Summary of results on Scots pine (Pinus sylvestris L.) height growth in IUFRO provenance experiments

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Summary

The data on height growth published to date from the IUFRO 1907, 1938 and 1939 provenance experiments on Scots pine *(Pinus sylvestris* L.) is evaluated jointly. For each experimental site of the 1907 and 1938 series the latest published height measurements were converted to units of standard deviation from the site mean. These deviations are plotted separately for each provenance onto a map of all the experimental sites for the given series. In this way it is possible to see simultaneously the relative performance of each provenance on all the sites where it was tested. Local provenances are usually among the better ones on any site. However best growing provenances come from lowland Central Europe, particularily from the Baltic countries and north and western Poland. These give superior growth on practically all sites from Scandinavia to Turkey and from Eastern Europe to Michigan, USA. If seed transfer is planned these highly adaptable, photoperiod independent, populations appear to be most suited. Scandinavian and outlier populations are useless except locally, and even there usually have lower heights than the adaptable ones. Montane provenances though somewhat better in height growth are also not to be recommended on lowland sites. Some domiciled populations, particularily from the Low Countries, are exceptionally valuable being good growing and adaptable. It is recommended that breeding programs be based on fast growing material that demonstrates low genotype X environment interactions.

Key words: Pinus sylvestris, provenance, genotype X environment interaction, adaptability.

Zusammenfassung

Die bisher veröffentlichten Ergebnisse aus den Messungen der Baumhöhe der IUFRO Kiefernprovenienzversuche *(Pinus sylvestris* L.) von 1907, 1938 und 1939 wurden zusammengefaßt. Für jede Versuchsfläche der Versuchsserien der Jahre 1907 u. 1938 wurden die zuletzt erhaltenen Werte in Einheiten der Standartabweichung vom Versuchsflächenmittel ausgedrückt. Diese Abweichungen sind getrennt für jede Provenienz und jede Versuchsserie in Landkarten eingezeichnet worden, die alle Versuchsorte umfassen. Auf diese Weise wurde es möglich, die relative Wuchsleistung jeder Kiefernprovenienz auf allen Versuchsflächen, auf denen diese vorkommt, zu beurteilen. Es stellte sich dabei heraus, daß auf jeder Versuchsfläche die lokalen Provenienzen sich gewöhnlich in der Spitzengruppe plazieren. Die wüchsigsten Provenienzen stammen jedoch aus dem zentraleuropäischen Tiefland, besonders aus Nord- und Westpolen. Sie zeichnen sich durch hervorragende Wuchsleistungen auf allen Versuchssorten von Skandinavien bis zur Türkei und von Osteuropa bis Michigan in den USA aus. Für etwaige Samentransfers sind diese hochanpassungsfähigen, photoperiodisch unabhängigen Populationen am besten geeignet. Die skandinavischen und die geographisch isolierten Kiefernherkünfte sind mit Ausnahme in ihrer Heimatgegend unbrauchbar. Aber auch dort sind sie in ihrer Wuchsleistung den anpassungsfähigeren Provenienzen unterlegen. Gebirgsherkünfte sollte man nicht im Tiefland anbauen, obwohl ihre Wuchsleistung etwas besser ist. Einige, besonders in den Niederlanden eingeführte Herkünfte, zeichnen sich durch gute Wuchsleistung und hohe Anpassungsfähigkeit aus und sind deswegen besonders wertvoll. Es wird vorgeschlagen, Züchtungsprogramme auf schnellwüchsige Herkünfte auszurichten, da sich diese durch eine geringe Genotyp X Umwelt-Interaktion auszeichnen.

Introduction

Trice, in 1907, 1938 and 1939, IUFRO (International Union of Forest Research Organisations) has organized international provenance experiments on Scots pine ***(Pinus sylvestris L.).*** A new serie is planned now by the IUFRO S2.03.05 Working party, Breeding Scots pine, thus a retrospective look at the older experiments is in order.

In contrast to the IUFRO 1938 Norway spruce experiment I summarized recently (GIERTYCH, 1976) there have been few attempts to evaluate jointly data on the international Scots pine experiments. WIEDEMANN (1930) presented a summary of the whole IUFRO 1907 experiment. He found that the southern provenances (French, Slovak, Bulgarian) have had poor height growth on all sites. The north Swedish provenance in southern Sweden was similar in performance to some continental ones but better than the W. European ones. In Holland and Brandenburg the Swedish provenance had poor height. The Ural provenance was poor in height except in Hessen. Latvian provenance proved good in Sweden and Belgium and medium elsewhere. The Brandenburg race grew well only locally. The Mazurian race was very good elsewhere expect in Hessen and Holland. The Rheinpfalz race was best or above average on all sites except in Saxony and Sweden. The Scottish provenance proved satisfactory in Holland, medium in Belgium and Brandenburg and poor in Slovakia. The Belgian provenance grew very well on all sites.

HEIKINHEIMO (1954) looked at the seedling fresh weight attained by 11 provenances from the IUFRO 1938 series in 5 nurseries (in Belgium, Poland, Germany and 2 in Finland). The northern Finnish provenances had smallest plants and southern (French, Italian) ones were heaviest, regardless of planting site. The others had less consistent performance, but strong provenance X environment interaction was demonstrated only be the Swedish provenance Böda (10) which had heavy plants in all nurseries except in southern Finland and Hungarian provenance Lenti (25) with decidedly smaller plants in northern Finland.

I know of no other joint analyses of results from these experiments.

Some authors when presenting data from their own planting sites make some comparisons with one or two other provenance areas (ECKSTEIN, 1973; ERTELD, 1950; DITTMAR, 1977) but generally only reference is made to previous measurements, if any, in their own experiments. There are of course several review papers on genetic variation in Scots pine which attempt to pool together knowledge on the performance of Scots pine races in various experiments (LANGLET, 1959; WRIGHT and BULL, 1963; BIALOBOK, 1967; GIERTYCH, 1970; PRZYBYLSKI *et al.*, 1976), however these are not comparative evaluations of international provenance experiments.

The present paper is an attempt to look simultaneously at height growth performance as reported in literature for all experimental areas of the IUFRO 1907, 1938 and 1939

Scots pine provenance studies. Only height is considered because this is the character that is most consistently reported upon. Except for one French site, Arboretum Les Barres, from which only data on stem diameters and basal areas are available (LACAZE, 1964), all latest reports from provenance experiments include the height measurement. This is as good a character as any, on which most volume tables are based. It is correlated with other growth parameters and inversely correlated with susceptibilities to climatic and biotic agents. Unfortunately however it does not consistently correlate with the number of stems or mortality which is an important character in itself. It is included in volume per unit area which would be a better character to consider. However it is not possible to evaluate races and experimental sites on the basis of this character or on stem number alone, due to lack of data (few reports) and incomparability caused by differences in original spacing, use of row plots on some sites etc.

There were practically no replicates on most planting sites in these experiments. Thus one can only consider the individual planting sites as replicates for the studies as a whole. In such a design provenance × planting site interactions are confounded by within provenance variation that would have shown up in replicates at a single planting site. However this variation is in any case small when compared to large provenance differences. Its importance is likely to increase in studies working on a more restricted genetic base as in national provenance experiments (KING, 1965).

Materials and Methods

The origin of seed used for the IUFRO provenance experiments on Scots pine is shown in *Table 1* and *Figure 1* for IUFRO 1907, in *Table 4* and *Figure 5* for IUFRO 1938 and in *Table 7* and *Figure 13* for IUFRO 1939. The planting sites from which data have been published at ages beyond the early seedling stage are indicated in *Table 2* and *Figure 2* for IUFRO 1907, in *Table 5* and *Figure 6* for IUFRO 1938 and in *Table 7* and *Figure 13* for IUFRO 1939. The basic data on these experiments including numeration of provenances was taken from WIEDEMANN (1930) and ECKSTEIN (1973) for the IUFRO 1907 experiment and from VEEN (1953) for the IUFRO 1938 and IUFRO 1939 experiments. Since VEEN's report has numerous errors in place names and geographic coordinates these were corrected using as far as possible information published in

Table 1. — Data on Scots pine provenances from the IUFRO 1907 experiment.

IUFRO no.	Provenance	Year collected	Age of mother trees	Lat. N	Long. E	Alt. in m
1	Scotland, Invernesshire Seafield For. Estate	1906/7	112	57° 14'	3° 42'W	200
2	Langeac, Haute Loire France	1906/7	80	44° 58'	3° 07'E	1140
3	Gruzianka, Olsztyn Poland	1906/7	120	53° 40'	21° 30'	130
4	Hasselt, Campine Beligum	1906/7	40	50° 54'	5° 40'	104
5	Kaiserslautern, Rhein Pfalz, W. Germany	1906/7	100	49° 25'	7° 45'	300
6	Kliewenhof, Latvia USSR	1906/7	120—140	56° 45'	25° 45'	10
6A	Kliewenhof, Latavia USSR	1905/6		56° 45'	25° 45'	10
7	Chorin and Biesental E. Germany	1906/7	120	52° 50'	14° 10'	40
8	Perm, Stroganov Estate USSR	1906/7	100—140	57° 00'	64° 00'	300
9	Creweno, Phillipopolis Bulgaria		125	42° 10'	23° 50'	1550
10	Jokkmokk, Sweden			66° 36'	20° 00'	260
11	Spiš, Smolnik Czechoslovakia		100	48° 45'	20° 45'	550
12	Bratislava, V. Levâre Czechoslovakia		100	48° 30'	17° 00'	210
13	Hoenderlo, Utrecht Netherlands			52° 10'	5° 20'	5

Table 2. — Location of planting sites of the IUFRO 1907 Scots pine provenance experiment.

Exp. no	Locality	Lat. N	Long. E	Alt. in m
1	Chorin, E. Germany	52° 50'	13° 50'	100
2	Tharandt, E. Germany	50° 58'	13° 33'	412
3	Gießen, Schiffenberg, W. Germany	50° 30'	8° 40'	200
4	Belle Etoile, Belgium	50° 50'	4° 25'	125
5	Belle Etoile, Belgium	50° 50'	4° 25'	125
6	Knickövel, Belgium	50° 36'	6° 02'	350
7	Hässleby, Jönköping, Sweden	57° 38'	15° 37'	180
8	Likavka, Ruzomberk, Czechoslovakia	49° 08'	19° 17'	560
9	Kootwijk, Netherlands	52° 10'	5° 50'	30

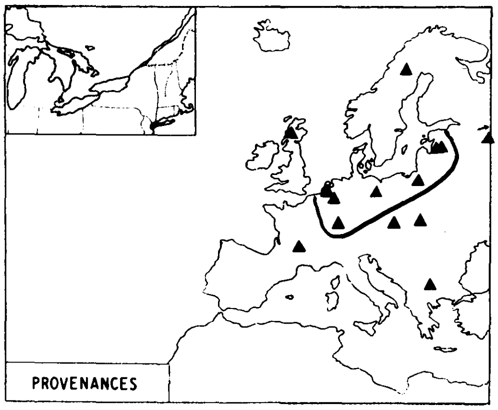


Figure 1. — Location of provenances from the IUFRO 1907 Scots pine experiment. The adaptable lowland Central European provenances shown in *figure 3* are delimited from the others shown in *figure 4.*

papers on these experiments in the respective countries. Planting sites of IUFRO 1907 have been assigned numbers by the author *(Table 2)* maintaining the sequence used by WIEDEMANN (1930) but ignoring defunct experiments. In IUFRO 1938 planting sites not mentioned by VEEN (1953) have been assigned new numbers *(Table 5).*

The latest available height measurements for these experiments are given in *Table 3* for IUFRO 1907 in table 6 for IUFRO 1938 and in *Table 7* for IUFRO 1939. These values are not comparable due to differences in age when last measured. Also some of the measurements concern mean height and others dominant height. To make the data comparable these were normalized (converted to units of standard deviation from the mean) for each planting site. Each provenance is considered in these units over all the planting sites that include it. For each provenance a map is prepared with the performance at each planting site plotted there as an ideogram showing the deviation from the mean. A black circle indicates a $\pm$ deviation of less than 0.30 σ, which corresponds to the radius of the circle. If at a site the provenance was planted but later died this is indicated as a +. The place of origin of the provenance is plotted as a triangle.

These maps were constructed only for provenances represented on at least three planting sites. An exception is made for three provenances of IUFRO 1907 represented on 2 sites only in view of the extreme value of this oldest experiment. The maps for IUFRO 1907 are shown in *Figures 1* to *4* and for IUFRO 1938 in *Figures 5—12.*

The advantages and disadvantages of this method of presentation have been discussed in the review of the Norway spruce IUFRO 1938 experiment (GIERTYCH, 1976) and they are equally pertinent here.

Results and Discussion

IUFRO 1907 Scots pine experiment

This study includes 13 provenances well scattered longitudinally and latitudinally in Europe *(Table 1, Figure 1)* and 9 planting sites. Initially there were 21 planting sites but 12 were lost or abandoned in the early stage of the experiment or were never heard from since WIEDEMANN's paper in 1930 and therefore presumably no longer exist. The Dutch planting site at Kootwijk was planted later (in 1911) and is said to have had seed from the same sources but possibly collected a year later and thus could be genetically different (WIEDEMANN 1930). Provenances 9—12 *(Table 1)* were acquired a year later and thus were not everywhere simultaneously outplanted, sometimes in a different plot. These were apparently lost in the Chorin (1) and Belle Etoile (4) trials since they were not reported upon since WIEDEMANN's 1930 paper. Provenance Hoenderlo was not initially considered part of the study, but since it was planted in Holland and in Slovakia it is now in the same situation as provenances 9 and 10 (from Bulgaria and Sweden) represented on only 2 sites.

There were no replicates in this study.

The performance of different provenances is presented in *Table 3* and *Figures 3* and *4*. Most conclusions of WIEDEMANN (1930) hold. It is obvious that the best provenances originate from lowland Central Europe *(Fig. 3).* The outlier or fringe populations were generally very poor on all sites *(Fig. 4).* Among these the montane Špis (11) provenance appears best. The fairly good Hasselt (4) and Hoenderlo (13) provenances *(Fig. 3)* are believed to be from domiciled

Table 3. — Average tree heights in the IUFRO 1907 Scots pine provenance experiment. + indicates 100% mortality.

Exp. no. as in table 2.	1	2	3	4	5	6	7	8	9
Mean or Dominant height	M	M	M	M	M	M	M	M	M
Age when measured	66	59	63	56	56	57	59	50	38
IUFRO Prov. no as in table 1									
1	18.3	14.9	21.8	19.7	19.9	19.4	21.1	18.2	8.8
2	16.2	13.3	21.0	18.7	17.7	20.2	19.9	18.2	5.9
3	22.5	16.8	19.5	22.3	22.3	22.1	23.5	20.1	8.0
4	20.9	17.2	22.8	22.7	20.7	20.6	21.7	17.8	8.4
5	20.8	16.7	22.3	21.3	20.3	21.2	21.0	17.2	9.5
6	21.0	16.2	23.0	21.5	21.0	24.4	22.2	17.5	8.5
6A		15.6	22.8	20.5	21.6	23.4	22.4		
7	22.5	16.4	22.0	21.5	21.6	21.2	22.0	17.6	8.2
8	+	14.8	21.1	18.0			20.8	18.7	
9							20.0	16.6	
10							21.6		5.9
11							20.4	18.9	8.7
12							19.4	18.7	7.4
13								17.5	10.2
Exp. mean	20.3	15.8	21.8	20.7	20.6	21.6	21.2	18.1	8.1
Reference	7	13	8	25	25	25	2	35	34

* 7: DITTMAR, O. (1977); 13: GEORGI, E. (1969); ECKSTEIN, E. (1973); 25: NANSON, A. (1968); 2: ANONYMUS (1974); 35: STASTNY, T. (1960; 34: SOEST, J. VAN (1952).

Table 4. — Data on Scots pine provenances from the IUFRO 1938 experiment.

IUFRO no.	Provenance	Year collected	Age of mother trees	Lat.N	Long.E	Alt. in m	Notes
1	Inari, Finland	1937	150–200	68°40′	27°37′	140	
2	Rovaniemi, Finland	1937	90–150	66°25′	26°36′	250	
3	Säämінki, Finland	1937	90	61°40′	28°55′	85	
4	Tonset, Norway	1937	80–120	62°22′	10°48′	550	
5	Målselv,Tromso,Norway	1937	50–120	69°06′	18°50′	75	
6	Åsnes,Hamar,Norway	1937	80–120	60°32′	12°11′	230	
7	Svanøy, Norway	1937	60–70	61°30′	5°07′	50	
8	Voxna, Sweden			61°20′	15°31′	200	
9	Tönnersjöheden,Sweden			56°40′	13°08′	100	
10	Böda, Sweden			57°18′	17°01′	5	
11	Vecmokas, USSR			57°03′	23°10′	80	
12	Susk, USSR			50°50′	26°00′	185	
13	Presov,Czechoslovakia	1935		49°00′	21°15′	500	
14	Talmacel,Romania		70	45°40′	24°08′	600	
16	Kandersteg,Switzerland	1936/37		46°29′	7°41′	1300	
17	Glen Garry,Scotland	1937	80–120	57°04′	4°55′W	150	
18	Herselt, Belgium	1936/37	40	51°03′	4°56′	20	cult.
19	Diever,Netherlands	1936/37	30–40	52°51′	6°21′	10	cult.
20	Brody /Pförten/,Poland			51°47′	14°46′	85	
21	Göddenstedt, W.Germany		80–85	52°59′	10°50′	75	
22	Ruciane, Poland	1938	130	53°41′	21°26′	120	
23	Elmstein, W.Germany	1936	120	49°20′	7°57′	325	
24	Zellhausen, W.Germany	1938	113	50°01′	9°00′	140	
25	Lenti, Hungary	1937		46°38′	16°33′	250	
26	Ambert, France			45°33′	3°45′	700	
27	Millau, France			44°10′	3°22′	825	
28	Les Angles,France	1937	>100	42°36′	2°07′	1570	
29	Bromarv, Finland	1937	80	60°03′	23°06′	15	
30	Modum, Norway	1937	70–110	60°04′	10°00′	300	
31	Val di Fiemme,Italy	1937	various	46°18′	11°20′	1100	
32	Griva, USSR	1936/37	60	55°58′	26°15′	160	
33	Breda, Netherlands	1937	35	51°34′	4°46′	10	cult.
34	Tinoava, Romania	1937		47°24′	25°22′	910	
35	Langensteinbach,W.Germany	1937		48°55′	8°30′	260	
36	Langenbrand,W.Germany	1937		48°47′	8°40′	525	
37	Supraśl IA,Poland			53°13′	23°22′	160	
38	Supraśl IB,Poland			53°13′	23°22′	160	
39	Bolewice IIA,Poland			52°24′	16°10′	90	
40	Bolewice IIB, Poland			52°24′	16°10′	90	
41	Susk IIIa, Poland			50°50′	26°00′	185	
42	Kuřivody,Czechoslovakia	1936		50°36′	14°43′	300	
43	Tišnov, Czechoslovakia	1936		49°21′	16°24′	375	
44	Třebon-Wittingau, Czechoslovakia	1936		49°00′	14°45′	450	
45	Vysoké Tatry,Czechoslovakia	1936		49°09′	20°13′	650	
46	Vindeln, Sweden			64°11′	19°35′	270	
47	Brännberg, Sweden			65°48	21°16′	100	
48	Vitsand, Sweden			60°23′	12°55′	175	
49	Axamo, Sweden			57°46′	14°03′	225	
50	Strömsund, Sweden			63°50′	15°33′	300	
51	Svenskådalen, Sweden			64°02′	13°04′	500	
53	Mustejki, USSR			54°08′	24°25′	130	
54	Rychtal, Poland			51°12′	17°55′	190	
55	Luboml, USSR			51°15′	24°05′	195	

stands since Scots pine is not indiginous in Beligum or Holland (Jalas and Suominen, 1973). Judging by their adaptability to various sites they probably originate from Germany (possibly Rheinpfalz) or the Baltic region.

The best provenance is Guzianka (3) from the Mazury region in N. Poland. Only in Gießen it grew very poorly. This very different result was already noticed by Wiedemann (1930) who suspected genetic reasons, though he does mention that it grows there on a more wet plot. Eckstein (1973) points out that something was wrong with this population already at the seedling stage since in spite of the largest available seed sample from this provenance it produced least plants so that when outplanted the plot was 20% smaller than for the other provenances and later mortality was greatest. The complete disagreement of its performance in Gießen with all other planting sites is not

Table 5. — Location of planting sites of the IUFRO Scots pine provenance experiment.

Exp. no.	Locality	Lat. N	Long.	Alt. in m
4	Herbeumont, Belgium	49°47'	5°13'E	415
6	Ruotsinkylä, Finland	60°22'	25°00'E	60
8*	Arboretum Les Barres, France	47°50'	2°45'E	673
9	Arboretum Royat, France	45°46'	3°02'E	850
10	Como, Brenna, Italy	45°40'	9°25'E	350
11	Como, Alzato, Italy	45°40'	9°25'E	350
12	Matrand, Eidskog, Norway	60°02'	12°15'E	110
17	Vincent State For., N.H., USA	43°06'	71°47'W	360
18	For State For., N.H., USA	43°09'	71°55'W	260
19	Wellston, Manistee, Mich., USA	44°16'	85°57'W	790
20	Herkimer State For., N.Y., USA	43°18'	75°07'W	415
21	Lubień, Poland	51°16'	19°47'E	200
22	Bugac, Kecskemét, Hungary	46°52'	19°40'E	150
23	Hůrky, Czechoslovakia	49°01'	14°38'E	500
24a	Finowtal /0.3 x 0.3/** E. Germany	52°48'	13°56'E	100
24b	Finowtal /1.0 x 1.0/** E. Germany	52°48'	13°56'E	100

* Only data on diameters and basal areas published

** Planting distance in m.

satisfactorily explained by genotype × environment interactions. One suspects that a mistake or some other mishap is involved here.

Apart from the Guzianka provenance in Gießen most GE interactions are provided by the Likavka (Slovakia) planting site on which all provenances appear to behave differently than elsewhere. Again one might suspect confusion of labelling, however this planting site is southernmost and at the highest altitude. A similar situation occurred with the Romanian planting site of the IUFRO 1938 Norway spruce experiment (Giertych, 1976) the validity of which was frequently suspected. One can well imagine however that high elevation and shorter days are important factors in determining growth performance on these sites. The existence of photoperiodic ecotypes of Scots pine in mountain regions has been demonstrated long ago (Karshon, 1949).

Since most planting sites are within or close to the region of origin of the best provenances the general conclusion might be drawn that local provenances are best or at least above average. This is particularily underlined by the Likavka planting site where the nearest Spiš and Bratislava provenances grow well. However lack of more extremely located planting sites made the conclusion premature as is well indicated by later experiments.

IUFRO 1938 Scots pine experiment

This experiment includes 53 provenances *(Figure 5, Table 4)*. Originally there were 2 more (nos. 15 and 52) but these are not represented on any of the planting sites. Provenance Kandersteg (16) is ignored by Dietrichson (1964) on the grounds that it is *Pinus mugo,* however the tree heights obtained by this population elsewhere (over 13 m in Belgium — *Table 6)* make this unlikely. The trees must have remained bushy in the Norwegion planting site at Matrand. Of the 18 original planting sites mentioned by Veen (1963) only from 9 have there been any published reports, however there are 6 other planting sites unknown to Veen from which data is available *(Table 5)*. On one of these (no. 24) Finowtal, there are two areas differing in the initial planting space, 0.3 × 0.3 m for 24a and 1.0 × 1.0 m for 24b. These two are treated separately considering the initial density as an environmental factor that could interact with genotypes. Conversely two New Hampshire USA sites (nos 17 and 18) are treated jointly employing the balanced averages calculated by Langlet (1959) from the original paper by Wright and Baldwin (1957). The arboretum Les Barres site no. 8 is ignored because from it only data on the stem diameters and basal areas has been published (Lacaze, 1964). There the best growth was demonstrated by provenance Ruciane (22) and other Central European ones (12, 20), while montane or Scandinavian ones grew poorly or died completely.

Performance of the different provenances on various sites is shown in *Table 6* and in *Figures 7—12.* The provenances which grew tallest on most sites again came from the same general region of lowland Central Europe.

The northern races from Scotland and Atlantic watershed of Scandinavia *(Fig. 7)* as well as from the Baltic watershed of Scandinavia *(Fig. 8)* are generally very poor on most sites which is the only result consistent with data on seedlings reported by Heikinheimo (1954).

Most of the genotype environment interactions are to be observed in Scandinavia. Some local provenances grow equally well as the best continental provenances. This is particularily true in S. Finland where Scandinavian races of similar or southern latitudes grow relatively well. However on this site only one lowland continental provenance (11 — *Fig. 11)* is included (it grows very well) and as a result the value of Scandinavian races is overestimated.

In SE Norway the local Vitsand (48) provenance is very good and also a Tromso (5) provenance is good. This is the only evidence in this study of a successful long distance (by 9° Latitude) transfer. Southward transfers are generally recommended in Sweden but only for about 2° Lat., (Stefanson and Sinko, 1967; Eiche and Andersson, 1974; Eriksson *et al.,* 1976; Remröd, 1976). However the lowland continental provenances planted in Norway *(Figures 9—11)* grew well above average. Thus while the general conclusion about the value of local provenances in Scandinavia or of small southward transfers appears to hold, there is evidence also to suggest that lowland continental provenances of high adaptability can grow there equally well or even better. Regretably these have not been tested or measured sufficiently enough in Scandinavia.

There is no question that Scandinavian provenances are useless on the continent. Also the Scottish provenance is nowhere to be recommended *(Figures 7 and 8)*.

The domiciled races from Belgium and Holland are generally very good, as are the provenances from NW Germany *(Fig. 9)*. The direction of transfer appears to be of little significance. Provenance Elmstein (23) shown in *Figure 9* only marginally belongs in this group. It is from a somewhat higher elevation (325 m) and exhibits poorer growth on eastward transfer.

The provenances from Western Poland shown in *Figure 10* belong to what I referred to as region Q in my attempt (Przybylski *et al.*, 1976) to reconcile the divisions of the range of Scots pine proposed by Wright and Bull (1963) and Patlai (1965). Provenance Chorin (7) from the IUFRO 1907 series probably also belongs here. Pine from that region is generally good growing, usually well above average for a given site.

Provenances from the Baltic countries *(Figure 11)* are very good indeed on most sites. The easternmost Griva (32) and north Ukrainian provenances (55, 12) are less reliable.

The montane provenances from Pyrenees, through Swiss, Italian and Hungarian Alps to the Carpathians *(Figure 12)* give generally average or below average height growths and therefore are not recommendable anywhere. Only

Table 6. — Average tree heights in the IUFRO 1938 Scots pine provenance experiment.

Exp. no. as in Table 5.	4	6	9	10	11	12	17+18	19	20	21	22	23	24a	24b
Mean or Dominant height	D	D	D	M	M	⁎	M	M	M	M	M	M	M	M
Age when measured	29	33	23	37	10	21	17	17	18	39	24	19	36	36
IUFRO no. as in Table 4														
1	1.5	6.3					1.5		1.6	14.8				
2	2.2	7.5	+			6.2	2.0		2.2	14.4				
3	10.1	10.8		13.1	1.4	6.7	3.9		5.3	14.1	8.0		11.6	11.7
4	6.4	8.9				6.5	2.8		3.6	15.0				
5	2.5	5.8	+			7.4	1.8		2.4					
6	10.5	9.6		12.9	1.7	6.3	4.1			12.7	8.6	6.4		
7	10.2	7.8	6.2	14.5	1.1	6.2	3.8			10.5		5.7		
8				15.1	2.0	6.8	4.1							
9		10.0					4.7		6.2					
10							5.2							
11	13.8	11.1		17.9	2.4	7.1	5.4		6.9	15.9	8.9	5.8		
12	12.4			18.2	2.3							7.7		
13	10.8		10.4	17.5	2.7									
14			8.5	16.2	0.8		5.2		6.8		8.5		+	+
16	13.2	6.1	5.5	+										
17	10.2	7.2				6.5	4.4			13.9		6.1		
18	12.9			17.5	3.0	7.1	6.8			16.1	9.3	8.3		
19	11.9			17.9	2.6	7.1	5.5		7.6	15.0	10.5		14.0	16.1
20	12.0		10.4	18.7	2.9	7.1	5.9		8.2	16.6	9.9	7.5	13.6	14.9
21	12.0			18.2	2.4	7.1	5.7		8.0	15.7	10.5	7.2	13.4	
22	11.9			18.7	2.8	7.1	5.8		8.1	15.7	9.7	7.7	14.4	16.2
23	13.6			18.6	2.5	7.1	5.8		8.0	14.0	9.2	6.8		
24	12.9			18.8	2.4		5.8		8.2		12.4	7.6		16.1
25				17.3	2.5		5.8		8.0		10.2			
26				13.5	1.3									
27				18.0	1.4									
28				14.3	1.3							7.2		
29							4.8	2.4	6.1					
30							4.6	2.5	5.5			7.3	11.8	14.1
31	10.4		8.6	14.7	1.8		5.2				10.5			
32							5.7		7.6		9.8		12.8	14.3
33								3.5	8.1			8.1		
34							4.9	2.4	6.3		7.2	5.3		
35							5.9		8.3					
36							5.9		8.1					
37							5.9	3.3	8.0					
38							6.0	3.2	8.0					
39							6.0	3.7	8.0			8.7		
40							6.0		8.0					
41							6.0		8.1					
42							6.0					8.3		
43							5.9					8.3		
44							6.3		8.1					
45							5.8		7.1			6.8		
46							3.0		3.8					
47							2.8		3.2					
48						7.5	4.7		5.4		8.8	6.4		
49						6.3	4.9		5.8			7.1		
50		9.5					3.0		3.5					
51							2.8		3.6					
53				18.5	2.4		6.2	3.1	8.1	17.0	9.5	8.0		
54	13.4			18.5	3.0		6.0	3.7	8.0	17.1			13.0	15.0
55			10.3	17.8	2.5		5.5	2.8	7.7	14.8	9.1	7.2		
Exp. mean	10.2	8.4	8.6	16.8	2.1	6.8	4.9	3.1	6.5	14.9	9.5	7.2	13.1	14.8
Reference*	25	17	21	38	1	6	22	33	32	5	23	40	7	7

\+ 100% mortality
⁎ sample trees only.

* 25: Nanson, A. (1968); 17: Heikinheimo, 0. a. Saarnio, R. (1972); 21: Lacaze, J. F. (1964); 38: Tocci, A. V. (1976); 1: Allegri, E. a. Morandini, R. (1949); 6: Dietrichson, J. (1964); 22: Langlet, 0. (1959); 33: Slabaugh, P. E. a. Rudolf, P. O. (1957); 32: Schreiner, E. J., Littlefield, E. W. a. Eliason, E. J. (1962); 5: Cierniewsk i, M. (1978); 23: Magyar, P. (1964); 40: Vincent, G. (1965); Dittmar, O. (1977).

Table 7. — IUFRO 1939 Scots pine experiment. Provenances and their mean tree heights at two locations in Canada (Petawawa For. Exp. Sta. Lat. 45° 55' N, Long. 77° 30' W) and Turkey (Bahçeköy, Lat. 41° 10' N, Long. 28° 58' E, Alt. 110 m).

							Canada	Turkey
Planting site							Canada	Turkey
Mean or Dominant height							M	D
Age when measured							10	25
IUFRO no.	Provenance	Year collec-ted	Age of mother trees	Lat. N	Long. E	Alt. in m		
1	Svanøy, Norway	1937	60 —70	61° 29'	5° 07'	50	0.7	6.8
2	Åsnes, Norway	1937	80—120	60° 30'	12° 10'	180	0.8	8.4
3	Troms (coast), Norway	1936		69° 10'	18° 00'	200	0.6	3.8
4	Troms (interior), Norway	1936		69° 10'	19° 30'	150	0.5	4.6
5	Småland, Sweden			57°	14°		1.3	9.7
6	Vindeln, Sweden			64° 12'	19° 50'	200	0.7	6.7
7	Inari, Finland	1936	150—200	68° 55'	27° 00'	140	0.4	4.2
8	Rovaniemi, Finland	1937	90—150	66° 30'	25° 45'	150	0.5	5.3
9	Orton Estate, Scotland	1938	100—115	57° 33'	3° 09'W	115	1.0	9.8
10	Balnagowan Wood, Scotland	1938	80—100	57° 16'	3° 39'W	240	1.7	
11	Murat, France			45° 06'	2° 52'	625	0.9	9.3
12	Luchon, France			42° 46'	0° 35'	>1000	+	
13	Bebenhausen, W. Germany	1938	116	49° 58'	8° 57'	135	1.5	10.7
14	Pisz, Poland	1939	c. 150	53° 38'	21° 48'	130	1.7	9.9
15	Rychtal, Poland			51° 10'	17° 52'	125	2.4	10.4
16	Vladimir, USSR			56°	40°	100	1.5	
17	Poltawa, USSR			49° 30'	34° 30'	100	2.2	11.0
18	Talmacel, Romania			45° 40'	24° 15'	600	1.4	10.1
19	Griva, USSR	1936/37	60	55° 50'	26° 25'	150	2.4	
20	Vecmokas, USSR			57° 00'	23° 07'	80	1.5	
21	Çatacik, Turkey			39° 33'	30° 30'	1350		9.8
22	Hungary			46° 40'	16° 40'	150		11.0
23	Norfolk County, Ont. cult.			43°	80° 30'W	200	2.4	
Exp. mean							1.3	8.3
Reference*							18	31

* 18: Holst, M. J. (1953); 31: Saatcioglu, F. (1967).

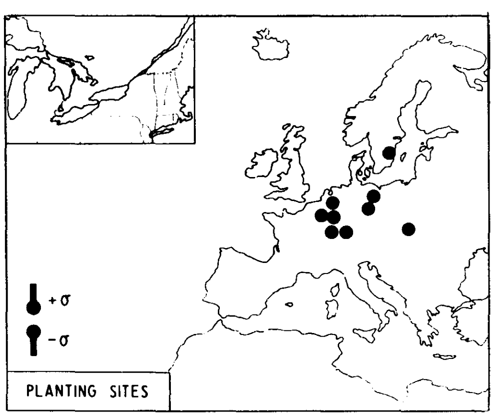


Figure 2. — Location of planting sites from the IUFRO 1907 Scots pine provenance experiment. Ideograms showing positive and negative deviations in tree height from the site average as used in *figures 3, 4, 7—12* are shown, here indicating dimensions corresponding to one standard deviation. The radius of the black spot corresponds to 0.30 σ. On all figures a triangle indicates seed origin and + indicates 100% mortality.

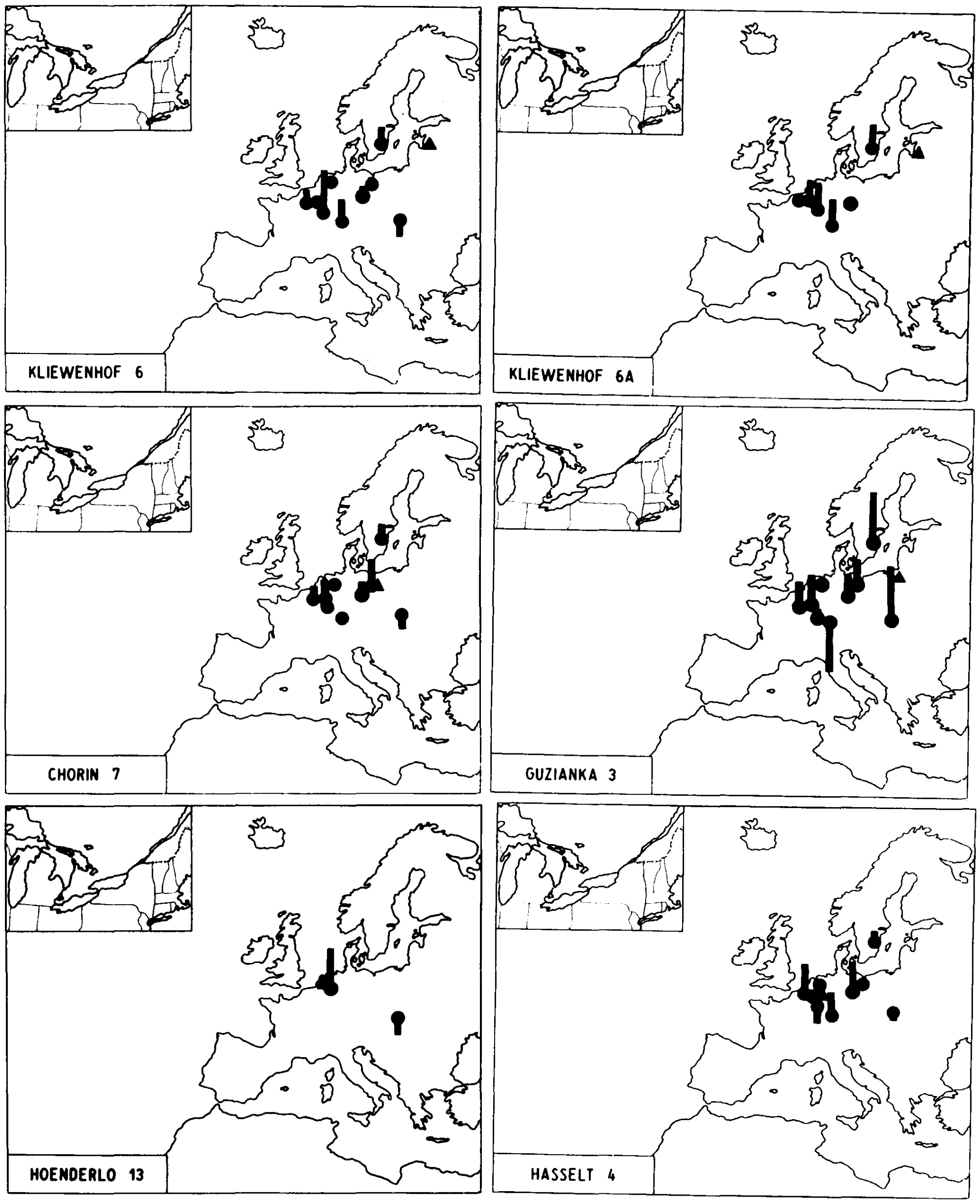
provenance Presov (13) of 500 m is somewhat above average on all sites *(Table 6)*. Even on the most elevated planting site (Arboretum Royat, 850 m) the montane provenances (14, 16, 31) are not any better than the continental lowland ones.

In the US planting sites, where the elevations are generally higher and latitudes lower the same general conclusions hold.

The split up of the Finowtal planting site into two (24a and 24b) on the basis of planting spacings proved unnecessary since similar results were obtained on both. Apparently there is no provenance × spacing interaction. Also there is little difference between the two close Italian sites, which at the same time differ substantially in the age of last measurement (10 and 37 yrs). It appears therefore that provenance × site interactions are of little importance. The interactions in Scandinavia appear to be primarily provenance × climate.

The Lubien planting site is said to be substantially affected by natural regeneration that was not kept under control during the early years (World War II) and therefore is contaminated (Przybylski and Sztuka 1968), however the performance of different provenances there is very much in agreement with results obtained elsewhere, thus the contamination must have been not too great.

Finally a word is needed about the provenances not given separate maps which were included on only one or two planting sites, primarily in USA *(Table 6)*. The Scandinavian provenances (nos. 10, 46, 47, 51) are very slow growing. The continental lowland ones are generally good (40, 41). The French, Central Massif montane provenances 26 and 27 tried on the Italian sites are growing very poorly except for prov. 27 in Brenna. It is interesting that some of the provenances from S. Germany (35, 36) and Bohemia (42, 43, 44), regions not represented much in the study, are above average. These fragmentary data do not alter the general conclusions to any extent. However they do indicate that possibly good adaptable races are also to be found south of the region identified here as best.



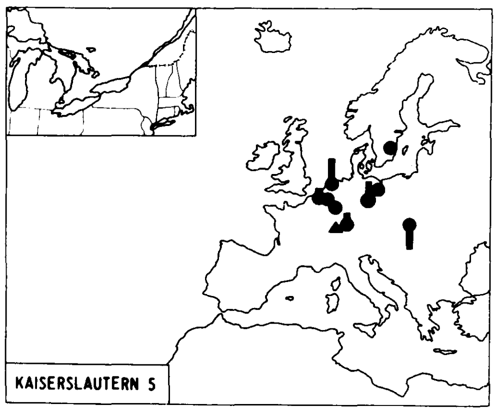
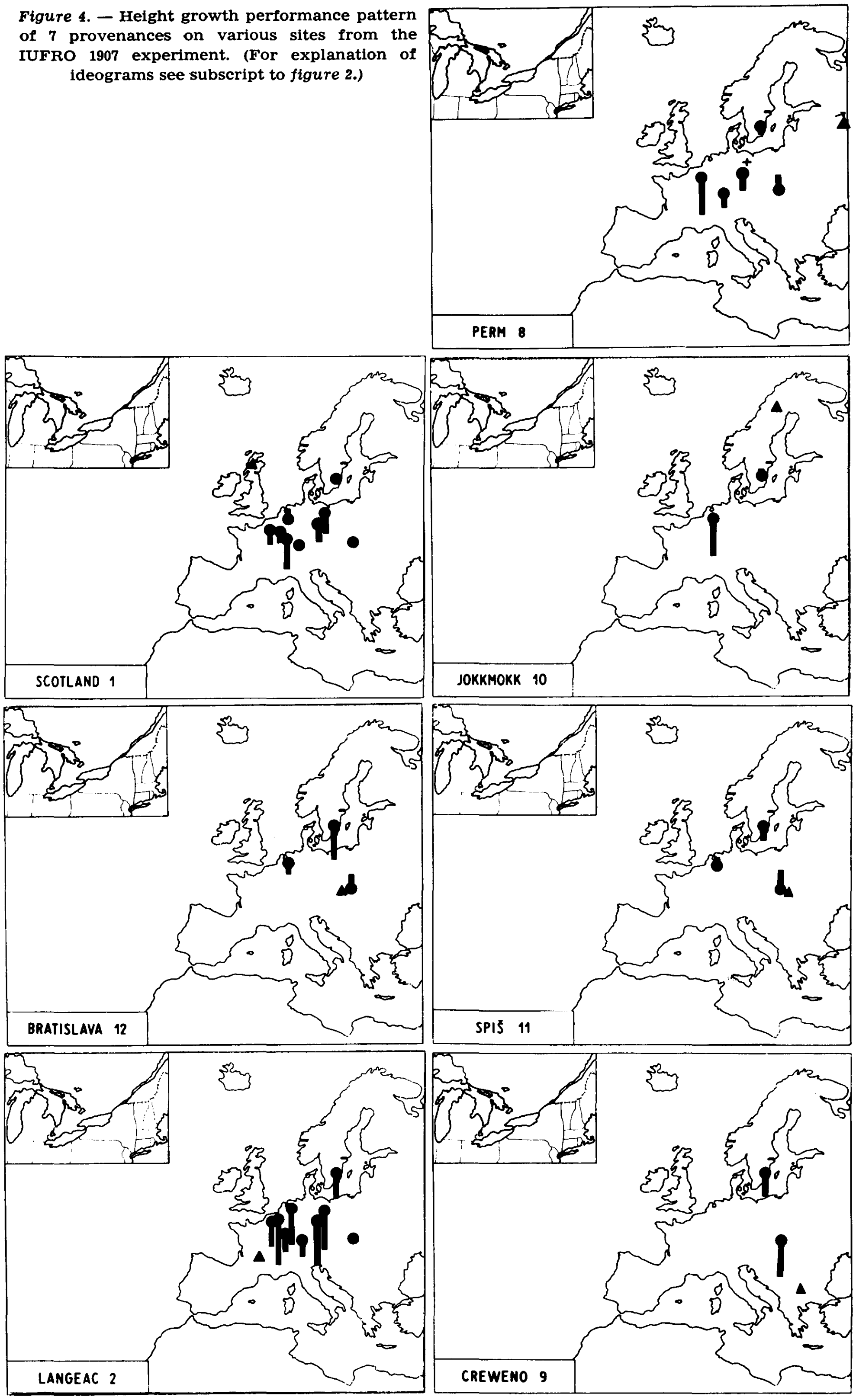


Figure 3. — Height growth performance patterns of 7 lowland Central European provenances on various sites from the IUFRO 1907 experiment. (For explanation of ideograms see subscript to *figure 2*.)

Figure 4. — Height growth performance pattern of 7 provenances on various sites from the IUFRO 1907 experiment. (For explanation of ideograms see subscript to *figure 2.*)



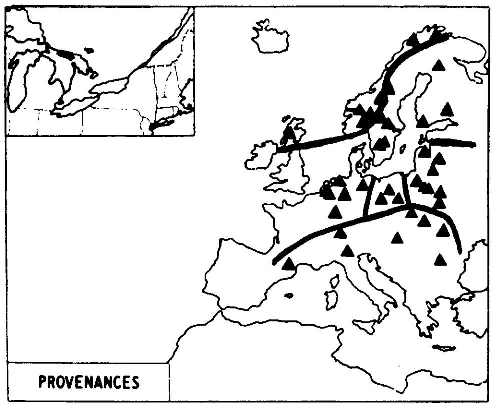


Figure 5. — Location of provenances from the IUFRO 1938 Scots pine experiment. The populations are grouped by regions as in *figures 7—12.*

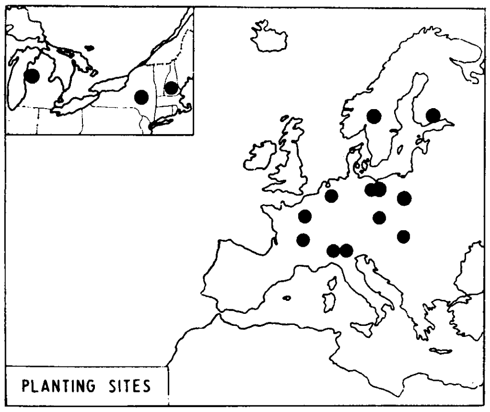


Figure 6. — Location of planting sites from the IUFRO 1938 Scots pine provenance experiment.

IUFRO 1939 Scots pine experiment

Due to the outbreak of World War II this experiment got planted on only two sites. It officially includes 20 provenances but 3 others were added by the participants, and since several grow on only one of the two sites, these added ones do not differ from the original in any way. Following the practice of not presenting performance maps for provenances represented on less than 3 sites the study is in the same category as the last mentioned provenances of IUFRO 1938 that grown on only 1 or 2 sites. There are many provenance experiments of this type all over Europe. However in view of the extreme location of the two planting sites, in Turkey and Canada, and the choice of many of the same provenances (some even collected the same year) as in the IUFRO 1938 experiment, this study represents an interesting supplement to the 1938 effort.

The basic data is presented in *Table 7* and the provenances and planting sites are plotted in *Figure 13.*

The Scandinavian provenances, nos. (1, 2, 3, 4, 6, 7, 8) grew poorly, both in Canada and Turkey. The southern Swedish provenance Småland (5) grew average in Canada and substantially above average in Turkey, as well as the local Çatacik (21) provenance. Both Scottish provenances had a similar above average growth. The lowland continental provenances (13, 14, 15, 16, 17, 19, 20) grew very well, similarly to the local Çatacik (21) Turkish provenance and the domiciled on Lake Ontario provenance Norfolk county (23).

The montane (11, 12, 18) provenances grew poorly in Canada but rather well in Turkey. In the latter area also the Hungarian provenance grew well. These montane provenances account for most of the genotype × environment interactions. It appears that in Turkey, on a lowland site, high elevation provenances from France, Romania and Turkey itself can attain tree heights comparable to those of the best provenances from lowland Central Europe.

General discussion

Results of the three IUFRO Scots pine provenance experiments generally concur. The old opinion that local races are best which continues to be voiced occasionally (Eiche and Andersson, 1974; Patlai, 1973; Barniškis, 1978) is confirmed to some extent in view of the fact that at many planting sites some nearby provenance is among the better ones. Thus the recommendation to choose a good local stand as a seed source remains perfectly valid.

While outlier populations are generally no good as seed sources, where native they may, due to the local adaptive advantage, give comparable growth to that of some of the good adaptable introduced races.

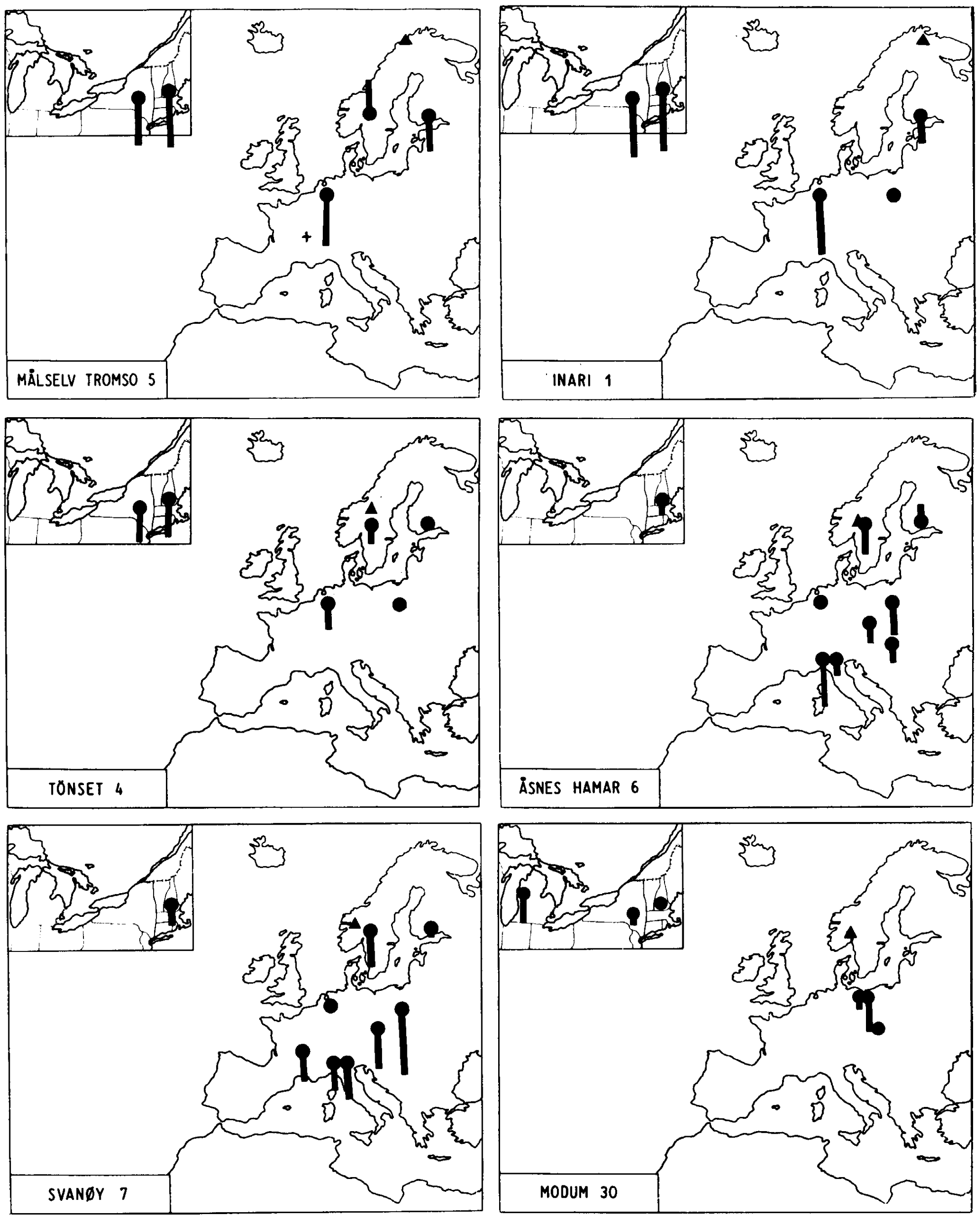
This local adaptive advantage appears to be particularily obvious in domiciled races of Scots pine, in the Low Countries and in Ontario, Canada. These highly selected and proven as successful in an alien environment races of Scots pine are particularly valuable as a source of fast growing adaptable genotypes.

In contrast to Norway spruce and European larch montane populations of Scots pine are not very adaptable in lowland plantings. They appear to be akin to outlier populations, possibly useful locally as the Spiš population in Likavka of the IUFRO 1907 study, but not much elsewhere. The success of these populations in Turkey is rather surprising since this is a southward, downhill transfer that is against climatic logic and opposite to all recommendations (Stefan and Sinko, 1967). Possibly adaptation to draught or some other pioneer quality is the linking factor here.

Having said all that could be said for local races it is now neceassary to come to the major conclusion of this study. It is obvious from all three series that the fastest growing and most adaptable races are to be found in lowland Central Europe. This particularily concerns the Baltic countries and north- and western Poland. Considering the fact that the first ever provenance experiment set up in 1820 with various populations of Scots pine by Vilmorin in France has shown the "Riga pine" to be best, (Wright and Bull, 1963) the results provided by the IUFRO series are nothing more than a confirmation of this very early conclusion. It is pertinent to add that the USSR experiments which include numerous eastern provenances (Patlai, 1965; Barniškis, 1978) also show the populations from NW Ukraine, western Biolorussia and the Baltic region to be best.

One might wonder why is this region so special in the whole range of Scots pine. Two possibilities come to mind. After the last glaciation vegetation returned to Central Europe westwards from the plains of Central Russia and northward across the mountain ranges (Carpathians, Sudety, Erzgebirge, Bohemian Forest etc.), In the lowlands of Central Europe these two waves of vegetation, both including Scots pine, met and whence a rich gene pool must have resulted with much heterozygocity.

The climate of Central Europe is transitory between Atlantic and continental. Some winters are mild and wet, others are very snowy and still others very cold snowless.



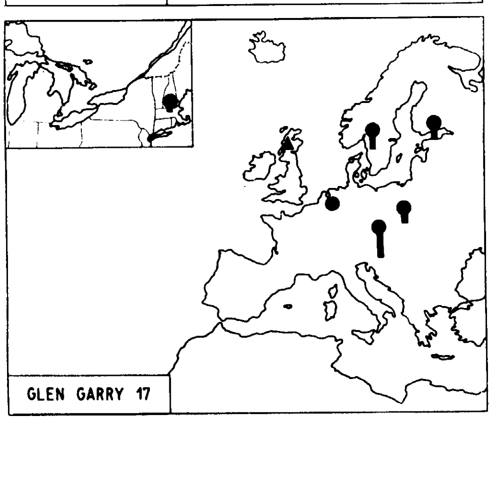


Figure 7. — **Height growth performance patterns of Scots pine provenances from Scotland and Atlantic watershed of Scandinavia on various sites from the IUFRO 1938 experiment. (For explanation of ideograms see subscript to *figure 2*.)**

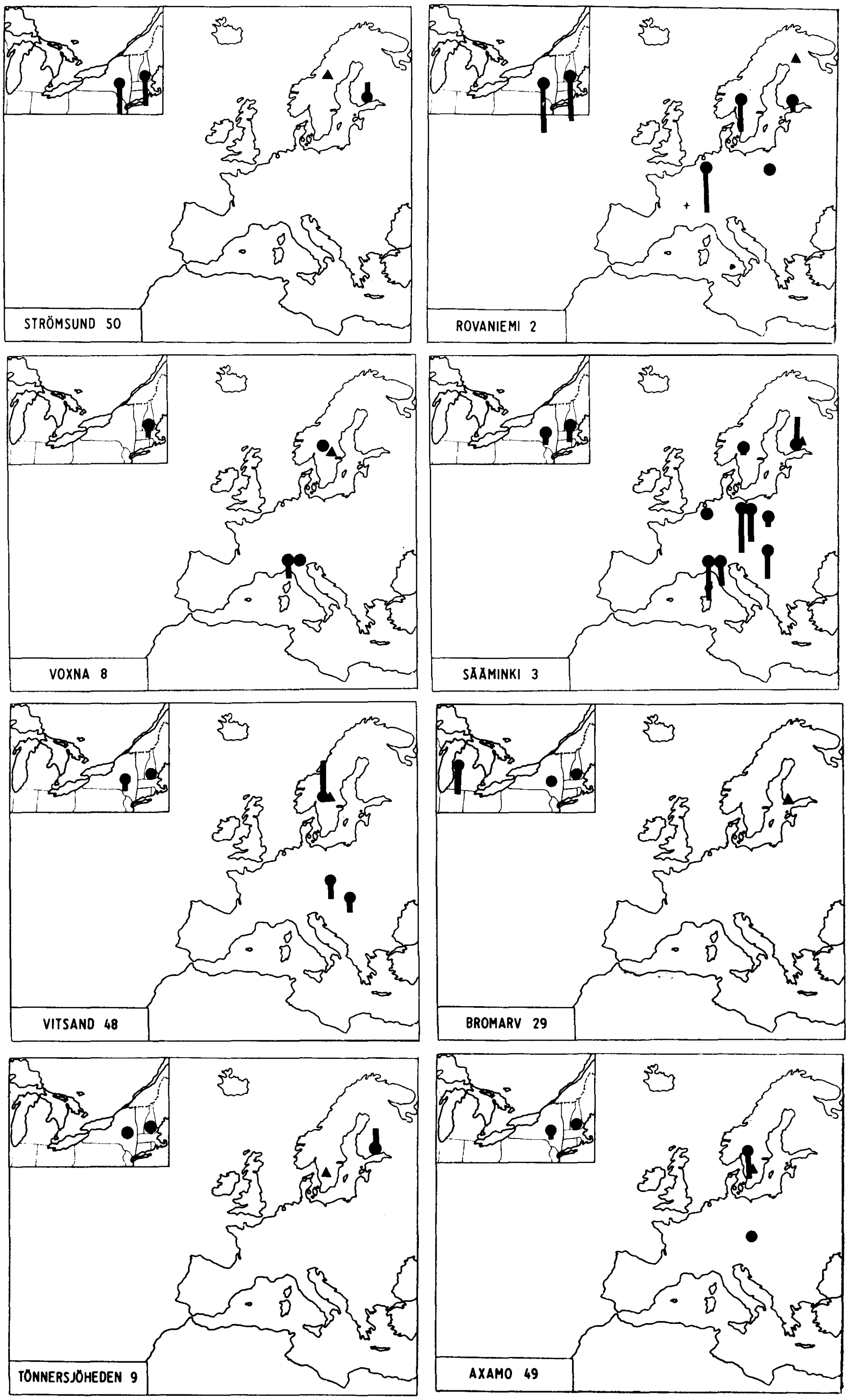


Figure 8. — Height growth performance of 8 provenances from the Baltic watershed of Scandinavia on various sites from the IUFRO 1938 experiment. (For explanation of ideograms see subscript to *figure 2.*)

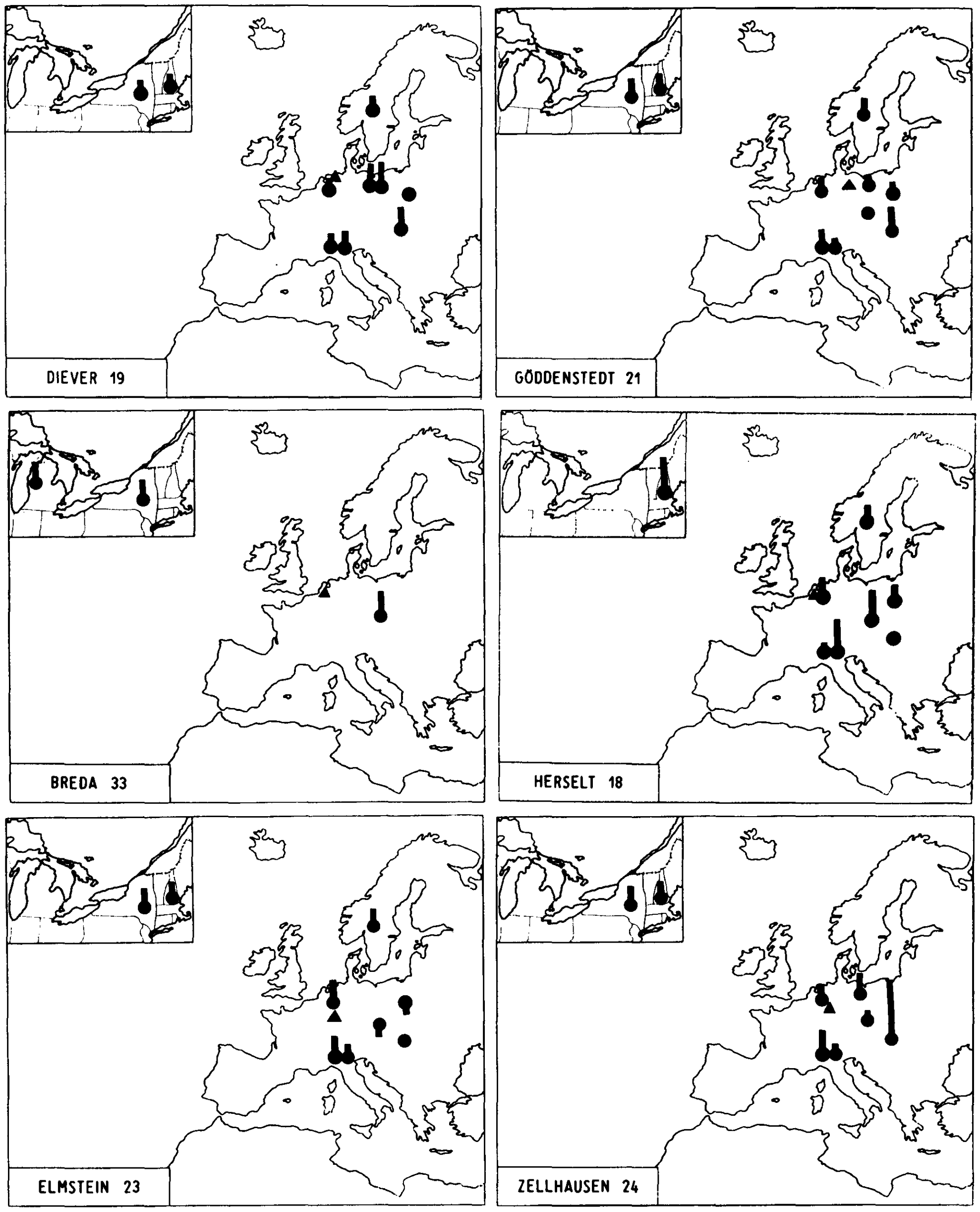
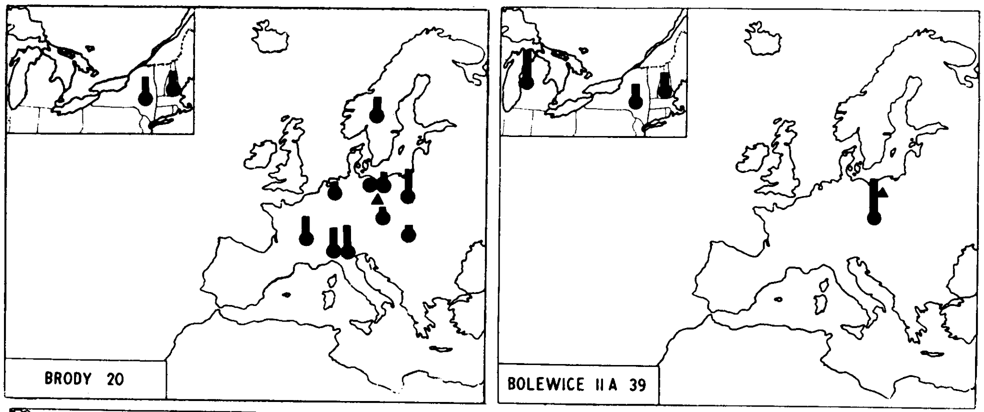


Figure 9. — Height growth performance patterns of Scots pine provenances from the Low Countries and West Germany on various sites from the IUFRO 1938 experiment. (For explanation of ideograms see subscript to *figure 2.*)

Summers can be wet or very dry. The vegetation has to be adapted to all these different conditions and thus adaptability is a character that was selected for. With the available rich gene pool this selection led to races that are capable of respectable growth in various climatic conditions, from Scandinavia to Turkey and from Eastern Europe to Michigan; in most places this growth is superior to that of local races.

This adaptability character of pine races declines in all directions from the optimum region. It is absent in Scandinavian and outlier populations, weak in south German and montane races and judging from USSR experiments also declines eastwards.

In New Zealand in a trial of Scots pine only outlier Spanish provenances were tested (Sweet, 1964) because of their greatest latitudinal agreement with the planting site. They all proved useless, but perhaps some Polish provenances might have proven better. It seems that latitude of origin is a factor of little significance when choosing provenances. Certainly photoperiod is not an important factor for adaptable lowland populations, and it is in the lowlands that Scots pine is usually planted. The presence of photoperiodic ecotypes in montane races demonstrated by Karshon (1949) is perhaps responsible for the lower adaptability of these provenances. Also the non-adaptable Scandinavian provenances may be photoperiod conscious which is indicated by the extreme caution with which Scandinavian authors approach the problem of latitudinal transfers for Scots pine (Stefanson and Sinko, 1967; Johnsson, 1971; Eiche and Anderson, 1974; Eriksson *et al.*, 1976; Remröd, 1976). It appears however that the adaptable Central European provenances utilize the vegetative period not by adapting to it photoperiodically but by being capable of short intensive extension growth during peak of the season,



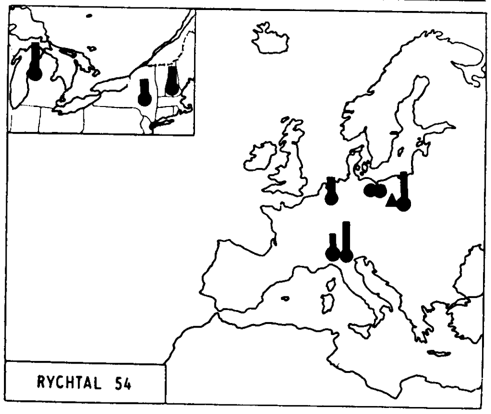


Figure 10. — Height growth performance patterns of 3 provenances from western Poland on various sites from the IUFRO 1938 experiment. (For explanation of ideograms see subscript to *figure 2.*)

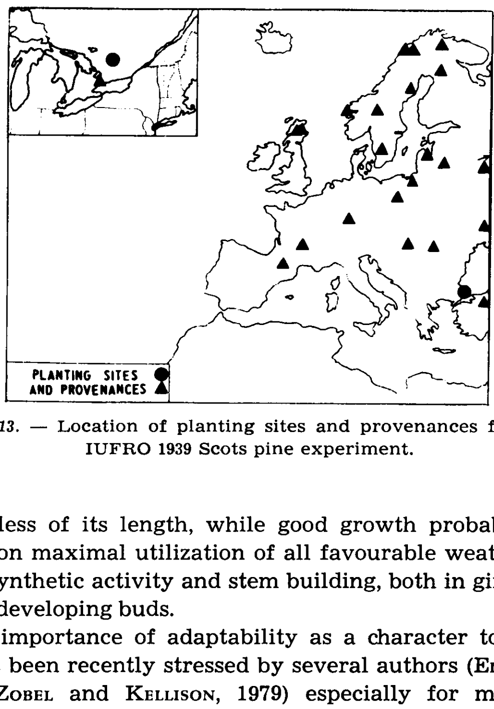


Figure 13. — Location of planting sites and provenances from the IUFRO 1939 Scots pine experiment.

regardless of its length, while good growth probably depends on maximal utilization of all favourable weather for photosynthetic activity and stem building, both in girth and inside developing buds.

The importance of adaptability as a character to select for has been recently stressed by several authors (Eldridge, 1974; Zobel and Kellison, 1979) especially for marginal land onto which forestry is being pushed. Mátyás (1974) points out that non-adaptive traits have a higher within provenance variance while characters of adaptive importance as growth and resistance have a higher between provenance variance.

It has been obvious for quite a while now that quality characters can relatively easily be bred for in seed orchard programs, but yield having lower heritabilities is best improved by appropriate choice of species or race. While local material may have a definite advantage being adapted and quality improvements are possible within it, a yield improvement often requires seed transfers. If these are to be made, use of adaptable (plastic) material is the safest approach. This study clearly shows where such populations of Scots pine are to be found. In highly bred material indigenity is of declining importance (as in poplars) thus the need for these populations will tend to increase.

Finally I wish to stress that a comparative analysis of results as presented here was only possible because original data from provenance experiments were published. With increasing brevity of scientific papers this is a declining practice, authors presenting only those results which in a most readable form substantiate the basic conclusions. I recommend strongly that all papers from provenance experiments should publish the basic data for each character and provenance or indicate where it has been published or is available.

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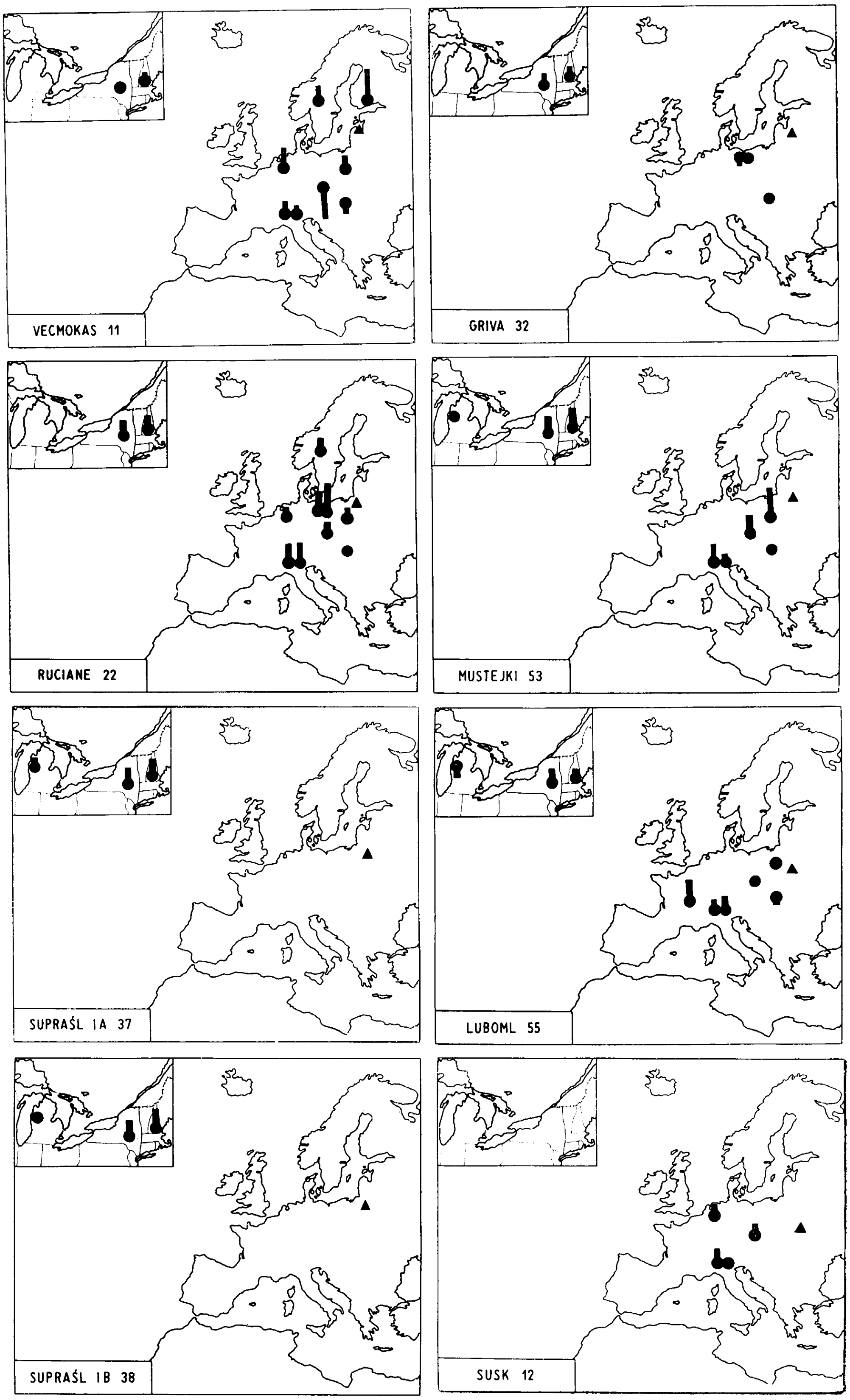

Figure 11. — Height growth performance patterns of Scots pine from the Baltic Countries on various sites from the IUFRO 1938 experiment. (For explanation of ideograms see subscript to *figure 2.*)

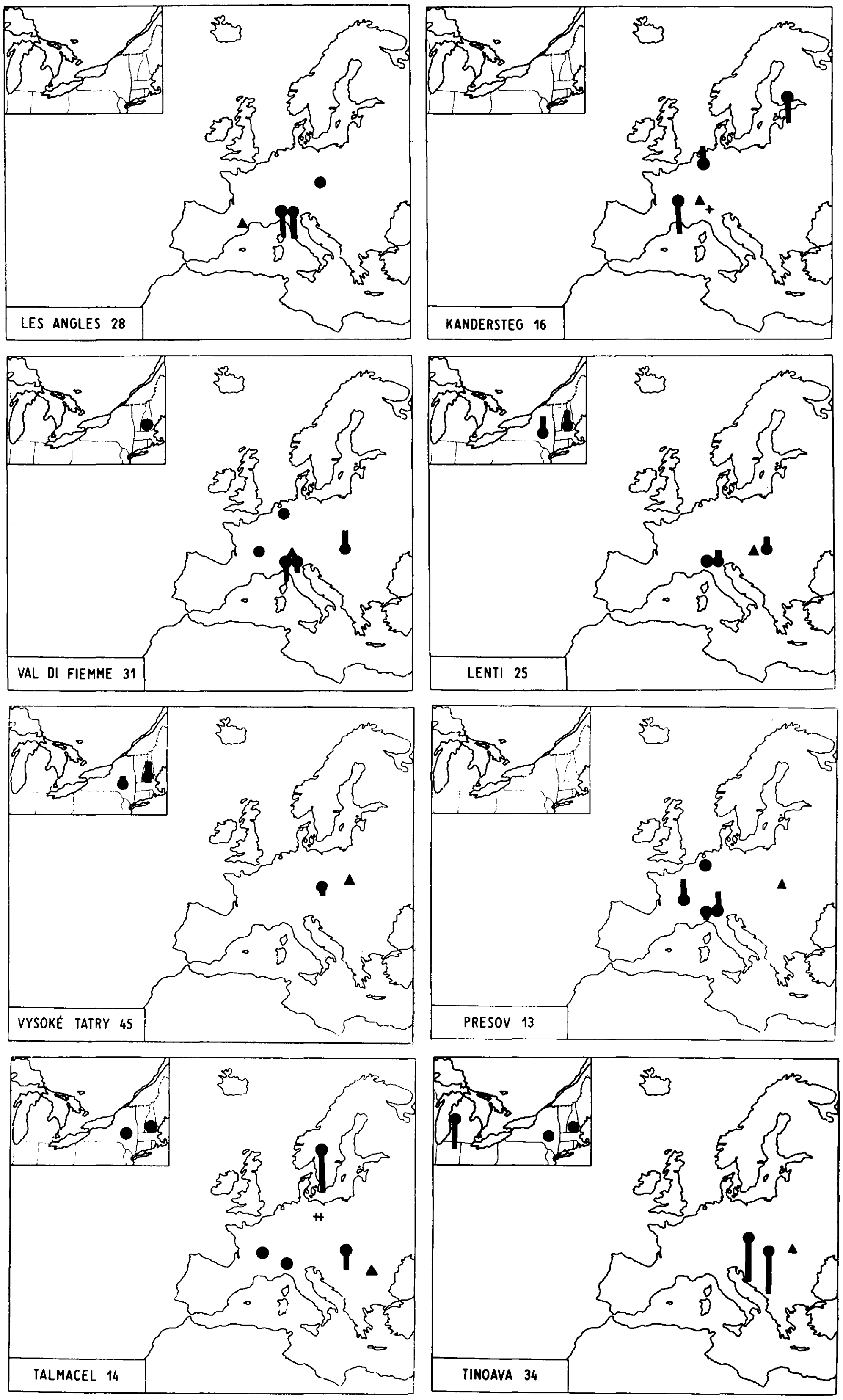

Figure 12. — Height growth performance patterns of montane provenances on various sites from the IUFRO 1938 experiment. (For explanation of ideograms see subscript to *figure 2.)*

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