douglas-fir mature wood is not formed before the 16th year. However, KELLER and THOBY (3) and Mc. KIMMY and CAMPBELL (4) have shown that juvenile-mature correlation for Douglas-fir wood density is high.

*** Characters assessed**

On each tree, four kinds of traits were taken into account:

. growth : total height at age 12, which was the last height to be easily measurable before the trees became too tall; breast-height girth at age 16.

. phenology : flushing during the 5th spring in the field, measured as the number of days after the first tree in the stand flushed that year (1976).

. wood densitometric traits : these traits were studied on the last 5 rings at both ends of each increment core, i.e. 10 rings per tree (14330 rings total). The X-ray densitometric methods were described by PERRIN and FERRAND (7). Each ring was scanned radially and spot-density was measured on 0.025mm-wide segments contiguous to each other. The following variables were calculated : minimum and maximum density; mean density; and heterogeneity which was defined as the standard deviation of spot densities. The mean of each variable was then calculated for the 10 measurements (5 years x 2 radii) made on each tree, mean density and heterogeneity being weighted by ring-width.

. indirect estimate of wood-strength with a Pilodyn penetrometer (6 J. model, with a 2.5mm needle). Two measurements were taken at breast height on the east and west sides of the tree, without removing the bark. The mean of these measures was then calculated. This assessment was made during the fall of 1984,at age 17. The purpose was to compare the results of this time-saving method with those of the densitometer. Attention must be paid to the fact that Pilodyn needle penetrated only a few of the annual rings submitted to densitometric analysis.

Overall, 8 traits were studied for each tree.

*** Statistical analysis**

. Overall analysis

A general analysis of variance was first performed using the following linear model :

$$Yijk = \mu + Pi + Fj(i) + Bk + Wijk$$, where:

Yijk = value of trait Y for the tree in block k, belonging to family j within provenance i;

μ = grand mean;

Pi = effectof provenance i;

Fj(i) = effect of family j within provenance i (nested factor)

Bk = effectof block k;

Wijk = residual error.

. Intra-provenance analysis

Within each provenance, a one-way variance analysis on block adjusted values was then performed using the following linear model:

$$Yij = m + Fi + Eij$$, where:

Yij = value of trait Y for j individual in i family;

Fi = i family effect;

Fij = residual error.

m = trait Y mean within the considered provenance.

A computer program ("INDEX", see CHRISTOPHE (1)) was used to compute additive genetic gains for 4 densitometric variables. This program employs a combined selection scheme which considers individual and family performance. This program also permits combining of several traits for index selection, with each trait receiving a separate weight chosen to optimize expected genetic gain. In the present study however, calculations were limited to evaluating the highest available gain on each trait.

RESULTS

. Overal analysis

. Block effects were found to be highly significant on all traits. The coefficient of variation (100 σ block/grand mean), was 2.4% for mean density, 3.2% for minimum density, 1.9% for maximum density; 3.9% for heterogeneity and 3.6% for Pilodyn value.

. Provenance effects were also highly significant, (see Annex 2). However the provenance-related coefficient of variation (100 σ provenance/grand mean) was small for all wood properties, Pilodyn included, ranging from 0.9 to 2.3%. For these traits, environmental, effects (i.e. block effects) were roughly twice as large as provenance effects.

. Annexes 3 to 6 illustrate the between and within-provenance variability of total height, wood heterogeneity, mean wood density and Pilodyn value. For wood density traits alone the family-related coefficient of variation (100 σ prog./grand mean), although twice as important as provenance related variability, remains limited, ranging from 2.2% (maximum wood density) to 4.9% (wood heterogeneity). Annex 7 shows the respective contributions to total variance for wood density traits of provenances (2 to 4%) and families (7 to 19%).

. Intra-provenance analysis

. Annex 8 shows the distributions of narrow sense heritability, of the 8 studied traits. The values obtained, although dispersed, are on the whole :

- very high for flushing, as usual,
- high for wood mean density and heterogeneity,
- medium for wood minimum and maximum density, and girth,
- relatively low for total height and Pilodyn.

. The "INDEX" program supplied estimates of maximum genetic gains in each provenance for each wood density trait when the top 10% of the trees were selected. The between provenance range of these estimates is small as shown below :

- mean wood density : from 10.7% to 11.3%
- mean minimum wood density : from 7.5% to 7.9%
- mean maximum wood density : from 6.6% to 6.9%
- heterogeneity : from 15.2% to 16.4%

The expected gains are low on minimum and maximum density, medium for mean density and relatively high for heterogeneity.

. Annex 9 illustrates the among-provenance distribution of additive genetic correlations for some traits. The estimated values are wide ranging but some trends show up.

Three correlations seem to be strongly unfavourable :

- positive correlation between mean wood density and wood heterogeneity. The Pilodyn value is negatively correlated with both traits;

- negative correlation between mean wood density and total height;

- negative correlation between mean wood density and flushing date.

On the other hand, the genetic correlation between total height and wood heterogeneity is in most cases (7 out of 10) either neutral or favourable.

The following table shows the estimated correlated response on a given trait (trait b) when 10% of the trees are selected according to another trait (trait a).

Trait a	Trait b	Correlated response on b when a is selected
Total height	Mean wood density	from - 4.07% to - 4.29%
Total height	Heterogeneity	from + 1.96% to + 2.12%
Mean wood density	Total height	from - 3.85% to - 4.19%
Mean wood density	Heterogeneity	from +10.8% to +11.7%
Heterogeneity	Mean wood density	from - 7.5% to - 8.01%

Although genetically antagonistic, both mean wood density and heterogeneity are worsened when total height is improved alone. Moreover, the reduction in height and consequently in volume associated with an increase in mean wood density is fairly large.

DISCUSSION - CONCLUSIONS

Five main conclusions can be drawn from the results.

. Environmental effects on wood quality traits are high. Any study aimed at revealing genetic variability of these traits thus has to precisely take into account environmental factors. It is also likely that wood characteristics are strongly influenced through silvicultural treatments, especially wide or narrow spacings.

. For the limited number of provenances concerned in this study, genetic variability is much higher at the family level than at the provenance level. The main genetic gains are thus to be expected by within-provenance selection. This result confirms the findings of Mc.KIMMY and CAMPBELL (4), also obtained on 10 provenances (8 from western Washington and 2 from northwestern Oregon).

. Potential genetic gains for wood density traits are small. For example, the wood heterogeneity values for Douglas-fir are high compared to other conifers (the difference between intra-ring maximum wood density and minimum wood density frequently exceeds 0.7-see (5)) and it is not certain that the maximum genetic gain of 16% on this trait would be of economic interest. On the other hand, the possible loss in mean wood density is limited when growth and flushing traits are improved.

. There seems to exist a strong negative correlation between wood mean density and homogeneity. It will be very difficult to obtain substantial genetic gains simultaneously on both traits.

. Unfortunately, the Pilodyn penetrometer does not seem very useful for selection purposes. It is greatly influenced by environmental factors and its genetic correlations with wood mean density and heterogeneity are not very high. This tool might thus be used for quick measurements not requiring high accuracy, the accurate wood density data being still obtained by densitometric analysis. These results contrast with the high correlations found between wood density and Pilodyn penetrometer measurement for mature trees of other species (NEPVEU and al. (6); SPRAGUE and al. (8)). Another study concerning the usefullness of Pilodyn penetrometer for Douglas-Fir selection might be of interest (the same rings being studied with Pilodyn and densitometer).

LITTERATURE CITED

(1)-CHRISTOPHE, C.
Programme de calcul d'indices de sélection sur individus appartenant à des familles de demi-frères.
INRA, Station d'Amélioration des Arbres forestiers, Document interne n° 78/3 (1978).

(2)-COWN, D.J.
Densitometric studies on the wood of young coastal Douglas-fir
Ph. D. thesis, Bristih Columbia University Canada (1976).

(3)-KELLER, R.; THOBY, M.
Liaisons entre l'état juvénile et l'état adulte pour quelques caractères technologiques et auxométriques chez le Douglas (Pseudotsuga menziesii)
Annales des Sciences Forestières 34 (3), (1977).

(4)-Mc. KIMMY, M.D.; CAMPBELL, R.K.
Genetic variation in the wood density and ring width trend in coastal Douglas-Fir.
Silvae Genetica 31 (2-3) (1982).

(5)-NEPVEU, G.
Variabilité génétique de la qualité du bois chez l'Epicéa et le Douglas.
Revue Forestière Française 36 (4), (1984).

(6)-NEPVEU, G.; VELLING, P.
Variabilité génétique de la qualité du bois chez Betula pendula Roth.
Silvae Genetica 32, 1-2 (1983).

(7)-PERRIN, J.R.; FERRAND, J.Ch.
Automatisation des mesures sur carottes de sondage de la densité du bois, de son retrait et des contraintes de croissance.
Annales des Sciences Forestières 41 (1), (1984).

(8)-SPRAGUE, J.R. et al.
Utility of the Pilodyn in selection for mature wood specific gravity in Loblolly Pine.
Forest Sci. 29, 4 (1983).

(9)-VONNET, G.
Contribution à l'étude de la variabilité génétique de la densité et de l'hétérogénéité du bois de Douglas.
Mémoire de DEA, Université de Nancy I, Biologie végétale (Octobre 1983).

ANNEX I : PROVENANCE DESCRIPTION

I.U.F.R.O. Number	Provenance name	Latitude (N)	Longitude (W)	Altitude (m)	Number of progenies
1050	Marblemount	48°35'	121°24'	120	15
1051	Sedro-Wooley	48°32'	122°19'	60	15
1053	Darrington	48°16'	121°38'	150	15
1054	Arlington	48°13'	122°04'	90	14
1057	Granite-falls	48°05'	122°02'	90	11
1063	Gold bar	47°51'	121°39'	120	14
1067	Skykomish	47°42'	121°20'	300	15
1075	Enumclaw	47°16'	121°56'	240	15
1088	Castle Rock	46°19'	122°52'	150	15
1090	Cougar	46°05'	122°18'	500	14

ANNEX 2 : AVERAGE PERFORMANCES OF THE 10 PROVENANCES AND F. TEST RESULTS

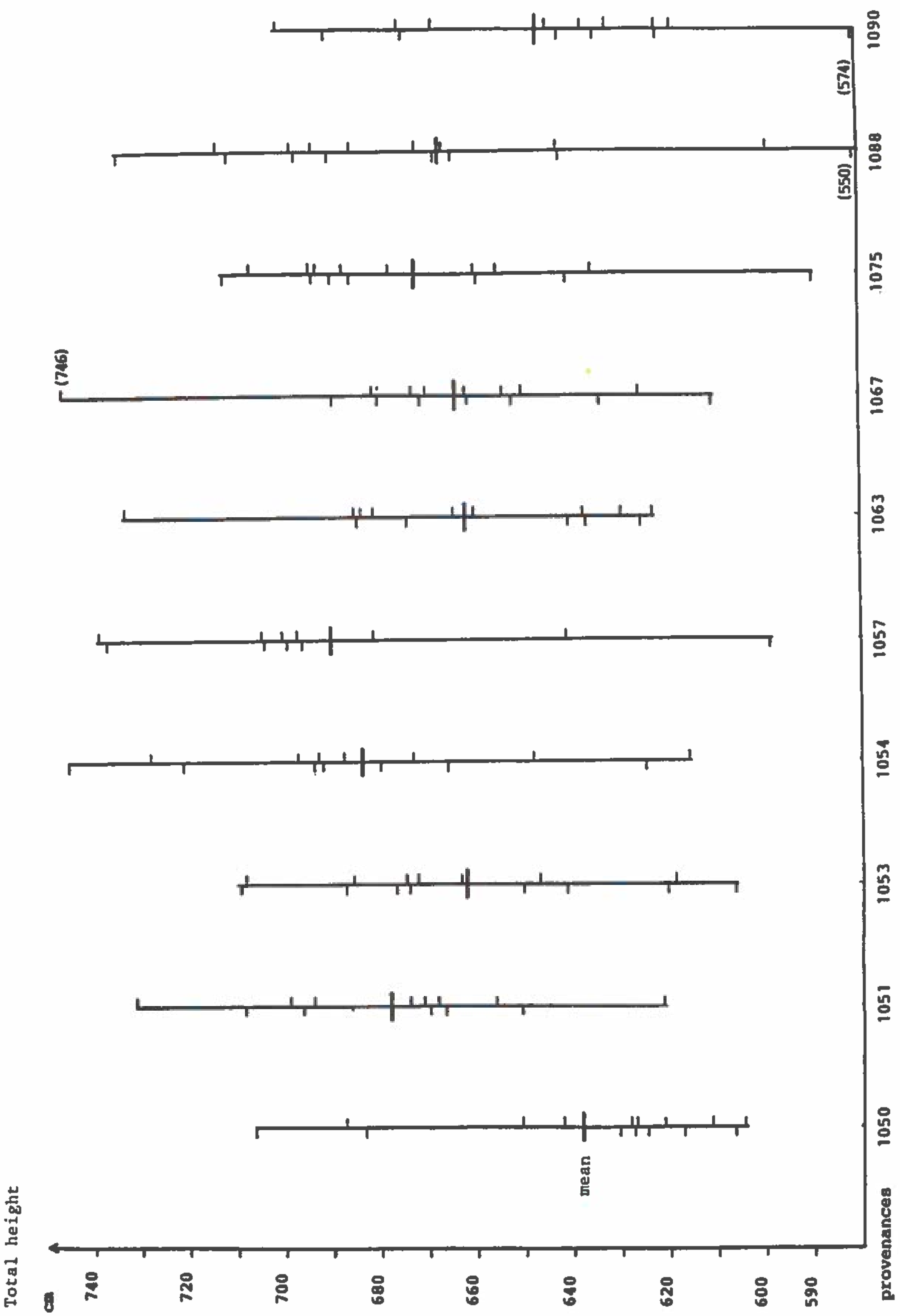
Traits \ Provenances	1050	1051	1053	1054	1057	1063	1067	1075	1088	1090	Grand mean	Coefficient of variation * (%)	F value of provenance effect (9 and 133 d.o.f.)
. mean wood density (kg/m^3)	477	486	474	481	463	468	478	484	489	487	479	1.3	2.43 **
. mean minimum wood density (kg/m^3)	236	233	228	231	225	233	226	234	235	237	232	1.4	2.76 **
. mean maximum wood density (kg/m^3)	927	947	939	941	914	928	930	944	930	914	932	0.9	2.85 **
. mean s.d. of density within an annual ring (heterogeneity (kg/m^3)	220	231	234	232	223	220	231	229	223	217	226	2.3	3.16 **
. Pilodyn mean depth of needle penetration (mm)	16.5	16.7	17.1	16.5	17.2	16.9	16.7	16.6	16.3	16.0	16.6	1.8	3.66 **
. Total height (12 years) (cm)	656	701	683	707	659	679	681	699	690	664	687	2.3	3.31 **
. Girth (16 years) (cm)	39	42	42	41	41	41	41	44	41	40	42	3,0	3.78 **
. Flushing date (9 years)(nb of days)	5.9	9.1	12.7	11.4	9.4	7.1	10.8	10.3	6.9	7.8	9.4	24.5	12.78 **

$$* \text{Coefficient of variation: } \frac{\sigma \text{ prov.}}{\text{Grand mean}} \times 100$$

** F test significant at the 1% level.

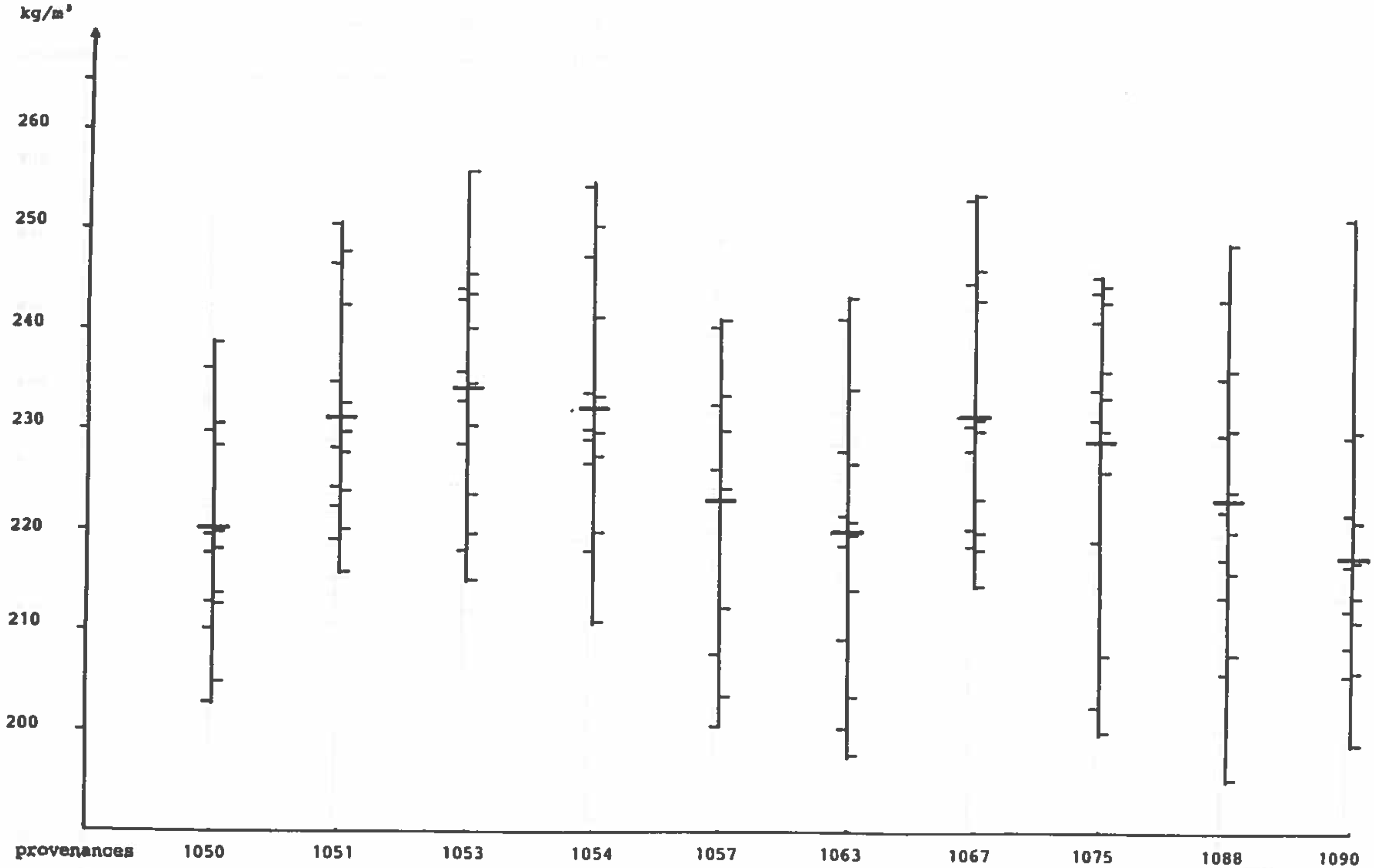
nota : - - - - smallest value
——— largest value .

ANNEX 3



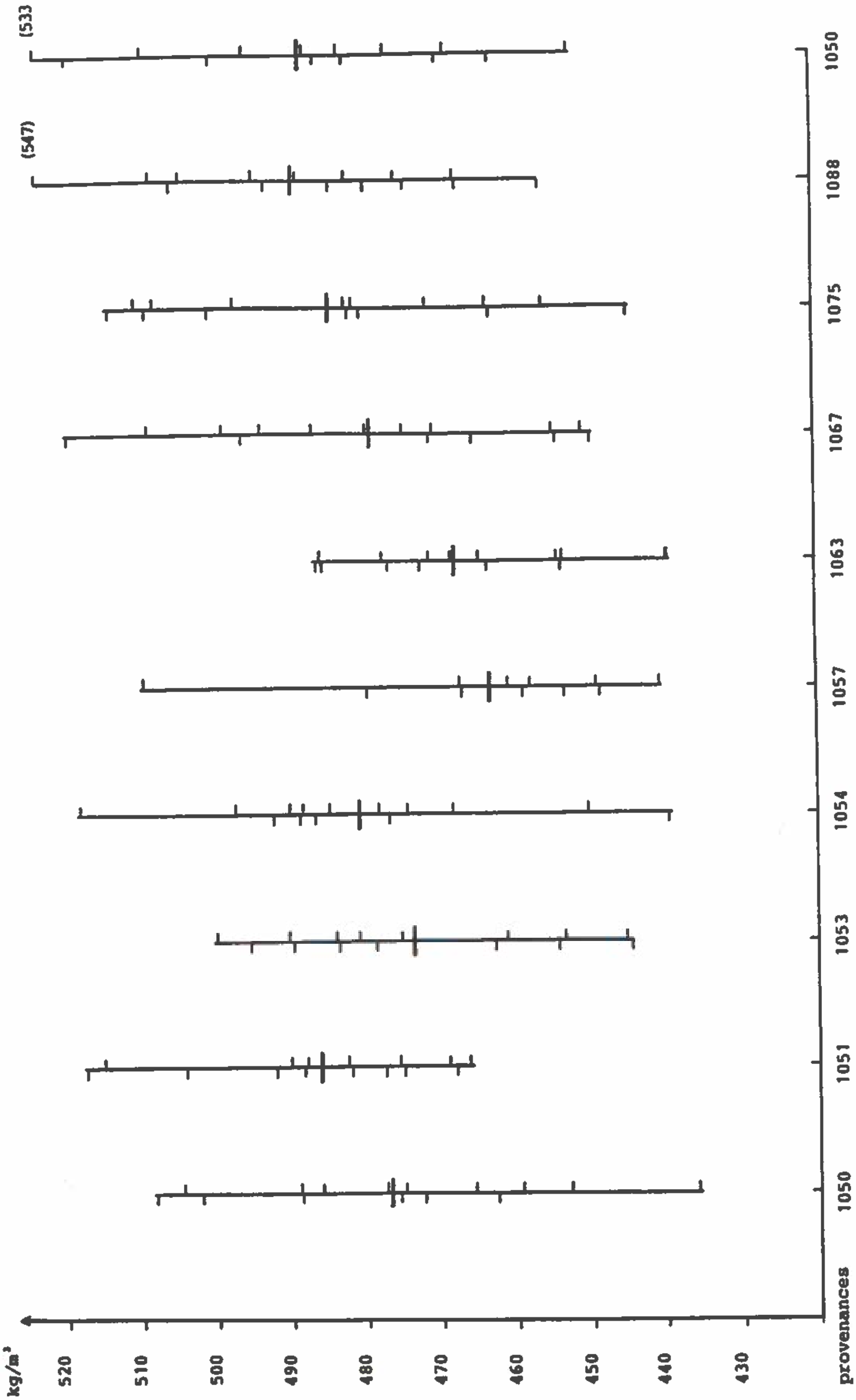
BETWEEN AND WITHIN PROVENANCE VARIABILITY OF TOTAL HEIGHT (12 years)

ANNEX 4



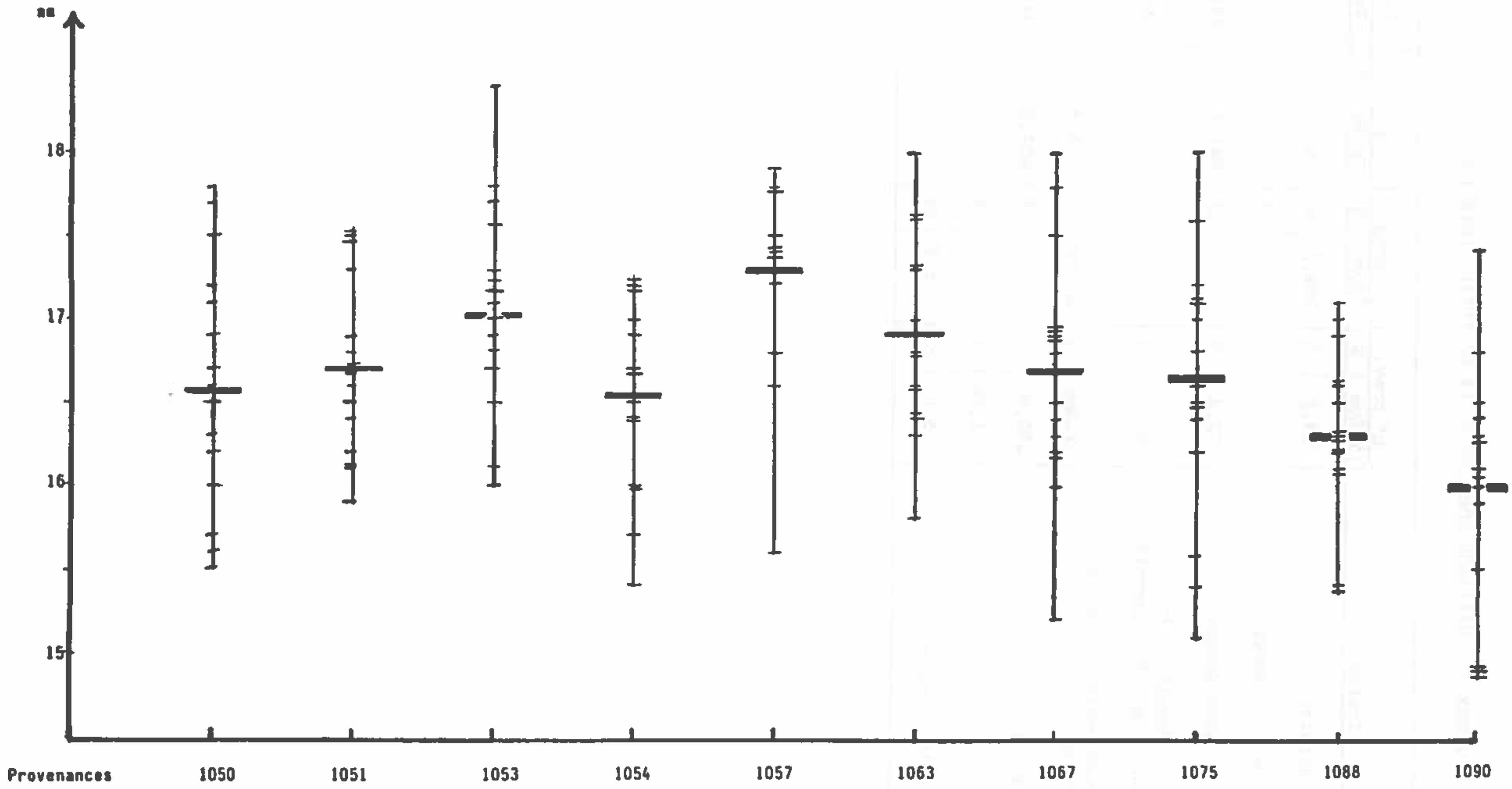
BETWEEN AND WITHIN PROVENANCE VARIABILITY OF WOOD HETEROGENEITY (s.d. of density within an annual ring).

ANNEX 5



BETWEEN AND WITHIN PROVENANCE VARIABILITY OF MEAN WOOD DENSITY

ANNEX 6

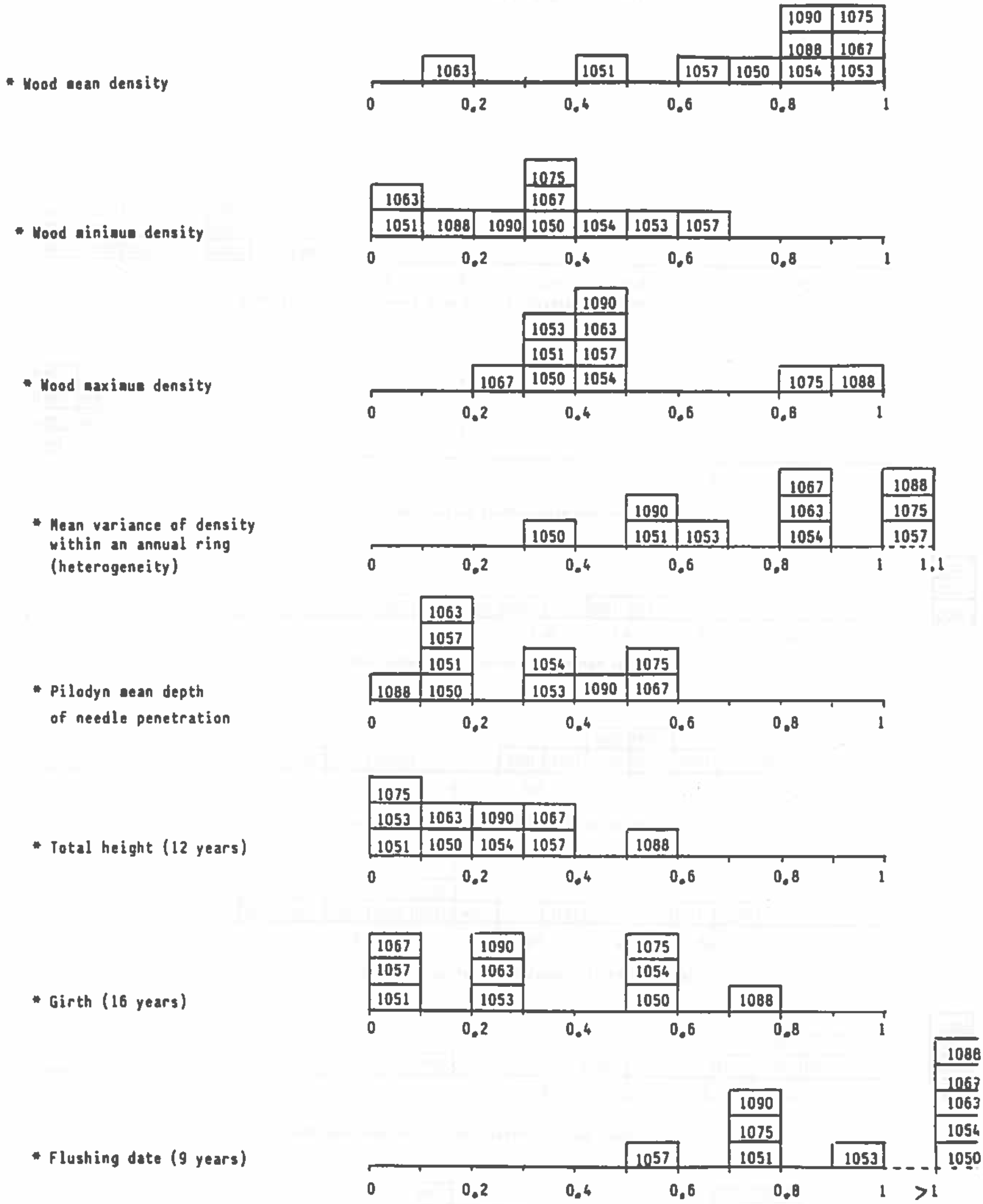


BETWEEN AND WITHIN PROVENANCE VARIABILITY OF DEPTH OF PILODYN NEEDLE PENETRATION

ANNEX 7 : VARIANCE COMPONENTS (% OF TOTAL VARIATION)

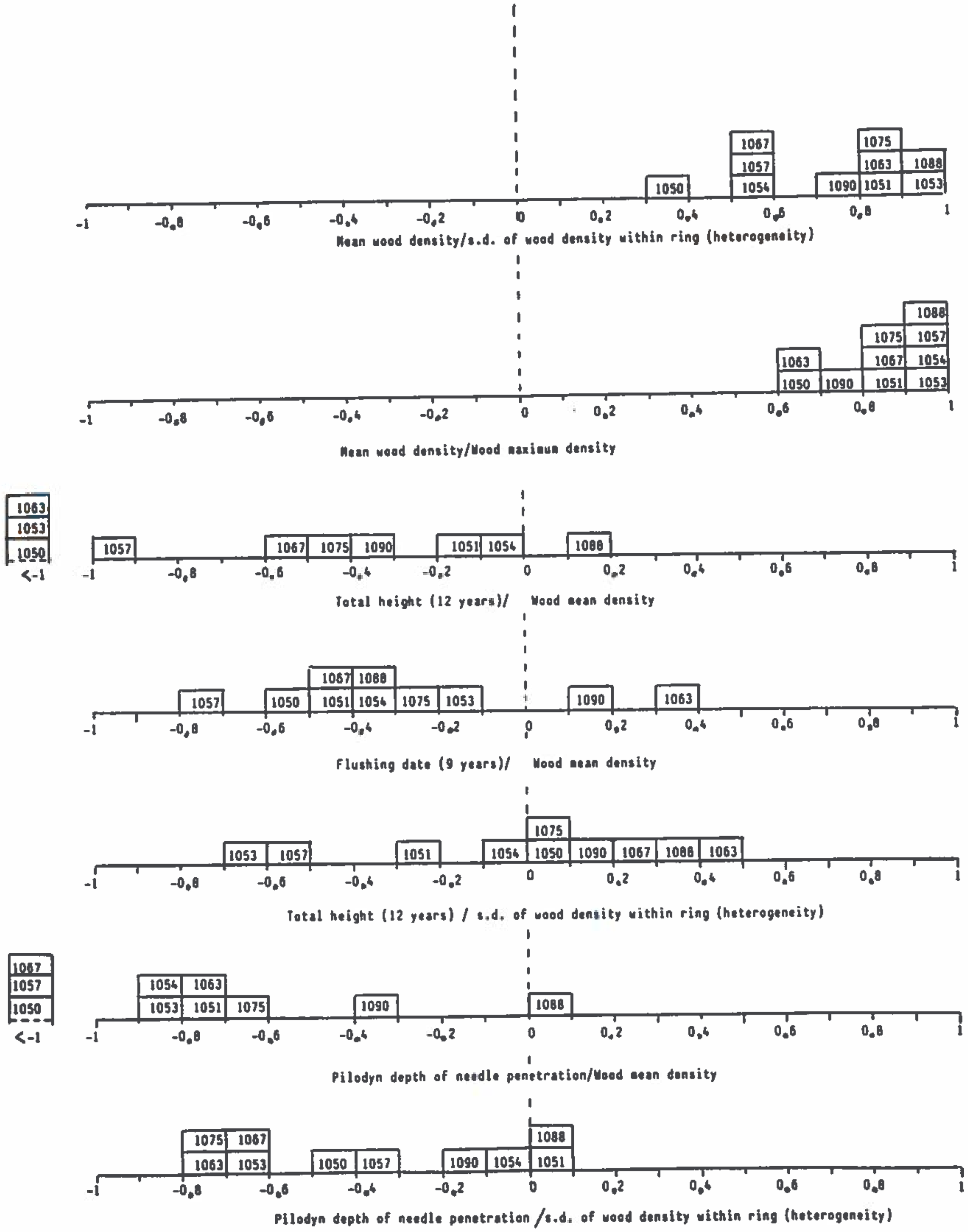
Traits	σ^2 prov.		σ^2 prog.		σ^2 w		σ^2 total
	Value	%	Value	%	Value	%	Value
. mean wood density	38.2	3	269.2	18	1167.2	79	1472.6
. mean minimum wood density	10.3	2	37.7	7	476.2	91	524.2
. mean maximum wood density	72.8	2	416.2	13	2841.5	85	3330.5
. mean s.d. of density within an annual ring (heterogeneity)	27.0	4	122.8	19	514.7	77	664.5
. pilodyn mean depth of needle penetration	0.089	3	0.179	7	2.416	90	2.684
. Total height 12 years	252.9	4	554.1	9	5607.8	87	6414.8
. Girth 16 years	1.58	3	3.67	8	41.64	89	46.89
. Flushing date 9 years	5.3	23	5.2	22	12.7	55	23.2

ANNEX 8 : DISTRIBUTION OF HERITABILITY ESTIMATES



Nota : Due to small progeny number per provenance, some heritability estimates have no significance (> 1).

ANNEX 9 : DISTRIBUTION OF ADDITIVE GENETIC CORRELATIONS BETWEEN SOME TRAITS



Nota : Due to small progeny number within provenance, some additive genetic correlations have no significance.

INTER-PROVENANCE VARIATION IN THE IUFRO DOUGLAS-FIR PROVENANCE/PROGENY TRIAL.

A.M.K. Fashler[1/], Y.A. El-Kassaby[1,2/] and O. Sziklai[1/]

[1/] Faculty of Forestry, University of British Columbia, Vancouver, B.C., Canada V6T 1W5

[2/] CIP Forest Products, Inc., Tahsis Pacific Region, Saanichton, B.C., Canada V0S 1M0

ABSTRACT

Height growth variation was studied in 384 open-pollinated families representing 48 provenances from the IUFRO Douglas-fir [Pseudotsuga menziesii (Mirb.) Franco] collections sampled from British Columbia to northern California. The test was established in a combined provenance/ progeny trial at the University of British Columbia Research Forest in Haney, B.C. in 1971. The study objectives were to estimate: a) the degree of genetic variation in height growth among and within provenances, b) the heritability of height growth, and c) the juvenile-mature height growth correlation. This information assists in selecting the best provenances and progenies for the test site.

Results from seed zone analyses showed that the most significant differences in the genetic variation in height growth of juvenile Douglas-fir trees were found in the relative sizes of the components of variance between provenances and between families within provenances. These differences were linked to the site adaptation of the provenance material. Estimates for additive genetic variance and heritability for seed zones were quite high. Low values for their respective standard errors indicated high reliability in results. High values of heritability indicated that there are opportunities for significant improvement by "triple tandem" selection.

Results from the juvenile-mature correlation analysis indicated that reliable selection of the best and deletion of the poorest provenances and families may begin at age five years. Estimates for genetic gain were made.

Keywords: Pseudotsuga menziesii, provenance/progeny trial, genetic variation, selection.

INTRODUCTION

The study of genetic variation in natural populations of a commercial tree species is needed to provide basic information for establishing an effective breeding strategy and implementing appropriate tree breeding programs. There have been several previous studies to estimate the extent of genetic variation in Douglas-fir populations (Silen, 1978; Namkoong et al., 1972; Rehfeldt, 1974; Christophe and Birot, 1979). The University of British Columbia IUFRO Douglas-fir combined provenance/progeny trial provides the opportunity to simultaneously assess the genetic characteristics of several populations collected from British Columbia to northern California.

The objectives of this investigation were to estimate: a) the genetic variation in height growth among and within provenances, b) the heritability of height growth, and c) the juvenile-mature height growth correlation. The estimates of these parameters were used to recommend the best selection strategy for the test site.

MATERIALS AND METHODS

Open-pollinated progeny of 48 provenances (Fig. 1) from the first (1966) and second (1968) IUFRO Douglas-fir seed collections (Fletcher and Barner, 1978) provided the material for this study. The provenance/progeny test was established in 1971 with 1+0 plugs at the University of British Columbia Research Forest, Haney, B.C. The test was established as a randomized complete block design with three replications; each provenance was represented by eight families and each family was represented by a five-tree row plot per block. Further information on experimental layout and the test site are given by Kvestich (1976). Height measurements were made in September 1975 and 1978. Mortality was very low and averaged 9.8% in May 1978. This low mortality minimized competition effects within the plantation for all years.

Statistical analyses were carried out for provenances arranged in groups according to seed zones (Haddock and Sziklai, 1966). Grouping was made according to four categories: three seed zones (1, 2, and 3) and a composite fourth representing interior provenances (seed zones 4, 5, 7, and 8).

The analyses of variance used were based on the following additive linear model:

$$Y_{ijkm} = \mu + \alpha_i + \beta_j + \psi_{ij} + \lambda_{(i)k} + \omega_{(i)jk} + \ell_{(ijk)m},$$

where: Y_{ijkm} = the measurement of the m^{th} tree in the k^{th} family in the j^{th} block in the i^{th} provenance;

μ = general mean;

α_i = the effect due to the i^{th} provenance;

β_j = the effect due to the j^{th} block;

ψ_{ij} = the effect due to the i^{th} provenance x the j^{th} block interaction;

$\lambda_{(i)k}$ = the effect due to the k^{th} family within the i^{th} provenance;

$\omega_{(i)jk}$ = the effect due to the k^{th} family within the i^{th} provenance x j^{th} block interaction, and

$\ell_{(ijk)m}$ = residual error term.

The significance of the highest order-interactions $[\omega_{(i)jk}]$ were tested and found to be non-significant (P < 0.01) (Fashler, 1979). Therefore, the previously-mentioned model was reduced to the form:

$$Y_{ijkm} = \mu + \alpha_i + \beta_j + \psi_{ij} + \lambda_{(i)k} + \varepsilon_{(ijk)m}$$

where $\varepsilon_{(ijk)m}$ includes both the sampling and experimental error $[\omega_{(i)jk} + \ell_{(ijk)m}]$. This new pooled error term increased the precision of the _F_-tests. Sources of variation, degrees of freedom and the expected mean squares for the new additive linear model are given in Table 1. The genetic interpretation associated with the above variance components permits the estimation of the additive variance (σ^2_A) from the following equation:

$\sigma^2_A = 4\,\sigma^2_{f/p}$ (Stonecypher _et al._, 1964; Christophe and Birot, 1979).

Narrow-sense heritabilities were estimated from the components of variance for each seed zone as follows:

$$h^2 = \frac{4\,\sigma^2_{f/p}}{\sigma^2_{f/p} + \sigma^2_e}$$

The standard errors of heritability estimates derived from the intraclass correlations were computed as follows:

$$S.E.\ h^2 \cong \frac{(1-t)\ (1+NBt)}{\sqrt{(NB)\ (F-1)/2}}$$ (Falconer 1960)

where: $t = 1/4\ h^2$,
N = number of trees within family (5),
B = number of blocks (3), and
F = number of families (8).

The ANOVA utilized the Mixed Model Least-Squares and Maximum Likelihood computer programs LSMLGP and LSML76 of Harvey (1968 and 1976). These programs were limited to a maximum of 10 provenances for each seed zone grouping. Eight provenances were eliminated when data was analysed on the seed zone level. The programs computed various parameters including estimates of variance and covariance components, heritability and its standard error as well as genetic, phenotypic and environmental correlations.

Juvenile-mature correlations were estimated through product-moment correlations between progeny annual growth and total height and product-moment correlations between total heights at various ages. Progeny annual growth was computed from the average of the last four years in height growth following the stabilization of the height increment coefficient of variation.

RESULTS AND DISCUSSION

The variation in height growth among and within seed zones was significant ($P < 0.05$). Table 2 summarizes the overall average eight year height growth variation among seed zones for the provenance/progeny trial. The observed large range in seed zone and provenance means indicates considerable genetic variation. This high variability in height growth suggests that substantial gains can be achieved through selection of the most desirable provenances. Considerable genetic variation in total height growth and height increment were also observed by Kvestich (1976) on the same material and by Christophe and Birot (1979) on 26 IUFRO Douglas-fir provenances from Washington.

Analyses of variance for 1972 to 1978 total height in all seed zones studied revealed significant differences ($P < 0.01$) for all hypothesized sources of variation. The presence of significant family within provenance variation gives the opportunity for selection of the best families in the best provenances.

Genetic Variation in Height Growth

Table 3 gives the components of variance for between provenance variation for all seed zone groupings. The patterns of variation differ appreciably in the relative sizes of some of the components of variance among populations studied (Table 3). In all seed zones, over half of the total phenotypic variation (53.68% to 62.32%) is concentrated in the trees-within-plots term, σ^2_e. This pooled error expresses various effects; genetic (includes $3/4\ \sigma^2_A + \sigma^2_D$ (dominance genetic variance) with the assumption of half-sibs) and environmental (measuring error, etc.). Because this value does not differ substantially between seed zones, it may be assumed that effects such as measuring errors and σ^2_D also remain constant between seed zones. The within provenance variance, which is in fact the difference among families within provenance ($\sigma^2_{f/p}$), also does not vary between the seed zones accounting for 5.45% to 8.07% of the total variation (averaged over seven years).

However, the relationship of $\sigma^2_{f/p}$ with respect to σ^2_p varies among the four seed zones (groups) (Table 3). For seed zone 1 and the interior provenances, σ^2_p is greater than $\sigma^2_{f/p}$ by a magnitude of approximately five with σ^2_p accounting for from 13.15% to 25.85% of the variation. This magnitude is reduced to approximately a two-fold difference for seed zone 3. The relationship is reversed for seed zone 2 where the component of the variation due to provenance effect is less than the percent due to family within provenance variation. These differences in the relative sizes of σ^2_p and $\sigma^2_{f/p}$ are important when considering selection strategies on the test site. In cases where σ^2_p is greater than $\sigma^2_{f/p}$, provenance selection for increased total height is indicated; in cases where σ^2_p is less than $\sigma^2_{f/p}$, family selection would be a more effective strategy.

The observed differences in variance component patterns may be caused by differences in the adaptation of the provenance material to the test site environment. Haney represents a low elevation site (about 120 m) within seed zone 3. The provenances from seed zone 1 and the interior zone represent trees adapted to very different conditions than the Haney area. For these seed zones the greatest differences in performance were evident at the provenance level. These provenances also exhibited the greatest differences between σ^2_p and $\sigma^2_{f/p}$. There still may be significant family within provenance variation in these provenances but it is not revealed at the Haney site. The provenances in seed zone 3 expressed a reduced difference between the magnitude of σ^2_p and $\sigma^2_{f/p}$. These provenances occur in the same seed zone as Haney but represent high elevation locations (average elevation 578 m) not well adapted to the test site. The provenances of seed zone 2 represent low elevations most similar to Haney (average elevation 209 m) and hence are most adapted to Haney conditions.

The above results suggest that in more adapted provenances, $\sigma^2_{f/p}$ and σ^2_e are the dominant contributors to phenotypic variation. For less adapted provenances, σ^2_p is of greater importance becoming greater than $\sigma^2_{f/p}$.

Estimation of Additive Genetic Variance (σ^2_A)

The additive genetic variance, its standard error and σ^2_A expressed as a percent of total phenotypic variation (σ^2_T) for total height are given in Table 4. A rather high percentage of total height variation is accounted for by σ^2_A with average estimates ranging from a low of 21.80%

for seed zone 1 to a high of 32.27% for seed zone 2. The component for σ_A^2 remains relatively constant between the years accounting for an average of 24.74% of the total variation in height for all regions (zones) combined. These estimates of σ_A^2 are lower than ($\cong 1/2$) the estimates obtained by Birot (1976) who analyzed first and second year height growth for a sample of the IUFRO Douglas-fir collection from Washington grown in France. Several of the provenances tested at Haney were included in his study. The estimates of σ_A^2 for first and second year total heights were 54% and 42%, respectively. Differences in the estimates of Birot (1976) and those presented in our study may be due to differences in the statistical model used, the test site, the test material, and the plantation age.

Examination of the ratio of the standard error of σ_A^2 (S.E.σ_A^2) over σ_A^2 multiplied by 100 (((S.E.σ_A^2)/σ_A^2) 100) (Table 4) reveal differences between seed zones. The average ratios for seed zone 1 and the interior provenances are very similar at 14.40% and 15.21%, respectively. While results for seed zones 2 and 3 are also comparable to each other averaging lower at values of 6.86% and 7.21%, respectively. The observed similarly in these ratios for pairs of zone groupings is important since it supports earlier observations, namely, that the more adapted provenances in seed zones 2 and 3 exhibit lower variation than the less adapted provenances from seed zone 1 and the interior group which express higher variability.

Estimation of Heritability (h^2)

Heritability estimates for total height growth for every seed zone (Table 5) indicate that this trait is under moderate genetic control. Heritability estimates range from 0.28 for 1978 total height in the interior provenances to 0.52 for 1972 total height in the seed zone 2 provenances and average 0.38 over all years and regions. Although the heritability estimate applies only to the experiment from which it was obtained and, furthermore, since genetic parameters should always be interpreted with caution (Falconer, 1960), the heritability estimates for height growth showed a declining trend in the early years. This trend was caused by the change in the relative increase of σ_p^2 versus $\sigma_{f/p}^2$. One explanation for the decline in h^2 estimates is a diminution of maternal effects.

The magnitude of h^2 values calculated for different zones are in agreement with Birot (1976) and Christophe and Birot (1979) but are greater than those of Campbell (1972), Orr-Ewing and Yeh (1978) and Yeh and Heaman (1982). Campbell (1972) estimated h^2 of juvenile Douglas-fir trees between 0.08 and 0.22 for first and second year height. These low estimates were mainly due to high family x location interaction. Nonetheless the presence of considerable genetic variance (high σ_D^2) indicates the potential for improvement in height growth. Orr-Ewing and Yeh (1978) also suggested that growth was under weak additive genetic control as indicated by low estimates for h^2. The heritabilities they presented had low reliability because of the unbalanced design and small size of the experiments.

Standard errors for h^2 based on seed zones at the Haney site are consistent at approximately 0.10 for all years and zones giving a high degree of reliability to these estimates.

Juvenile-mature Correlation

Increases in product-moment correlation coefficients between total heights at various ages are inversely associated with the number of years between measurements (Table 6). The coefficient of determination (R^2) values are similar for all relationships in all zones and are all significant ($P < 0.01$). The total height in 1972 and 1973 accounts for almost half of the variation in 1977 and 1978 total height. Between 58% and 63% of the variation in 1978 total height can be explained by variation in 1974 total height. Variation in 1975 total height explains approximately 75% of the variation in 1978 total height. The R^2 for 1976 and 1977 versus 1978 total height is over 0.80 (Table 6). In general, results from height measurements at early ages projected forward four to five years can predict over 50% of height growth variation in later years. The strong correlation between heights at very early ages and later years indicates that selection can be made at early ages to predict later performance with minimal risk of losing good individuals. Measurements should be continued to determine if the high relationship of the early juvenile to later juvenile growth and growth in later age classes is perpetuated.

The product-moment correlations between progeny annual growth (P.A.G.) and total height are significant ($P < 0.01$) at all ages with R^2 increasing throughout the test period. However, R^2 does not account for greater than 50% of the variation until 1975. It is, therefore, suggested to wait until at least age five or later to make selections. Nursery effects are not considered significant in this test since all the trees received similar treatment before outplanting. Similarity in genetic parameter estimates for all years also indicates that early results do not vary significantly from later ones.

Results from the ranking of provenances according to mean 1975 and 1978 total height for all provenances (data not in table) indicate little change in the ranking of the best 25% of the provenances suggesting good reliability in selection of the best provenances at age five. The largest deviation in performance between 1975 and 1978 occurs in seed zone 2, but it should be noted that all of the top seven provenances in seed zone 2 are greater than 350 cm in total 1978 height. The performance of the remaining provenances also does not change significantly so the removal of the poorest trees at age five may be feasible as well. Early evaluation will allow for testing of a greater number of families and provenances which will lead to a higher selection intensity.

Selection Strategy for the Test Site

The overall assessments of the genetic variation among the various Douglas-fir provenances suggest that a "triple tandem" selection (i.e., the best single individual from each of the few best families from each of the few best provenances) would yield the greatest increase in height growth. In addition, the relatively high amount of σ_A^2 indicated by the high h^2 values suggest that there are opportunities for significant improvement by selection in provenance and progeny tests of Douglas-fir. Nevertheless, the differences in genetic variance among regions for σ_p^2 and $\sigma_{f/p}^2$ and the resulting differences in genetic parameters may cause varying responses to selection among regions. This possibility should be further investigated by studying the within provenance variance individually. Birot (1976) and Christophe and Birot (1979) found significant differences in genetic variance between trees within provenances as well as among provenances.

The response to selection (R) at the test site was estimated from the relationship $R = i\,\sigma_p^2 h^2$ (Falconer, 1960) where i is the intensity of selection and σ_p^2 is the phenotypic standard deviation. Using a selection intensity (i) of only one in four individuals, the estimates of genetic gains for every seed zone and different years are given in Table 7. Results with this relatively low selection intensity indicate genetic gains from 17.90% in 1972 to 10.96% in 1978 for all regions (Table 7).

The genetic gain estimates suggest that appreciable improvement in height growth rate of Douglas-fir is possible by merely selecting from the top individuals from any provenance. However, the results of the seed zone and provenance performance show that even greater gains can be achieved by selecting the best individuals from the best families from the best provenances in the best seed zones. For example, comparing the mean 1978 total height of provenance 53 (Matlock) at 387.7 cm to the mean for the whole 48 provenances at 297.2 cm, an increase in total height growth of almost 33% is suggested. If the best individual within provenance 53 is also selected (1978 total height of 580 cm), a further gain of 70% above the average is indicated.

CONCLUSION

Based on the observed patterns of genetic variation and the performance of provenances and progenies at the test site, selection of provenances from seed zones 2 and 3 (Washington sources Matlock (52 and 63), Naselle (67) and Oregon sources Vernonia (83), Waldport (87), Coquille (89) and Brookings (91) in seed zone 2; British Columbia sources Squamish (25) and Chilliwack (27) and Washington sources Perry Creek (42) and Gold Bar (61) in seed zone 3) would produce the tallest trees at the Haney and comparable planting sites. Some provenances from seed zone 1 also exhibit excellent growth (Duncan (32), British Columbia and Mill City (96), Oregon). In addition, from the information on σ_A^2, h^2, and juvenile-mature correlation, it is evident that individual tree and family selection in the provenances of the best zones in 1975 will yield significant improvement in total height growth.

Applying these results to a Douglas-fir tree improvement program in south coastal British Columbia, the best provenances in seed zones 2 and 3 would be selected because of their significantly greater rate of height growth. Specific individual families or trees may be selected below the top provenances in the best zones. Selection of some exceptional provenances in other seed zones (for example, seed zone 1) may also be desirable to increase the genetic base of the resulting breeding program and to provide the material for interracial crosses to further expand the available genetic variation. The number of provenances selected would depend on the specific program objectives.

LITERATURE CITED

Birot, Y. 1976. Genetic parameters variations between some populations of Douglas-fir: consequences on selection. Proc., IUFRO Joint Meeting on Advanced Generation Breeding, Bordeaux, August: 19-38.

Campbell, R.K. 1972. Genetic variability in juvenile height-growth of Douglas-fir. Silvae Genetica 21(3-4):126-129.

Christophe, C. and Y. Birot. 1979. Genetic variation within and between populations of Douglas-fir. Silvae Genetica 28(5-6):197-206.

Falconer, D.S. 1960. Introduction to quantitative genetics. Ronald Press Co., New York. 365 pp.

Fashler, A.M.K. 1979. Intraspecific variation in non-selected natural populations of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). M.F. Thesis, Univ. of B.C. 74 pp.

Fletcher, A.M. and H. Barner. 1978. The procurement of seed for provenance research with particular reference to collections in NW America. Proc. IUFRO Congr., Vancouver, 1978, Vol. I:141-154.

Haddock, P.G. and O. Sziklai. 1966. Seed collection zones for Douglas-fir in Canada. Sexto Congreso Forestal Mundial, Madrid (6 CFM/E/C.T. I/15).

Harvey, W.R. 1968. Least-squares and maximum likelihood general purpose program. Ohio State Univ. 35 pp.

Harvey, W.R. 1976. Mixed model least-squares and maximum likelihood computer program. Ohio State Univ. 76 pp.

Kvestich, A.M. 1976. Studies in height growth of selected Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) provenances and progenies. B.S.F. Thesis, Univ. of B.C. 55 pp.

Namkoong, G., R.A. Usanis, and R.R. Silen. 1972. Age-related variation in genetic control of height growth in Douglas-fir. Theor. and Appl. Genet. 42:151-159.

Orr-Ewing, A.L. and F.C.H. Yeh. 1978. Survival and growth traits of racial crosses with Douglas-fir. Res. Note No. 85, Province of B.C., Ministry of Forests. 44 pp.

Rehfeldt, G.E. 1974. Genetic variation of Douglas-fir in the northern Rocky Mountains. USDA For. Serv. Res. Note INT-184. 6 pp.

Silen, R.R. 1978. Genetics of Douglas-fir. USDA For. Serv. Res. Pap. WO-35. 34 pp.

Stonecypher, R., F.C. Cech and B.J. Zobel. 1964. Inheritance of specific gravity in two and three-year-old seedlings of loblolly pine. Tappi 47:405-407.

Yeh, F.C. and C. Heaman. 1982. Heritabilities and genetic and phenotypic correlations for height and diameter in coastal Douglas-fir. Can. J. For. Res. 12:181-185.

Table 1. Analysis of variance and expected mean squares for among provenance variation

Source of variation	d.f.[1/]	E.M.S.[2/]
Provenances	(P-1)	$\sigma^2_e + BT\ \sigma^2_{f/p} + FT\ \sigma^2_{pb} + BFT\ \sigma^2_p$
Blocks	(B-1)	$\sigma^2_e + FT\ \sigma^2_{pb} + PFT\ \sigma^2_b$
Prov. x Blocks	(P-1) (B-1)	$\sigma^2_e + FT\ \sigma^2_{pb}$
Family/Prov.	P(F-1)	$\sigma^2_e + BT\ \sigma^2_{f/p}$
Residual	BPF(T-1) + P(F-1)(B-1)	σ^2_e

1/ P, number of provenances (48); B, number of blocks (3); F, number of open-pollinated families (8); and T, number of trees within open-pollinated family (5).

2/ σ^2_p, provenance variance; σ^2_b, block variance; σ^2_{pb}, variance due to provenance x block interaction; $\sigma^2_{f/p}$, variance among families within provenance; $\sigma^2_e = \sigma^2_{bf/p} + \sigma^2_{w/k}$ where $\sigma^2_{bf/p}$, variance due to block x family within provenance interaction; $\sigma^2_{w/k}$, within plot variance; and k, the harmonic mean of number of trees per plot.

Table 2. Total 1978 height differences between seed zones

Seed zone		Average 1978 total height (cm)	Standard deviations (cm)
1		284.2	97.7
2		347.8	101.4
3		313.4	96.2
IP 1/	4	273.9	80.1
	5	253.3	86.8
	7	200.4	68.4
	8	164.7	76.0
Average		297.2	104.9

1/ IP, interior provenances.

Table 3. Components of variance for all seed zones

Seed zone	Year	σ^2_p	σ^2_b	σ^2_{pb}	$\sigma^2_{f/p}$	σ^2_e
1	1972	24.92 (14.43)[1/]	1.76 (1.01)	32.66 (18.78)	10.28 (5.91)	104.27 (59.97)
	1973	133.82 (20.74)	0.00 (0.00)[2/]	138.21 (21.42)	33.81 (5.24)	339.39 (52.60)
	1974	352.02 (25.37)	0.00 (0.00)	235.47 (16.97)	72.09 (5.20)	728.07 (52.46)
	1975	630.75 (26.97)	24.54 (1.05)	274.60 (11.74)	148.67 (6.36)	1206.48 (53.89)
	1976	1139.94 (29.04)	48.09 (0.34)	393.58 (10.03)	236.32 (6.02)	2107.43 (53.69)
	1977	2113.86 (31.73)	177.09 (2.66)	550.16 (8.06)	324.87 (4.88)	3495.31 (52.47)
	1978	3437.20 (32.67)	521.28 (4.95)	758.31 (7.21)	477.99 (4.54)	5326.65 (50.63)
2	1972	4.32 (1.98)	0.00 (0.00)	32.97 (15.01)	23.72 (10.85)	157.50 (72.08)
	1973	23.62 (3.16)	10.84 (1.43)	124.11 (16.42)	68.82 (9.12)	528.67 (69.92)
	1974	36.74 (2.44)	27.06 (1.78)	235.31 (15.65)	121.29 (8.07)	1083.25 (72.04)
	1975	71.65 (2.94)	21.13 (0.87)	381.65 (15.67)	173.51 (7.13)	1787.36 (73.39)
	1976	209.57 (4.80)	16.85 (0.39)	769.75 (17.64)	302.30 (6.93)	3064.51 (70.24)
	1977	411.97 (5.87)	12.99 (0.19)	1276.36 (18.18)	510.19 (7.27)	4809.12 (68.50)
	1978	598.10 (5.95)	0.00 (0.00)	1636.80 (16.28)	713.54 (7.10)	7105.36 (70.67)
3	1972	19.20 (9.83)	0.00 (0.00)	52.05 (26.64)	13.08 (6.69)	111.03 (56.84)
	1973	88.02 (12.34)	0.00 (0.00)	220.60 (30.92)	37.04 (5.19)	367.74 (51.55)
	1974	179.17 (12.63)	0.00 (0.00)	418.47 (29.50)	75.67 (5.33)	745.45 (52.54)
	1975	279.47 (12.42)	0.00 (0.00)	556.84 (24.75)	117.72 (5.23)	1296.27 (57.60)
	1976	543.20 (14.19)	0.00 (0.00)	902.20 (23.56)	177.85 (4.64)	2206.19 (57.61)
	1977	925.61 (14.92)	0.00 (0.00)	1404.69 (22.64)	325.56 (5.25)	3547.45 (57.19)
	1978	1384.07 (15.73)	0.00 (0.00)	1700.75 (19.33)	552.32 (6.28)	5162.56 (58.67)
IP[3/]	1972	25.05 (27.12)	2.73 (2.96)	5.44 (5.89)	5.83 (6.31)	53.30 (57.72)
	1973	117.75 (29.62)	11.47 (2.88)	36.27 (9.12)	25.55 (6.43)	206.57 (51.95)
	1974	222.12 (25.76)	46.84 (5.43)	70.56 (8.18)	58.11 (6.74)	464.63 (53.89)
	1975	381.25 (23.65)	111.62 (6.93)	96.78 (6.00)	98.05 (6.08)	924.26 (57.34)
	1976	650.33 (23.18)	186.96 (6.66)	184.66 (6.58)	145.03 (5.17)	1638.84 (58.41)
	1977	1267.18 (25.74)	306.17 (6.22)	352.16 (7.15)	235.17 (4.78)	2763.10 (56.12)
	1978	2129.03 (28.52)	0.00 (0.00)	676.50 (9.06)	327.08 (4.38)	4332.47 (58.04)

1/ Percent of estimated phenotypic variance.
2/ Negative component estimate.
3/ Interior provenances.

Table 4. Additive genetic variance (σ^2_A), standard error of σ^2_A (S.E. σ^2_A), S.E. σ^2_A ratio (((S.E. σ^2_A)/σ^2_A) 100), and σ^2_A as a percent of total phenotypic variance (σ^2_A/σ^2_T) for total height.

Seed zone	Year	$\sigma^2_A \pm$ S.E.[1/]	S.E.σ^2_Aratio	σ^2_A/σ^2_T
1	1972	41.12 ± 6.01	14.61	23.64
	1973	135.26 ± 19.67	14.54	20.96
	1974	288.35 ± 42.05	14.58	20.80
	1975	594.67 ± 77.06	12.96	25.44
	1976	945.28 ± 130.88	13.85	24.08
	1977	1299.47 ± 194.86	15.00	19.52
	1978	1911.97 ± 291.29	15.24	18.16
Average			14.40	21.80
2	1972	94.86 ± 5.82	6.14	43.40
	1973	275.29 ± 17.76	6.45	36.48
	1974	485.14 ± 33.12	6.83	32.28
	1975	694.04 ± 50.24	7.24	28.52
	1976	1209.20 ± 86.94	7.19	27.72
	1977	2040.77 ± 142.35	6.98	29.08
	1978	2854.15 ± 203.66	7.14	28.40
Average			6.86	32.27
3	1972	52.30 ± 3.49	6.67	26.76
	1973	148.16 ± 10.52	7.10	20.76
	1974	302.67 ± 21.43	7.08	21.32
	1975	470.87 ± 34.97	7.43	20.92
	1976	711.38 ± 55.79	7.84	18.56
	1977	1302.22 ± 96.06	7.38	21.00
	1978	2209.26 ± 153.08	6.93	25.12
Average			7.21	22.07
IP[2/]	1972	23.31 ± 3.27	14.01	25.24
	1973	102.18 ± 13.64	13.35	25.72
	1974	232.42 ± 30.88	13.29	26.96
	1975	392.19 ± 55.64	14.19	24.32
	1976	580.12 ± 89.14	15.37	20.68
	1977	940.67 ± 112.72	12.40	19.12
	1978	1308.30 ± 217.02	16.59	17.52
Average			15.21	22.80

1/ Estimates of σ^2_A are all significant at the 0.01 level.

2/ Interior provenances.

Table 5. Heritability estimates and their standard errors ($h^2 \pm$ S.E.) for total height

Year	Seed zone			
	1	2	3	IP[1/]
1972	0.36 + 0.10	0.52 ± 0.11	0.42 ± 0.10	0.39 ± 0.10
1972	0.36 ± 0.10	0.46 ± 0.11	0.37 ± 0.10	0.44 ± 0.10
1974	0.36 ± 0.10	0.40 ± 0.10	0.37 ± 0.10	0.45 ± 0.11
1975	0.42 ± 0.10	0.35 ± 0.10	0.33 ± 0.09	0.38 ± 0.10
1976	0.40 ± 0.10	0.36 ± 0.10	0.30 ± 0.09	0.33 ± 0.09
1977	0.34 ± 0.10	0.38 ± 0.10	0.34 ± 0.10	0.31 ± 0.09
1978	0.33 ± 0.10	0.37 ± 0.10	0.39 ± 0.10	0.28 ± 0.09

1/ Interior provenances.

Table 6. Juvenile-mature correlation (R^2 values are presented in Table)[1/]

Variables		Seed zone			
Dependent	Independent	1	2	3	IP[2/]
1972 total height vs.	1973 total height	0.82	0.80	0.81	0.83
	1974	0.70	0.67	0.72	0.73
	1975	0.54	0.49	0.58	0.57
	1976	0.47	0.40	0.51	0.56
	1977	0.40	0.34	0.45	0.47
	1978	0.31	0.29	0.38	0.42
	P.A.G.[3/]	0.16	0.11	0.20	0.26
1973 total height vs.	1974 total height	0.91	0.90	0.92	0.92
	1975	0.71	0.68	0.74	0.71
	1976	0.62	0.57	0.66	0.64
	1977	0.54	0.49	0.58	0.58
	1978	0.41	0.41	0.49	0.51
	P.A.G.	0.22	0.18	0.25	0.30
1974 total height vs.	1975 total height	0.88	0.86	0.87	0.84
	1976	0.81	0.76	0.79	0.78
	1977	0.72	0.67	0.71	0.71
	1978	0.58	0.58	0.61	0.63
	P.A.G.	0.35	0.31	0.36	0.40
1975 total height vs.	1976 total height	0.95	0.94	0.94	0.96
	1977	0.87	0.87	0.87	0.88
	1978	0.72	0.77	0.75	0.75
	P.A.G.	0.52	0.53	0.52	0.56
1976 total height vs.	1977 total height	0.95	0.96	0.96	0.96
	1978	0.83	0.86	0.85	0.86
	P.A.G.	0.67	0.69	0.68	0.71
1977 total height vs.	1978 total height	0.91	0.93	0.93	0.94
	P.A.G.	0.81	0.82	0.82	0.84
1978 total height vs.	P.A.G.	0.90	0.89	0.89	0.92

1/ All the simple correlations are significant at the 0.01 level.

2/ Interior provenances.

3/ P.A.G. = Progeny annual growth calculated as
(the height increments of 1975 + 1976 + 1977 + 1978) ÷ 4.

Table 7. Estimates of genetic gain for height growth in cm and in % of population mean.

Year	Seed Zone 1		Seed Zone 2		Seed Zone 3		Interior		Average % of pop. mean
	(cm)	(%)	(cm)	(%)	(cm)	(%)	(cm)	(%)	
1972	4.74	15.72	8.61	23.10	5.75	16.96	3.69	15.82	17.90
1973	8.55	15.14	13.83	18.89	9.16	13.81	8.25	18.75	16.65
1974	12.53	14.64	17.08	15.09	13.04	12.99	12.65	18.83	15.39
1975	19.02	15.74	19.06	11.99	15.26	10.80	14.94	15.27	13.45
1976	23.82	14.50	25.69	11.88	18.02	9.40	17.15	12.83	12.15
1977	25.85	11.62	34.09	11.84	26.02	10.15	20.88	11.73	11.34
1978	30.93	10.88	40.24	11.22	36.27	11.31	23.51	10.41	10.96

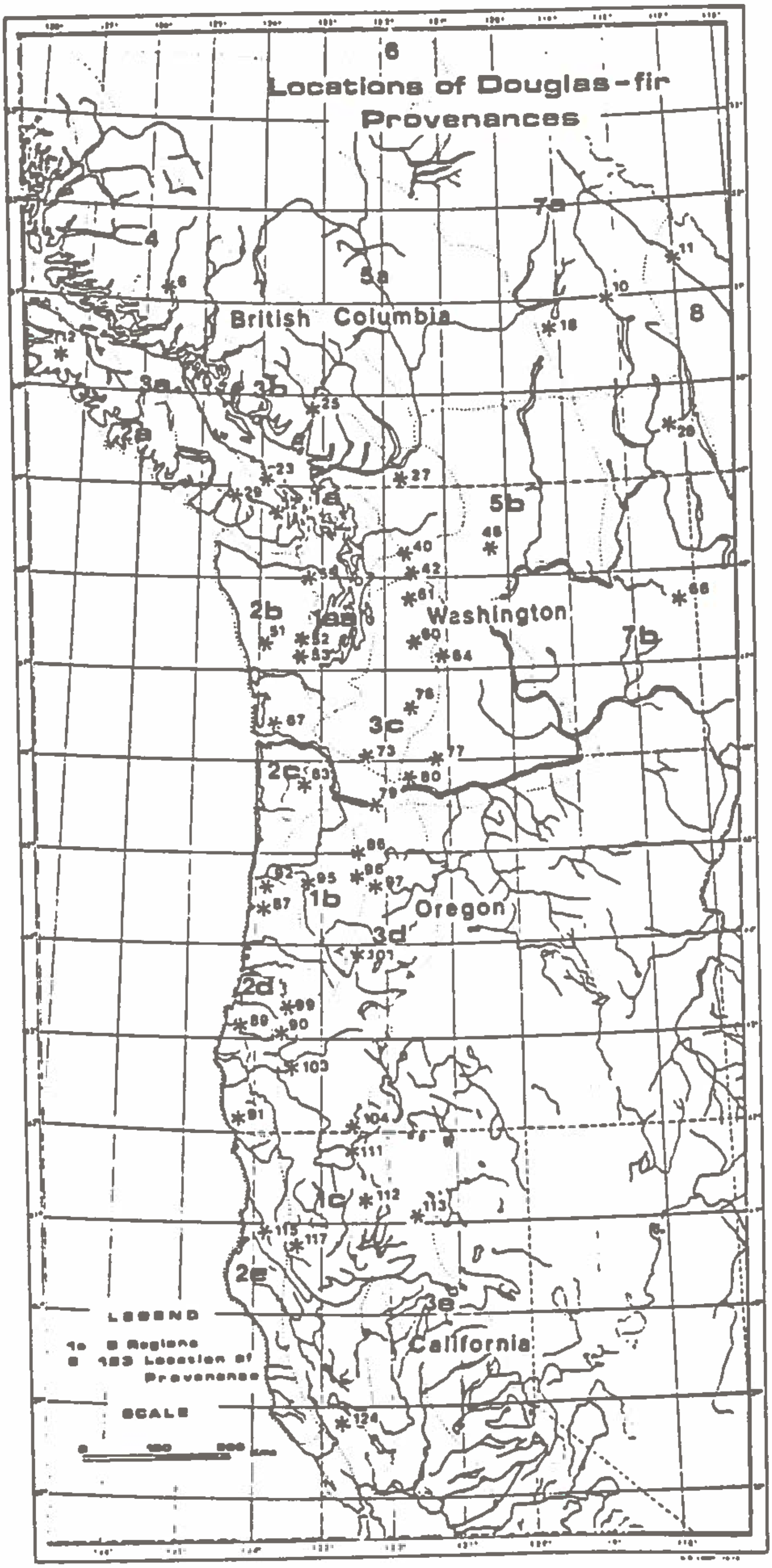


Fig. 1. Location of the 48 Douglas-fir provenances

SESSION III

IUFRO DOUGLAS FIR DATA BASE

STATUS REPORT - 1985

PAPER PRESENTED TO THE IUFRO-W.P. S2.02.05,

MEETING IN VIENNA, AUSTRIA, JUNE 1985

A.M. BRUNET * and B. ROMAN-AMAT **

* A.F.O.C.E.L. Division Informatique
30, Boulevard Foch
77300 FONTAINEBLEAU - France.

** I.N.R.A. Station d'Amélioration des Arbres forestiers
ARDON - 45160 OLIVET - France.

- ABSTRACT -

A short insight is given into the Douglas-fir IUFRO provenances data bank. The structure of this bank is recalled and its present content is given in three annexed tables. Some questions which are thought to be of importance for the bank future are raised in conclusion.

INTRODUCTION

The IUFRO Douglas-fir (var. menziesii) seed lots were distributed to 33 different countries around the world. At the Göttingen (GFR) meeting in 1973, it was decided that a data bank be set up, to allow easy storage and retrieval of the big amount of information gathered in all these provenance experiments. In 1978, at the Vancouver (Canada) meeting, Y. BIROT proposed the project of a computer based-data bank, which was accepted.

The data bank was thus created through 1979 and 1980 on the AFOCEL computer (MODCOMP 7860. CLASSIC) at Fontainebleau (France). The first data sheets were received in late 1980 and early 1981.

The present paper aims at presenting the present structure, content and functionning of the data base. A few questions are then raised for the future.

1. BANK STRUCTURE

The structure of the bank is intangible. The following five separate file exist.

. File 1 is called : "**Provenances**". It contains all informations about the IUFRO Douglas-Fir provenances : location, climate, topography, genetic history and biosystematics. (45 data items for each provenance).

. File 2 is called "**Distribution**" : For each test-site within each institution within each country, this file contains the list of the IUFRO provenances represented (yes or no for 188 provenances).

- File 3 is called "**Test sites**" : This file contains informations about field experiments : location, climate, topography, soil, plantation technique and experimental design (45 data items per site).

- File 4 is called "**Performances**". For each provenance in each test site, it contains for three traits the results of assessments made at different ages up to 10 years :

  - flushing : the assessment method is indicated through a code;

  - total height : centimeters are to be used;

  - survival, in percentage.

For flushing and total height, the provenance mean and standard deviation, as well as the number of trees observed, have to be indicated.

The number of data items in this file is not restricted.

- File 5 is called "**List of Codes**". It contains the codes to be used when storing data into files 1 to 4. For example, countries and institutions within countries are specified by codes.

Access to each file is possible through a limited number of keys:

- IUFRO provenance number (files 1, 2 and 4);

- country >(coded) > institution (coded) test site (coded) and IUFRO provenance number, or IUFRO provenance number and country > institution> test-site (files 2,3 and 4).

- country > institution > test site (file 3).

- country > institution > test site and provenance and age, or provenance, age, and country > institution > test site or age, provenance, country > institution > test site : (file 4).

- variable name and code (file 5).

The data, recorded on special sheets which have been distributed to participants, are centralized by INRA at Orléans, then stored by AFOCEL at Fontainebleau. The data bank belongs to the IUFRO working group and to the participant institutions.

2. PRESENT CONTENT OF THE BANK

. So far, file 1 is empty. In 1985, INRA will send to AFOCEL, under appropriate format, the information about location and climate of the IUFRO provenances.

. The content of file 2 is shown on annexes 1 and 2. Annex 1 is focused upon the number test-sites and provenances owned by each institution. Among the 33 potential participants, only 8 have up to now sent data. Nevertheless, 12 institutions and 62 test sites have already been recorded. Annex 2 just gives the repartition of all the provenances between all the sites and the total number of test sites per provenance, varying from 0 to 41.

. Annex 3 was built by selecting informations in files 3 and 4. Each test site is characterized by altitude (ALT, meters), Longitude (Long, minutes), Latitude (LAT, minutes), Mean annual rainfall (MAR, centimeters), Mean annual temperature (MAT, tenth of Celsius), date of planting (PLANT, month and year), number of provenances (PRO). This annex also indicates the number and kind of assessments made in each test-site : ages of first and last assessments stored into the bank (columns AGE) and number of assessments stored into the bank (columns NB). It seems especially important to be in possession of the latter informations before asking for a general exploitation of the bank content.

3. FUNCTIONNING OF THE BANK

The data stored in the bank may be exploited in two different ways.

. The normal way is to retrieve data in one or several files by using keys and then to print them. Examples given :

- Listing of all ecological features for all the provenances (file 1).
- Listing of all test sites for a given country (file 2).
- Listing of site informations of all test-sites (file 3).
- Listing of available performances of a given provenance in a choosen test-site; available performances of a given provenance in all test sites of an institution, or a country, or in all countries; performances of all provenances in all test-sites at a given age (file 4).

Generally speaking, the results of such exploitations are big amounts of paper.

. Programms might be written in order to answer other questions. For example, the results given in annexes 1, 2 and 3 were obtained by AFOCEL in such a way. This information may be much more synthetic than the one obtained with the normal way of exploitation. However, this work is costly and the number of such programms will have to be strictly limited.

. So far, no other exploitations were made than the listing of the whole content of all files and those presented with this paper.

4. QUESTIONS FOR THE FUTURE OF THE BANK - CONCLUSION

The present state of this data-bank calls for two kinds of questions :

. New data entry : All available informations have not been entered into the base yet. Therefore, is it necessary to call for :

- new participants to the bank ?
- new data from the present participants ? Is the limit of ten years after planting for data recording maintained ? Is it necessary to foresee recording of new traits, such as girth and volume growth, forking, branching habits, fungi attacks,-....?

. Two different kinds of exploitations may be set up :

- answering of individual questions of participant members: is it possible to draw a comprehensive list of these questions ?
- periodical general exploitation of the bank, in order to give an evaluation of the provenances over all sites. This big amount of work could be done by a thesis student or a sabbatical researcher for example, under close scrutiny of a senior Douglas-fir breeder.

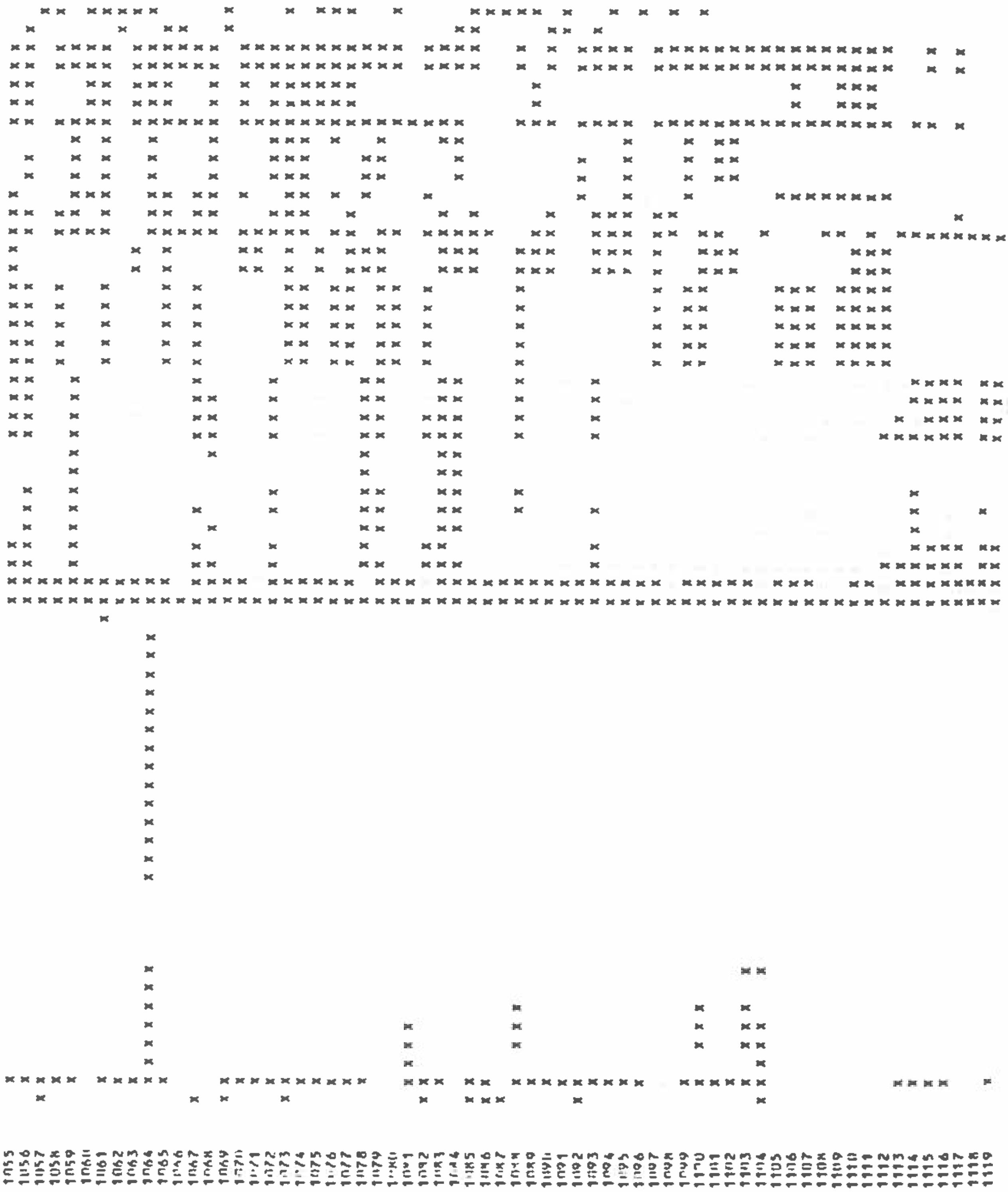
Giving answers to these questions seems to be the major task set for the working-group meeting planned in Vienna in June 1985.

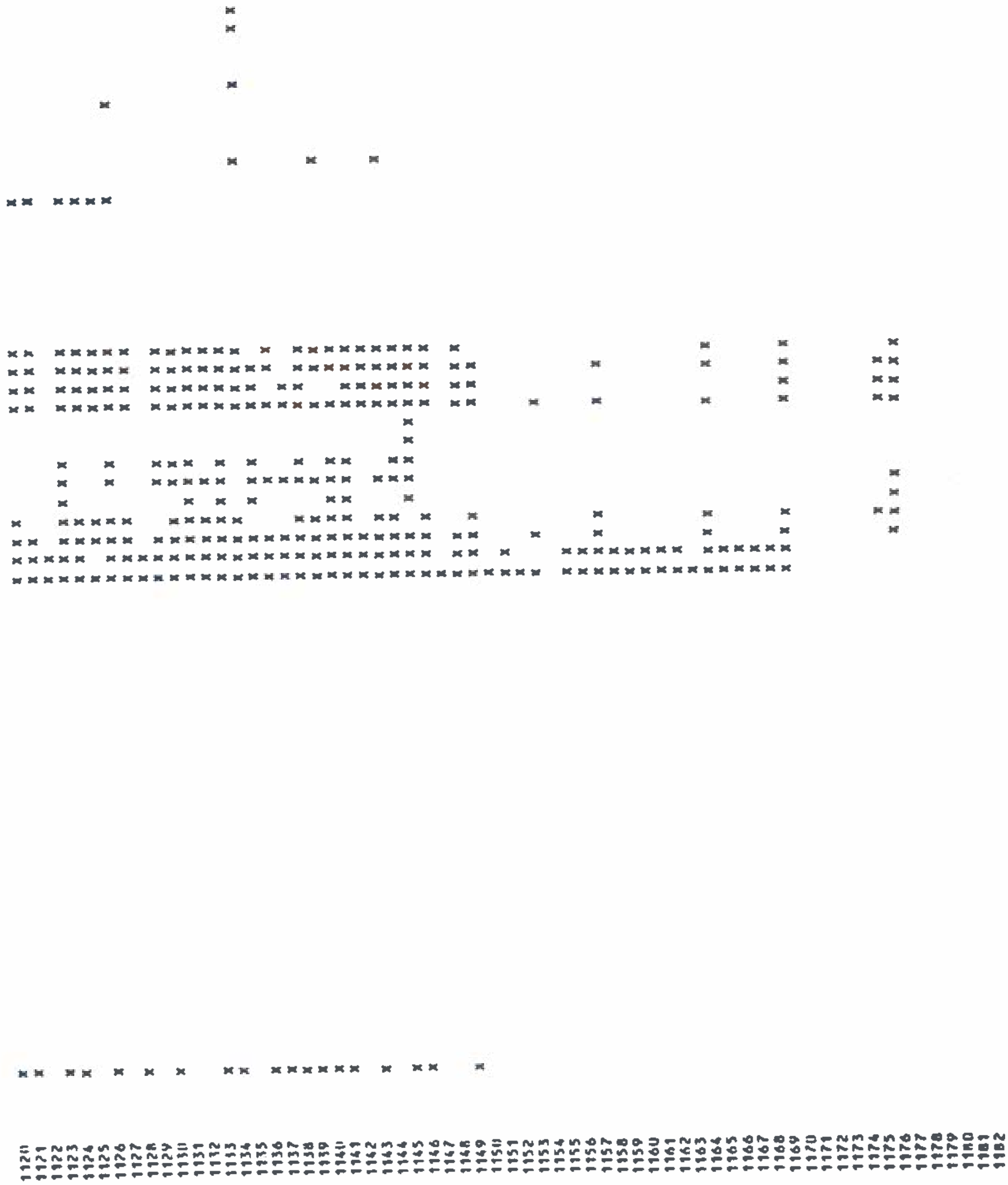
ANNEX I

CODE	INSTITUTION	TEST SITES	PROVENANCES PER SITE
	BELGIUM		
4 1	STATION DE RECHERCHES DES EAUX ET FORETS - GROENENDAAL	1	26
	CANADA		
5 1	UNIVERSITY OF BRITISH COLUMBIA VANCOUVER	1	99
5 2	BRITISH COLUMBIA FOREST SERVICE RESEARCH BRANCH - VICTORIA	24	FROM 3 TO 21
	DENMARK		
8 1	STATION EXPERIMENTALE FORESTIERE KLAMPENBORG	1	15
	FRANCE		
9 1	INSTITUT NATIONAL DE LA RECHERCHE AGRONOMIQUE - ORLEANS	2	FROM 151 TO 168
9 2	ASSOCIATION FORET CELLULOSE - PARIS	11	FROM 10 TO 74
	FEDERAL REPUBLIC OF GERMANY		
11 1	INSTITUT DE RECHERCHE FORESTIERE DU LAND DE HESSE - HANN. MUNDEN	13	FROM 36 TO 93
11 2	INSTITUT DE RECHERCHE FORESTIERE DU LAND DE BASSE SAXE - ESCHERODE	4	FROM 53 TO 99
11 3	INSTITUT DE RECHERCHE FIRESTIERE DU LAND DE BAVIERE - TEISENDORF/OBB	1	96
	ITALY		
14 1	INSTITUT POUR LES PLANTES LIGNEUSES TURIN	1	22
	NEDERLAND		
18 1	RESEARCH INSTITUTE FOR FORESTRY AND LANDSCAPE PLANNING - WAGENINGEN	2	FROM 44 TO 50
	NORWAY		
19 1	NISK - STEND.	1	51

ANNEX 2

COUNTRY	04	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	05	08	09	09	09	09	09	09	09	09	09	09	09	09	09	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	14	15
INSTITUTION	01	01	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	02	01	01	01	02	02	02	02	02	02	02	02	02	02	02	01	01	01	01	01	01	01	01	01	01	01	01	01	02	02	02	02	03	01	01
TEST SITE	01	10	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	01	02	01	02	03	04	05	06	07	08	09	10	11	01	02	03	04	05	06	07	08	09	10	11	12	13	01	02	03	04	01	01	01
PROVENANCES|																																																												
1001		x																									x	x	x												x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	
1002	x																										x	x	x																															x
1003		x																										x	x												x	x	x	x	x	x	x	x		x				x	x	x	x	x		
1004																											x	x	x																			x						x			x	x		x
1005		x																										x	x												x	x	x	x	x	x	x	x	x	x				x	x	x	x	x		
1006																												x	x												x	x	x	x	x	x	x	x						x	x	x	x	x		
1007		x																										x	x	x	x						x	x		x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x		
1008		x																										x	x	x	x						x	x			x	x	x	x	x	x	x	x		x	x	x		x	x	x	x	x	x	
1009																											x	x	x																															
1010		x																										x	x	x	x	x	x				x	x	x		x	x	x	x	x	x	x	x	x	x				x	x	x	x	x		
1011																												x	x																															
1012		x																									x	x	x																															x
1013		x																										x	x	x	x	x					x	x			x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	
1014																												x	x												x	x	x	x	x			x						x	x	x	x	x		
1015																												x	x												x	x	x	x	x			x	x					x	x	x	x	x		
1016																												x	x	x		x	x				x	x			x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x		
1017																												x	x												x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
1018	x	x																									x	x	x												x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x		
1019		x																										x	x	x	x						x	x		x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x		
1020																												x	x												x	x	x	x	x	x	x	x		x				x	x	x	x	x		
1021	x		x	x	x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x												x	x	x	x	x			x		x	x	x	x	x			x	x	x	x
1022																												x	x												x	x	x	x	x	x	x	x	x	x				x	x	x	x	x		
1023	x	x																									x	x	x																			x	x	x				x	x	x	x	x		x
1024		x		x	x	x	x	x								x											x	x	x	x	x	x	x	x	x		x	x	x	x								x	x	x	x	x	x	x	x	x	x	x		x
1025		x																									x	x	x																			x		x	x	x	x	x			x	x		x
1026			x	x	x			x																			x	x	x																	x	x	x	x	x				x	x	x	x	x		x
1027			x	x	x		x	x																				x	x																	x	x			x	x	x	x	x			x	x		
1028		x																										x													x	x	x	x	x	x	x	x		x			x	x	x	x	x	x		
1029		x																									x	x	x																															x
1030	x	x	x	x	x		x	x																				x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x		x	x		x			x	x		x
1031	x																										x	x	x																			x											x	x
1032	x	x		x	x	x		x	x	x	x	x									x							x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x			x	x		x	x	x	x	x	x	x	x	x	x
1033		x																										x	x																		x						x	x	x	x	x		x
1034			x	x	x		x	x																				x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x		x
1035		x																										x	x	x	x						x	x		x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x	x	x	
1036	x	x	x	x	x		x	x																				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x					x			x	x		x
1037			x	x	x		x	x																				x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x			x						x						x
1038		x	x	x	x			x	x	x	x	x	x															x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x						x			x	x		x
1039	x	x																										x	x																		x												x
1040		x	x	x	x		x	x																				x	x												x	x	x	x	x			x	x					x			x	x		x
1041		x	x	x	x		x	x																				x	x	x	x		x	x			x	x	x	x	x	x	x	x	x			x	x	x	x	x		x	x	x	x	x		x
1042	x	x		x	x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x																				x		x	x	x	x	x	x	x	x		x
1043	x	x	x	x	x		x	x																				x	x																x	x			x				x	x	x	x	x		x
1044																												x																																
1045		x	x	x	x		x	x	x	x	x	x																x	x	x							x	x	x	x								x	x	x	x	x	x	x	x	x	x	x		x
1046	x	x																										x	x	x	x	x	x	x	x	x	x	x	x	x						x	x	x		x	x	x	x	x	x	x	x	x		
1047	x	x																									x	x	x												x	x	x	x	x						x	x	x	x	x		x	x	x	
1048																												x	x	x							x	x	x	x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	
1049		x																										x	x	x		x	x	x	x		x	x	x	x						x	x			x				x	x	x	x	x	x	
1050		x																										x	x																		x			x	x	x	x			x	x		x
1051	x	x																										x	x	x	x						x	x	x	x								x	x		x	x	x	x	x	x	x	x		x
1052		x																										x	x	x							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
1053	x	x																									x	x	x																														x	x
1054	x	x																										x	x																	x	x	x		x	x	x	x	x			x	x		x




1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182

COUNTRY	1	1
	8	9
INSTITUTION	0	0
	1	1
TEST SITE	0	0
	2	1

PROVENANCES

1001			20	1062	X		6	1122			2
1002	X	X	7	1063	X		12	1123			13
1003			17	1064	X		36	1124			10
1004	X	X	10	1065		X	20	1125			8
1005			18	1066		X	7	1126		X	14
1006		X	16	1067			21	1127			8
1007			24	1068			19	1128			3
1008		X	25	1069	X		7	1129			9
1009		X	4	1070			12	1130			11
1010			25	1071		X	9	1131			11
1011		X	3	1072			21	1132			9
1012	X	X	7	1073	X		24	1133			12
1013		X	26	1074			19	1134			13
1014			13	1075			11	1135			9
1015			14	1076	X		18	1136			8
1016			23	1077	X		19	1137			7
1017		X	21	1078		X	22	1138			11
1018		X	23	1079		X	25	1139			10
1019			23	1080			12	1140			11
1020		X	17	1081			7	1141			12
1021	X		39	1082		X	18	1142			7
1022			17	1083		X	23	1143			11
1023	X		15	1084			22	1144			10
1024	X	X	34	1085	X		13	1145			13
1025		X	14	1086			6	1146			9
1026	X		19	1087	X		5	1147			1
1027		X	17	1088	X		24	1148			7
1028		X	18	1089	X		11	1149			8
1029		X	6	1090			11	1150			1
1030	X		35	1091	X		6	1151			2
1031	X	X	9	1092			10	1152			1
1032	X	X	41	1093			18	1153			3
1033	X	X	12	1094			11	1154			
1034	X		35	1095			14	1155			2
1035		X	26	1096	X	X	6	1156			2
1036	X		32	1097			14	1157			6
1037	X	X	26	1098			7	1158			2
1038	X	X	35	1099		X	16	1159			2
1039	X	X	8	1100	X		19	1160			2
1040	X		26	1101	X		13	1161			2
1041	X	X	34	1102	X	X	13	1162			2
1042	X	X	35	1103			10	1163			1
1043	X		19	1104			11	1164			7
1044			1	1105		X	12	1165			2
1045	X		30	1106		X	14	1166			2
1046			27	1107		X	12	1167			2
1047			18	1108		X	7	1168			2
1048		X	24	1109			13	1169			3
1049			21	1110			15	1170			
1050			11	1111		X	17	1171			
1051	X		22	1112		X	15	1172			
1052		X	28	1113			7	1173			
1053	X	X	9	1114			13	1174			
1054	X		16	1115			13	1175			4
1055			24	1116			10	1176			8
1056		X	28	1117		X	14	1177			
1057	X		6	1118		X	4	1178			
1058	X		15	1119			11	1179			
1059			23	1120		X	11	1180			
1060	X		11	1121		X	10	1181			
1061	X	X	23					1182			

ANNEX 3

CODE	INSTITUTION	TEST SITE	ALT	LONG	LAT	MAR	MAT	PLANT	NO PRO	FLUSHING AGE	FLUSHING NB	T.HEIGHT AGE	T.HEIGHT NB	SURVIVAL AGE	SURVIVAL NB
BELGIUM															
4 1	STATION DE RECHERCHES DES EAUX ET FORETS - GROENENDAAL	01 SOY	260	529	5017	104	80	05/72	26	2- 2	1	12-12	1	12-12	1
CANADA															
5 1	UNIVERSITY OF BRITISH COLUMBIA VANCOUVER	10 MAPLE RIDGE	183	7355	2958	236	904	05/71	99	-		2- 9	6	2- 8	5
5 2	BRITISH COLUMBIA FOREST SERVICE RESEARCH BRANCH - VICTORIA	01 PORT RENFREW	245	7457	2919	225	83	03/69	15	-		8- 8	1	8- 8	1
		02 SOOKE (MUIR CREEK)	140	7432	2905	136	91	11/68	21	-		8- 8	1	8- 8	1
		03 LOOKOUT MOUNTAIN	1035	7438	2936	302	5[illegible]	05/69	21	-		8- 8	1	8- 8	1
		04 HEMMINGSEN 71	410	7455	2918	238	53	03/71	8	-		8- 8	1	8- 8	1
		05 MUD BAY	95	7487	2967	147	95	03/73	13	-		8- 8	1	-	
		06 KEMANO	230	7672	3210	203	72	05/73	18	-		8- 8	1	8- 8	1
		07 PIGGOTT CREEK	790	7523	2988	190	52	05/71	3	-		8- 8	1	8- 8	1
		08 SOOKE HIGH	760	7433	2911	399	52	04/71	3	-		8- 8	1	8- 8	1
		09 OYSTER RIVER	60	7512	2993	153	90	03/73	3	-		8- 8	1	8- 8	1
		10 POWELL RIVER LOW	245	7454	2992	121	110	03/73	3	-		8- 8	1	8- 8	1
		11 CHILLIWACK	215	7301	2945	190	91	03/70	4	-		8- 8	1	8- 8	1
		12 HARRISON LAKE	245	7305	2972	181	99	03/70	3	-		8- 8	1	8- 8	1
		13 SPUZZUM	305	7291	2981	178	79	03/70	3	-		8- 8	1	8- 8	1
		14 PEMBERTON	360	7371	3017	107	80	03/70	4	-		8- 8	1	8- 8	1
		15 LOIS LAKE	185	7455	2992	118	87	03/70	3	-		8- 8	1	8- 8	1
		16 KLINAKLINI	90	7535	3071	159		03/70	3	-		8- 8	1	8- 8	1
		17 BELLA COOLA	135	7583	3147	160	68	10/69	3	-		8- 8	1	8- 8	1
		18 SALTSPRING ISLAND	365	7409	2925	132	49	02/71	3	-		8- 8	1	8- 8	1
		19 DOVE CREEK	275	7509	2983	158	111	04/71	4	-		8- 8	1	8- 8	1
		20 QUADRA ISLAND	180	7515	3009	221	85	03/71	3	-		8- 8	1	8- 8	1
		21 KELSEY BAY	395	7551	3019	243	85	05/72	3	-		8- 8	1	8- 8	1
		22 KENNEDY LAKE	335	7533	2947	353	91	05/72	3	-		8- 8	1	8- 8	1
		23 GOLD RIVER	365	7560	2985	356	80	04/71	3	-		8- 8	1	8- 8	1
		24 COAL HARBOUR	45	7651	3037	240	101	03/70	3	-		8- 8	1	8- 8	1

CODE	INSTITUTION	TEST	F	ALT	LONG	LAT	MAR	I	PLANT	NB PRO	FLUSHING AGE	FLUSHING NB	T.HEIGHT AGE	T.HEIGHT NB	SURVIVAL AGE	SURVIVAL NB
DENMARK																
8 1	STATION EXPERIMENTALE FORESTIERE KLAMPENBORG	01	SILKEBORG		574	3368	72	69	05/71	15	-		9- 9	1	4- 4	1
FRANCE																
9 1	INSTITUT NATIONAL DE LA RECHERCHE AGRONOMIQUE - ORLEANS	01	PEPINIERE D ORLEANS	112	114	2869	72	110	05/73	168	3- 3	1	3- 3	1	-	
		02	FORET D ORLEANS P 692	130	135	2875	60	113	04/75	151	-		7- 7	3	9- 9	1
9 2	ASSOCIATION FORET CELLULOSE - PARIS	01	MAZEROLLAS	400	160	4541	120	101	03/79	72	6- 6	1	6- 6	1	6- 6	1
		02	ROYERE	600	110	2751	156	98	04/79	54	-		-		-	
		03	LES HAYERS	200	555	2809	113		04/80	28	-		-		-	
		04	LE CHESNE	170			97		04/80	42	-		-		-	
		05	SAINT ETIENNE	600			130		05/80	31	-		-		-	
		06	SELONGEY	420	308	2856	74	116	05/80	11	-		-		-	
		07	SAINTE CROIX AUX MINES	550			110		/	10	-		-		-	
		08	ROUISSE	700			122	107	/	74	-		-		-	
		09	KERPERT	220			94		3/79	55	-		-		-	
		10	PERRUEL		57	2966	70	100	03/79	63	-		-		-	
		11	BOIS DU RABEY	90	81	2975	100	101	/	60	-		-		-	
FEDERAL REPUBLIC OF GERMANY																
11 1	INSTITUT DE RECHERCHE FORESTIERE DU LAND DE HESSE - HANN. MUNDEN	01	BAD HOMBURG	400	512	3015	85	75	04/73	54	-		11-11	1	11-11	1
		02	HILDERS	505	589	3026	80	64	04/73	54	-		11-11	1	11-11	1
		03	WALDSOLMS	355	513	3025	75	74	04/73	54	-		11-11	1	11-11	1
		04	BENSHEIM	95	512	2978	60	99	04/73	54	-		11-11	1	11-11	1
		05	HIRSCHHORN	255	535	2967	99	83	04/73	54	-		11-11	1	11-11	1
		06	FRANKENBERG	595	516	3066	100	50	05/73	51	-		11-11	1	11-11	1
		07	ROTENBURG	270	582	3061	64	78	04/73	51	-		11-11	1	11-11	1
		08	WANFRIED	440	613	3070	60	72	04/73	93	-		11-11	1	11-11	1
		09	BAD SOODEN ALLENDORF	750	592	3074	100	50	05/73	47	-		11-11	1	11-11	1
		10	GAHRENBERG	170	575	3085	73	80	03/74	57	-		10-10	1	10-10	1

CODE INSTITUTION	TEST SITE	ALT	LONG	LAT	MAR	MAT	PLANT	NB PRO	FLUSHING AGE	FLUSHING NB	T.HEIGHT AGE	T.HEIGHT NB	SURVIVAL AGE	SURVIVAL NB
	11 WANFRIED	307	610	3071	61	73	04/76	36	-		-		-	
	12 KALBACH	435	585	3022	280	72	03/76	36	-		-		-	
	13 FRANKENBERG	480	513	3067	90	67	04/76	36	-		-		-	
11 2 INSTITUT DE RECHERCHE FORESTIERE DU LAND DE BASSE SAXE - ESCHERODE	01 BREMERVOERDE	20	910	5324	75	90	04/73	99	-		9- 9	1	9- 9	1
	02 KATZENELNBOGEN	338	759	5016	67	85	04/73	54	-		9- 9	1	9- 9	1
	03 NEUMUENSTER	45	959	5405	76	80	04/73	53	-		9- 9	1	9- 9	1
	04 HEIGENBRUECKEN	300	910	4958	100	75	04/73	96	-		9- 9	1	9- 9	1
11 3 INSTITUT DE RECHERCHE FORESTIERE DU LAND DE BAVIERE - TEISENDORF/OBB	01 HEIGENBRUECKEN BAVARIA	300	563	3001	100	75	04/73	96	-		9- 9	1	9- 9	1
ITALY														
14 1 INSTITUT POUR LES PLANTES LIGNEUSES TURIN	01 MILLEROSE	330	745	4505	78		04/70	22	-		11-11	1	11-11	1
NEDERLAND														
18 1 RESEARCH INSTITUTE FOR FORESTRY AND LANDSCAPE PLANNING - WAGENINGEN	01 SLEENERZAND	20	405	3170	80		04/71	50	5- 5	1	10-10	1	10-10	1
	02 SPRIELDERBOS	40	341	3134	76		03/73	44	6- 6	1	10-10	1	10-10	1
NORWAY														
19 1 NISK - STEND.	01 MOBERGLIEN	100	327	3610	217	66	04/71	51	-		10-10	1	10-10	1

S E S S I O N IV

SITE REQUIREMENTS AND SILVICULTURE OF DOUGLAS FIR IN NORTH-WESTERN GERMANY

Hans-Jürgen OTTO
Ministerium für Ernährung, Landwirtschaft und Forsten
Calenberger Str. 2, D-3000 Hannover, W.Germany

Influence of Natural Environment and Growth of Douglas Fir.

Climatic Factors: In comparison with northwestern German climatic factors, the climate of western Oregon, Washington and B.C. seems to be - in a more superficial view - more favorable to growth of Douglas fir.

Emphasis has to be put on the following facts (Figure 1):

- In western America as well as in northwestern Germany there is a peak of winterly rain, which is more distinct in America. On the other side, a second summer-peak of precipitation can be found in Germany. During July and August a low level of rain is to be noted in northwestern America.
- The difference between precipitation peak and low levels is extremely pronounced in America.
- Distribution of rain in northwestern Germany is more balanced.
- Precipitation between May and September in northwestern Germany is as high or even higher than in America (Figure 2).

Mean temperatures during the year are given in Figure 3 and can be described mainly in the following facts:
The level of average mothly temperatures is markedly higher in northwestern America. In the winter time, the temperatures in northwestern Germany oscillate around the freezing point.
In summary, the low point of summer rains during the midst of the vegetation period and a distinctly higher temperature level in America should be stressed.

These facts lead to the following consequences:
- The milder temperature in America, combined with abundant rains, give rise to a continued photosynthetic-activity of Douglas fir during winter. It can amount to a quarter of total physiological activity during the year, and in wetter years it can be 2 to 5 times higher than in dry years.
- Douglas fir in America reaches spring time as a very well water - saturated plant, and in the beginning vegetation season enougth water is available in the water storage of soils and high spring precipitations. The frightening spring drought of northwestern Germany does not harm American plantations.
- During the summer, precipitation near the Pacific coast is lower than in northwestern Germany, while temperatures are higher.

Figure 1: Yearly course of precipitation

Jahresgang der Niederschläge

1. Matlock (Wash.) - Tsuga heterophylla-Zone
   2654 mm/Jahr (104 m ü. NN)
2. Darrington (Wash.) - Tsuga heterophylla-Zone
   1544 mm/Jahr (168 m ü. NN)
3. Campbell R. (BC) - Douglasien-Zone, feuchte Unterzone
   1496 mm/Jahr (79 m ü. NN)
4. Nanaimo (BC) - Douglasien-Zone, trockene Unterzone
   981 mm/Jahr (30 m ü. NN)
5. Ottenstein - WBez.Unteres Weser-Leine Bergland (UW)
   878 mm/Jahr (220 m ü. NN)
6. Cloppenburg - WBez.Ems-Hase-Hunte-Geest
   807 mm/Jahr (40 m ü. NN)
7. Lüneburg - WBez.Ost-Heide
   644 mm/Jahr (35 m ü. NN)

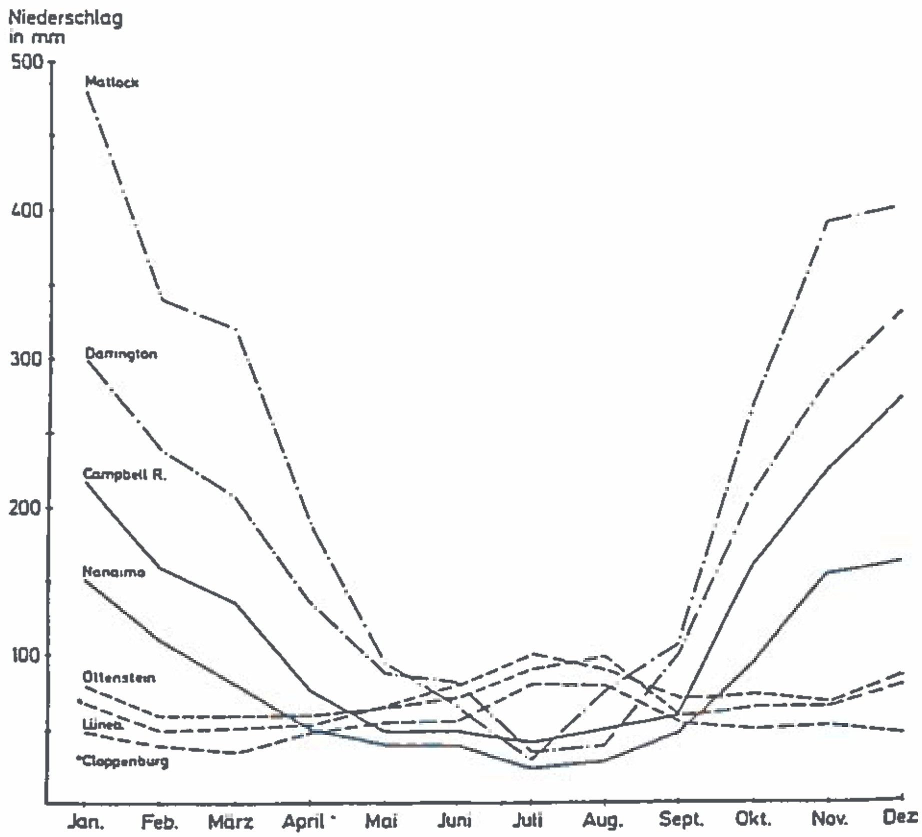


Figure 2: Comparable precipitation from May till September

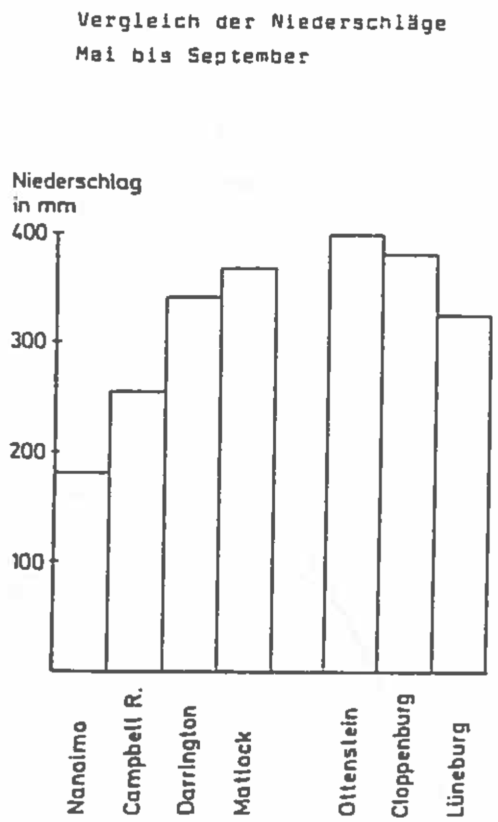
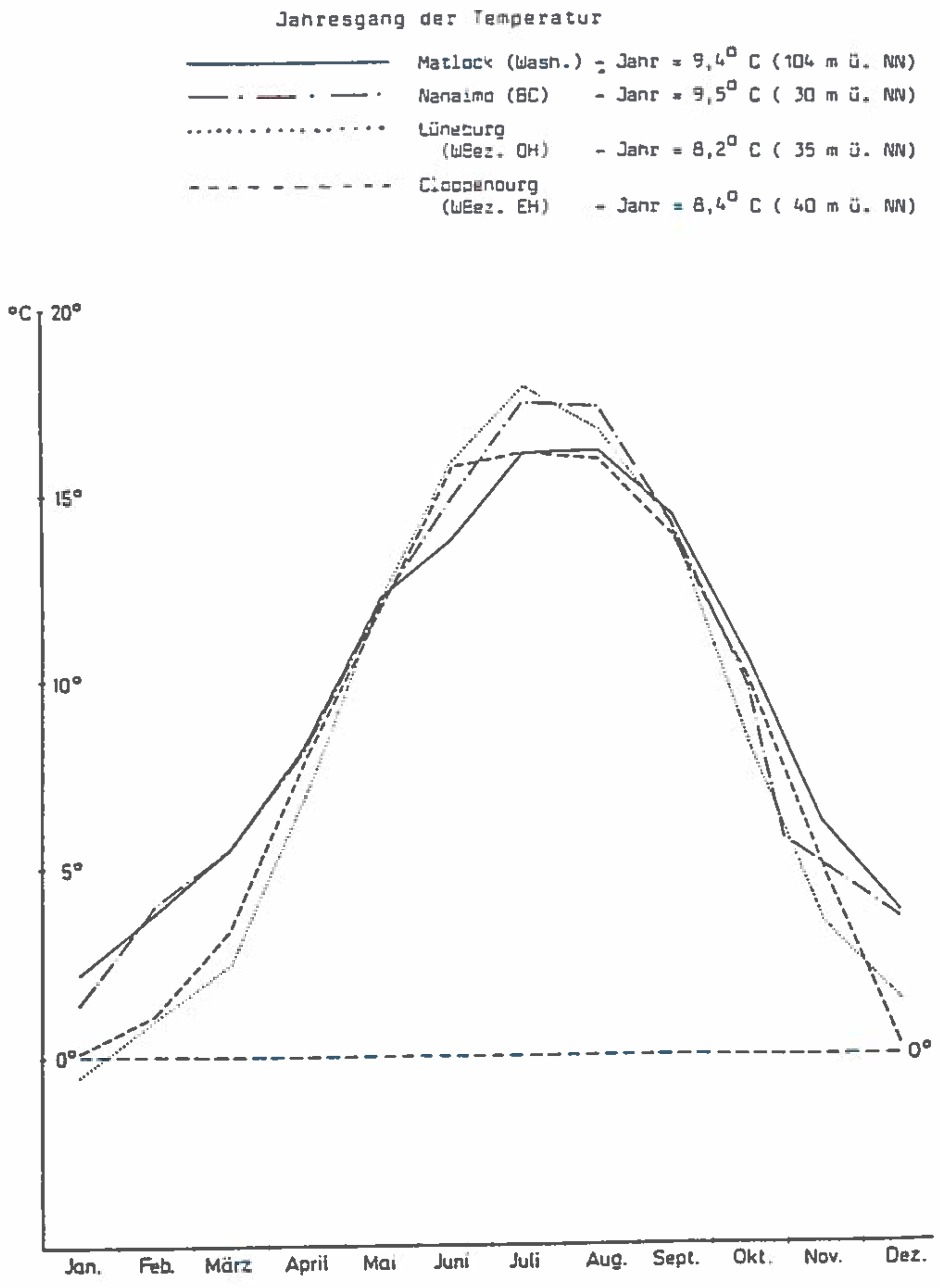


Figure 3: Yearly course of temperature



This means that there can be more drought stress in Douglas fir in America. On Vancouver Island the most monthly shoot growth is in May, when there is enough rain and already good warmth. With sinking precipitation during the following months shoot elongation becomes shorter and shorter. During August the yearly shoot growth has ceased and bud set accomplished.

- On the other hand in northwestern Germany growth of Douglas fir will be regularly stimulated in vegetation time; so it can continue up to autumn. There is more risk of insufficient balance of physiologic activity. In badly stabilized plants autumn frosts and the more frequent winterly oscillation around the freezing point can easily harm the plants, while the phenomenon of winter frost drought is more an exception in America.
- Nevertheless, in comparison with other species, Douglas fir is better adapted to dry site conditions than most of the competitive species of the same areas. So it wins in interspecific competition when the regional climate is dry, as for instance in the rain shadow area of the Vancouver Island ranges or the Puget Trough. On the other side it disappears - so near the coastal line - where precipitation exceeds 4500mm /year or 450 to 480 mm during May and September.
- High July and August precipitation, combined with rather high temperatures, can be of some importance for prolepsis. The results of some prolepsis studies done in Switzerland there are many assumptions that genetic tendencies to prolepsis are not so pronounced in interior Douglas fir than in coastal provenances. The latter can more easily form a second shoot when warmth and humidity during summer are high - like in northwestern Germany. In reverse the genetic predisposition does not lead to the formation of second sprouts when warm and dry summers inhibit physiological activity.

Geologic and Edaphic Factors: In comparison with the situation in northwestern Germany the following facts have to be stressed:

- Low altitude regions of B.C. and northwestern Washington are often formed by pleistocene sediments, mainly in the preferred provenance areas below 400 m. Their physical structure and evolution can easily be compared with northwestern German site conditions.
- Mainly near the foot of the southern Olympic Mountains and on Vancouver Island soils of short periglacial transport are so coarsely structured - very often one can find 40 to 60% of soil volume in coarse stones - that in spite of high precipitation the water storage capacity of the soils must be estimated at a rather low level. The drainage of soils is very accentuated. In the Cascade Mountains shallow and stony soils are also frequent. Here too water storage capacity can be low and evaporation high.
- So in spite of high yearly precipitation Douglas fir in America can be exposed to dry stress conditions more frequently. It may even not be overemphazised to constate that site humidity in northwestern Germany is frequently better.
- An important difference has to be noted in the chemical properties of American and German soils. All American soil samples brought to chemical analysis showed clearly lower acidification. PH - values where found between 4,0 and 5,0, so never in the range of aluminium and other heavy metals activity. In solutions calcium and magnesium contents had a high level, the solubility of aluminium and iron an inferior one. Corresponding to this the effective nutrient exchange capacities

where high. These intact chemical properties of American soils guarantee a good nutrient supply to the roots. It can also be characterized by a good mineralisation of the humus layers and a great diversity of lifeforms in the humus.
On the other hand, German soils are much more acid, and all chemical exchange properties worse.

Synecological Facts: Favorable climatic conditions, non disturbed soils with low acidity and young rocks with short transport of their sediment material provoke in coastal western forests of America heavier competition. Many strong wooden species struggle for light, warmth, water and nutrients. Soil vegetation is denser and normally composed of more species than in northwestern German glacial areas.

Intraspecific competition in the inner Douglas fir stands also is severe. An outstanding sign in large second growth stands is the long duration of tenacious struggle. Very slowly and in any case much slower than in most of the competitive German stands is a definite surrender of the weaker stems of Douglas fir. In the absence of thinnings, small trees, long dominated, do not die, but continue to compete and to inhibit normal diameter development of the dominating trees.

Intraspecific competition and its consideration in natural stands can teach possibilities for mixing stands in planned forestry. Tsuga heterophylla is the most shade tolerant species. It infiltrates older Douglas fir stands. Its strong use of water capacities and its shadowy canopy prevents natural regeneration of Douglas fir. Indeed, the latter will vanish in the presence of Tsuga and cannot be considered as a climax species.

In competition Thuja plicata will be pushed to wetter places. Its regenerations is not so dense, its humus decomposes quickly, and its shade tolerance is not so marked as the one of Tsuga.

Abies grandis also is less shade tolerant than Tsuga, but its good growth properties means stronger competition stress to Douglas fir.

In Europe, Thuja and Grand fir could be interesting species for mixed stands with Douglas fir.

Site Choice for Douglas Fir in Northwestern Germany: In a long-term silvicultural planning for Lower Saxony, a future area of 36 000 ha of Douglas fir on a total of 315 000 ha of State forests in this state has been planned. Since 1975, about 7000 ha of young stands have been planted.

The planned area is much smaller than the ecological potential. As a matter of fact, about 150 000 ha to 200 000 ha could be planted with Douglas fir. This would be more than 50 % of all State forests.

Actual planning, based on site mapping, takes into view pleistocene soils in order to replace inferior production of Scotch pine with higher productivity of Douglas fir.

Planning concentrates upon glacial sands where there is not a high water table. Loamy sands should be preferred; they may have non loamy undergrounds and sometimes a rest of glacial till.

In mountain areas, southern and western expositions up to 400m above sea level and sandy soils ought to be chosen.

German sites normally are more homogeneous, transported and eroded over longer distances, often more degraded and very normally more acid than those in America.

Site - influenced risks are stress situations in spring drought, combined with this factor the risk of wildfires, the risk of winter frost drought, late frost in spring, early frost in fall and in larger plantations the risk of attack of Phomopsis pseudotsugae.

An advantage for the described soils is the optimal decomposition of Douglas fir humus, a better utilization of site properties for high timber production and ecological diversity of shrub and herb layers under Douglas fir.

Plantation Risks and Consequences: After a strong storm in the fall of 1972 large areas without protecting canopies of older stands have been planted with Douglas fir. They confirmed the traditional problems with clear cut plantations. Drought and frost problems, combined with Phomopsis attacks, harmed a lot of those reforestations.

In a general view, a well-confirmed experience is, that under German site conditions any injury to physiological freshness of the plants will be disastrous.

So, optimal rules for Douglas fir plantations can be listed as follows:

- Root under cutting in the nursery one or two years before planting shall help to produce a compact root system.
- A well - balanced shoot: root ratio is better than big but weak plants.
- To avoid spring drought, a general rule must be to plant only under canopy or with side protection of older trees. In any case it will be more advantageous to create an artificial canopy of alder, larch, birch or even pine and never to plant into open air fields (clear cuts).
- Filling up of older and too heavily lightened stands should not begin before an age of at least 40 years in Scotch pine stands. This is because after 5 to 10 years Douglas fir will need light and demands heavy thinning or the opening of the canopy.
- Every care taken in plantation to prevent the plants from drying out is to be recommended. This means good organisation of plantation works without field-heeling in of the plants, accurate soil preparation, no planting into humus layers, deep enough planting, preferance to early spring plantations with more chances of rain and temperate warmth conditions.
- Even with respecting those precautions plant losses will stay normal. So plantations in Germany should never be too thin. 1600 to 2500 plants/ha take into consideration a sufficient number of reserve plants.

Stand Development, Stand Risks and Consequences: Age classes show a predominance of younger Douglas fir stands in northern Germany. Traditionally those were thinned too moderately, too late and the cuttings concentrated upon the understory trees. Considering intraspecific competition in Douglas fir it must be emphasized that every dominated tree of the understory will continue to compete for a very long time. This may demonstrate that our traditional opinion, that Douglas fir would not need early help because of its early height differentiation has been a wrong conclusion.

Too late thinnings taking out only some stems will provoke severe deterioration of stand stability against storms and wet snow. Considering this we were led to the following thinning rules:
- 1600 to 2500 plants/ha have to be reduced to at least 1500 to 2000 plants, when the plantation reaches an upper height of three meters. Mainly on poorer soils groups of plants ought to be cleared up. At the latest with an upper height of 7 to 10 m this stem reduction has to be achieved.
- Early cleanings should follow and take out bad stem forms. Several years later transport - logging lines must be opened every 30 m.
- With a dominant height of 10 to 13 m a first thinning should be carried out. Every 5 to 6 m about 250 to 300 future trees will be freed from competitive trees and pruned up to 6 m. In order to improve the bad water storage capacity of poor glacial sands, the understory should also be reduced.
- Second thinnings in dominant heights of 13 to 16 m will continue these operations. At the same time, the crop trees have to be checked. Again some competing trees will be eliminated and the understory thinned.
- The further thinnings will be more liberal in consideration of the stands establishments.

The Question of Mixed Stands: Until now most German Douglas fir stands have been planted as monocultures. The most important reason is the high productivity of Douglas fir. No increase can be obtained by mixing other species with Douglas fir.

So the aim in mixed stands can be neither an increase of productivity nor ecological diversity or protection against windthrow, which can be obtained by early and heavy thinnings as shown above. On the other side one has to admit a severe risk of forest fires. In Douglas fir it is as severe as in Scotch pine stands. The only species we know today to reduce wildfire risk in Douglas fir stands is beech. The following silvicultural rules for the introduction of this species can be adopted:
- From the beginning of mixed stands Douglas fir/beech it is evident, that beech will need help against the strong competition of Douglas fir and its shadowy canopy.
- Plantations should be executed with about 1000 beech to 2000 or 2500 Douglas fir plants.
- Early plant reductions in Douglas fir and the following heavy thinnings as shown above will continue to maintain good development of beech.
- In older stands, beech litter inhibits the establishment of dry grass layers which might burn easily, and its understory canopy does not allow fires to climb into the upper canopy of Douglas fir.

Some old Douglas fir stands in Lower Saxony show a similar mixture with the described effects. In these, beech is taking part in the lower canopy level of Douglas fir or it is staying in the understory as wanted.

Mixtures with other species don't allow any conclusions today. Some places with mixtures of Thuja plicata and Abies grandis have been installed.

Rotation Time and Regeneration: Until now rotation time in Douglas fir remains unclear.

Aimed diameters of about 30 to 50 cm will certainly be possible with an age of 60 or 70 years. On the other side the longtime growth of the species (as well as its excellent health) allows us to adopt a longer rotation time. Only external influences, for instance acid rain, could restrict a long rotation. So a large margin in rotation time is possible. For now in Lower Saxony we did adopt 100 years. For this decision economic reasons have been most important. Intensive and expensive operations in young stands are combined with bad prices for thinned material. So it seems to be reasonable to accentuate the phase of thicker timber. A longer rotation time changes the proportion of expensive and high yield periods in favour of the latter. About 100 years seems to be - under German conditions - the adequate compromise between economic factors, maximal productivity and silvicultural possibilities in Douglas fir. The actual exercised cuts may alternate widely around this fixed point.

The latter possibility has great importance for questions of silvicultural regeneration. After the storm of 1972 in many places spontaneous natural regeneration of Douglas fir was found. These examples occur so often, that we can reckon with this possibility as a normal way of regeneration. So in future times we can conceive the following rules:
- In cases of too early regeneration in too young stands we will have the extraordinary chance to earn seedling as propagation material in stands which during a longer lifetime have proven their adaptation to our site conditions.
- Thinnings in older stands beyond 60 or 70 years should successively concentrate upon the mature stems which have the desired diameter. With this big clearcut areas will be avoided.
- Consequent cuts of thick stems will lead us to an irregular opening of canopies. Installation and development of regeneration in uneven-aged groups of young Douglas fir will become possible. The cut of the last old tree will be determined by market prizes and the young regenerations conditions. This may cover a long time.
- In mixed stands with beech there will be only little hope to get natural seedlings of beech, because it will probably be impossible to produce seeds in the understory level. So artificial regeneration of beech some time before the installation of natural Douglas fir regeneration will be necessary.

For this, the best silvicultural methods are not yet found. In this field scientific research and practical experience will have to cooperate as they always did in German forestry.

SUMMARY

In the first part, climatic, geologic and edaphic factors in the Douglas fir area of Western Washington, Oregon and B.C. are compared with site conditions in northwestern-Germany. Silvicultural possibilities and problems with this species are discussed on this basis.

Synecological facts, mainly interspecific and intraspecific ecological factors are then considered.

In a second part silvicultural consequences in a given situation are shown.

Plantations of Douglas fir have to respect spring drought and alternating winter frost. Any loss of plant freshness has to be avoided. Early planting in spring, accurate soil preparation, and canopies of older stands can avoid problems. Site choice shows similar conditions as in America.

Heavy and long endurance of natural competition in Douglas fir stands needs early and continued operations of plant number reduction and thinnings in order to avoid snowbreak and windthrow.

A means of preventing wildfires can be possible with a mixture of Douglas fir and beech. Litter of beech will also inhibit the development of dry grass layers and the canopies in the understory will not allow fires to climb into the crowns. Mixtures with Thuja plicata and Abies grandis also seem to be possible.

Rotation time in northwestern Germany for Douglas fir is 100 years with a broad flexibility around this fixed point.

Natural regenerations is possible in Germany. It can be used in continual silvicultural methods and will determine Douglas fir forestry in the future.

L I T E R A T U R E

FRANKLIN/DYRNESS, 1973: Natural vegetation of Oregon and Washington, USDA Forest Service General Techn. Rep. PNW 8

HARTMANN, G., 1977: Gefährdung von Douglasienkulturen durch Pilzkrankheiten in Nordwestdeutschland; FHW, H.5, S. 73 - 77

KRAMER/TUYLL, 1981: Der Einfluß des Ausgangsverbandes auf die Entwicklung von Douglasienbeständen, Teil I u. II; AFJZ, 152 Jg, S. 31 - 39 und S. 97 - 102

KRAMER, H., 1983: Wachstum und Behandlung der Douglasie im pazifischen Nordwesten von Amerika; Schriften a.d. Forstl. Fak. der Universität Göttingen, Bd. 75, 114p

KRAMER/SMITH, 1985: Bestandesbegründung der Douglasie in Britisch-Kolumbien, Kanada; FArch, 56. Jg. S. 9 - 13

v. LÜPKE, B., 1979: Wasserhaushalt und Trockensubstanzproduktion bei Douglasien nach dem Verpflanzen; AFJZ, 150. Jg. S. 78 - 82

v. LÜPKE, B., 1981: Besserer Kulturerfolg bei Douglasien nach Unterschneiden in der Baumschule; FArch, 52. Jg., H. 1, S. 10 - 13

MARCET, E. 1975: Bemerkungen und Beobachtungen über den Augusttrieb (mit besonderer Berücksichtigung der Douglasie); Schweiz. Z. Forstw. 126 : 214 - 237

MUHLE/RÖHRIG et.al., 1976: Untersuchungen von Douglasien-Pflanzungen der Jahre 1974 und 1975 in Nordwestdeutschland; "Aus dem Wald", Mitt. a.d. Nds. LFV; H 29

Nds. LFV, Merkflatt Nr. 4, 1982: Hinweise zur Pflanzung von Douglasien und Behandlung von Kiefernanflug in Douglasienjungwüchsen

Nds. LFV, Merkblatt Nr. 15, 1982: Entscheidungshilfen für die Bestandespflege von Douglasienreinbeständen im schlagweisen Hochwald

OTTO, H. J., 1984: Standortskundliche Aufnahmen und Gliederungen in wichtigen Herkunftsgebieten der Douglasie des westlichen Washington und Oregon sowie in Südwest-Britisch-Kolumbien-Versuch eines Vergleiches mit den Anbaubedingungen in Nordwestdeutschland; "Aus dem Walde", Mitt. a.d. Nds. LFV, H 38, 1984, 269 p.

v. STRALENDORFF, L., 1979: Erfahrungen mit der Douglasie bei der Wiederaufforstung von Orkanflächen; AFZ, S. 16 - 21

- P O S T E R -

IMPLICATIONS OF NATURAL GROWTH PATTERNS

L.C. KUIPER
Department of Silviculture Agricultural University Wageningen
The Netherlands

SUMMARY

A few results of a 1984 study on the structure and dynamics of natural Douglas fir forests in the Pacific Northwest (likely to be of interest to tree breeders), are presented. These include:

* the implication of natural height growth patterns for the procedure of selecting individual trees;
* some silvicultural implications for Douglas fir plantations, which are derived from observations on the intense within stand competition in natural second growth stands.

Height growth patterns

Let us suggest that from provenance trials it appeared that one of the areas most suited for your country to obtain seed from was the area west of Mount Rainier in the state of Washington. Let us further assume that for research purposes you now wanted to start selecting on an individual tree basis and that you were interested in height growth mainly. You intend to select in natural stands in order to know for sure that the population is from a local seed source. the question arises: on what criteria are you going to select a tree for height growth potential?

This problem will be illustrated with two examples of a 140 yr old Douglas fir stand in the Pack Experimental Forest located near Eatonville (La Grande), 15 miles west of Mount Rainier (Figure 1). This is an experimental forest of the College of Forest Resources of the University of Washington. The two plots are located on an east facing slope of Hugo Peak at an elevation of approximately 500 m. Figure 3 gives an impression of what these plots look like: it is a graphical representation of the actual forest structure, for which all trees in a 10 m wide strip were measured including dbh, topheight and crown dimensions.

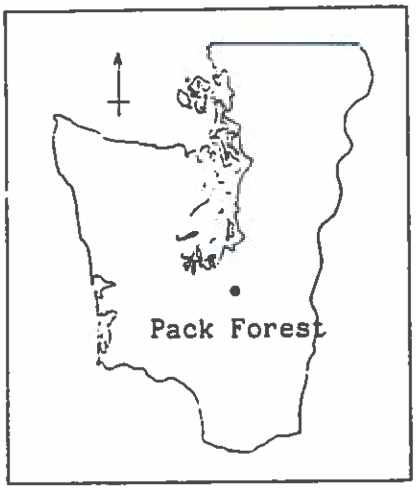


Figure 1: Location of Pack Forest in western Washington.

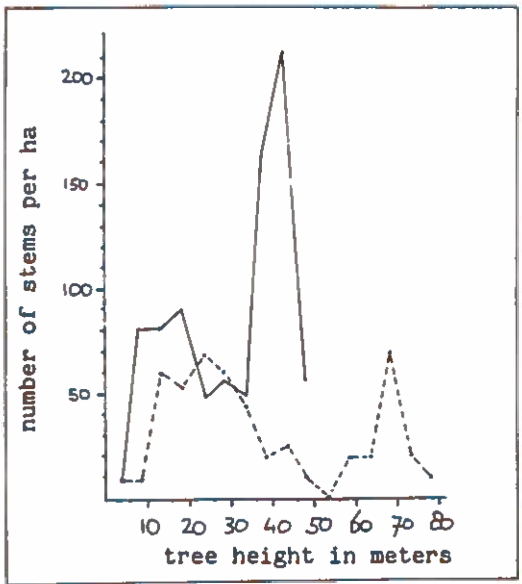


Figure 2: Height distribution of stems (5 m intervals) of both Hugo Peak plots: plot 1 solid line; plot 2 dashed line. Note that both curves show a distinctly two-storied structure. The overstory shows a clear shift in the distribution of stems from plot 1 to 2.

Plot 1 on the left (0.11 ha in size) consists of 820 trees/ha with an average dominant height of 40 m (Figure 2 and 3), a basal area of 120 m2/ha and a total standing volume of 1540 m3/ha of which 93 % is Douglas fir and 7 % western Hemlock.

Plot 2 on the right (0.14 ha in size) consists of 490 trees/ha with an average dominant height of 70 m, a basal area of 140 m2/ha and a total standing volume of 2480 m3/ha of which 88 % is Douglas fir, 3 % western Hemlock and 9 % western Red Cedar.

The question now is: in what stand would you select your individual trees? From plot 1 on the left or from plot 2 on the right, both lying very close to each other and both essentially of the same age. More likely than not you would select a tree from plot 2, wouldn't you? But why?

As will be shown the marked differences in height growth between both plots are the result of differences in site conditions rather than of genetic differences. In fact both stands most likely originated from the very same trees.

To explain this the developmental history has to be taken into account, which is very essential when dealing with natural stands:
About 180 yr ago a fire burned down a major part of the forests in this area. Such intense catastrophic fires usually obliterate previous stands, leaving only a few scarred survivors (Hemstrom and Franklin, 1982). On top of a hill fires tend to be more intense than at the base of a slope: heat goes up, dries out to forest more and consequently burns it more completely. Appa-

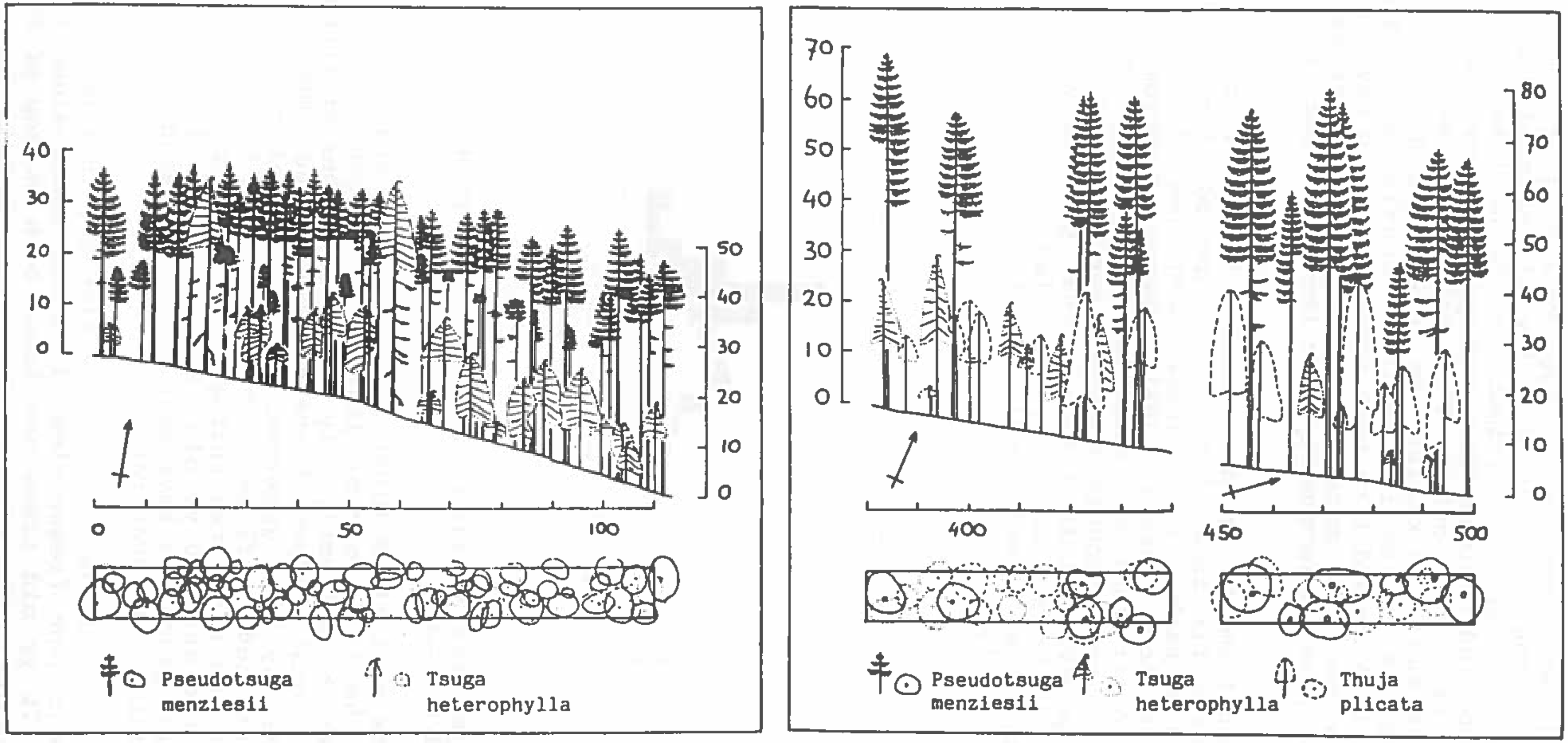


Figure 3: Vertical diagrams of the structure of the two Hugo Peak plots.

rently this is what happened at Hugo Peak at that time, because at the base of the slope still a few old scarred Douglas firs are found. These trees are estimated to be at least 350 yr old. There are some indications that perhaps two fires have occured 10 yr apart from each other. This makes some sense, because the first one may have killed the forest but not have burned it down completely, leaving behind a considerable amount of dead wood fuel. A second fire then naturally could have followed. The few survivors, no more than 5 or 6 trees alltogether in the Hugo Peak area, consequently were the source for regenerating the area.

As can be seen from the age-distribution (Figure 4) the regeneration of Douglas fir took place over a period of more than 100 yr, which is a rather long establishment period especially on an east facing slope (Harris, 1984). However, Hemstrom and Franklin (1982) report that the pulse of regeneration which begins soon after a fire, produces a skewed age structure. The number of trees regenerating in a single year generally rises to a peak within 20 yr and may drop to a low level within 50 yr, or may continue at slowly declining levels for 100 - 150 yr (Franklin et al, 1979).

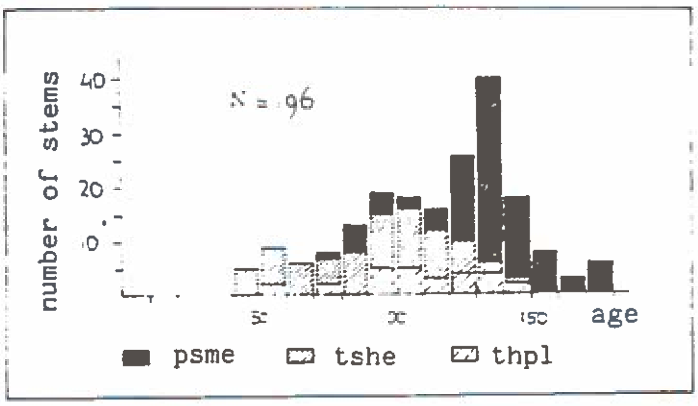


Figure 4: Age distribution for the whole of Hugo Peak forest (d.b.h.-age).

This suggests that there might have been more than one regeneration wave: the first one originating from the 5 or 6 scarred trees from which apparently only a limited number of trees (about 15 % of the total number of stems) regenerated. The second and largest wave may have appeared at a time that these trees on their turn started to flower and were responsible for regenerating most of the area: two thirds of the number of Douglas firs is between 130 and 150 yr old (Figure 4). In later years the remaining gaps gradually have been filled up, accounting for 15 % of total Douglas fir regeneration.

The distribution of the various age classes, in theory representing different gene frequencies, is quite equal along the transect. E.g. 170 yr old trees are found both on top of Hugo Peak as at the bottom of the slope, and the same is true for the Douglas firs in the 130-150 yr age class. Therefore the phenotypic differences observed (height growth) cannot be explained by a shift in gene frequencies.

Why the trees at the bottom of Hugo Peak are so much taller than the ones on top of Hugo Peak, which is after all only a distance of 500 m and cannot have been a real barrier for seed dispersal, thus can only be explained by site differences. The whole area is from vulcanic origin and the soils are developed from andesite bedrock. On top of Hugo Peak the soil is rather shallow, dry and not very loamy, whereas at the bottom the soil is deeper, much moister und quite loamy.

The site differences are also reflected by the understory vegetation: the topmost parts have a dense cover of salal (Gaultheria shallon), indicative for rather poor sites. When proceeding towards the bottom the salal cover is replaced by a vegetation type dominated by swordfern (Polystichum munitum), which is characteristic for better sites (Figure 5).

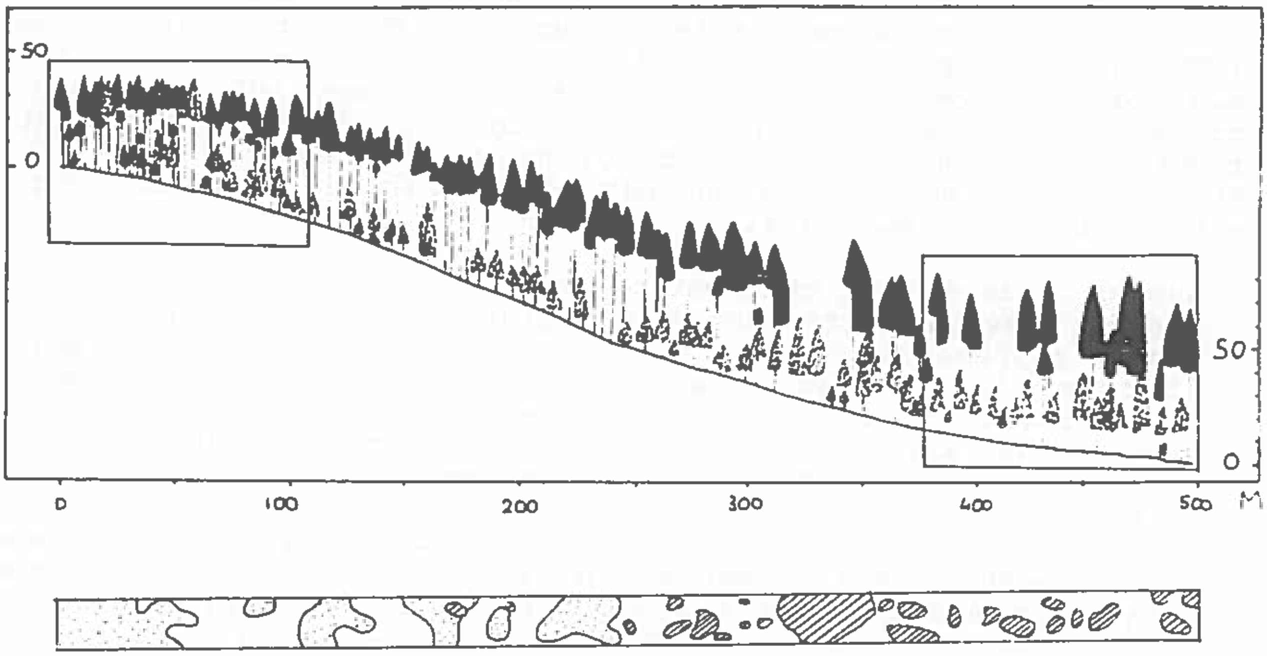


Figure 5: Location of both plots on the Hugo Peak transect as a whole. Note the change in understory vegetation along the transect:
[dotted box] = Gaultheria shallon type
[hatched box] = Polystichum munitum type

So, if the differences in height growth are the result of site differences, would it still make any sense to select trees from the second stand only? It is easier to climb a 40 m high tree than one of 70 m.

It would be interesting if someone takes the challenge and does some progeny testing of this particular stand. At least it is a well documented example.

Within stand competition

Second growth stands that have developed naturally without human interference form a valuable baseline against which we can measure the growth patterns and health of our managed forests. The study of natural stand development has significance for the design of new silvicultural systems for Douglas fir grown outside its natural range.

The developmental history of the second growth stands was such, that most of the accessible areas in western Washington were railroad logged in the 1920's. Often large amounts of slash and other logging residues remained on the sites and frequently these were burned by natural fires. Usually natural regeneration followed. These so called second growth stands have not been managed and therefore constitute a "field test" to study the absence of human impact on stand development. With current logging rates however it will not be many years before most of these natural second growth stands have disappeared.

Since growth patterns differ on different sites, two examples of 55 yr old second growth Douglas fir stands are presented here: the Bethel Ridge plot in Pack Forest at an elevation of 500 m on a rather poor site, and the Humptulips plot at an elevation of 150 m on a good site (Figure 6). The latter is not the IUFRO-Humptulips stand north of Humptulips but located a little east of the town: when driving north on highway 101 just before crossing the Humptulips river turn right on the East Humptulips road. After 3 miles thousands of ha of excellent Douglas fir stands begin, which unfortunately too are scheduled to be logged within the next few years.

A number of important observations can be made:

- besides obvious differences in height growth between the two plots, representing site class 4 and site class 1 respectively, stocking levels and crown dimensions differ considerably, as is illustrated by a map of stump positions and crown projections of all trees in a 50 by 20 m strip (Figure 7). Note the fewer trees and the larger crowns of the trees on the better site.
- the distibution of the trees over the social groups by volume and by number is represented in Figure 8. It is striking how many intermediate and suppressed trees are still alive at age 55: on the poor site these constitute up to 50 % of all trees; on the good site this is even 70 %. Total number of stems for the Bethel Ridge plot is 900 trees/ha and total volume is 777 m3/ha; for the Humptulips plot these figures are 475 trees/ha and 900 m3/ha respectively.
- the above data suggest that severe within stand competition takes place up to an age of 55 yr at least and that the competition is greater on the better sites. Douglas fir shows a strong tendency towards stratification, the splitting up in social groups. This may partially explain the typical "wavy" structure of the canopy observed in many pure Douglas fir stands (Figure 6, above).
- crown lengths in average are between 35 and 40 % of the top-height on both plots, the dominant and codominant trees having larger crowns in general than the intermediate and suppressed trees (Figure 9).

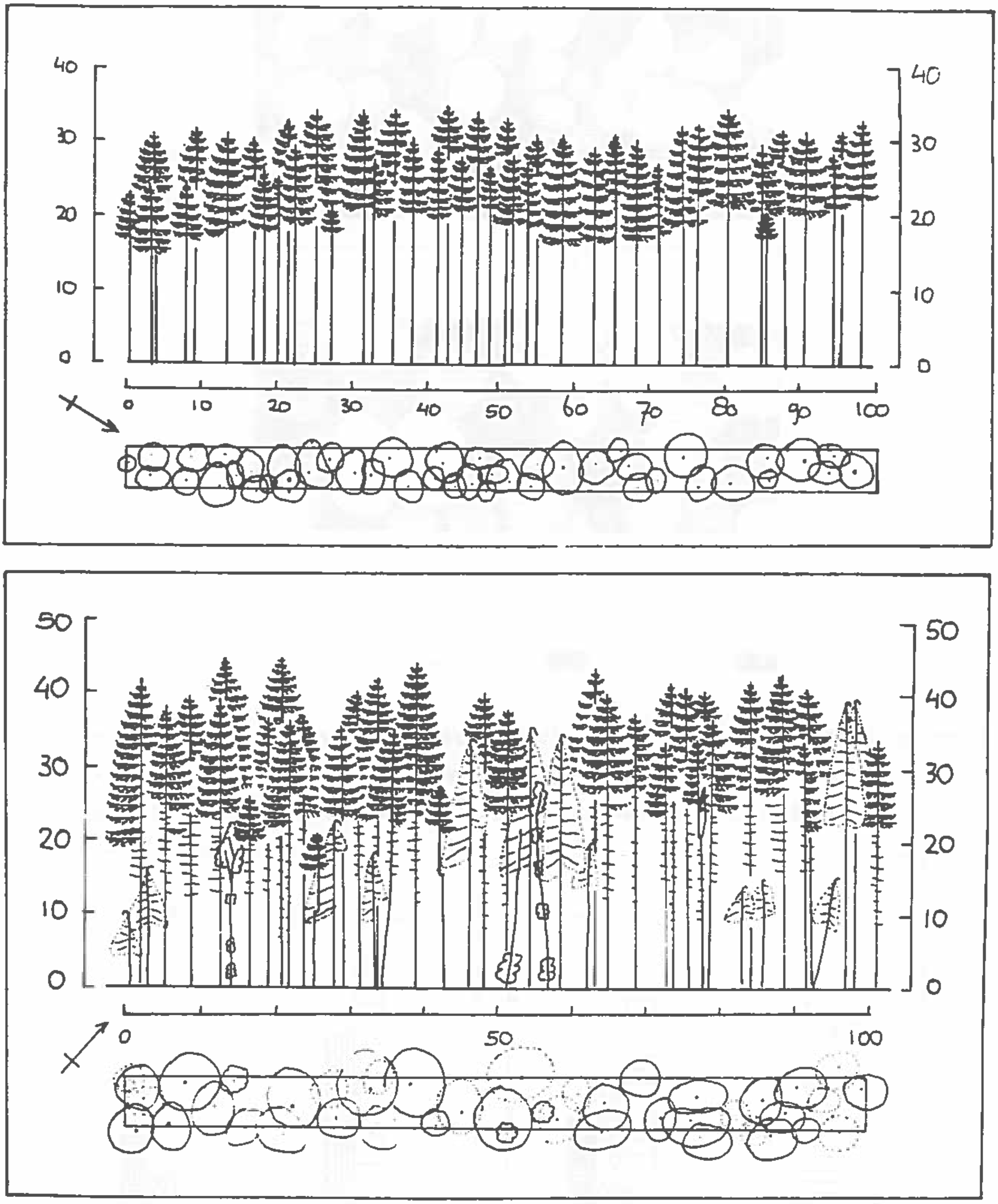


Figure 6: Vertical diagrams of two natural second growth Douglas fir stands: Above: the Bethel Ridge plot; below the Humptulips plot.

= Douglas fir

= western hemlock

= red alder

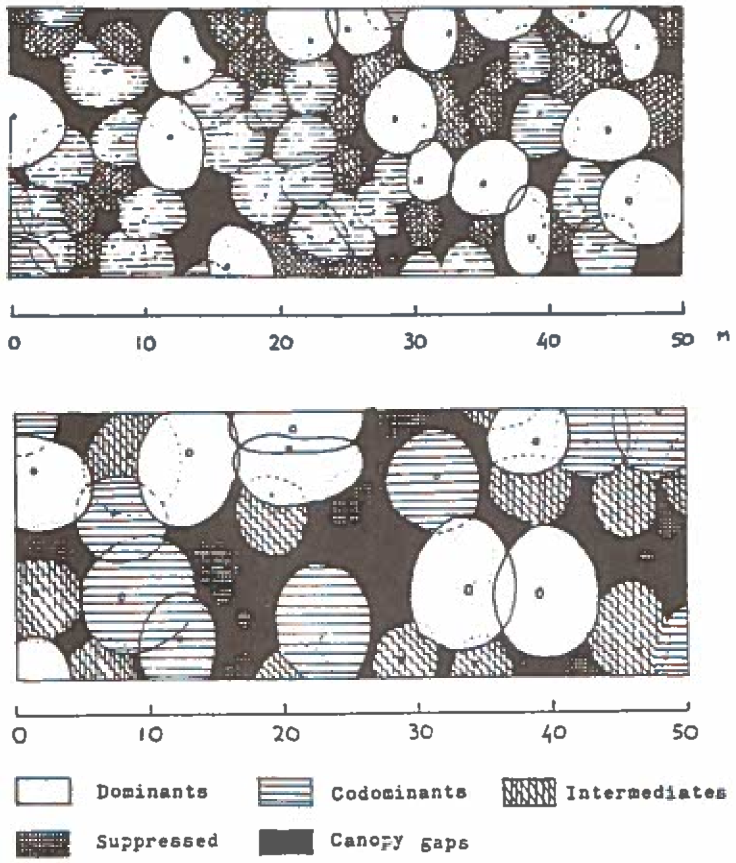


Figure 7: Map showing the stump positions and crown projections of all trees in a 50 by 20 m strip for the Bethel Ridge plot (above) and the Humptulips plot (below).

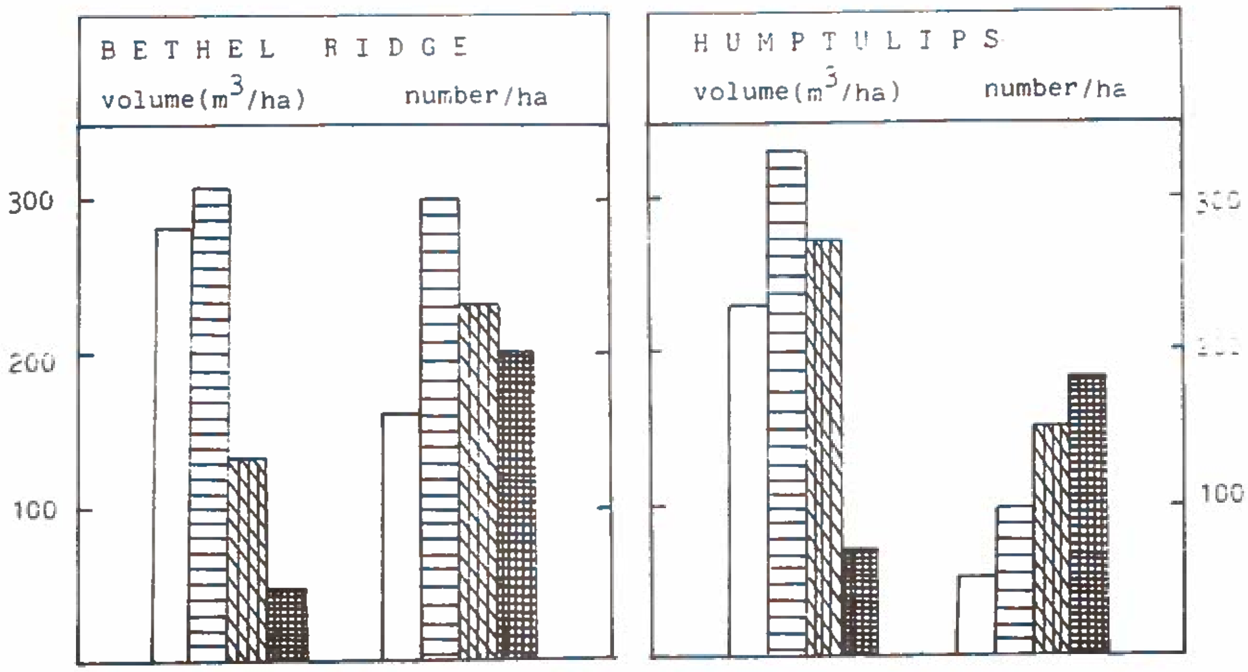


Figure 8: Distribution of the stems over the social groups by volume and by number. (▭ = dominant; ▤ = codominant; ▨ = intermediate; ▦ = suppressed).

- the age distibution pattern often is such that dominant and codominant trees are somewath older than neighbouring intermediate and suppressed trees, being one of the reasons why they could reach dominance.

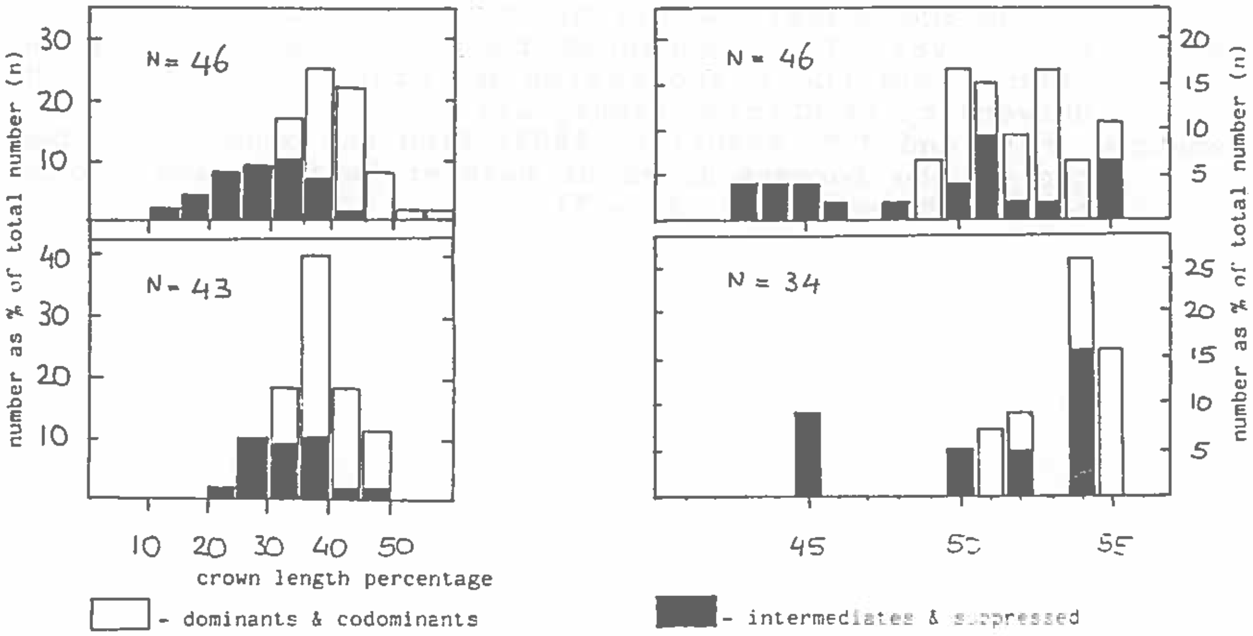


Figure 9: Crown length as percentages of top heights for Douglas fir. Bethel Ridge above; Humptulips below.

Figure 10: Age distribution over the social groups for Bethel Ridge (above) and Humptulips (below).

What silvicultural implications can be derived from these observations?

A silvicultural system for Douglas fir frequently used in The Netherlands consists of a selection of 200 so called "future trees" per ha at a dominant height of 15 m. These future trees are released from neighbouring tree competition through successive high-thinning operations. Little attention is being paid to the remaining trees. only from the point of view of stand stability some thinning takes place in this category.

When one or more site factors such as soil moisture or nutrient content are limiting to tree growth, as is often the case with Dutch Douglas fir stands grown on poor sandy soils, a more intensive high- and low-thinning combined in which many more trees are removed than just the ones competing directly with the future trees should be recommended, considering the above data on within stand competition. A strong overall thinning regime seems to be better especially to enhance soil moisture availability, given the substantial interception of precipitation by Douglas fir crowns.

A second point to consider is that of social positioning: if the social position of trees can be influenced by small differences in age, this opens up a way to successfully integrate natural regeneration into the silvicultural system: by interplanting the regeneration with 2 - 3 yr old seedlings of a good provenance at a wide spacing. Once given an advantage of 2 yr most likely they will remain in a dominant position throughout the rotation with a minimum of human interference and of costs.

LITERATURE CITED

Franklin, J.F., McKee, A., Swanson, F.J., Means, J. and Brown, A., 1979: Age structure analysis of old-growth Douglas -fir stands: data versus conventional wisdom. Bulletin of the Ecological Society of America 60, 102.

Harris, L.D., 1984: The fragmented forest. Island biogeography theory and the preservation of biotic diversity. The University of Chicago Press, 211 p.

Hemstrom, M.E. and J.F. Franklin, 1982: Fire and other disturbances of the forests in Mount Rainier National Park. Quarternary Research 18, 32 - 51.

- P O S T E R -

RESEARCH OF NATURAL CONIFEROUS ECOSYSTEMS IN BOREAL AND ALPINE REGIONS. - HERE AN EXAMPLE FROM THE DOUGLAS-FIR REGION IN THE PACIFIC-NORTHWEST

by

Gabriele NOSSWITZ-DELLAGIACOMA
Waldbau-Institut der Universität Freiburg
Federal Republic of Germany
Bertoldstr. 17, D-7800 Freiburg i.Br.

We try to investigate NATURAL/VIRGIN CONIFER ECOSYSTEMS for the following reasons:

I To record DATA on NATURAL ECOSYSTEMS, which outside of National Parks, Reserved Areas and very Remote Areas will soon be lost due to utilization, natural disturbance and exploitation.

II To study the STRUCTURE (composition, species distribution, height and diameter distribution), STABILITY and DYNAMICS of NATURAL FOREST ECOSYSTEMS, which are not yet or only very little influenced by man.

III To find out more about the NATURAL REGENERATION and the UNDISTURBED STAND DEVELOPMENT of Tree Species, which have been introduced into our European Forests.

IV To develop SILVICULTURAL SYSTEMS and TREATMENTS, which are based on the NATURAL STAND DEVELOPMENT, in order to manage our "introduced forest stands" in Europe in the best way from an ECOLOGICAL and ECONOMICAL point of view.

METHOD

Per plot and profile the following DATA was recorded and analyzed:
Place, date, slope, exposition, height above sea level, plotsize.
Tree number, coordinations of the tree (location), tree species, diameter (1,3), total height, height of the first living branch (crown length), canopy class, overall vigor, crown condition, bole condition, rooting condition (in organic or mineral matter), single or cluster, and disturbances (esp. fire scars).

Natural Regeneration of forest species (height, density, vigor, species, number per sqm (m2)).

In addition crown diameters are measured and/or a crown projection was made.

The Age was determined by coring, counting of rings in stumps or by a stem analysis as well as by the stand history (fire/ disturbance history) if known/recorded.

Dynamics and Stability was studied with the help of growth measurements, the stand disturbance history, repeated observations and mortality check ups (periodically).

EXAMPLES from NATURAL CONIFEROUS ECOSYSTEMS in the Pacific North-west (USA/CND)

1. OLD GROWTH >250/400 years
   a) Picea sitchensis mixed with Tsuga heterophylla and Thuja plicata Natural research area, Lake Quinault, Olympic Penninsula, WA
   b) Douglas-fir mixed with Tsuga heterophylla and Thuja plicata MacMillan Bloedel Park, Port Alberni, Vancouver Island, Canada.
      (cathedral grove)

2. STRUCTURE PROFILES
   Natural regenerated Douglas fir stands (second growth) - ca. 60 - 80 years old - mixed with Tsuga heterophylla and Thuja plicata (few - mostly Douglas-fir).
   a) near Ladysmith, Vancouver Island, B.C. 190 m elevation
   b) near Chilliwack, British Columbia 680 m elevation

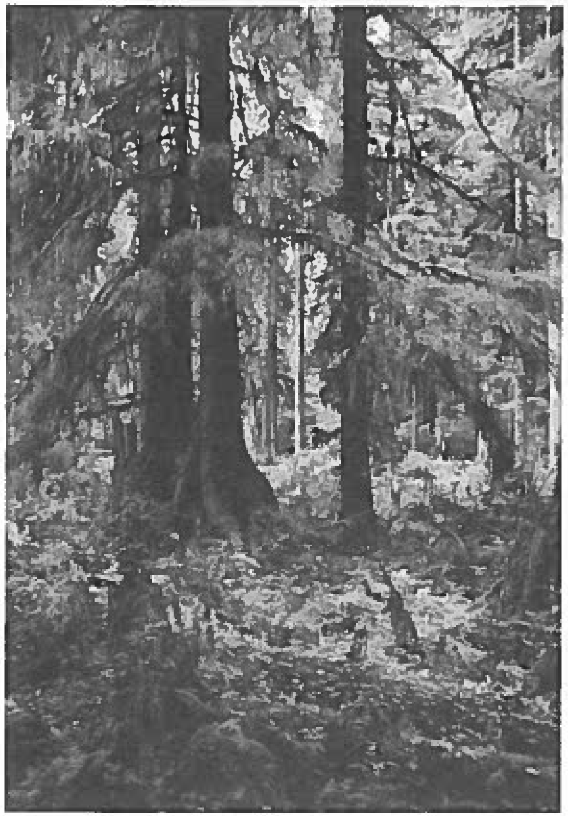
3. STAND MAPPING
   - Species and Diameter Distribution
   - Distribution of Living and Dead Trees
   - Spacing and Distribution Pattern

   Natural Douglas-fir ecosystem (mixed with Tsuga heterophylla and Thuja plicata) at Hugo's Peak, Pack Forest, La Grande, WA. Naturally regenerated after a hot fire; Age ca. 130-180 years. Exposition South-East, 500 - 510 m NN.

OLD GROWTH

1a) Sitka Spruce (Picea sitchensis) mixed with Tsuga heterophylla and Thuja plicata (single ones/few)

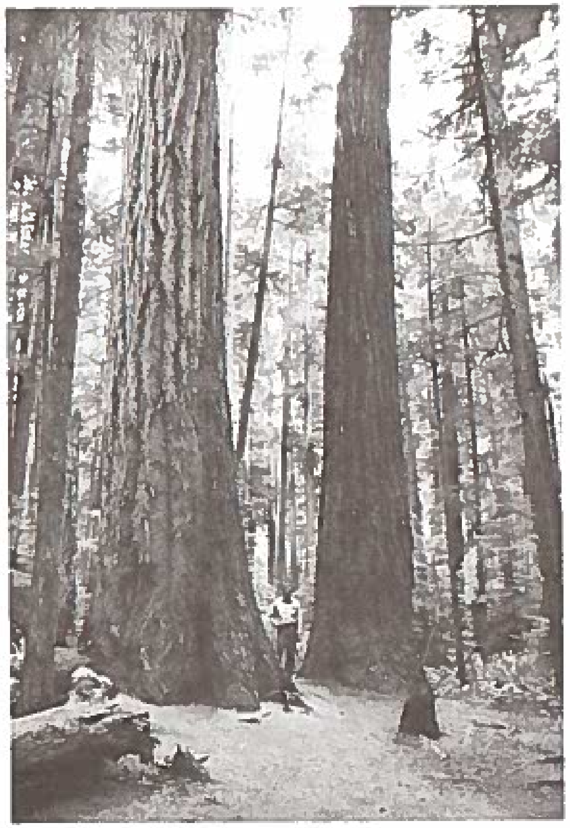
Natural Research Area, Lake Quinault, Olympic Penninsula, Washington State



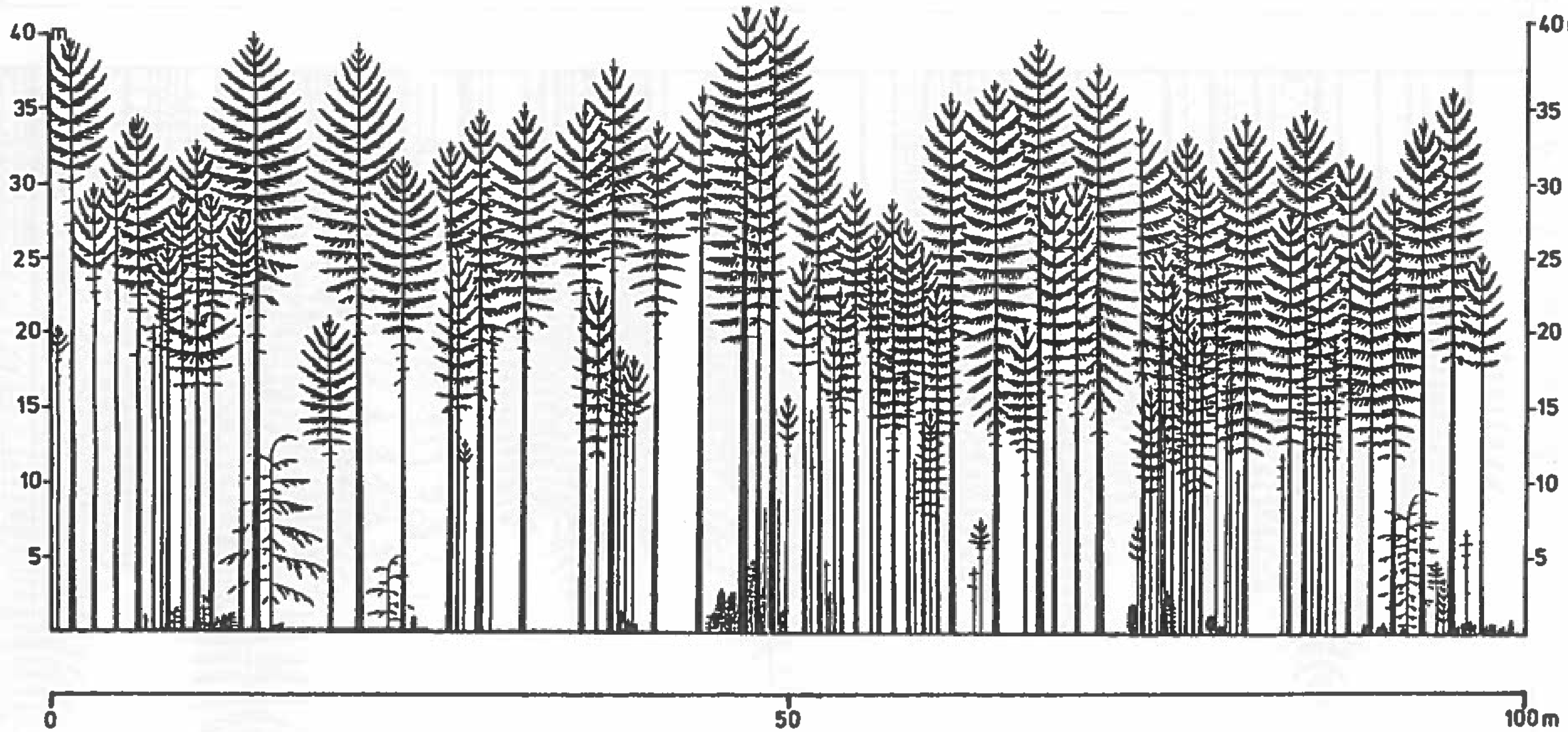
OLD GROWTH

1b) Douglas-fir (Pseudotsuga menziesii) mixed with Tsuga heterophylla and Thuja plicata.

MacMillan Bloedel, (Cathedral Grove), Port Alberni, Vancouver Island, B.C. Canada



2 a

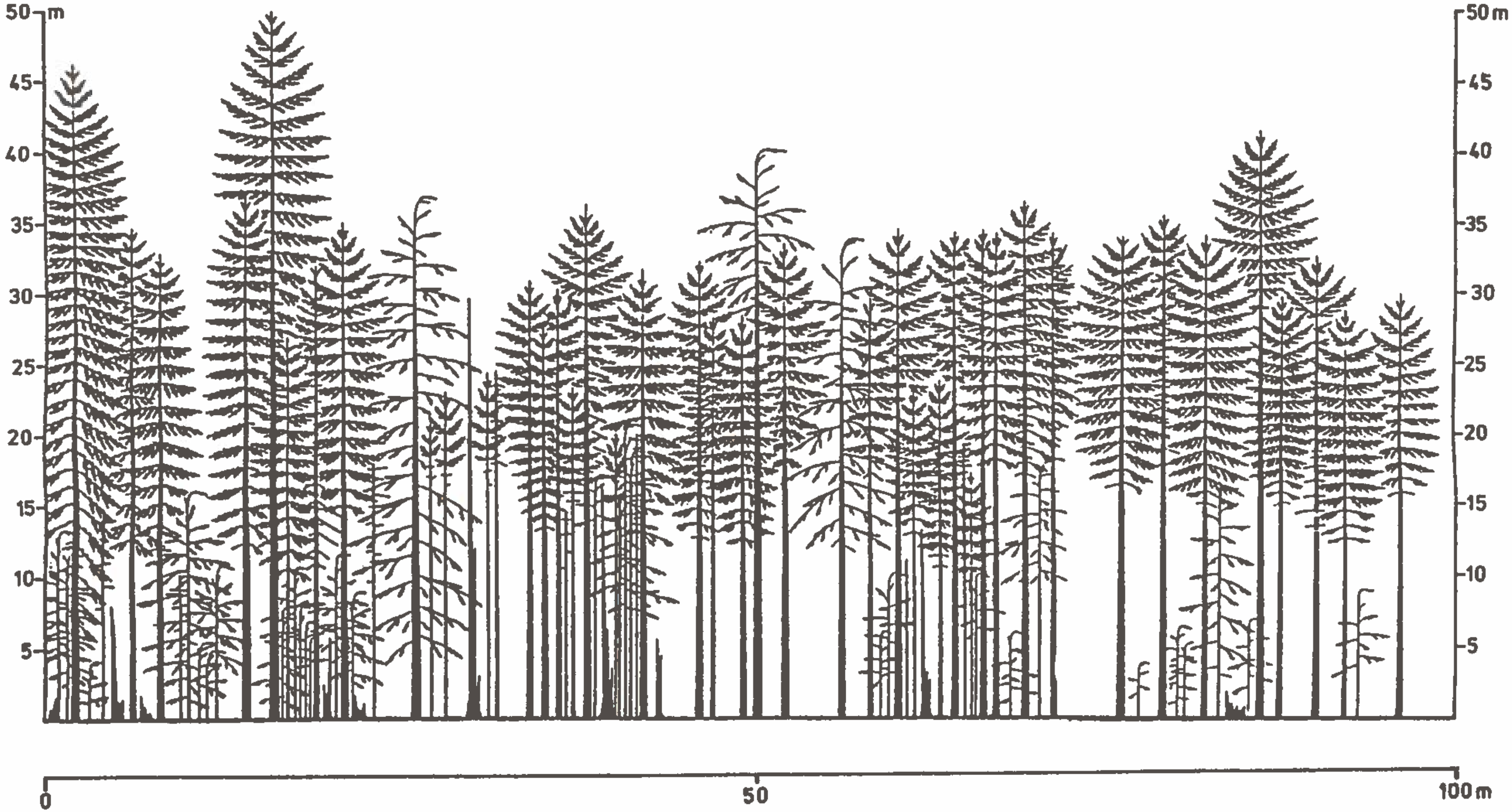


Douglasienbestand (60-80jährig) bei Ladysmith, Vancouver Island, B.C. Kanada

Seehöhe 190 m

(Pseudotsuga menziesii var. menziesii, Tsuga heterophylla)

2 b



Douglasienbestand (60-80jährig) bei Chilliwack B.C. Kanada

Seehöhe 680 m

(Pseudotsuga menziesii var. menziesii, Tsuga heterophylla)

APPLYING THE RESULTS OF DOUGLAS-FIR PROVENANCE RESEARCH TO PRACTICAL FORESTRY

- AN EXAMPLE FROM BAVARIA -

W. F. Ruetz

Bayer. Landesanstalt für Forstliche Saat- und Pflanzenzucht
D - 8221 TEISENDORF, FEDERAL REPUBLIC OF GERMANY

Presented at the Meeting of the IUFRO Working Party
S. 2.02.05 "Douglas-Fir Provenances"

Vienna, Austria, June 10-15, 1985

ABSTRACT

Although Douglas-fir has been grown in Germany for over 100 years, the IUFRO provenance trial stimulated a new interest in Douglas-fir in the seventies. Examples are given of how the results of these provenance trials have changed the seed import guidelines for Douglas-fir into the Federal Republic of Germany and how these results have led to provenance recommendations for the various growing regions in Bavaria.

Combining the best provenances on the proper site with proper silviculture will hopefully assure good plantation survival and a broad base for future tree breeding work with Douglas-fir.

Key words: Douglas-fir, Seed-import, Provenance recommendations, Silviculture

INTRODUCTION

Douglas-fir (Pseudotsuga menziesii mirb Franco) is the most important introduced species in the Federal Republic of Germany which is approximately the same size as the state of Oregon and stretches from Latitude 48° to 55°, this is in the same latitude as a large portion of the indigenous Douglas-fir range in Northwest America (see Fig. 1).

Numerous provenance trials, including those of the IUFRO collection have been established throughout the Federal Republic of Germany. The results of these trials have made it possible to limit the import of Douglas-fir seed into the Federal Republic to the proven provenances and to give certain provenance recommendations to the forest districts. The provenance studies often go hand in hand with silvicultural practices to get optimal plantation success and to incorporate silvicultural treatments with genetic improvement. Some examples of the application of provenance research to practical forestry will be presented here.

PROVENANCE TRIALS AND SEED-IMPORT GUIDELINES

Until the late sixties the import of Douglas-fir seed from North America into the Federal Republic of Germany was based largely on a list of provenance names. The names were often quite ambigious such as "French Creek, Washington" and often lacked a elevational designation. Frequently nothing was known about the provenances which were imported

The establishment of seed zones in the Pacific-Northwest in the mid-sixties and the results of numerous provenance trials including the IUFRO provenance trial combined made it possible to establish new Douglas-fir seed-import guidelines.

These guidelines base the import on seed-zone and elevation. The seed-zones are divided into three categories:

1. Import allowed
2. Import allowed with certain restrictions as to amount, and elevation
3. Import not allowed (Fig. 2).

These import guidelines thus restrict the import to those regions whose provenances have proven themselves in respect to growth, frost resistance, form, disease resistance etc. in a number of field trials. Douglas-fir seed can be imported from a few seed-zones in Northern Oregon, the J-shaped region around Puget-Sound and the southwestern corner of British Columbia including Vancouver Island with exception of the extreme southeast-corner and the Gulf islands. Provenances from these regions have performed well in a number of field trials not only in Germany but in central Europe in general (Fig. 3). (Günzl, 1981; Heis et.al., 1984; Kleinschmit et.al., 1979; Schober et.al., 1984, and others).

PROVENANCE TRIAL RESULTS AND PROVENANCE RECOMMENDATIONS

The IUFRO provenance collection stimulated numerous other provenance specific seed collections in the seventies. In Bavaria two such collections were carried out in 1971 and 1976 whereby the collections were only made in those areas from which promising results could be expected. It also included an elevational sampling up to 1000 m in such areas as Cascadia, Oregon; Randle, Snoqualmie and Darrington, Washington; as well as certain "borderline" provenances from the Cascade crest. Field trials with these provenances were established on a wide variety of sites throughout Bavaria. The goal of these trials was to further refine the provenance recommendations for the different regions in Bavaria.

The results of two such trials in the Spessart mountains of northwest Bavaria are depicted in Figures 4 und 5. Both trials are identical with respect to experimental design and provenances tested as well as soil type. On the drier site in Gemünden which also has a somewhat milder climate the variation between the fastest growing provenance and the slowest lies between 119 % und 67 %. In Brückenau which is characterized by a more mesic site and a colder climate the variation between the fastest and slowest growing provenance is slightly greater 124 % and 61 %. What was particularly interesting is the fact that the northern Oregon and southern Washington provenances (seed zones 461, 430, 422) performed better on the milder site in Gemünden. Most provenances from northern Washington (seed zones 402, 403, 411, 412) and the provenance from the southern Olympic Mountains (Matlock, seed-zone 030) were above the experimental mean on both sites. The poorest performance was obtained from the Interior - British Columbia provenances; these suffered especially under late spring frosts.

The results of over 20 such field trials enabled us to give preliminary provenance recommendations for Bavaria (Ruetz 1981). Basically these recommendations divide the growing regions of Bavaria into 4 climatic zones and recommend those provenances (and elevations) which have proven themselves in field trials in those regions.An excerpt from these recommendations is depicted in Figure 6 whereby especially well performing provenances are listed with the seed-zone in fat print. For example, only in the mildest regions of Bavaria and on dry sites can we recommend provenances from North-Oregon and from the seed-zone 221 in Washington. Provenances from the seed-zone 030 have generally performed well and have had little spring frost damage thus we recommend it especially for sites susceptible to late spring frosts.

These recommendations of course are preliminary and can be modified if the future results of our field trials warrant it. In this first approximation we have tried to be quite generous in our recommendations not only because certain districts have had particularly good results with a certain provenance, but also to avoid narrowing the choice down to one or two provenances where problems can occur obtaining sufficient plants and even in obtaining the correct provenance at all. What is most important is that the forest districts register the provenance of each plantation. In the future the performance of such plantations will be our best provenance trials. Had this been done 80 years ago the percentage of Douglas-fir in German forests would be considerably higher today.

SILVICULTURAL TREATMENT AND FUTURE DIRECTIONS IN DOUGLAS-FIR BREEDING

To be successful in introducing a species one has to be successful in plantation establishment. This can only happen if the provenance, the site and the silvicultural treatment fit together (Larsen et.al., 1978; Ruetz und Foerst, 1984).

Douglas-fir will grow on a wide variety of sites found in Bavaria, the critical factor is often the climate with extended frost periods and temperatures frequently below -20° C and occasionally even below -30° C. This is often combined with a light snow cover which makes Douglas-fir very susceptible to winter-drought injury (Wagner and Koch, 1977).

To reduce such damage Douglas-fir is frequently planted under shelterwood or in small clearings up to 0,5 hectare under a strip cutting scheme. The strips are usually laid out in a north-south direction and are no wider than one tree length of the older stand on the west side of the strip. This assures a more shaded clearing and a longer, heavier snow cover on the site, thus reducing frost injury (Ganghofer, 1884; van Soest, 1959). (Fig. 7).

The trees are planted in the early spring with a 2 x 2 or 2 x 3 m spacing. All trees are fertilized during early spring of the second year so that they outgrow weed competition more rapidly. After a period of 5 years when the plantation is well established the strip cutting process is repeated. Planting success with this scheme usually gives more than 90 % survival.

One might ask "Why the dense planting?" This is done to give us more choices in tree selection during the first thinning which is carried out between the ages of 15 and 20 years. During this first thinning trees with wavy-crooked stems, bushy trees, trees with heavy and numerous branches per whorl trees infected with Rhabdocline and damaged trees are removed. Thus we hope to get some genetic gain through the first selective thinning. The criteria of course are the proper provenance, the appropriate site and proper silvicultural treatment to assure good survival thus allowing a broad base for future tree selection and tree breeding (Wilusz and Giertych, 1974).

LITERATURE CITED

Ganghofer, A., 1884: "Anbau-Versuche mit ausländischen Holzarten" Das Forstliche Versuchswesen, Band II, p. 153-196.

Günzl, L., 1981: "Ergebnisse aus den österreichischen Douglasien-Provenienzversuchen". Forstl. Bundesversuchsanstalt Wien - Informationsdienst 203. Folge, Aug. 1981, p. 8.

Heis, H., W. Ruetz, F. Bentz, 1984: "Auswertung von drei Douglasien-Provenienzversuchen im Alter von zehn Jahren in Oberösterreich". Allgemeine Forstzeitung Nr. 11, p.325-328 Nov. 1984.

Kleinschmit, J., J. Svolba, H. Weisgerber, M. Jestaedt, R. Dimpflmeier, W. Ruetz, H. Dieterich. 1979; "Ergebnisse aus dem internationalen Douglasien-Herkunftsversuch von 1970 in der Bundesrepublik Deutschland - II. Ergebnisse der Feldversuche im Alter 6". Silvae Genetica 28. Heft 5-6, p. 173-256, 1979.

Larsen, J. Bo, O. Muhle, H. Lobeck, 1978: "Untersuchungen zur Bestandsbegründung der Douglasie". Schriften aus der Forstl. Fakultät der Univ. Göttingen und der Nieders. Forstl. Versuchsanstalt, Band 52, p. 331.

Ruetz, W.F., 1981: "Douglasien-Herkunftsempfehlungen - ein Vorschlag für Bayern". Allg. Forstzeitschrift Nr. 41, p. 1074-1077.

Ruetz W.F., K. Foerst, 1984: "Grundsätze für den Anbau der Douglasie in Bayern". Bayer. Staatsministerium für Ernährung, Landwirtschaft und Forsten - Herausgeber,pp. 17.

Schober, R., J. Kleinschmit, J. Svolba, 1984: "Ergebnisse des Douglasien-Provenienzversuches von 1958 in Nordwestdeutschland (II. Teil)". Allg. Forst- und Jagdzeitung Nr. 155,p. 53-80.

Soest, I. van, 1959: "Erfahrungen mit der Douglasie in der niederländischen Forstwirtschaft". Allgemeine Forstzeitschrift, Nr. 8, p. 155-157.

Wagner, F., H. Koch, 1977: "Umfang und Folgerung der Frosttrocknisschäden bei der Douglasie in Niederbayern/Oberpfalz". Allg. Forstzeitschrift Nr. 12, P. 279.

Wilusz, W., Giertych, M., 1974: "Effects of classical silviculture on the genetic quality of the progeny". Silvae Genetica 23/4, 1974, p. 127-130.

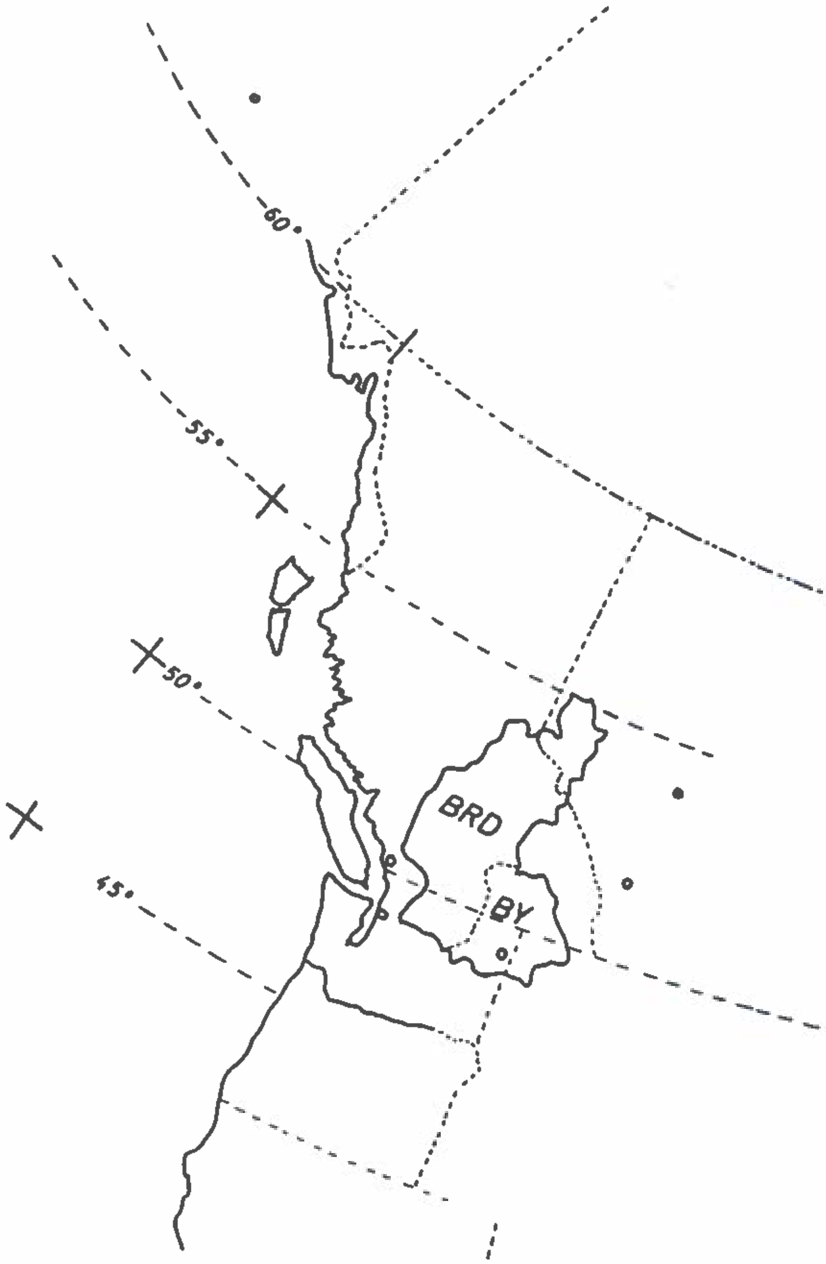


Figure 1 : Relative size and latitudinal location of the Federal Republic of Germany (BRD) and Bavaria (BY) in comparison to the Pacific Northwest.

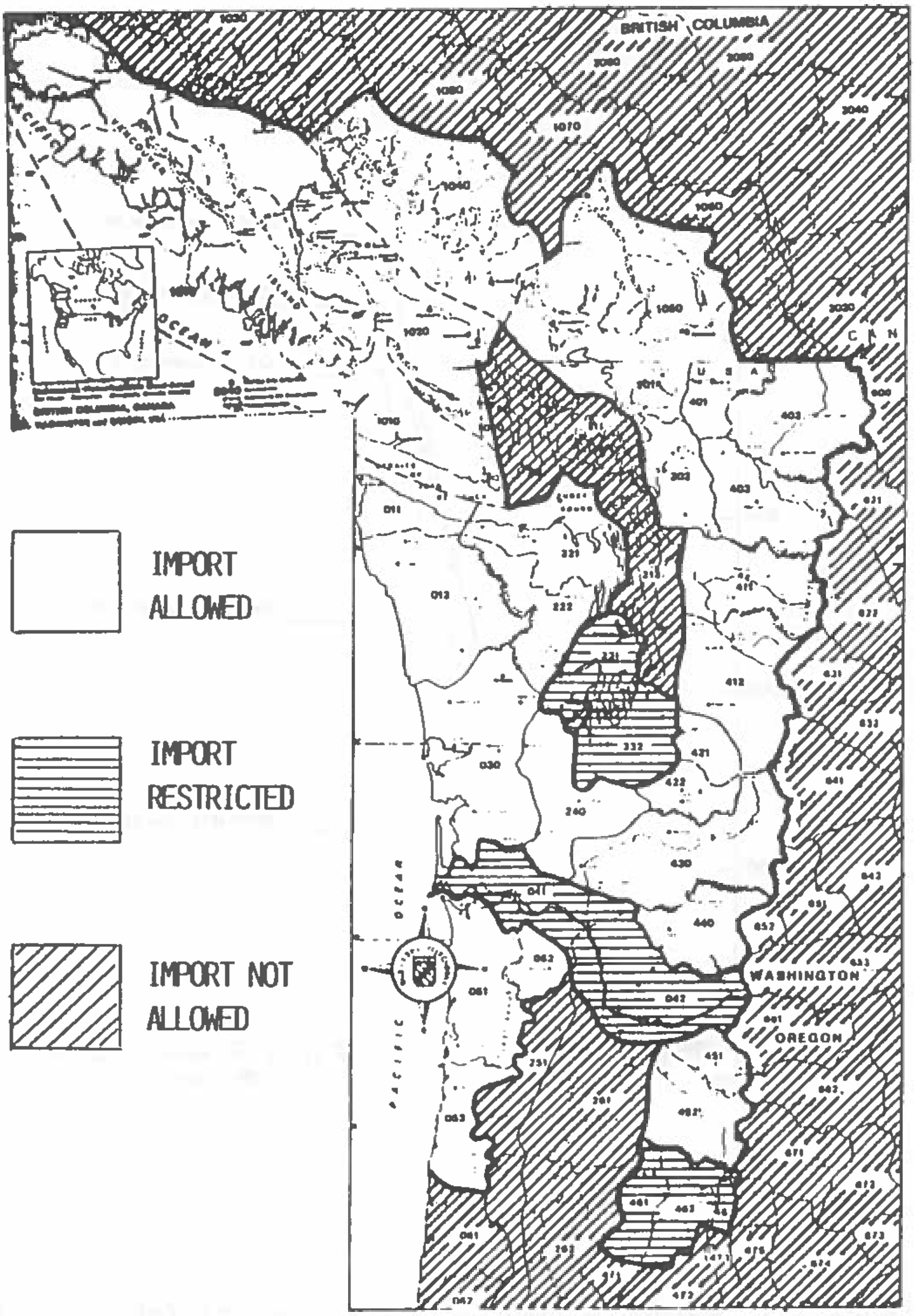


Figure 2 : Import guidelines for Douglas-fir seed into the Federal Republic of Germany as based on Pacific-Northwest seed-zones.

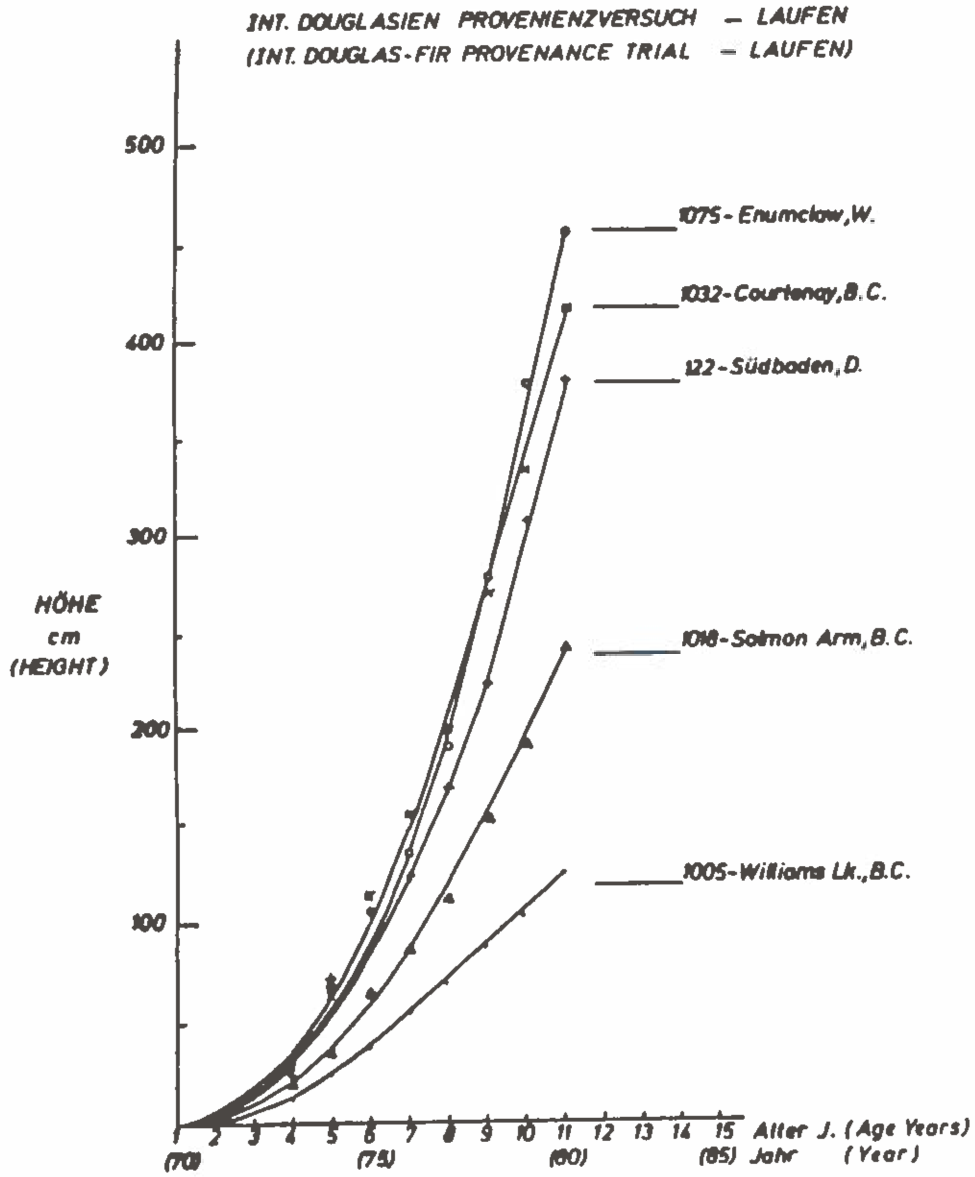


Figure 3 : Heigth growth of 5 provenances representing two coastal, one German, one interior-wet-belt and one northern interior provenance.

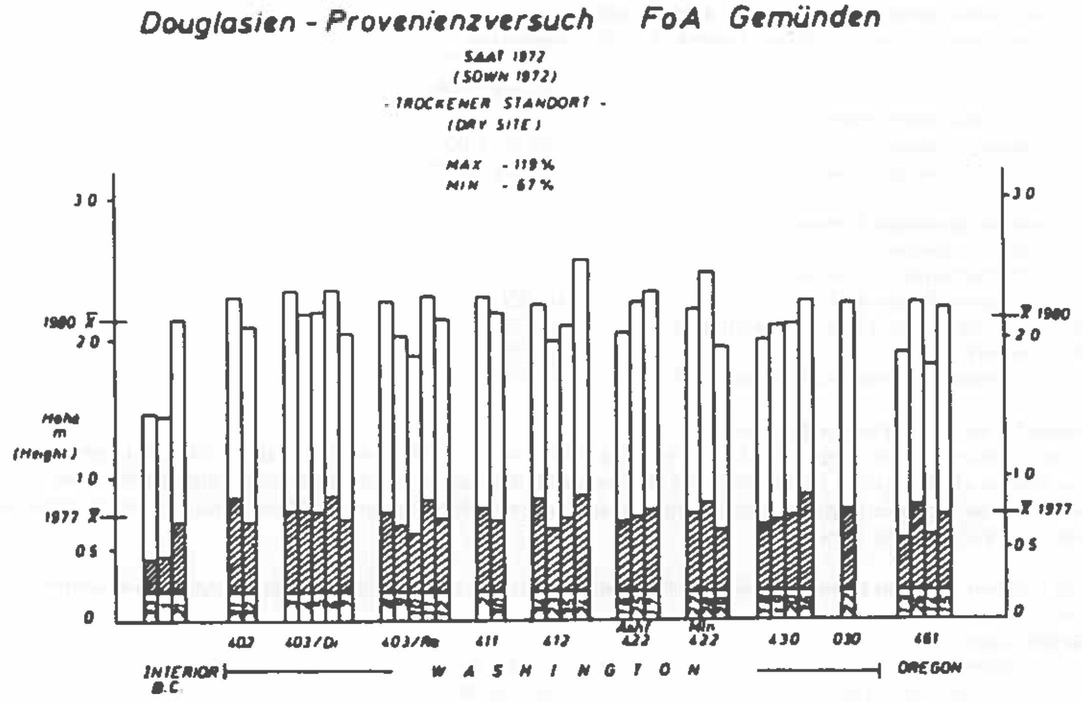


Figure 4 : Height growth of 36 provenances on a relatively dry site in the forest district Gemünden.

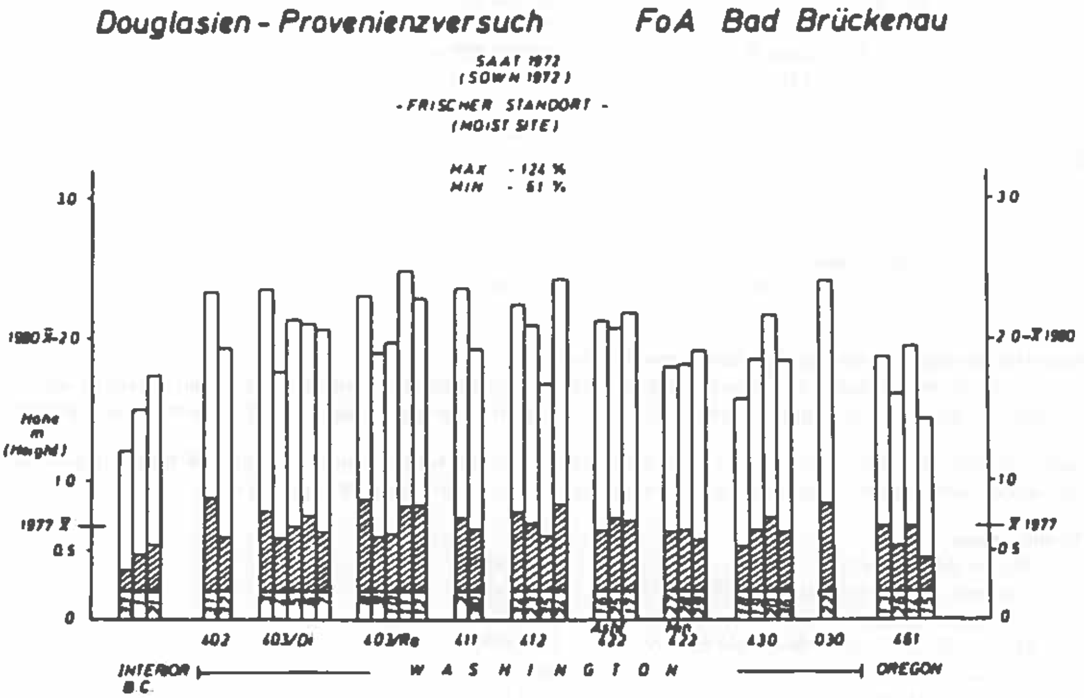


Figure 5 : Heigth growth of 36 provenances on a mesic site in the forest district Bad Brückenau.

c) Für trockenere Standorte – nur in sehr milden Lagen:

221	Port Angeles, Sequim, Elwha, Louella G. S., W.	bis 600 m
451	ZigZag, Government Camp, Cherryville, O.	300 bis 1 000 m
452	Estacada, Clackamas, O.	300 bis 1 000 m
461	Mill City, Sweet Home, Abiqua, Cascadia, Santiam, O.	300 bis 1 000 m
462	Detroit, Cascadia, Santiam, O.	300 bis 1 000 m

d) Für niederschlagsreiche Standorte:

1010	West Vancouver I., Gold River, B. C.	bis 600 m
1020	Ost Vancouver I., Courtenay, Nanaimo, Sayward, B. C.	bis 600 m
1030	Port Hardy, Alert Bay, Nimpkish, B. C.	bis 600 m
1040	Sechelt, B. C.	bis 600 m
1050	Chilliwack, Vancouver, Squamish, B.C.	bis 600 m

2. Herkünfte für mittlere Lagen Bayerns

Für diese Gebiete, höhere Lagen des Spessarts, Teile Schwabens, das Alpenvorland und die tieferen Lagen des Bayerischen Waldes, eignen sich die Herkünfte vom Gebiet westlich des Kaskadenkammes in Washington (Höhen über 150 m) sowie Herkünfte vom Küstengebirge und Olympic Mountains in Washington sowie Herkünfte von Vancouver Island und Südwest-British Columbia, Kanada.

Für die höheren Lagen in diesem relativ großen Gebiet wird empfohlen, auch die höheren Douglasien-Herkünfte zu verwenden:

a) Für alle Lagen

011	Clallam Bay, Tatoosh, W.	150 bis 750 m
012	Forks, Quinault, Hoh R., W.	150 bis 750 m
201	Bellingham, Nooksack, W.	150 bis 750 m
202	Mt. Vernon, Arlington, Sedro Woolley, W.	150 bis 750 m
222	Hoodsport, Mt. Walker, Lk. Cushman, W.	150 bis 750 m
240	Centralia, Chehalis, W.	150 bis 750 m
401	Glacier, Mt. Baker, W.	150 bis 750 m
402	Concrete, Marblemount, Skagit, R., W.	150 bis 750 m
403	Darrington, Suiattle, R., W.	150 bis 750 m
411	Skykomish, Startup, Index, Gold Bar, W.	150 bis 750 m
412	Snoqualmie, Enumclaw, W.	150 bis 750 m
421	Old Baldy, Mt., W.	150 bis 750 m
422	Ashford, Elbe, Mineral, W.	150 bis 750 m
430	Randle, Cowlitz, Packwood, W.	150 bis 750 m
1010	West Vancouver I., Gold River, B. C.	150 bis 750 m
1020	Ost Vancouver I., Courtenay, Nanaimo, Sayward, B.C.	150 bis 750 m
1030	Port Hardy, Alert Bay, Nimpkish, B. C.	150 bis 750 m
1040	Sechelt, B. C.	150 bis 750 m
1050	Chilliwack, Vancouver, Squamish, B. C.	150 bis 750 m

b) Für spätfrostgefährdete Lagen:

030	Humptulips, Matlock, Grisdale, W.	150 bis 750 m

3. Herkünfte für rauhe, kontinental getönte Lagen Bayerns

Für diese Gebiete des Vorderen Bayerischen Waldes und der Vor-Rhön eignen sich am besten die Herkünfte vom Westabhang der Kaskaden in Washington oberhalb 600 m sowie Herkünfte aus Südwest-British Columbia oberhalb 450 m.

Für spätfrostgefährdete Lagen können auch noch Herkünfte aus dem Küstengebirge und Olympic Mountains verwendet werden, wobei dann jedoch auf ausreichenden Schutz gegen Frosttrocknis geachtet werden muß.

a) Für alle Lagen:

401	Glacier, Mt. Baker, W.	über 600 m
402	Concrete, Marblemount, Skagit R., W.	über 600 m
403	Darrington, Suiattle R., W.	über 600 m
411	Skykomish, Startup, Index, Gold Bar, W.	über 600 m
412	Snoqualmie, Enumclaw, W.	über 600 m
421	Old Baldy, Mt. W.	über 600 m
422	Ashford, Elbe, Mineral, W.	über 600 m
430	Randle, Cowlitz, Packwood, W.	über 600 m

Figure 6 : Excerpt from the provenance recommendations for different growing regions in Bavaria.

Figure 7: Strip cutting scheme for Douglas-fir.
Strips 1 to 1 1/2 tree lengths wide.

Characterization of Seed Samples of Douglas-Fir by Short Term Investigations on Bud Set. (A preliminary report).

J.Nather
Federal Forest Research Station, Vienna
Institute for Silviculture

Presented at the meeting of the IUFRO Working Party S.2.02.05, Vienna, June 10 - 15, 1985.

Objectives

A prerequisite for successful growing of Douglas fir out of its natural range - like for any other introduced species too - is the choice of a suitable provenance, best adapted to the new growing conditions. Comparisons of environmental properties between place of origin and location of afforestation are necessary for a first step of introduction but often will not be enough. The most reliable hints for a choice of a provenance can be obtained by short term tests. Out of several groups of characters that of adaptation seems to be more useful than those of growth or volume production, which must be assessed by long term trials without any doubt.

Refering to the problems of early testing, there are three objectives for such tests:

1. The most interesting question is, whether a seed lot is adapted to the growing periode or not. When transfering a Douglas population one of the most important factors will be the length of the growing periode, because unfavourable temperature extremes are often the delimiting factor, particularly in subcontinental climatic regions (early or late frost sensitiveness respectively). This characteristic can simply be assessed by investigations on flushing and bud set respectively. As many authors emphasized how close other important characters like growth potential and hardyness in general are correlated particularly to bud set, it seems reasonable to concentrate research first of all to this trait.
2. There is a need for test results also for identification of seed lots. When we got positive experience with a particular provenance and we want to get the same reproductive material again after some years we only can compare seed lots by short term identity tests. No certificate can prove the genetic identity free from doubt without basing on such test results. This may get more importance in the future when cone collection will happen more and more in second growth stands and seed zones are not sufficient indicators for the genetic property of a seed lot.
3. Test results finaly can also serve for control, for supervising seed production and seed trade.

Method

As we had some experience with similar investigations on bud set by a method developed by K. Holzer for identifying Norway spruce samples of different altitudes, we applied the same method with 38 Douglas fir samples first in 1980. As this first tests gave sufficient results, we continued with further series until 1984 with a total of 327 samples.

The method is quite simple: After sowing in late April or early May there is an exact assessment of the course of forming terminal buds at the end of the first growing periode. Mature terminal buds are counted at 5 terms every 10 to 14 days beginning about 1 week after first buds can be found. After the last term the single figures (given in percents of the whole number of the seedlings of a sample) are summarized and give a Bud-Set-Index (BSI). By this way for instance we found with an interior source (Johnson Lake, B.C., 1000 m):

First counting (10.9.)	35 %	(plants with mature terminal buds)
Second counting (26.9.)	77 %	
Third counting (10.10.)	98 %	
Fourth counting (24.10.)	100 %	
Fifth counting (7.11.)	100 %	(last counting)
Bud-Set-Index (sum)	410	

In comparison a coastal population for instance Alsea-Mary's Peak, Or. of the same series achievs BSI 40 with five countings: 0+3+9+10+18.

By our experience the best and distinct differentiation of test samples can only be found at the end of the first growing periode (with 1-year-old seedlings) and of course with unselected populations (no seed grading for instance). Of course there are environmental influences on different series by different weather conditions as well as by changing soil properties (humidity, nutrition, texture) when the tests are carried out in the open field. But results are always comparable within a particular series even when varying in a special range from year to year. So for instance we had earlier bud set causing higher index numbers in a dry hot summer in comparison to a wet August periode with delayed cessation in an other year. Samples with low BSI are changing in a wider range as high indices do, which are rather stable in different years. The disadvantage of field tests can only be met by replications and by using standards for comparison. To avoid environmental influences this investigations are intended to be carried out under well defined conditions in a climatic chamber in the future.

Material

The tests were carried out with commercial seed samples, when reliable data about seed zones and elevation were available. Many of the samples were chosen from lists in direct contact with recommended firms. The distribution comprises the entire area which may be of interest in largest sense for planting in Central Europe from B.C. (7 samples) to Washington (42) and Oregon (29) from coastal or West Cascade (51) respectively to interior and transition (27) regions respectively. Attention was also payed to exact elevation data of samples comprising the range from 150 m to 1800 m. In addition to original seed samples from the Pacific NW region we tested 22 samples from European and Austrian collections respectively.

Results

Refering to the course of bud set three types are to be distinguished with original test samples from the Pacific NW as shown in Fig. 1:

1) Due to delayed bud set only up to 30 % of seedlings show mature terminal buds at the end of the last survey and BSI therefore is less than 100. At this state of development early frosts, occuring in the test place during first half of October as a rule, frequently cause heavy damages in the nursery.
2) After a delayed beginning (at first and second counting) bud set is speeded up and achieves finaly 90 - 100 %. BSI of this group is between 100 (120) and about 300.
3) First mature terminal buds can already be found, at the end of August, no lammas shoots are formed, the percentages of seedlings with terminal buds increase to more than 90 % very soon and BSI achieves up to 400 and even more.

That means that by BSI of single samples or means for seed zones respectively the adaptability to a particular growth periode can be evaluated as well as a geographical arrangement can be indicated. Low BSI-numbers represent the sensitive coastal type and can be found without any exception only in seed zones west of the Cascade crest from southern B.C. to Washington and northern Oregon in elevations below 1000 m as a rule. This area known from many provenance trials for best growing but sensitive seed sources correspond in general to the division by Savarin and Snyberg (cit. by Herman) for the coastal Douglas fir according to terpene investigations.

BSI-numbers increase up to 200 and more at higher elevations as well as in some parts east of the crest (up to 300), when site conditions become more extreme or continental. This type corresponds to the intermediate or transition type and is distinguished by an average growth potential; genetically it seems to be closer to the coastal type than to the interior form. Whereas all samples of the interior show BSI-numbers above 300 up to 400, in some cases even more.

In comparison to this original material some european collections were tested as mentioned before (Fig. 2). With only few exceptions BSI amount throughout less than 100, frequently remarkable low (about 40), corresponding with growth over average and a rather high percentage of injuries. Thus the conclusion is permissible, that most of this stands of unknown seed sources originate from regions west of the Cascade crest and from low elevations as a rule and belong more or less close to the coastal type. One can further presume that interior types if planted, could not stand the competition with indigenous species. Old stands are often the surviving rest of a population with an originally greater variation.

BSI and Altitude

Whithin regions one can recognize also a clinal altitudinal differentiation. With increasing elevation BSI increases as Fig. 3 shows for west Cascade provenances (coastal type). Deviations are only in low and high altitudes, probably due to a smaller number of samples. Single graphs differ from year to year because of different conditions but show the same trend. Although there were not enough samples for a significant result, oberservation let presume in some cases a slightly increase of BSI also in low altitudes (lower timberline to dry basins) corresponding to a slight decrease of growth as mentioned some times in personal communications.

Location	seed zone and elev.	BSI	height (cm)	rel.growth (% of mean)	height:diameter ratio
Johnson Lake	3050-900	398	20,0	74	77
Heffley Lake	2040-650	396	22,1	81	67
Adams Lake	3040-500	347	22,3	82	72
Eagle Bay	3040-400	249	23,4	86	81
Naches	641-30	258	21,9	81	73
Cle Elum	431-25	240	22,7	84	78
Cascadia	461-25	201	29,0	107	91
Pine Grove	662-40	186	24,7	91	82
Trout Lake	652-30	173	25,5	94	88
Trout Lake	652-25	108	25,3	93	90
McKenzie Ridge	472-45	173	25,2	93	76
Irenental (Austria)	-	169	26,1	96	82
Oakridge	482-50	152	23,5	86	78
Oakridge	482-25	78	31,9	117	100
Marion Lake	463-35	139	24,8	91	80
Lewis River	440-35	129	24,9	92	92
Lewis River	440-25	82	24,9	92	113
Mt. Hood	661-40	121	25,4	93	91
Mt. Hood	661-30	92	27,8	102	87
Hood River	661-20	108	27,9	103	100
Clear Lake	473-30	120	28,4	104	77
Sisters	675-35	118	29,1	107	91
White Salmon	653-30	89	29,3	108	95
White Salmon	653-20	89	29,1	107	100
Detroit/Idanha	462-25	94	26,5	97	86
Deutschwald (Austria)	-	91	24,5	90	88
Snoqualmie	412-30	88	30,4	112	95
Snoqualmie	412-20	25	33,0	121	85
Concret/Mt.Backer	402-35	79	29,4	108	101
Concret	402-20	43	28,8	106	96
Grafenegg (Austria)	-	73	31,4	115	95
Sequim/Louella	221-15	69	29,7	109	102
Old Baldy Mt.	421-25	65	27,2	100	88
Darrington	403-30	60	30,3	111	105
Ashford	422-15	51	28,6	105	99
Randle	430-25	51	26,5	97	110
Randle/Cowlitz	430-25	49	28,9	106	90
Estacada	452-25	46	27,2	100	97
Estacada	452-15	35	34,1	125	100
West Centralia	241-30	49	30,2	111	94
Lake Stevensen	411-15	28	30,6	113	99
ZigZag Mt.	451-30	27	30,9	114	110
Alsea	061-20	21	28,4	104	95
Südbaden (FRG)	-	18	30,7	113	88

Table 1: Douglas-fir-samples of the 1982 series. Bud-Set-Index-numbers and height growth of 2-0 seedlings.

BSI and Growth

Correlation between growth periode and other traits as for instance growth potential has been stressed repeatedly. Table 1 records the height growth of 2-year-old seedlings for 1982 series (for example) arranged by BSI and further the relative growth (% of overall average) and the relation height to diameter (H:D). The correlation BSI and height growth is also shown in Fig. 4. With decreasing BSI we find general increase of seedlings height. As the best growing sources with 125 % and 121 % above average respectively seed samples from Estacada (seed zone 452) and Snoqualmie (seed zone 412) were found with BSI 25 respectively 35. Whereas the interior provenance Johnson Lake with BSI 398 achieved only 71 % of average height.

In another graph the relative growth of a sample is shown in comparison with BSI (Fig. 5). Up to BSI-numbers of about 100, 80% of all samples show better growth than overall average. At BSI 120 and more height growth of all samples is below average. Interior samples of B.C. show slower growth even as seedlings at age of 2 years. The difference of heigth growth between Johnson Lake (B.C.) and Snoqualmie or Darrington respectively amounts 100 to 120 %. Of some interest are samples from the East Cascade region as for instance Cle Elum or Trout Lake. Although classified as interior they show an intermediate position in BSI as well as in growth potential.

BSI and Frosthardyness

The seedlings grown under homogenous conditions as concerns soil, nutrition, climate etc. were exposed to the natural course of weather without any protection measure. As usual for the subcontinental climate character of eastern Austria first frost with temperatures below zero (about -2 C) occure between October 5 and 10. The test samples show different sensitiveness to early frost which could be correlated to BSI. Low index numbers show high percentages of about 70 % of frost injuries, but with increasing indices injuries decrease significantly. Higher BSI numbers normaly show no or only slight frost injuries. But it was found that some samples particularly from the transition area show sensitiveness to late frost due to an early flushing which is normally no problem for samples with low BSI numbers below 100.

But inspite of the high percentages of injuries with 1 year old seedlings in sources originating from the area west of the Cascade crest, many plants survive under the given conditions without enduring damages due to their remarkable height growth potential.

Silvicultural Conclusions

BSI proves as an indicator for the adaptation of a provenance to the growth periode which is an essential character for successful cultivation. Because of a correlation to growth potential and sensitiveness, BSI allows better recommendations concerning the use of a provenance and necessary supporting silvicultural measures.

Sources with index numbers below 100 are characterized by the highest growth potential, but due to their low hardyness can only be successfully planted in areas with moderate climate and protected sites (no frost pockets) and additional support should be given by silvicultural measures like planting under shelter-

wood, pioneer trees or with side protection.
More hardyness can be found in seedlings from the transition zone and from higher altitudes with BSI between 100 and 300, but growth potential is often decreasing more or less considerably. This provenances can be used also in more subcontinental sites and will not need such careful protection measures as low-index sources do.
For harsch climatic conditions and also for mountain regions above 900 m, seed lots with BSI of more than 300 (250) will be rather suitable. They will show enough hardyness but also slower growth performance.
All tested seed samples originating from well growing stands in Europe show low BSI numbers and above-average growth indicating an origin in the Douglas-fir optimum west of the Cascade. Even if only a part of the original population survived and the variation might be selected by the local conditions, we should use this stands as valuable seed sources in the future.

Literature:

Hermann, R.K., 1981: "Die Gattung Pseudotsuga - ein Abriß ihrer Systematik, Geschichte und heutigen Verbreitung". Forstarchiv 1981, S. 204.

Holzer, K., 1964: "Feststellung der Höhenstufe bei Fichtensaatgut durch Testung in der Kulturkammer". In Forstsamengewinnung und Pflanzenanzucht für das Hochgebirge. BLV München - Basel - Wien. S 74 - 82.

Holzer, K.; Nather, J., 1974: "Die Identifizierung von forstlichem Vermehrungsgut". In "100 Jahre Forstliche Versuchsanstalt". S 13 - 42.

Jestaedt, M., 1980: "Untersuchungen über die Jugendentwicklung von Douglasienprovenienzen in Hessen". Mitt. d. Hess. Landesforstverw. Bd. 16.

Larsen, J.B., 1978: "Untersuchungen über die winterliche Trockenresistenz von 10 Herkünften der Douglasie (Pseudotsuga menziesii)". Forstwiss. Cbl. 97, S. 32 - 40.

Ruetz, W.F., 1981: "Douglasien-Herkunftsempfehlungen - ein Vorschlag für Bayern". Allg. Forstzeitschr. Nr. 41, S. 1074-1077.

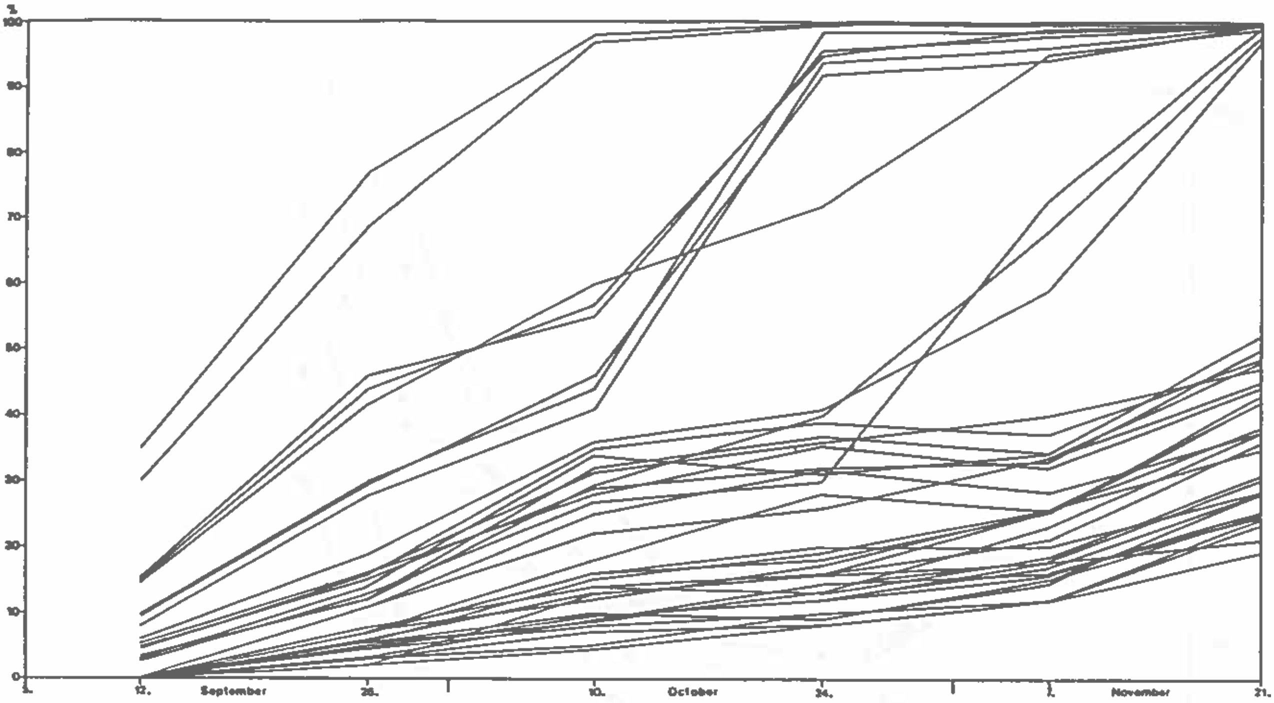


Fig. 1: Progress of bud set of test series 1984 - Samples from the Pacific NW.

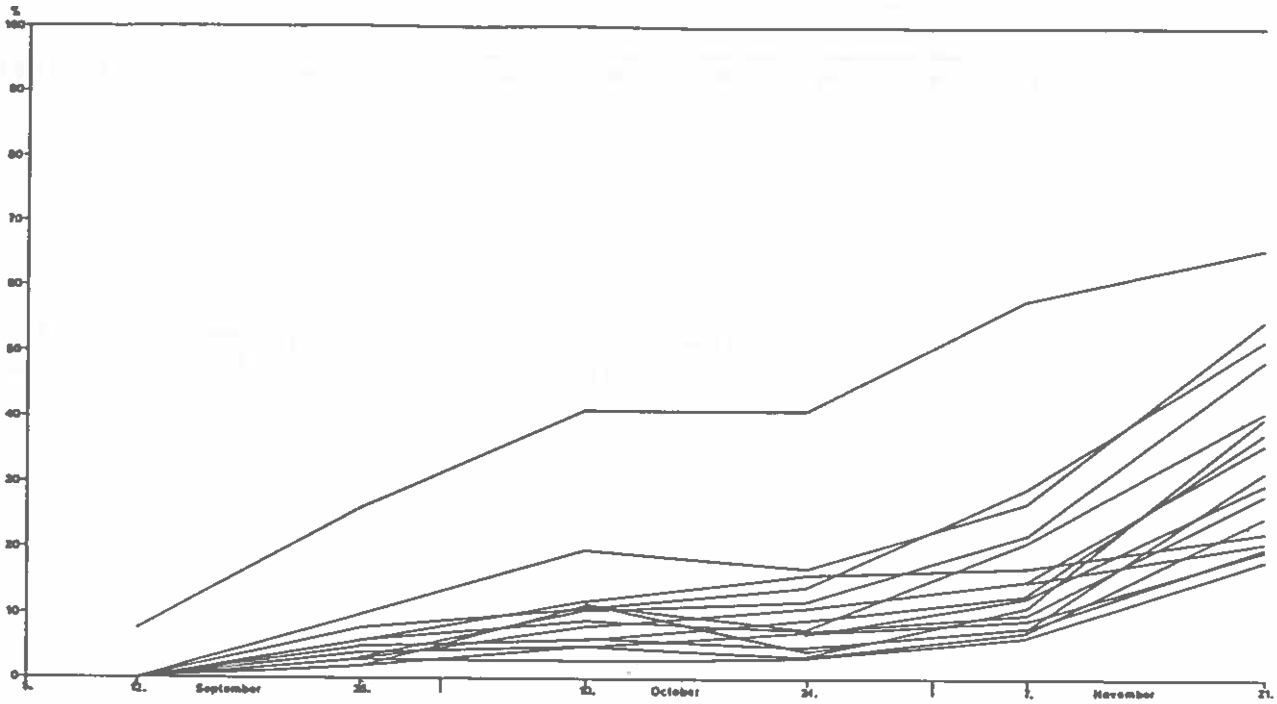


Fig. 2: Progress of bud set of test series 1984 - Samples from Europe.

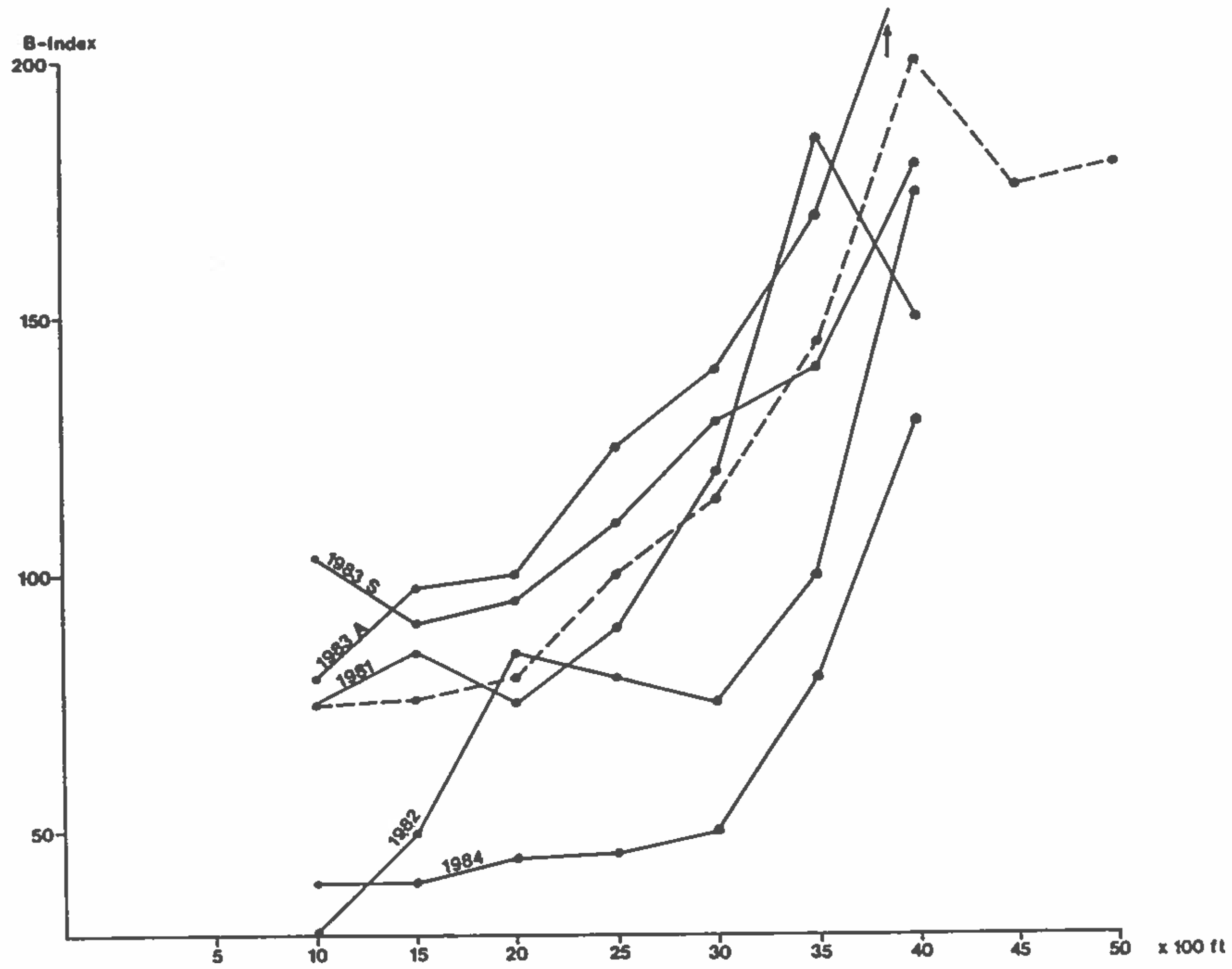


Fig. 3: Mean values for Bud-Index numbers with increasing altitude. "Costal" samples of series 1981, 1982, 1983 (two different nurseries), 1984.

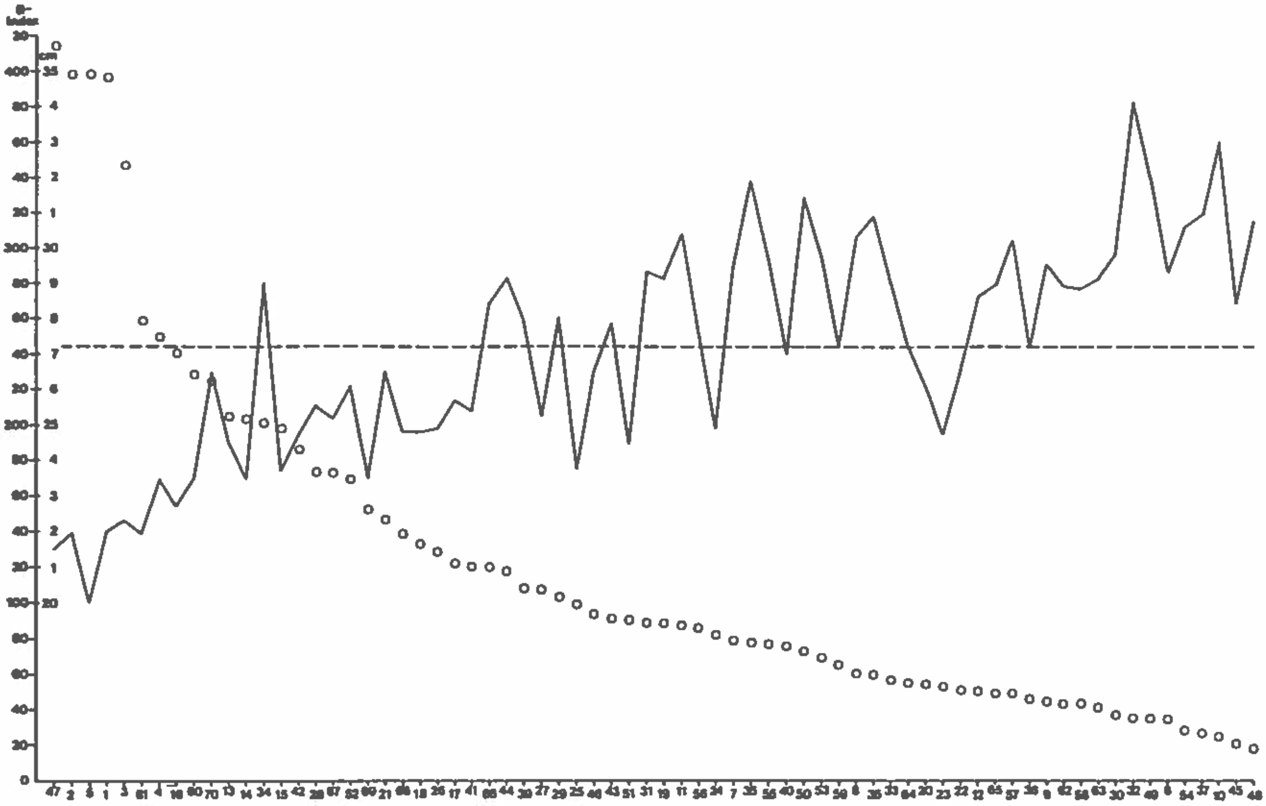


Fig. 4: Douglas fir 1982. - 2-0 seedlings. Average hight at different Bud-Index numbers.

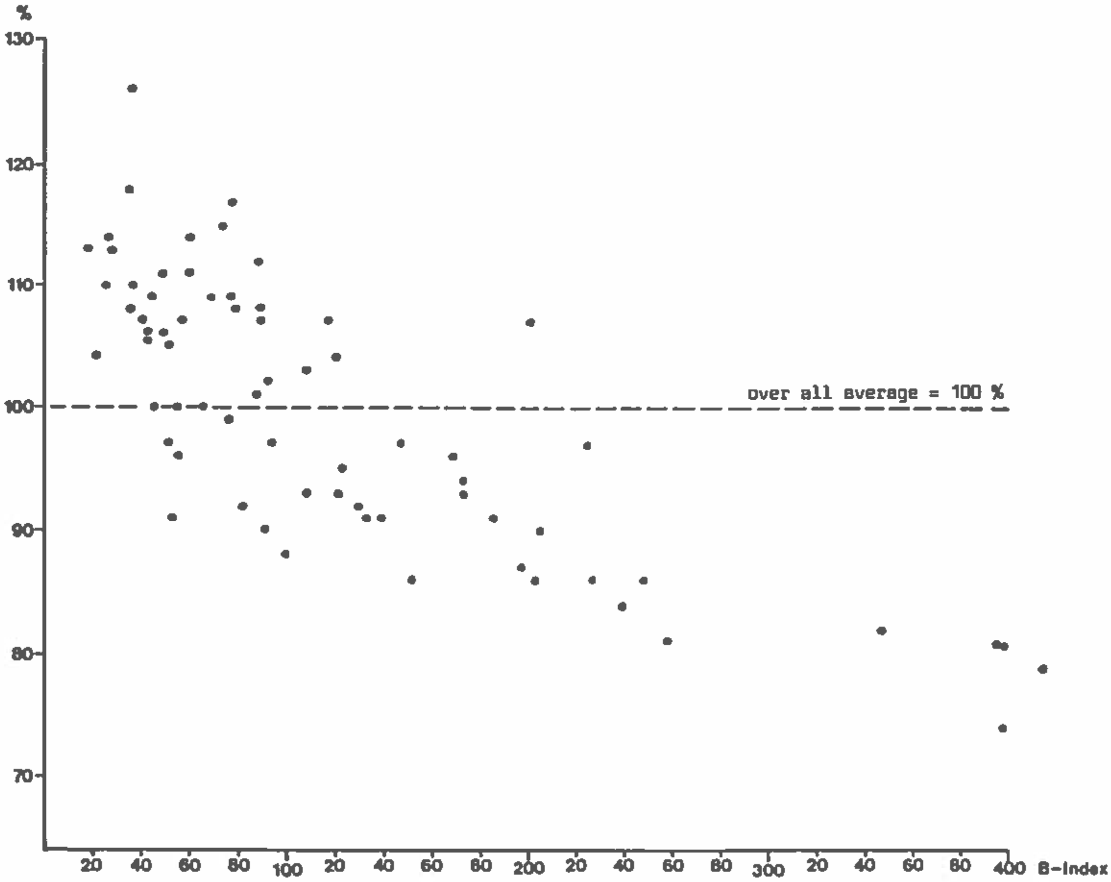


Fig. 5: Relative growth (% of mean value) of Douglas fir 2-0 seedlings, series 1982 at different Bud-Index numbers.

REPORT ON DISCUSSIONS TO PAPERS PRESENTED AT IUFRO WORKING PARTY S2.02 - MEETING VIENNA JUNE 11th - 14th 1985

J. O'DRISCOLL
Forest & Wildlife Service, Dublin, Ireland

SESSION I

1) First results of American Douglas fir provenance trials in France - D. Michaud, AFOCEL, Limoges, F.

Paper reported on the growth of 186 provenances of Douglas fir growing in France. Relationships between growth, latitude of origin, elevation and date of flushing were also presented. Polycyclic growth was also discussed.

Discussion - Paper 1.

Discussion centred on the pattern of polycyclic growth. In reply to a question whether or not it was confined to west Cascade provenances the author stated that some showed this characteristic while others did not. The effect of altitude of seed source was not measured. The only G x E interaction observed was that the lower elevation test sites had a greater degree of polycyclic growth. It was pointed out that in Ireland polycyclic growth was clearly related to provenance origin and elevation of seed source. There was however no apparent differences between test sites. Polycyclic growth also had a detrimental effect on form as it was the lateral buds which showed the tendency to polycyclic growth. In the following year this gave rise to forking.

2) The international short term Douglas fir (Pseudotsuga menziesii) provenance experiment in West Norway - S. Magnesen, Norwegian Forest Research Institute, Stend, N.

Fifty one provenances were tested on one site. Results of survival, growth and form were presented.

Discussion - Paper 2.

Establishment is the major problem in the growing of Douglas fir in Norway. Over 60 % of the plants of a particular provenance can be killed in the first year, particularly over the winter period. Further deaths were attributed to weed competition. Survival is better in the interior provenances compared with the coastal ones. On the question of growth there was considerable variation both between and within provenances. This applied particularly to British Columbian provenances. One of the better provenances was from high elevations in the Cascade range which had good growth and hardiness. A similar result was found in Bavaria. On the question of the relationship between growth and form the author found that stem and branch sinuosity were correlated with vigour. The poorer stem form was found in the coastal provenances, these having broad crowns and wavey stems and branches.

Rhabdocline does occur in Norway when the trees are 3 to 4 metres in height. Thereafter it tends to decrease. It is more severe on interior provenances. A similar pattern of attack has been recorded in Britain. However, no trees have as yet been observed to have grown through the susceptible phase. the disease also persists from year to year. In southern Germany Rhabdocline is most severe in frost hollows and where it is densely planted. The situation can be improved by thinning which allows a freer circulation of air. This is borne out by its absence from plantations located on slopes.

Experience in eastern Norway has shown that Douglas fir does not grow well and is the poorest of all species tried. Due to the large variation within the species a lot of work would be required to find a suitable genotype for its introduction into eastern Norway. In west Norway it will only bee used on poorer sites where it can out-perform Norway spruce.

3) Results of IUFRO Douglas fir experiments in Britain at 10 years - R. Lines, BFC Edinburgh.

Reports on 10 year results of a 45 provenance Douglas fir experiment planted on 5 sites in UK. Characteristics measured were height and diameter.

Discussion - Paper 3.

In drawing up stability parameters for the experiment the method of Finlay and Wilkinson was used. This method indicates that those with the value closest to 1 are the most stable and in Britain these are also the most productive. Home collected origins were not more productive than imported origins. No difference in survival was recorded among the Puget Sound provenances under test. On the question of the correlation between survival and planting technique it was stated that normal management practice was used in establishing experiments and that local Staff was used. Recent studies in Britain with Douglas fir has shown that root regeneration is only 50 % that of Sitka spruce. In addition the species is very sensitive to moisture stress at time of planting. Damage to roots from rough handling of plants also tends to reduce survival percentage.

4) Results in two test sites of provenance of IUFRO collection of Pseudotsuga menziesii (Mirb.), Franco in Galicia. G. Toval, Centro Forestal de Lourizan, Pontevedra.

Eighty-seven IUFRO provenances were tried on two sites, one at low elevation and the other at high elevation. Criteria used for comparison were survival and growth.

Discussion - Paper 4.

Survival did not vary between sites but growth did. Coastal provenances from Washington and Oregon were the most vigorous. Name of the most vigorous one was not known, only their IUFRO number.

5) Results of IUFRO Douglas fir provenance experiment in the Federal Republic of Germany. J. Kleinschmit, J. Svolba, H. Weisgerber, R. Dimpflmeier, W. Ruetz and Th. Widmaier.

Performance of 113 provenances on 6 sites is reported. Criteria used for comparison were survival, growth, time of bud set and length of growing season.

Discussion - Paper 5.

Results have shown that provenances exhibit different survival rates between sites. This raised the question of the level of survival that must be present to allow a valid comparison to be made. If survival is low the genetic composition of each site will be different thus excluding any possibility of comparison. In the Federal Republic average loss ranges from 25 - 35 %. It must be borne in mind that a newly introduced species is growing in a new invironment and is being subjected to severe selection pressures. This will naturally lead to different population composition. Comparisons between sites are only made where the provenances are adequately represented. Experience in Sweden with lodgepole pine has shown that only certain phenotypes grow and that these represent only a proportion of the genotypes. It was pointed out that in the species native distribution only certain trees flower. These in fact, can only be the ones represented in a provenance experiment. The most valid method of between site comparison is by use of clonally propagated material.

The most vigorous provenances in the German experiment were from the Darrington region of Washington. Similar results were found in Belgian trials. This posed the question whether to use home collected seed or to make further collections in the Pacific North-West. It is the intention of the Federal Republic of Germany to make further collections in those regions which have performed well in German trials. Selections in the wild stands may be on an individual tree basis. This intention is based on the fact that the genetic base of the home grown population is unknown and in fact it may be too narrow. Experience in Britain has shown this to be the case. In addition work in Canada demonstrates that inbreeding depression sets in very rapidly after the S1 generation.

6) Comparative research with German and American Douglas fir provenances. H.M. Rau, Hessische Forstliche Versuchsanstalt.

German provenances of Douglas fir are compared with American origins to ascertain if they can be used as seed sources for future German Douglas fir plantations.

Discussion - Paper 6.

The potential of first generation material was clearly demonstrated in many trials. As a result it is the intention to extend this type of trial to southern Germany. In France fifty first generation provenances are under comparison with IUFRO material. Forty to forty five are as vigorous as the Washington material. Based on these results home collected origins are preferred to imported seed when cone crop is poor in the Pacific North-West. In addition to the provenance comparison progeny testing of individuals from these better stands is also being carried out. These will form the nucleus of French origin seed orchards. This programme is feasible because these stands were originally of Washington origin. This is not the case in Sitka spruce where Oregon and Californian origins would have been the preferred sources. Home grown stands are however unlikely to supply the entire seed requirements. At present both Germany and France import 2/3 of their requirements from the Pacific North-West. Home collections will have the problem of Megastigmus, particularly in poor seed years. Individual trees can however be protected by the injection of a systemic insecticide. This is unlikely to be widely used due to its high cost.

7) Lammas shoots and height growth of Douglas fir. T. Widmaier, H. Dagenbach and U. Hauff, Stuttgart.

Influence of lammas growth on total height growth is examined and results presented.

Discussion - Paper 7.

In this experiment lammas growth represented 50 % of the total growth. In France, in a similar trial, it represented 25 - 30 %. Where lammas growth occurred in one year it had a detrimental effect on the growth in the following year. Its effect on form was not studied.

8) Variation of cone scale and seed morphology in Douglas fir (Pseudotsuga menziesii). R.K. Scagel, R. Davidson, Y.A. E.-Kassaby, O. Sziklai UBC, Vancouver, Canada.

Cone morphology of Douglas fir was examined using ten variables to differentiate between different populations.

Discussion - Paper 8.

This method can be potentially used to identify origins where records are not available. Degree of error was stated to be 5 % which is equivalent to 1 of latitude. A Swiss example was quoted where probable latitude origin can be given. It was pointed out that when Swedish Norway spruce material from one region is grown in another region, the cones get bigger. No increase in size occurs when it is from its native region. The best possible way of determining the origin of unknown lots was possibly by the use of all available techniques and not by one particular method alone.

9) Relationship of Pseudotsuga menziesii with other Pseudotsuga species inferred from karyotype reconstruction. O. Sziklay, Y.A. El Kassaby and R.K. Scagel, UBC, Vancouver, Canada.

Chromosome morphology was used to differentiate between the eight species of the genus Pseudotsuga.

Discussion - Paper 9.

The trait used in the multi-variate analysis was the length of the two arms of the abnormal chromosome. What effect this abnormality would have on possible crosses with P. macrocarpa was not known. Such a cross was reported but no information was available about it.

SESSION II

1) Douglas fir in Belgium: Breeding strategy and the evolving seed orchard. L. Paques and A. Nanson, Station de Recherches Forestieres, Groenendaal, Belgium.

Discussion - Paper 1.

Some doubts were expressed as to the viability of the evolving seed orchard, not least of which was one of costs. It was pointed out that because of the high price of land in Belgium this type of orchard would make the best use of a very scarce and expensive commodity. The suggestion of locating in the south of France was countered by the difficulty of organisation. Another problem raised was that of the need to frequently replace clones in the field orchard. It was suggested that clones be containerized until such time as they were tested. The proven ones could then be outplanted in the orchard. This method had however been tried in France but deaths of 50 to 80 % had shown it not to be all that feasible. Such work had also been carried out in Finland with birch and had been very successful. Work in Britain with containerized grafted spruce has shown that they flower readily and early. This will permit the establishment of a research seed orchard of proven clones at an early date.

Rooted cuttings as an alternative to grafted material was proposed. The problem with such material is that success depends on age. When young stock material is used successful rooting rates of 50 to 70 % can be achieved. These grow on as normal trees and flower early. With older material the problem is not only one of low success rate but also one of plagiotrophic growth.

It is hoped to establish 8 ha of this type of Douglas fir orchard. No date is as yet available on the likely production from such areas.

2) Stem sinuosity measurement in young Douglas fir progeny tests.
W.T. Adams and G.T. Howe, OSU, Corvallis, Oregon.

Describes method of assessing stem bends visually and discusses potential for genetic improvement of this trait.

Discussion - Paper 2.

In the study carried out the degree and frequency of sinuosity varied from site to site. German experience shows it to be most frequent in northern Germany, mainly in young plantations. In Ireland it is very frequent in all the IUFRO trial sites and is most severe in the faster grown provenances. Fast rate of growth associated with good site types was also felt to be a contribution factor in both Norway and Canada where only the faster growing provenances showed this charateristic. However, in natural stands in its native habitat the degree of sinuosity was very low. In Britain it is worst in the earlier years and then tends to disappear. This raised the question of what effect this characteristic would have on the end product. No firm evidence was available on this point but a reported French study implied that compression wood in Douglas fir may be related to incidences of sinuosity. Various suggestions were made as to the main cause of this stem deformation. Included were sun scald - highly unlikely in countries with a high rain fall, snow, wind or copper deficiency.

Two possibilities exist in this area: 1) that trees have different abilities to take up nutrients and 2) an over supply of nutrients could include deficiency symptoms. It was however felt that sinuosity was not typical of copper deficiency symptoms. The present study indicated that the trait was under genetic control but what was its cause was not known.

Isoenzyme patterns in Douglas fir. W.T. Adams, Corvallis, Oregon.

One hundred and five seed collections were made throughout the natural range of Douglas fir. From each forty seeds at random were chosen and used for isoenzyme analysis. Each was scored at 21 loci. Results indicated that there was no subculturing within the coastal Douglas fir lots - all were closely related 2) The Sierra Nevada samples clustered in with the coastal samples 3) Eastern Cascade samples cluster very late with the coastal samples and 4) Eastern Oregon and Washington samples - not clear as to which group they belong.

3) Selection of trait for growth form and wood density in Douglas fir progeny. J.N. King, J.C. Heaman and F.C.H. Yeh, Vancouver, British Columbia.

Describes detailed study of Douglas fir full sib families with particular reference to quality traits.

4) Natural variability of some wood internal traits of coastal Douglas fir in a French progeny test. Implications on breeding strategy. J.Ch. Bastian, B. Roman-Amat, G. Vonnet, INRA, Orleans, France.

Results of a provenance progeny test where wood densitometric traits are correlated with growth characteristics.

Discussion - Paper 3 and 4.

The importance of density is dependent on the species. In France it is very important in Norway spruce and less so in Douglas fir. What is of greater significance is the degree of wood heterogeneity. This is however, difficult to measure. In the Canadian study there was a low correlation between growth and density and what effect this will have on product value is debatable. The French aim is to grow Douglas fir at wide spacing and to high pr ne the logs early so that they will be suitable for peeling.

The value of the Pilodyn to test for wood density was raised. With Norway spruce it is quite efficient, however, for Douglas fir it is not very efficient. It is suitable for choosing the best trees but not for too detailed analysis. When used by Weyerhaeuser to study entire discs it was found to be quite satisfactory.

5) Interprovenance variation in the IUFRO Douglas fir provenance/ progeny trial. A.M.K. Fashler, Y.A. E. Kassaby and O. Sziklai, UBC, Vancouver, Canada.

Reports on detailed study of 48 provenances represented by 384 families. Traits evaluated include genetic variation in height growth, heritability of higher growth and juvenilemature height growth correlations.

Discussion - Paper 5.

The pattern of results in this experiment are similar to those found in Europe. The J shaped region around Matlock and Darrington and around the base of the Olympic Peninsula is consistently the best. If provenances from Oregon are used there is a greater degree of mortality. If the results of this experiment were to be implemented in British Columbia it could alter the genetic composition of the native population. However, this is unlikely to occur as the B.C. Forest Service have rules which state that seed material for any particular zone should not be moved more then 1 north or south.

SESSION III

1) IUFRO Douglas fir Data Base. A.M. Brunet and B. Roman-Amat, AFOCEL, Fontainbleau and INRA, Orleans, France.

Update on present position of data base was given.

Discussion - Paper 1.

To date only twelve institutions representing 62 test sites in eight countries have forwarded data. Three characteristics have been recorded, flushing, height and survival. The question now arises what new data should be collected, should non participating countries be invited to send in their data and at what age should any new measurements be taken. It was the general opinion that any future measurements should be kept simple. Experience with the Sitka spruce working party was given as an example where difficulty was found in getting all the prescribed measurements taken. It was agreed that every effort should be made to encourage non participating countries to send in their data.

To date there has been little demand for the centralized data, there has been generally a one way flow of information, inwards but not outwards. It was suggested that each Researcher should be consulted before information was supplied. It was felt that this would be contrary to the spirit of IUFRO and that it should be available to all interested paries.

As most of the beneficiaries of this project are EEC member countries it was suggested that EEC be approached to provide funds for any future work on it.

SESSION IV

1) Site requirements and silviculture of Douglas fir in north western Germany. H.J. Otto, Hannover, Fed. Rep. Germany

Ecological conditions in the species natural range and those of north-western Germany are compared. These are used to choose suitable provenances and sites for German conditions.

4) Experiences with Douglas fir provenances in Bavaria. W. Ruetz, LASP, Teisendorf, Fed. Rep. Germany.

Results from provenance experiments are applied in practice. Three to five percent of annual planting programme is with Douglas fir. Recommended sources are from the J shaped region around Darrington and the Puget Sound.

5) Douglas fir in Austria. J. Nather, FBVA, Schönbrunn, Austria

Importance of correct choice of provenance is stressed. Bud set is used to determine most suitable origins and is also used to develop a bud index.

Discussion - Paper 1, 4 and 5.

Less fertile sites are chosen for Douglas fir to ensure that ring width is not too great. This ensures that the proportion of early to late wood is better balanced. This has the effect of reducing wood heterogeneity. Sites chosen are those too dry for Norway spruce and too wet for Scots pine. Method of Douglas fir establishment in Belgium varies to that in use in Germany. Plants are usually planted in late May/early June. Though buds may have flushed this avoids the harsh dry March winds. Density of planting is 400 Douglas fir in 1000 Norway spruce. The spruce is planted two years in advance of the Douglas fir. It was pointed out that this method was used in Germany 20 years ago. Today they prefer to plant early relying on side shade from adjacent stands.

Concluding remarks of Working Party:

1) All those who have not supplied data to the Data Base will be requested to do so.

2) A request was made that a bibliography of all papers on IUFRO Douglas fir experiments should be prepared.

3) Proceedings of the meeting will be published by the end of the year. Latest data for receipt of updated articles is August 1st 1985.

4) Should a further collection be made in the species natural range and who should carry it out. As the local cost of such a collection would be in the region of $50/hour it would be cheaper to send somebody out to collect it. Seed at present in storage at Humlebaek, Denmark was considered to have been too long in storage.

   Any future collection should concentrate on family identity within five to ten of the best provenances. As each country will have different preferences too rigid rules of co-operation would be of little value. At present some countries have moved to the second phase and have already established seed stands of the better provenances.

5) It was agreed that the Working Party should not hold a meeting during the IUFRO meeting in Yugoslavia in 1986. The next meeting should be in the Pacific North West in 5 years time and be a joint one with the Sitka spruce, lodgepole pine, grand fir and noble fir Working Parties.

IUFRO-W.P. S. 2.02.05

"Breeding Strategy for Douglas-Fir as an Introduced Species"

June 9. - 15.1985, Vienna, Austria

- Program -

Monday, June 10	Arrival, Registration and possible participation in the "Norway Spruce provenance meeting" W.P. 2.02.11 - to be held in the same institute.
Tuesday, June 11	
10,00 - 10,30	Welcome. Opening Address.
10,30 - 12,30	Section I: RESULTS OF IUFRO PROVENANCE TRIALS AND PHYSIOLOGICAL STUDIES.
	D. Michaud: Premiers resultats d'essaisde provenances americaines de Douglas en France.
	S. Magnesen: The International short term Douglas-fir Provenance Trials in West Norway.
	R. Lines and C.J.A. Samuel: Results of the IUFRO Douglas-fir Experiments in Britain at 10 Years.
	Y. Simsek: Ergebnisse des Internationalen Douglasien-Provenienzversuches von 1973/74 in der Türkei.
12,30 - 14,00	LUNCH in cafeteria
14,00 - 17,00	Section I: Continued.
	G. Toval: Results in two test sites of provenances of the IUFRO collection of Pseudotsuga menziesii in Galicia.
	J. Kleinschmit, J. Svolba, H. Weisgerber, R. Dimpflmeier, W. Ruetz, Th. Widmaier: Results of the IURFO Douglas-fir Provenance Experiment in the Federal Republic of Germany at Age 14.
	H.M. Rau: Comparative Research with German and American Douglas-fir Provenances.
	Th. Widmaier: Lammas Shoots and Height-growth of Douglas-fir.
	R.K. Scagel, R. Davidson, Y.A. El Kassaby, O. Sziklai: Variation of Cone Scale and Seed Morphology in Douglas-fir.
	O. Sziklai, Y.A. El Kassaby, R.K. Scagel: Relationship of Pseudotsuga menziesii with other Pseudotsuga Species inferred from Karyotype Reconstruction.

17,00 - 20,00 — Welcome party in the Institute together with participants of the Norway spruce W.P. Meeting.

Wednesday, June 12

9,00 - 12,00 — Section II: DOUGLAS-FIR BREEDING-PRESENT AND FUTURE

A. Nanson, L. Paques: Breeding of Douglas-fir in Belgium through an "Evolving Seed Orchard"

W.T. Adams, G.T. Howe: Stem Sinuosity Measurements in Young Douglas-fir Progeny Tests.

J.N. King, B.P. Dancik, C.J. Heamann, F.C.H. Yeh: Selection of Traits for Growth, Form and Wood Quality in Douglas-fir Progeny.

J. Ch. Bastien, B. Roman-Amat, G. Vonnet: Natural Variability of some Wood internal Traits of coastal Douglas-fir in a French Progeny Test. - Implication on Breeding Strategy .

A.M.K. Fashler, Y.A. El Kassaby, O. Sziklai: Inter-Provenance Variation in the IUFRO Douglas-fir Provenance/Progeny trials.

12,00 - 12,30 — Section III: STATUS REPORT ON DOUGLAS-FIR DATA BANK.

A.M. Brunet, B. Roman-Amat: IUFRO Douglas-fir Database, Status Report 1985.

12,30 - 14,00 — LUNCH in cafeteria

14,00 - 16,00 — Section IV: DOUGLAS-FIR SILVICULTURE AND UTILIZATION OUTSIDE ITS NATIVE RANGE.

H.J. Otto: Site Requirements and Silviculture of Douglas-fir in Northwestern Germany.

L.C. Kuiper: Implications of Natural Growth Patterns.

G. Nosswitz-Dellagiacoma: Research of Natural Coniferous Ecosystems in Boreal and Alpine Regions. - Here an Example from the Douglas-fir Region in the Pacific Northwest.

W.F. Ruetz: Applying the Results of Douglas-fir Provenance Research to Practical Forestry. - An Example from Bavaria.

J. Nather: Characterization of Seed Samples of Douglas-fir by Short-term Investigations on Bud-set (A Preliminary Report).

Discussion of presented papers, seed procurement and future direction of the working group including participation in the IUFRO congress in Ljubljana, Yugoslavia in 1986.

16,00 — Tour of Vienna.

Thursday, June 13 8,00 - 21,00	Excursion along the Danube-Valley together with Norway-spruce W.P. See Excursion Guide for details
Friday, June 14 8,00 - 22,00	Excursion to the Burgenland together with Norway-spruce W.P. See Excursion Guide for details
Saturday, June 15	Departure of participants.

O. Sziklai - Chairman W.P. S. 2.02.05

W.F. Ruetz - Co-Chairman W.P. S. 2.02.05

J. Nather - Local Coordinator

EXCURSION REPORT

On June 13 and 14, 1985 a two days excursion followed to the sessions. This excursion was guided together with the Norway spruce group, which held a meeting in Vienna at the same time.

Thursday, June 13: The program of the first day included Douglas fir plantations in the Province of Lower Austria, along the Danube valley.

In the morning the Forest estate Grafenegg was visited. Owner of this estate is Franz Albrecht Metternich-Sandor, the forest manager. Forstdirektor Dipl. Ing. Österreicher

The forest ist managed in 4 districts:

Manhartsberg with about 1000 ha forested land,
2 lowland (riparian) forests along Danube valley more than 3000 ha,
Asparn (northern Lower Austria) with about 600 ha (about half coppice)

Annual felling budget is about 16.000 m3, in the district Manhartsberg alone: 5.234 m3. The district is situated in the southern part of Manhartsberg ridge, that divides the Waldviertel (wooded quarter) from the Weinviertel (quarter of vineyards), altitude is from 230-466 m, on the average 420 m.

The climate data are: average annual temperature 7,5 C, average precipitation per year 608 mm, but with great fluctuation (330 -670 mm). Main precipitation falls in the summer months, frequently as thunderstorms, low winter humidity (with little snowpack) and drought in spring.

The dominant forest type is oak-hornbeam.

Bedrock is predominantly gneiss and granulite, belonging to the bohemian mass. This gives poor skeletal brown soils, often shallow to medium depth, occasionally more or less heavy loess layers tending to heavy grass and brush growth. Loess sites are reserved for oaks since other species grow unsatisfactory.

Sites on silicious bedrocks are mostly poor, stony sites, with drought problems. Oak will not satisfy and yields must be achieved by other conifers. The main species is scots pine (nearly 70 %), but yields only boles of class diameter IIa, IIb and Ib which is difficult to sell. Spruce gives better quality only on better sites of lower parts of north slopes, but often suffers by root and butt rot (Fomes annosus (Fr.) Bref.).

Therefore experiments with Douglas fir, which were started 90 years ago, are of great importance. This species can contribute to an essential increase of yield because of its vitality and growth potential and is planted in increasing extend since 10 years, also on dryer sites. Contrary to Scots pine Douglas fir covers the ground better and prevents grass growth which has an unfavourable effect on the waterregime. Natural regeneration of Douglas fir shows sufficient adaptation of this species to the conditions of this region. There are no doubts that Grand fir can also be used in this district.

Regeneration of Douglas fir without fencing is possible but as a rule plantations will be fenced because of injuries by roe deer.

There is abundant regeneration of Scots pine within fences.

Stop 1. Provenance trials of the Federal Forest Research station, Institute for Forest genetics, established Spring 1977. 26 Provenances with 80 seedlings each, 20 per group, four replications spacing 2 x 2 m. Results after 8 years are given in the following list.

IUFRO Nr	Seed zone	Provenance	No Plants	losses in %	height in cm	variation in cm	rank
1057	202	Granite Falls/W, 90 m	42	40	409,3	46,1	1
	422	Ashford Elbe/W,500-650 m	53	24	402,6	14,4	2
1062	012	Forks/W, 90 m	49	31	393,9	25,7	3
	403	Darrington/W,650-800m(G)	53	29	386,8	89,4	4
	430	Randle/W, 500-650 m	49	30	381,1	49,2	5
	403	Darrington/W, 350-500 m	55	29	380,4	38,5	6
	412	Snoqualmie Pass/W,800-950 m (G)	40	49	375,6	22,7	7
1058	011	Lake Crescent/W, 300 m	42	37	374,6	42,0	8
1085	430	Randle/W, 340 m	29	51	371,8	41,3	9
1091	440	Yale/W, 120 m	46	32	368,7	57,2	10
1050	402	Marblemount/W, 120 m	56	25	367,6	53,1	11
1080	232	Yelm/W, 60 m	40	39	365,4	39,4	12
1060	221	Sequim/W, 60 m	36	42	363,9	38,0	13
1088	430	Castle Rock/W, 150 m	42	46	363,7	21,4	14
	412	Snoqualmie River/W,500-650 m	47	34	362,5	17,2	15
1075	412	Enumclaw/W, 240 m	35	49	361,9	54,2	16
1089	041	Cathlamet/W, 200 m	50	32	361,5	44,7	17
	631	Cle Elum/W, 650-800m(RR)	111	18	356,3	66,5	18
		Standard 350-700 m	54	21	352,4	46,6	19
	403	Darrington/W, 500-650 m	48	29	350,6	57,9	20
1073	030	Humptulips/W, 140 m	49	36	348,7	9,6	21
	422	Ashford Elbe/W, 350-500 m	48	35	348,4	10,1	22
1069	412	North Bend/W, 150 m	53	17	347,8	19,3	23
	430	Randle/W, 350-500 m	44	39	345,7	30,4	24
	631	Cle Elum/W, 650-800 m	57	24	341,2	6,8	25
	3040	Adams Lake/BC, 500-650 m	59	11	331,3	7,1	26

Stop 2. Department 11 b, 90 years, 85 % Scots pine, 15 % Norway spruce, single Douglas fir: 34 - 36 m height, BHD 60-70 cm; Scots pine 22 m, BHD 30 cm.

Cone Collection of douglas fir 1980 1400 kg cones, 42 kg seed (3%)

Seedling testing results: (Method described in paper p...by J.Nather). Bud forming index about 60, that complies with West Cascade, low elevation, but somewhat inhomogeneous, particularly in flushing which is relatively early. Frost injuries of 1 year old seedlings were rather high, but good healing and good growth potential.
(Population of Douglas fir at Asparn, index no is significant higher, thus transition zone).

Stop 3. Department 11 g, 98 years, 60 % Douglas fir, 40 % Scots pine. 36 m hight, 72 cm diameter, 5,85 m3 volume (for the best Douglas fir)

Stop 4. Department 11 k, 95 years, 4,8 ha 70 % Douglas fir, 30 % Scots pine. Douglas fir: 32 m height, 54 cm diameter, in comparison Scots pine 23 m, 28 cm diameter.

Treatment: 1974-1975 opening up and fencing, 1980-1981 secondary fellings to promote cone production and regeneration

Site class: Douglas 10, Scots pine 6

Aboundant regeneration of Douglas fir up to 22 years.

Vineyards also belong to this estate and the owner invited the group to an excellent lunch with fried chicken and home-grown wine.

In the afternoon the group moved to Forest estate Waldhof, where the owner, Mr.H.Giese, welcomed the participants of the excursion and gave some introductory information.
After taking over the enterprise in 1957 increased planting of foreign species as an alternative to insufficient growing indigenous species was recommended by Dr. Querengässer, the advisor of the owner. From the beginning plants were grown in own nurseries and seed was imported directly from provenances along the Cascade crest and Salmon Arm from interior, B.C.
At the present time about 140 ha are stocked with foreign species, new plantations of about 8 ha are made every year.
The stands are located at altitudes between 250 and 580 m, on the average 400 m. Precipitation is about 550 mm with 320 mm during the growing season. Mean temperature of the year is 8,3 C, during growth period 16 C.
Forest type: oak-hornbeam region, in general "wine climate".
Bedrock gneiss, partly with loess cover. Mostly shallow, podsolic brown soils, litter has been used for many centuries until 30 years ago.
Species are Scots pine 46 %, Spruce 10 %, Fir, Larch 7 %, Douglas and other introduced species 16 %, broad leaved 21 %. Percentage of foreign species in age class I is 100 %.

Excursion stop: department 15 c 3, area 1,3 ha.
In a bad growing scots pine stands of 20 years in 1961-63 each second row was removed and replaced by Douglas fir and Grand fir, spacing 1,5 x 2 m.
Development of the stand:

1961 plantation 80 % Douglas fir, 20 % Grand fir,	3600 p/ha
1966-75 removal of Scots-pine-screen, plant reduction to	3300 p/ha
1976 removal of 800 stems	2500 p/ha
1979 removal of 900 stems	1600 p/ha
1985-86 reduction to	900 p/ha

Douglas fir has site class 10, scots pine (age 45) site class 6.
Further data: average height of dominant trees 16,6 m with BHD 21,4 cm, no of stems 1030, basal area 23,39 m2/ha.
Total volume production to date 278 m2, current total increment 6,32 m3/year.

The excursion continued to the Forest estate Göttweig. Owner of this enterprise is the Benediktine monastery Göttweig, founded 1183 by Bishop Altmann of Passau.
Head of the Forest office: Dr. W. Moser.
The forest estate is the most important economic basis of the monastery, which also has vineyards, a small farm and a restaurant. The total wooded area in 1985 is 4994 ha in 3 management districts. Spruce is represented with 67 %, Scots pine 19 %, Douglas fir 2 %, other conifers 4 %, broad leaved species 8 %. There are old Douglas fir plantations at 27 locations totalling about 500 stems over all districts, 2 of these belong to the slow growing blue type (glauca). But no indications on provenance are available. Some old trees can be seen along the excursion route.

Between 1983-85 there were planted 122.000 seedlings, (10 % Douglas fir, 12 % Grand fir) in district Göttweig, furthermore 57.200 (16 % Douglas fir, 11 % Grandis) in districts Kleinwien and Meidling.

Excursion stop 1.
District Kleinwien, department 5 c2, Douglas fir has been planted 1979 after Scots pine and oak
4 year transplants of the provenance Darrington
Broad leaved species, particularly oaks in groups are promoted after the loss of Douglas fir plants; the goal is a mixed stand to maintain the indigenous oak.
Excursion stop 2.
Provenance trial for Douglas fir.
The sample plot, situated in the forest district Dunkelsteinerwald, ranger district Klein-Wien (600 m a.s., level to moderately inclined to NE), was established in 1977 as a single plot experiment with different provenances of Douglas fir each cultivated in 6 rows (plants 2/2) without replications. The first measurement of total heights in the sample took place in the middle of August 1981. At this time heights of the first 25 trees of each row were measured. Two years later a second survey of total heights was done in the same way. The data were analysed by analysis of variance and paired comparison of means.

	Provenance				
Plot	1	2	3	4	5
Mean height in cm 1981	114	140	148	131	128
Mean height in cm 1983	207	276	294	250	254
Difference in cm	93	136	146	119	126

The results from the comparison of means:

1. SHUSWAP LAKE: Significant differences of height-means are guaranteed to all other plots and are most pronounced. An incrase of these differences can be observed from 1981 to 1983.
2. CONCRETE: Significant mean-differences could not be found neither for 1981 nor for 1983 except for SHUSWAP LAKE.
3. SNOQUALMIE RIVER: The differences between height-means were guaranteed to all provenances except CONCRETE both 1981 and 1983. All significances increased.
4. ASHFORD ELBE: Only to SHUSWAP LAKE and SNOQUALMIE RIVER guaranteed differences could be established with an increasing annual trend.
5. SNOQUALMIE PASS: Became better between 1981 and 1983 than ASHFORD ELBE because of the second best growth (in % of total height 1981)

In the evening the participants were invited to dinner by the governmental anthorities of Lower Austria at Göttweig with a possibility for personal contacts to local forest officers. The Speaker of the group thanked to the Austrian colleagues and officials for their hospitality.

Friday, June 14:

On the second excursion day, Friday June 14, 1985 the group visited Spruce and Douglas plantations in the province of Burgenland. After a short visit to a test plot with 25 provenances of Norway spruce (one of in total 42 plots in different regions of Austria), the next excursion stop was Drassmarkt with a Douglas provenance trial of the Federal Forest Research Station, Institute for forest genetics, head L.Günzl. The trial was established in 1979 at an abandoned field (owner A. u. F. Schlögl, Drassmarkt) after fencing, with 28 provenances, with 3 year old transplants, with 4 replications, spacing 2,5 x 1,5 m. Age is 7 years at present.
Altitude 350 m, annual average temperature 8,7 C, annual precipitation 672 mm.
Site: loamy sand, well supplied with nutrients, moderate humid.

Results after 5 years are shown in the following list:

Seed Zone	Provenance	No. Plants	losses in %	height in cm	variation in cm	rank
411	Sultan, Olney Creek/W 220m	84	7	341,4	19,0	1
	Rev.Manhartsberg,Baum II/A	89	1	340,4	13,6	2
412	North Bend,Black Lake/W,400m	81	8	327,9	12,2	3
403	Darrington,Suiattle/W,70m	89	2	325,3	13,3	4
403	Darrington,Texas Pond/W,340m	85	3	324,4	18,4	5
412	North Bend,Klaus Lake/W,330m	89	4	323,5	16,1	6
030	Matlock/W, 120 m	77	5	322,2	33,5	7
430	Randle,Packword Woods CR./W, 800 m	78	5	318,4	25,8	8
403	Darrington,Round Mountain/W, 250 m	74	6	315,9	35,5	9
403	Concrete,Pressentin Creek/W, 120 m	82	7	314,9	8,9	10
042	Yacolt,Spotted Deer/W,600m	82	5	314,8	21,1	11
430	Morton,Randle Peterm.H./W, 800 m	67	9	313,6	30,2	12
030	Wynnoochee, Satsop/W, 160m	71	9	309,3	12,8	13
	Rev.Manhartsberg,Baum I/A	75	10	305,7	24,9	14
402	Concrete,Jackmann Creek/W, 160 m	84	3	302,1	16,4	15
412	Snoqualmie River/W,350-500m	78	3	301,4	13,8	16
411	Skykomish,Beckler River/W, 300 m	73	10	300,9	24,4	17
	Versuchsmittel		8	300,8	21,4	
403	Darrington/W, 950-1100m	75	5	297,0	25,4	18
	Rev.Manhartsberg,Baum III/A	67	20	296,8	27,8	19
411	Skykomish,Foss River/W,340m	81	8	296,3	31,1	20
240	Pe Ell,Sand Creek/W,270m	73	4	295,3	9,5	21
	Rev.Manhartsberg,Baum IV/A	70	15	294,2	15,8	22
411	Skykomish,Miller River/W, 270 m	72	11	292,4	17,7	23
422	Mineral/W, 650 m	68	12	289,3	19,8	24
412	Snoqualmie Pass/W,650-800m	67	13	280,9	24,7	25
	Kandern/BRD, über 800 m	53	24	264,6	20,8	26
3040	Salmon Arm/BC,850-1000 m	75	8	224,3	20,1	27
3040	Adams Lake/BC,500-650 m	81	2	188,2	10,9	28

After an excellent lunch as guest of the Directorate of Esterhazy estate, welcomed by Forest Dir.Dr.Perlaki, the group visited the Dr.P.Esterhazy Forest Estate Lackenbach guided by the head of the forest office Dipl.Ing. H.Wolf. A Douglas fir stand was shown in the department 35 b, in the District Lackendorf/Rietzing (test plot 155 of Institute for Yield Research and Economics, Federal Forest Research station, explained by H.Rannert).

This stand was established in 1926 with 3 year old seedlings of medium height of 30 cm. The provenance was not indentified but belongs to the "green type" (viridis). The afforestation, planted as hole-plantation (spacing 1,25 x 1,10), was neither fenced nor protected against damage by game.

Development: Apart from occasional removal of single stems a first thinning was made at age 37 in the Autumn 1959 when the stand became a trial plot. At the same time regular distributed Z-stems (crop trees) were selected and pruned up to 12 m. Further cuttings were made first of all in intervals of 2 or 3 years, since 1970 in intervals of 5 years, aiming for a freestanding crown of the Z-stems.

Forest protection: Besides frost injuries from the winter 1928/29, which are not recognizable any more, during the sixties one could recognize some damage by debarking from red deer, some snowbreaks and slight attack by needle cast disease of some trees. In 1975 and again 1979 one of the predominant trees was thrown by heavy winds. It is remarkable that up to now root rot was not found in the felled stems.

Growth performance: In 1981 the growing stock (timber volume) per ha was 616 m3, the total volume production at least 921 m3 (volume removed before establishing as a trial plot is unknown). The total volume production corresponds with site class 15 of yield tables for Douglas fir (of Baden Württemberg).

The next measurement in connection with a thinning is planned for the Autumn 1985.

Yield (calculated per ha)	age 37 (1959)	age 58 (1981)
No. of stems	1030	365
Maximum diameter cm	34,7	56,6
Minimum diameter cm	11,4	27,6
BHD (average tree of basal area) cm	20,2	38,4
Height " m	20,0	32,1
H/D ratio "	99	84
BHD (of dominant tree) cm	29,8	45,5
Height " m	22,0	33,4
Basal area m2	33,0	42,2
Volume m3	296	616
Total thinning yield m3	57	305
Total volume production m3	353	921
Average total increment m3/ha/yr	9,8	15,8

Continuing the tour 2 further trial plots of Inst.II (Forest genetics) of the Federal Forest Research Station, were visited. The first stops was a Douglas and Grand fir pronance trial from 1980, age now 5 years, as shown on the folowing list.

Seed Zone	Provenance	No. Plants.	losses in %	height in cm	variation in cm	rank
Douglasie						
	SHK Südbaden/BRD	87	6	257,0	12,6	1
402	Concrete/W,500-650 m	82	9	248,5	18,5	2
403	Darrington/W,950-1100 m	87	5	242,4	43,2	3
403	Darrington/W,65-350 m	89	2	237,2	32,0	4
412	Snoqualmie River/W,500-650m	83	7	226,5	39,8	5
403	Darrington/W,650-800 m	84	13	224,6	28,8	6
412	Snoqualmie River/W,350-500m	79	12	219,7	29,7	7
422	Ashford Elbe/W,500-650 m	87	4	218,3	39,1	8
412	Snoqualmie/W, 350 m	90	5	216,1	21,7	9
403	Darrington/W, 350-500 m	81	10	214,5	33,6	10
	Versuchsmittel		7	211,4	28,0	
	Kandern/BRD,über 800 m	85	7	208,4	18,9	11
412	Snoqualmie Pass/W,650-800m	88	8	207,8	18,7	12
403	Darrington/W, 800-950 m	77	13	207,6	30,6	13
412	Snoqualmie Falls/W,150-650m	91	6	197,1	21,6	14
430	Randle/W, 350-500 m	85	12	194,1	15,7	15
3040	Salmon Arm/BC,850-1000m	91	1	170,7	15,2	16
3040	Adams Lake/BC,500-650m	86	7	168,1	35,7	17
3040	Shuswap Lake/BC,500-700 m	86	6	146,1	20,8	18
Abies grandis						
403	Darrington/W,600-750m 2/2-j	90	4	111,1	17,4	1
653/2.5	Little White Salmon/W, 600-750 m	93	6	104,1	19,6	2
	Versuchsmittel		7	86,6	15,8	
653/3.5	Mountain Road/W,900-1050m 1/2-j.	77	15	85,9	17,7	3
	Clearwater/I,900-1050m 2/2-j	85	7	81,0	9,3	4
675/3.0	Santiam Pass/O, 750-900 m 1/2-j.	88	6	78,1	8,1	5
675/3.5	Santiam Pass/O, 900-1050 m 1/2-j.	41	5	59,3	18,5	6

Finaly there was a short stop at an A.Grandis trial of 1981. Forest data are also given in a following list.

Seed Zone	Provenance	No. Plants.	losses in %	heigth in cm	variation in cm	rank
461	Santiam River/O,450-600m	85	15	118,1	17,0	1
675	Santiam Pass/O,600-650m	91	9	108,1	16,5	2
675	Santiam Pass/O,750-900m	79	7	107,5	14,1	3
461	Santiam River/O,750-900m	95	5	103,8	10,3	4
461	Santiam River/O,600-750m	87	13	103,8	14,6	5
461	Santiam River/O,300-450m	91	9	103,2	1,8	6
653	Little White Salmon/W,600-750m	84	16	98,1	5,6	7
675	Santiam Pass/O,900-1050m	80	6	96,7	4,7	8
675	Santiam Pass/O,1050-1200m	93	7	96,5	8,8	9
652	Trout Lake/W	92	8	94,7	5,3	10
652	Mountain Road/W,900-1050m	80	20	86,2	11,5	11
641	Naches/W	77	23	77,6	10,0	12
	Versuchsmittel		11	99,5	11,1	

The group moved back to Eisenstadt, capital of the province, where a guided walk through the famous Esterhazy castle was organized. A sozial evening with rustic buffet in a wine cellar was a joyous conclusion of a profitable meeting and an interesting tour, appreciated by all of the participants.

MEMBERSHIP LIST

IUFRO - Douglas-fir Improvement Working Group S.2.02.05

Australia

PEDERICK, Dr. L. A
Forests Commission Victoria
GPO Box 4018
Melbourne 3001
Victoria
Australia

Austria

NATHER, J.
Forstliche Bundesversuchsanstalt
A-1131 Wien-Schönbrunn
Austria

BEIN, Dipl. Ing. O.
IUFRO Secretary
Bundesversuchsanstalt
Tirolergarten
A-1131 Wien-Schönbrunn
Austria

Belgium

NANSON, Dr. A.
Station de Recherches forestieres
B-1990 Groenendaal-Hoeilaart
Belgium

PAQUES, L.
Station de Recherches forestieres
B-1990 Groenendaal-Hoeilaart
Belgium

Canada

BOWER, Dr. R.C.
MacMillan Bloedel Ltd.
65 Front Street
Nanaimo, B.C. V9R 5H9

DANCIK, Dr. B.P.
Dept. of Forest Science
University of Alberta
Edmonton, Alberta
T6G 2H1

DEVITT, Mr. B.
Pacific Forest Products Ltd.
P.O. Box 10
Victoria, B.C. V8W 2M3

EL-KASSABY, Dr. Y.
Pacific Forest Products Ltd.
Forestry Centre
8067 E. Saanich Road, R.R. #1
Saanichton, B.C.
VOS 1M0

FASHLER, Ms. A.
211 - 1111 Haro Street
Vancouver, B.C.

HEAMAN, Mr. J.C.
Research Branch
Ministry of Forests
1450 Government Street
Victoria, B.C. V8W 3E7

ILLINGWORTH, Mr. K.
Research Branch
Ministry of Forests
1450 Government Street
Victoria, B.C. V8W 3E7

JAQUISH, Mr. B.C.
Kalamalka Research Station and
Seed Orchard
Ministry of Forests
3401 Reservoir Road
Vernon, B.C.
V1B 2C7

KELLOGG, Dr. R.
Forintek Canada Corp.
6620 N.W. Marine Drive
Vancouver, B.C.
V6T 1W5

KENWOOD, L.G.
Reid Collins and Associates Ltd.
1178 West Pender Street
Vancouver, B.C.
V6E 3X4

KING, Mr. J.N.
Department of Forest Science
University of Alberta
Edmonton, Alberta
T6G 2H1

KORELUS, Mr. V.J.
Pacific Forest Products Ltd.
Forestry Centre
8067 E. Saanich Road, R.R. #1
Saanichton, B.C. V8W 2M3

SZIKLAI, Dr. O.
Forest Sciences Department
Faculty of Forestry
University of British Columbia
Vancouver, B.C.
V6T 1W5

YING, Dr. C.C.
Ministry of Forests
1450 Government Street
Victoria, B.C.
V8W 3E7

Denmark

BARNER, H.
Tree Improvement Station
Trogerupvej 21
DK-3050 Humlebaek
Denmark

MADSEN, S.
Statens Forstlige Forsogsvaesen
Springforbivej 4
DK-2930 Klampenborg

Finland

HAGMAN, M.
Department of Forest Genetics
Forest Research Institute
SF-01590 Maisala
Finland

France

BASTIEN, J.C.
I.N.R.A.
Station d'Amelioration des
arbres forestiers
Ardon
F-4516 Olivet - France

MICHAUD, M.D.
Association Foret Cellulose
9 Av. Garibaldi
F-87 Limoges - France

ROMAN-AMAT, B.
I.N.R.A.
Station d'Amelioration des
arbres forestiers
Ardon
F-45160 Olivet
France

Great Britain

FLETCHER, Dr. A.M.
Forestry Commission
Northern Research Station
Roslin, Midlothian
EH25 9SY
Scotland

FOREST SERVICE
Department of Agriculture
Dundonald House
Belfast, BT4 3SB
Northern Ireland

LINES, R.
Forestry Commission
Northern Research Station
Roslin Midlothian
EH25 9SY
Scotland

Hungary

KERESZTESI, Dr. B.
Forest Research Institute
P.O. Box 17
Budapest, Hungary

Ireland

O'DRISCOLL, J.
Research Branch
Forest and Wildlife Service
Sidmonton Place
Bray, Co-Wicklow
Ireland

PFEIFER, A.R.
Research Branch
Forest and Wildlife Service
Sidmonton Place
Bray, Co-Wicklow
Ireland

Italy

DE VECCHI, Dr. E.
Instituto per le piante da
Legno e l'ambiente S.P.A.
Corso Casale n. 476
I-10132 Torino
Italy

Korea

HYUN, Prof. S.K.
Institute of Forest Genetics
Office of Forestry
P.O. Box 24
Suweon
Geonggido 170
Republic of Korea

Netherlands

EVERS, P.
De Dorschkamp
P.O. Box 23
NL-Wageningen
Netherlands

KRIEK, W.
Research Institute for Forestry
and Landscape Planning
"De Dorschkamp"
P.O. Box 23
NL-6700 AA Wageningen
Netherlands

KUIPER, L.
Department of Silviculture
Agricultural University
Postbus 342
NL-Wageningen
Nehterlands

Norway

MAGNESEN, S.
Norwegian Forest Research
Institute-Bergen
N-5047 Stend
Norway

Poland

BURZYNSKI, G.
Instytut Badawczy Lesnictwa
Zaklad Nasiennictwa I Selekcji
ul. Wery Kostrzewy 3
PL-00-973 Warszawa
Poland

MEJNARTOWICZ, Doc. Dr. hab L.E.
Institute of Dendrology
PL-62-035 Kornik
Poland

ZATESKI, Dr. I.A.
Instytut Badawczy Lesnictwa
Zaklad Nasiennictwa I Selekcji
ul. Wery Kostrzewy 3
PL-00-973 Warszawa
Poland

Portugal

D'ALPUIM, M.
Estacao Florestal Nacional
Tapada Das Necessidades
P-1300 Lisboa
Portugal

DE AGUIAR, A.P.M.A.
Estacao Florestal Nacional
Tapada Das Necessidades
P-1300 Lisboa
Portugal

ESTACAO FLORESTAL NACIONAL
Tapada das Necessidades
P-1300 Lisboa
Portugal

Spain

BLANCO, J.L.
Centro Forestal de Lourizan
Apartado, 8.111
E - Madrid
Spain

TOVAL, G.
Centro Forestal de Lourizan
Apartado, 127
Pontevedra
Spain

Sweden

PERSSON, Prof. A.
SLU
S-770 73 Garpenberg
Sweden

Turkey

SIMSEK, Dr. Y.
Ormancilik Arastirma Enstitüsü
P.K. = 24
Bahcelievler/Ankara
Turkey

TULUKCU, M.
Marmara ve Trakya Ormancilik
Arastirma Müdürlügü
P.K. = 93
Kocaeli/Turkey

U.S.A.

ADAMS, Dr. T.
Department of Forest Sciences
Oregon State University
Corvallis, Or. 97330

BLAIR, Dr. R.
Potlatch Corp.
P.O. Box 1016
Lewiston, Id. 83501

CAMPBELL, Dr. R.K.
U.S.F.S. Forestry Sciences
Laboratory
3200 Jefferson Way
Corvallis, Or. 97330

CHING, Dr. K.K.
College of Forestry
Oregon State University
Corvallis, Or. 97330

CONKLE, Dr. M.T.
U.S. Forest Service
Pacific Southwest Forest
and Range Experiment Station
Institute of Forest Genetics
Box 245
Berkeley, Ca. 94701

COPES, Dr. D.
USFS Forestry Sciences Laboratory
3200 Jefferson Way
Corvallis, Or. 97330

DANIELS, Dr. J.D.
Daniels and Consultants
Forest Genetics Consultants
611 E. Street
Centralia, Wa. 98531

FINS, Dr. L.
Dept. of Forest Resources
College of Forestry, Wildlife and
Range Sciences
University of Idaho
Moscow, Idaho 83843

FRANC, G.
U.S.D.A. Forest Service
Forest and Range Experiment Station
1221 South Main
Moscow, Id. 83843

HERMANN, Dr. R.K.
College of Forestry
Oregon State University
Corvallis, Or. 97331

HOWE, Dr. G.
Department of Forest Sciences
Oregon State University
Corvallis Or. 97330

KITZMILLER, Dr. J.
U.S.D.A. Forest Service
Tree Improvement Center
2741 Cramer Lane
Chico, Ca. 95926

LESTER, Dr. D.T.
Crown Zellerbach Ltd.
Forestry Research Division
P.O. Box 368 Wilsonville
Oregon 97070

MASTERS, Dr. C.
Weyerhaeuser Co.
505 W. Pearl Street
Centralia, Wa. 98531

PALPANT, Mr. E.H.
545 Orlando Avenue
State College, Penna. 16801

PIESCH, Dr. R.
Weyerhaeuser Co.
505 W. Pearl Street
Centralia, Wa. 98531

RANDALL, W.
U.S.D.A. Forestry Sciences
Laboratory, 3200 Jefferson Way
Corvallis, Or. 97331

REHFELDT, Dr. G.
U.S.D.A. Forest Service
Forest and Range Experiment
Station, 1221 South Main
Moscow, Id. 83843

SILEN, Dr. R.
U.S.F.S. Forestry Sciences
Laboratory
3200 Jefferson Way
Corvallis, Oreg. 97331

SORENSEN, Dr. Frank
U.S.F.S. Forestry Sciences
Laboratory
3200 Jefferson Way
Corvallis, Oregon 97331

STEINHOFF, Dr. R.J.
U.S. Forest Service
Intermountain Station
1221 S. Main Street
Moscow, Id. 83843

STETTLER, Sr. R.F.
College of Forest Resources
University of Washington
Seattle, Wa. 98105

STONECYPHER, Dr. R.
Weyerhaeuser Co.
P.O. Box 420
Centralia, Wa 98531

THEISEN, Mr. P.A.
U.S. Forest Service
Box 3623
Portland, Or. 92208

WHEELER, Dr. N.
Weyerhaeuser Co.
P.O. Box 420
Centralia, Wa. 98531

WHITE, Dr. T.
International Paper Co.
P.O. Box 3860
Portland, Or. 97208

WILSON, Mr. B.C.
Division of Forest Land
Management
Department of Natural Resources
Olympia, Wa. 98504

West Germany

DIMPFLMEIER, Dr. R.
Bayer. Landesanstalt für
forstl. Saat- und Pflanzenzucht
Forstamtsplatz
D-8221 Teisendorf
West Germany

KLEINSCHMIT, Dr. J.
Nieders. Forstl. Versuchsanstalt
-Abt. Forstpflanzenzüchtung
D-3513 Escherode
West Germany

LARSEN, Prof. Dr. J.B.
Institut für Waldbau
Büsgenweg 1
D-3400 Göttingen
West Germany

LESSEL-DUMMEL, Dr. A.
c/o Baumschule C. Appel
Bismarckstra. 59
D-6100 Darmstadt
West Germany

NOSSWITZ, G.
Waldbau-Institut der
Universität Freiburg
Bertoldstra. 17
D-7800 Freiburg i.Br.
West Germany

RECK, Dr. S.
Institut für Forstgenetik
und Forstpflanzenzüchtung
Sieker Landstra. 2
D-2070 Grobhansdorf 2
West Germany

RUETZ, Dr. W. F.
Bayer. Landesanstalt für
forstl. Saat- und Pflanzenzucht
Forstamtsplatz
D-8221 Teisendorf
West Germany

SCHMIDT-VOGT, Prof. Dr. H.
Waldbau-Institut der
Universität Freiburg
Bertoldstra. 17
D-7800
Freiburg i.Br.
West Germany

STEPHAN, Dr. B.R.
Institut f. Forstgenetik
und Forstpflanzenzüchtung
Sieker Landstra. 2
D-2070 Grobhansdorf
West Germany

WEISGERBER, Dr. H.
Institut f. Forstpflanzenzüchtung
Hess. Forstl. Versuchsanstalt
Prof. -Oelkers-Stra. 6
D-3510 Hann. Münden
West Germany

BREAKDOWN BY COUNTRY

	Country	# Members
1.	Australia	1
2.	Austria	2
3.	Belgium	2
4.	Canada	14
5.	Denmark	1
6.	Finland	1
7.	France	3
8.	Great Britain	3
9.	Hungary	1
10.	Ireland	2
11.	Italy	1
12.	Korea	1
13.	Netherlands	3
14.	Norways	1
15.	Poland	3
16.	Portugal	3
17.	Spain	2
18.	Sweden	3
19.	Turkey	2
20.	U.S.A.	27
21.	West Germany	10
	TOTAL MEMBERS	86

PLEASE SEND ANY ADDENDUM TO:

Dr. O. Sziklai
Forest Sciences Department
Faculty of Forestry
2357 Main Mall
University of British Columbia
Vancouver, B.C.
V6T 1W5, CANADA