Genetic reactivity of Norway spruce to climate change based on experimental results from IPTNS-IUFRO 1964/68 test in Poland

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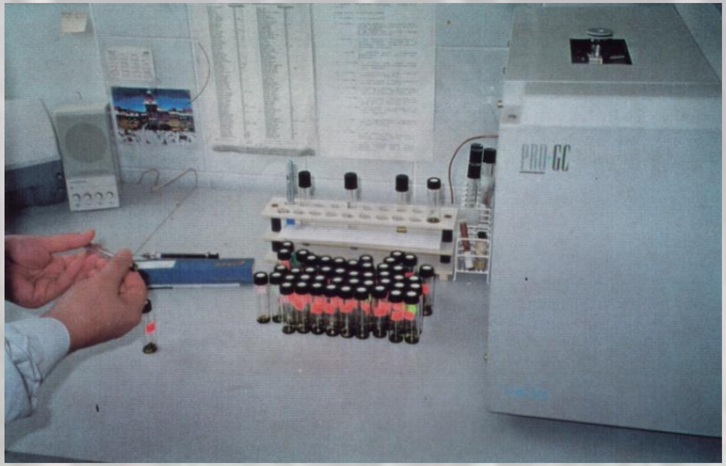
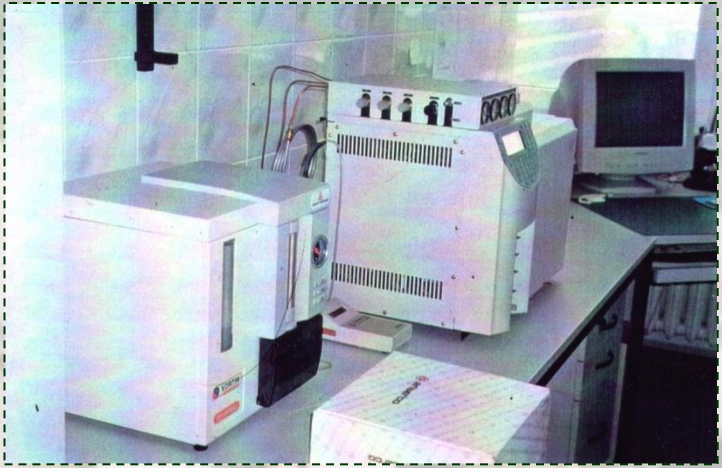




Research interests:

- **national progeny test program in Poland and in Europe (specialy for Norway spruce, Silver fir and European beech)**
- **conservation of gene resources (specialy in the Carpathian Mts.)**
- **forest reproductive material**
- **gene markers for provenances of Norway spruce**

Genetic reactivity of Norway spruce to climate change based on experimental results from IPTNS-IUFRO 1964/68 test in Poland

IUFRO 1964/68 - History

In 1959 Professor Olaf Langlet from the Stockholm Faculty of Forestry proposed that an international inventory provenance trial of Norway spruce be established. Prof. Langlet offered to establish such a trial. By 1964 Langlet already collected 1614 seed samples and an extensive international interest in the experiment developed. Langlet chose from his collection 1300 seed lots and these were sown in a nursery of the Institut für Forstgenetik in Schmalenbeck near Hamburg under the control of Professors Wolfgang Langner and Klaus Stern. In 1966 the seedlings were transplanted to a commercial nursery of Pein & Pein in Halstenbeck, near Hamburg. There, under the supervision of Dr Walter Neugebauer, the seedlings were grown till 1968 when each one was individually supplied with a label and prepared for transport to wherever the experimental areas were to be established. From the Institute at Schmalenbeck this work was co-ordinated by Dr E. Masching. Up to that stage there were no replicates. Finally 1100 populations were qualified for the experiment. For each of the populations there was a sufficient number of transplants needed by co-operators to include them in all of the planned 20 experimental areas. The populations were divided into 11 groups of 100 populations each, with a maximally even representation of the whole range of the species in each group. As a result each group in itself is already an experiment encompassing the whole range of the species. **In all, 20 trial areas were established, 3 in Germany and Sweden, 2 in Belgium and Norway and one each in Austria, Canada, Czech Republic, England, Finland, France, Hungary, Ireland, Poland and Scotland.**

The experimental design was proposed by Prof. Klaus Stern. As a result the experiment includes 1100 populations each represented by 25 trees on each trial area, treated as single-tree plots. Since each of the 11 groups of populations covers the whole range of spruce, it was assumed that blocks with populations from different groups would have similar means and variances. No 2.02.11 Norway Spruce Provenances, under the leadership of Jon Dietrichson and Peter Krutzsch, which took over responsibility for the international co-ordination of efforts pertaining to the 1964/68 experiment.

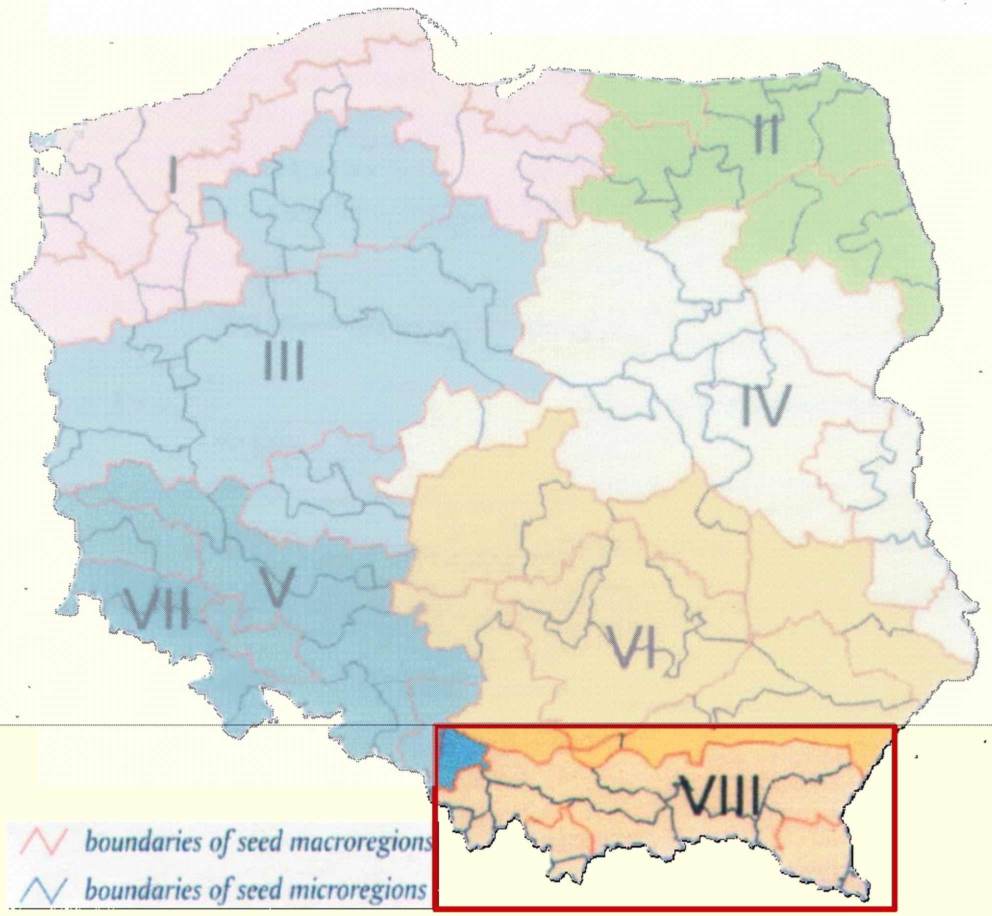
The Polish trial area was established by Prof. Stanisław Bałut in the Experimental Forest of the Cracow Agricultural University in Krynica.

The trial has a full set of 1096 provenances. It is the most elevated planting site (750 m) for the whole experiment. The experiment covers provenances from the natural range of the species and from the area where spruce was introduced by man. Poland is represented by 92 provenances. Among all the provenances considered, 528 have a strictly defined (accurate to a stand) location, so they can be reproduced and used in practice. The material is thus representative of the whole Picea abies species to the degree that has no parallel in any previous research.

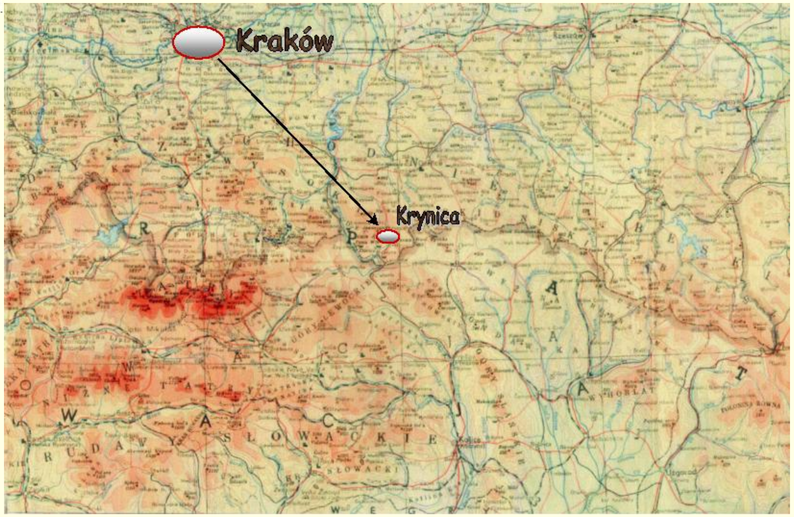
To avoid the effect of crown closure for as long as possible, a 2 × 2 m spacing was employed. As a result each block covers 1 ha. The specimens representing individual provenances are randomly distributed over the block area.

(prof. M. Giertych)

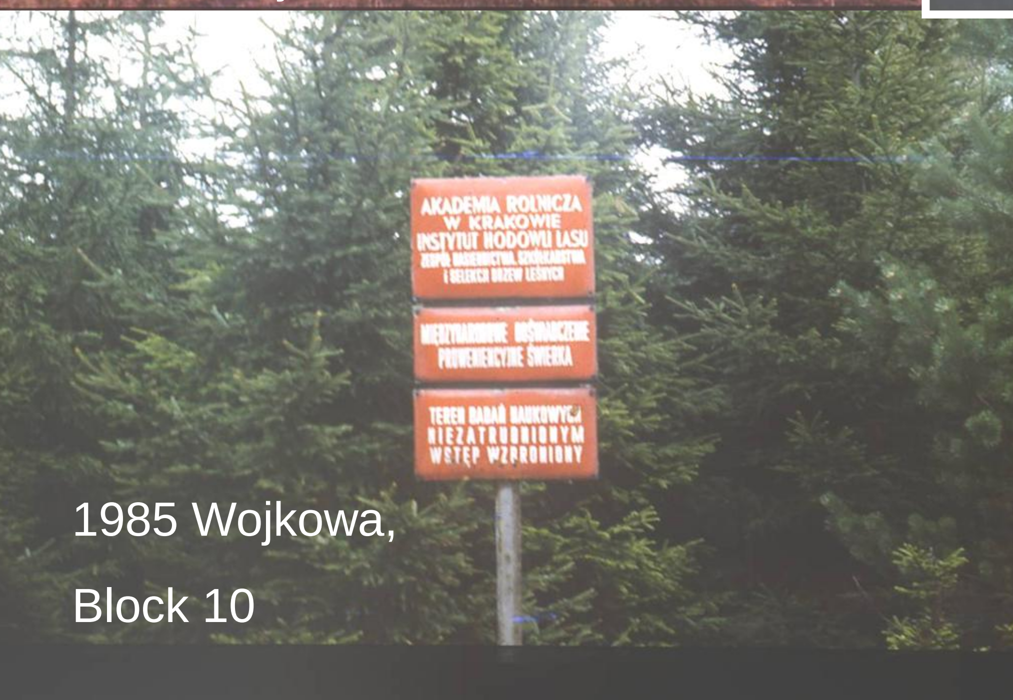
Division of Poland into seed regions againt the backround of natural-forest regions (I-VIII)



I. Baltic natural forest region
II. Mazury-Podlasie region
III. Great-Pomeranian region
IV. Mazowsze-Podlasie region
V. Silesian region
VI. Region central Polish
VII. Sudeten region
VIII. Carpathian region



1970 Wojkowa, Block 02



1985 Wojkowa,

Block 10

Location of blocks of the international provenance test of Norway spruce (area No 19 Poland). Krynica Experimental Forest Station

Forest Range	Block No	Geographical coordinates		Altitude (m)
		Longitude	Latitude	
Kopciowa	05	21°01’	49°28’	**705**
Wojkowa	02	20°58’	49°21’	**795**

Records from 1956–1965 (after Baliński, 1974)

Attitude	Average of temerature in year [°C]	Percipation [mm]	Period wit average tejmperature above 5°C	Snow covering period [date]	Period without frosts [days]	Period of snow covering in year [days]
800	*4,3*	*1000*	*179*	*2.XI – 15.IV*	*170*	*120*

Records from 1969–1988. Data base for belt 600 a 850 m abave sea level (Beskid Sądecki Mts) According to Dep. of Forest Protections and Forest Climatology. Forestry Faculty in Cracow

Years	Temp. Average (°C)	St. deviation	Precipitation (Mm)	St. deviation	Wegetation (days above 5°C)	Snow covering Days
1969	4,9	7,0	990	49	190	128
1972	5,6	6,9	885	55	180	85
1975	5,9	7,3	1020	45	187	126
1978	4,2	6,9	1190	55	181	124
1983	6,1	7,7	1175	57	198	134
1988	5,3	7,6	1117	53	184	133

Investigations

Investigations

Investigations:

Height in age 6, 9, 12, 15, 20, 25 (1969, 1972, 1975, 1978, 1983 and 1988)

The observations and measurements of the tree height were carried out in 11 blocks of the IPTNS-IUFRO test 1964/68 in Krynica. Each block contained 100 provenances of 25 young trees each on average. The measurements were carried out in the years 1969, 1972, 1975, 1978, 1983 and 1988.

The mean heights in blocks, locations and years were converted into values expressed in units of the standard deviation for the given year and block.

Methods of statistical analysis

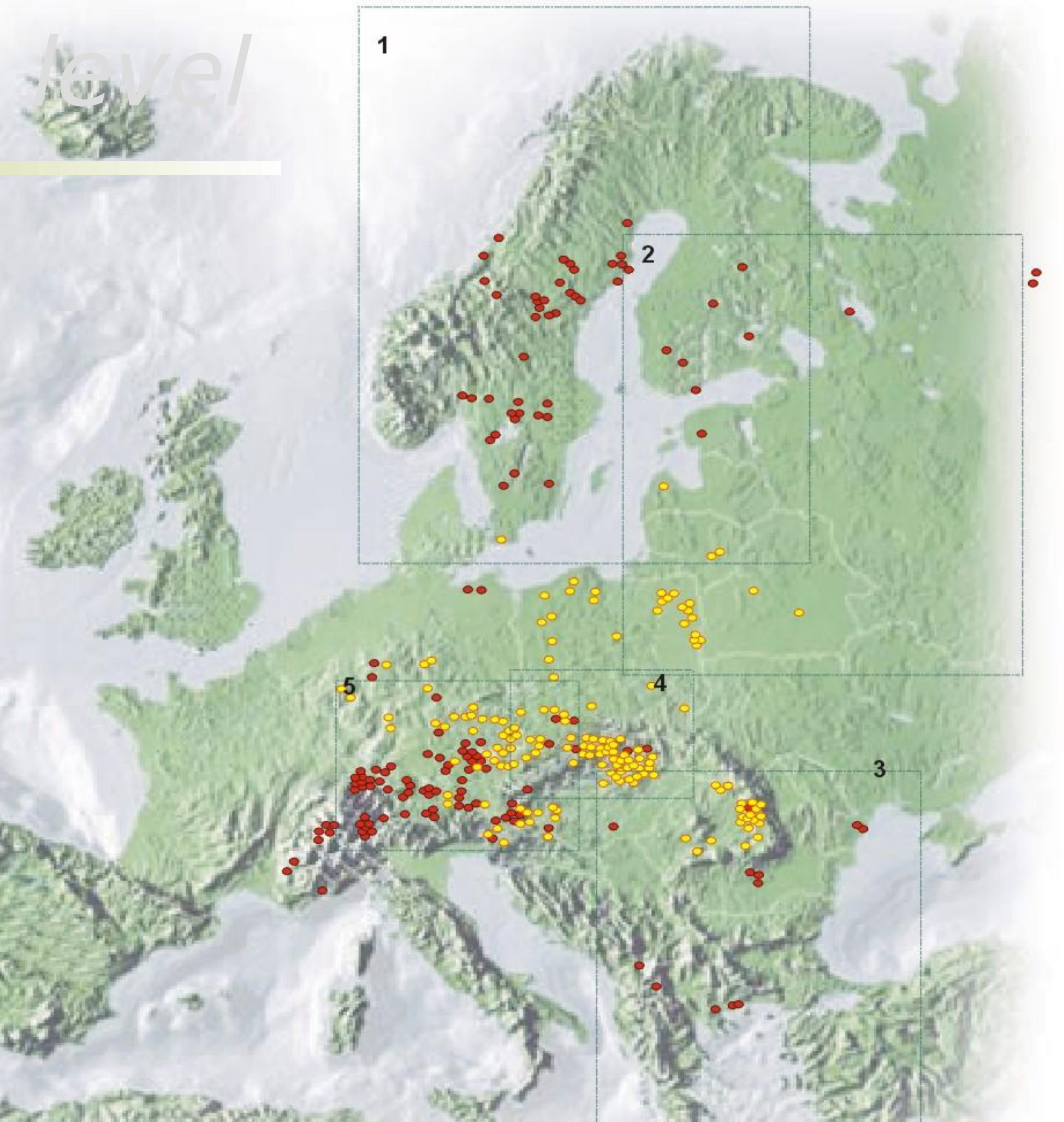
In evaluating the variability between the regions and between the years analysis of variance was applied with repetitions.

Cluster analysis with Euclidean distance was used for grouping similar regions.

The calculations were carried out in the STATISTICA software package.

Provenace level

Provenance level



REGIONS:

1 – Scandinavian provenances
2 – N-NE provenances
3 – South provenances
4 – Carpathian provenances
5 – Alp provenances

Distribution of Norway spruce provenances with high and short tree height (based on measurments of 1978, tree age 15 years)
Provenance test of Norway spruce IPTNS – IUFRO 1964/68 in Krynica

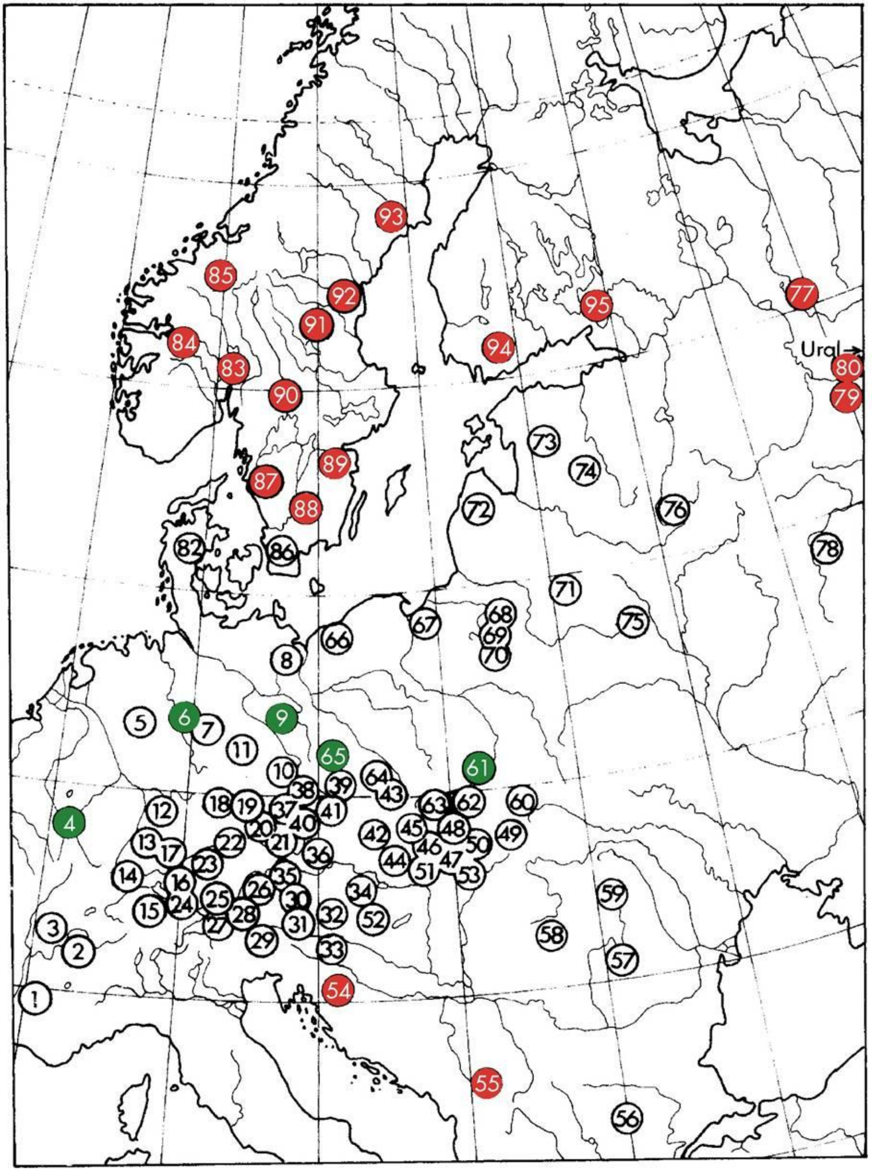
Differentation of average height of spruce provenances in relationship with attitude. (IPTNS-IUFRO 1964-68)

Altitude	Mean height in unit of standard deviation. Age 25 years		
	100 m	200 m	300 m
Powyżej 1700	-	-0,87	-0,95
1601-1700	-0,87		
1501-1600	-1,04	-0,32	-0,95
1401-1500	-0,29		-0,34
1301-1400	-0,55	-0,36	-0,34
1201-1300	-0,17		
1101-1200	-0,29	-0,20	-0,09
1001-1100	-0,07		
901-1000	0,10	0,14	-0,09
801-900	0,20		0,23
701-800	0,04	0,24	0,23
601-700	0,49		
501-600	0,41	0,26	0,19
401-500	0,15		
301-400	-0,27	-0,44	0,19
201-300	-0,61		-0,26
101-200	-0,14	-0,21	-0,26
0-100	-0,29		

Krutzsch regions level

Location of provenance regions of Krutzsch (1–95) after Schmidt-Vogt (1977)
Mean height of Norway spruce provenances in different years of observation.
Height is given in units of standard deviation from the block mean, IPTNS-IUFRO 1964/68, Krynica 1969

Age 6 years



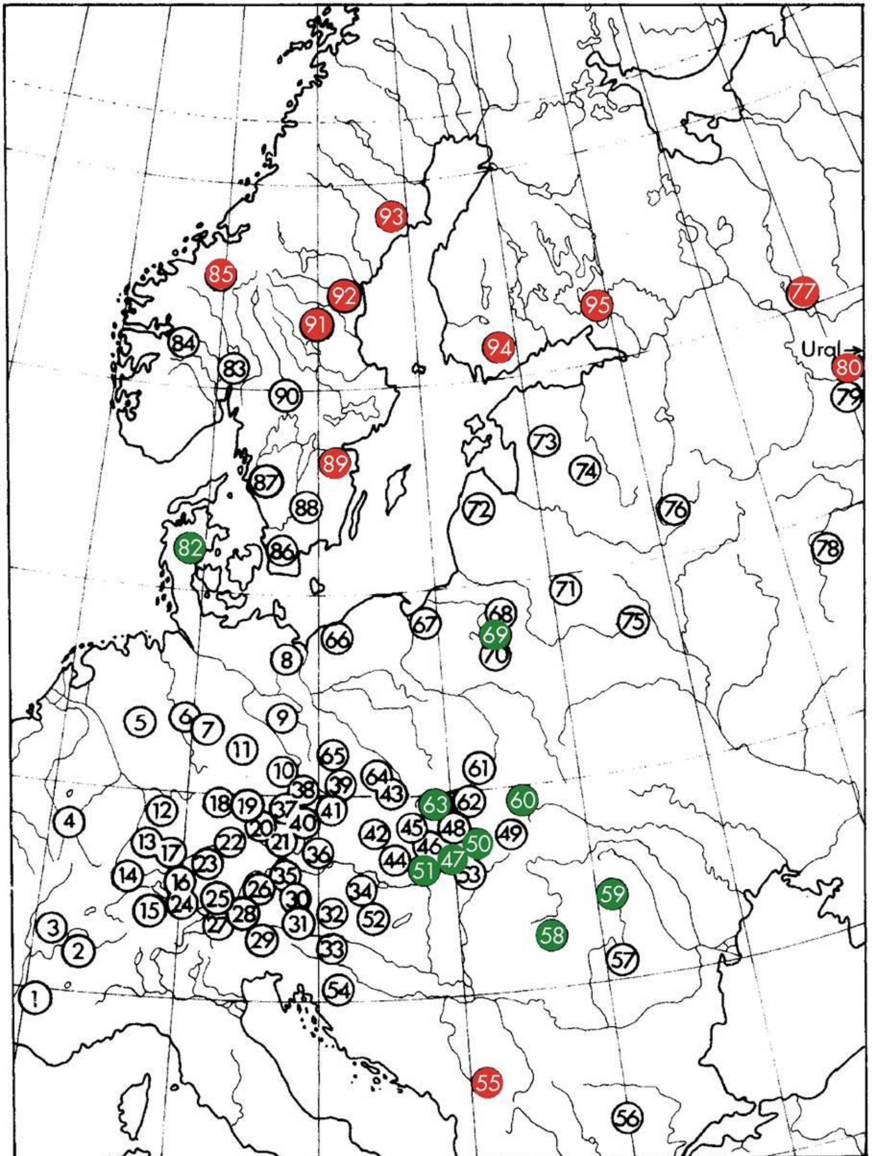
● $\overline{H}_{1969} \leq \bar{x} - 1S$ ● $\overline{H}_{1969} \geq \bar{x} + 1S$

No	Provenance	1969
1	Massif Central, Dauphine; France	0.86
2	West Alps: France	-0.58
3	Jura; France	-0.07
4	Ardennes, Vosges, Eifel; Belgium, France, Germany	1.04
5	Rheinisches Schiefergebirge, Hessian, Foothills; Germany	0.59
6	Harz Mts 1; Germany	1.30
7	Harz Mts 2 (Westerhof); Germany	0.52
8	Mecklenburg Lakeland, Schwerin, Rostock; Germany	0.18
9	Lausitz; Germany	1.18
10	Erzgebirge; Czech Republic	0.11
11	Thuringerwald; Germany	0.09
12	Odenwald; Germany	0.76
13	Schwarzwald (Baden-Wurttemberg); Germany	0.26
14	Breisgau; Germany	-0.28
15	West (Lepontine) Alps; Switzerland	-0.51
16	Swabian Upland (Wurttemberg); Germany	0.19
17	Swabian Jura; Germany	0.49
18	Franconian Jury; Germany	0.93
19	Franconia, Upper Palatinate; Germany	0.83
20	Bavarian Forest; Germany	-0.11
21	Bohemian Forest; Czech Republik, Germany	-0.10
22	Swabian-BavarianUpland (Bavaria) 1; Germany	0.92
23	Swabian-BavarianUpland (Swabia) 2; Germany	0.67
24	Swabian-BavarianUpland (Swabia) 3; Germany	0.04
25	Bavarian Alps; Germany	-0.28
26	East Alps; Germany	0.15
27	Tyrol; Austria	-0.15
28	Tyrol-Salzburg; Austria	0.17
29	East Alps; Italy	-0.27
30	Niedrige Tauern, Styria; Austria	0.20
31	Carinthia-Styria; Austria	0.07
32	Styria (N-E) 1; Austria	0.11
33	Styria (S-E) 2; Austria	0.49
34	Styria (E) 3; Austria	-0.10
35	Upper Austria; Austria	0.12
36	Bohemian Upland, Lower Austria; Czech Republic, Austria	0.69
37	West Bohemia; Czech Republic	0.63
38	Central Bohemia; Czech Republic	0.42
39	Sudetes (Krkonose, Tafelgebirge); Czech Republic	-0.03
40	South Bohemia; Czech Republic	0.73
41	Bohemia; Czech Republic	0.53
42	South Bohemia, Moravia; Czech Republic	0.41
43	Moravia 1; Czech Republic	0.74
44	Moravia 2; Czech Republic	0.40
45	Moravia 3; Czech Republic	0.20
46	Velka Fatra, Mala Fatra, Slovakia	0.85
47	Nizke Tatry; Slovakia	0.19
48	Tatras; Slovakia, Poland	-0.62

No	Provenance	1969
49	East Slovakia (Spis); Slovakia	0.44
50	Slovenske Rudohorie; Slovakia	0.19
51	Stiavnicke Pohorie; Slovakia	0.73
52	West Hungary; Hungary	0.14
53	North Hungary; Hungary	-0.81
54	Dalmatia; Croatia	-1.01
55	Montenegro; Yugoslavia	-1.44
56	Rhodope Mts; Bulgaria	-0.75
57	Southern Carpathians, Transylvanian Upland; Romania	-0.66
58	Bihor Mts,Transylvanian; Romania	0.12
59	East Carpathians; Romania	-0.12
60	East Beskids (Tarnawa); Poland	0.21
61	Little Poland Upland; Poland	1.16
62	Babia Góra, Beskid Sądecki; Poland	0.25
63	Beskid Śląski, Beskid Żywiecki;Poland	-0.10
64	Kłodzko Valley; Poland	0.59
65	Silesian Lowland, Great poland Lowland; Poland	1.31
66	West-Pomeranian Lakeland; Poland	0.46
67	East-Pomeranian Lakeland, Warmia, Masuria; Poland	0.24
68	Masurian Lakeland; Poland	0.29
69	Augustów Lakeland, Podlasie; Poland	0.49
70	Białowieża Primeval Forerst; Poland	-0.14
71	Vilnius Lakeland, Belarus Lakeland; Lithuania, Belarus	-0.13
72	Latvia, Estonia, 1	-0.70
73	Latvia, Estonia, 2	-0.54
74	Latvia, Estonia, 3	-0.69
75	Belarus	-0.25
76	East Russia (Valdai Hills); Russia	-0.91
77	Russia 1	-1.78
78	Russia 2 (Central Russian Upland, Smolensk-Moscow Heights)	-0.55
79	Udmurtsk (Upper Kama Upland); Russia	-1.52
80	West Siberia; Russia	-1.63
81	Knusk; Russia	0.23
82	Jutland,(Denmark)	0.32
83	Bogstad (Ostland); Norway	-1.18
84	S-E Norway; Norway	-1.67
85	Central Norway; Norway	-2.13
86	Scania; Sweden	-0.68
87	Gotland, Smaland (S-E Sweden); Sweden	-1.18
88	Gotland; Sweden	-1.42
89	Sondermanland (S-E Sweden); Sweden	-1.53
90	Central Sweden; Sweden	-1.47
91	Norrland; Sweden	-1.72
92	Madelpad, Angermanland; Sweden	-2.26
93	S-E Sweden Cost; Sweden	-2.38
94	South Finland; Finland	-1.35
95	Karelian; Finland, Russia	-1.99
96	Hudson, Ontario; Canada	0.20

Krutzsch regions level

Location of provenance regions of Krutzsch (1–95) after Schmidt-Vogt (1977)
Mean height of Norway spruce provenances in different years of observation.
Height is given in units of standard deviation from the block mean, IPTNS-IUFRO 1964/68, Krynica 1978 **Age 15 years**



● $\overline{H}_{1978} \leq \bar{x} - 1S$ (red)

● $\overline{H}_{1978} \geq \bar{x} + 1S$ (green)

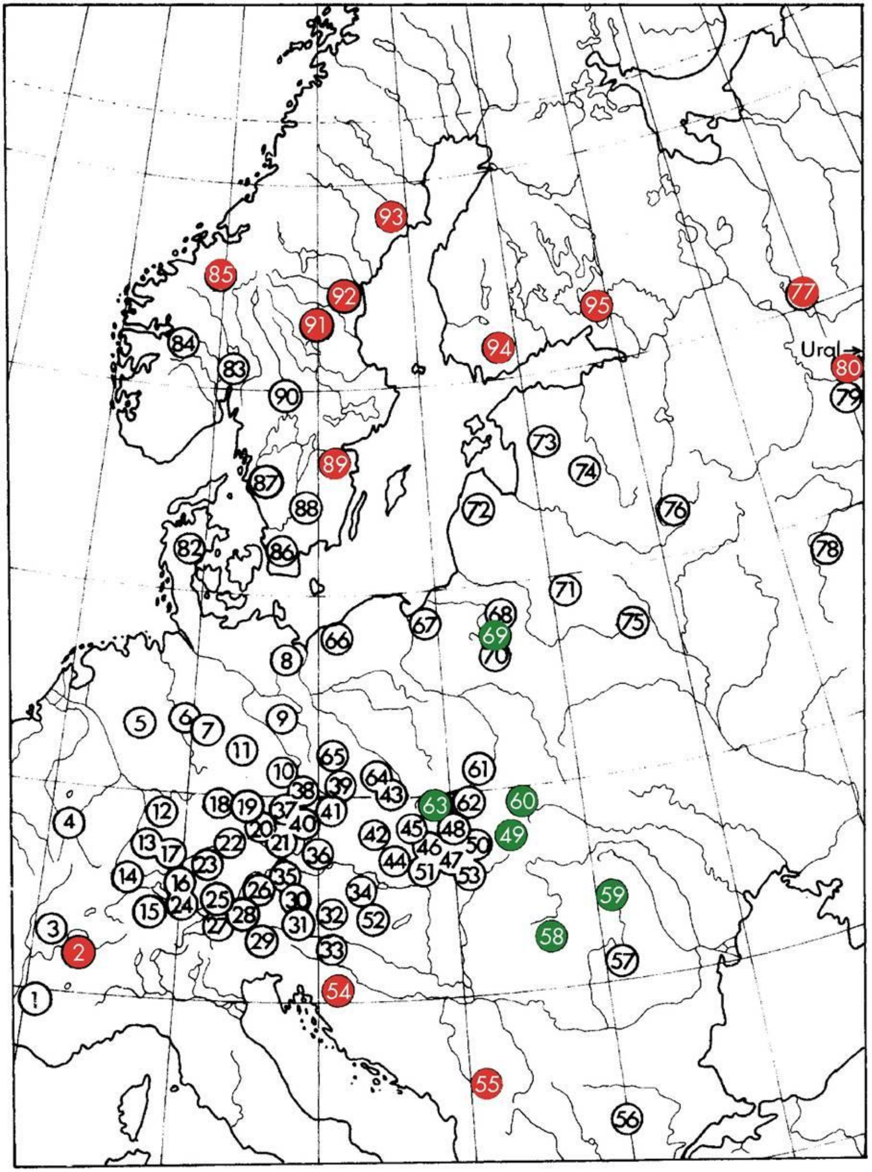
No	Provenance	1978
1	Massif Central, Dauphine; France	-0.70
2	West Alps: France	-0.78
3	Jura; France	-0.48
4	Ardennes, Vosges, Eifel; Belgium, France, Germany	0.64
5	Rheinisches Schiefergebirge, Hessian, Foothills; Germany	-0.06
6	Harz Mts 1; Germany	0.16
7	Harz Mts 2 (Westerhof); Germany	0.16
8	Mecklenburg Lakeland, Schwerin, Rostock; Germany	-0.57
9	Lausitz; Germany	0.04
10	Erzgebirge; Czech Republic	0.57
11	Thuringerwald; Germany	-0.09
12	Odenwald; Germany	0.17
13	Schwarzwald (Baden-Wurttemberg); Germany	-0.36
14	Breisgau; Germany	-0.74
15	West (Lepontine) Alps; Switzerland	-0.77
16	Swabian Upland (Wurttemberg); Germany	-0.27
17	Swabian Jura; Germany	-0.26
18	Franconian Jury; Germany	0.22
19	Franconia, Upper Palatinate; Germany	0.66
20	Bavarian Forest; Germany	-0.15
21	Bohemian Forest; Czech Republik, Germany	-0.35
22	Swabian-Bavarian Upland (Bavaria) 1; Germany	-0.24
23	Swabian-Bavarian Upland (Swabia) 2; Germany	-0.19
24	Swabian-Bavarian Upland (Swabia) 3; Germany	-0.26
25	Bavarian Alps; Germany	-0.20
26	East Alps; Germany	0.02
27	Tyrol; Austria	-0.64
28	Tyrol-Salzburg; Austria	-0.19
29	East Alps; Italy	-0.30
30	Niedrige Tauern, Styria; Austria	-0.08
31	Carinthia-Styria; Austria	-0.09
32	Styria (N-E) 1; Austria	-0.01
33	Styria (S-E) 2; Austria	0.39
34	Styria (E) 3; Austria	-0.39
35	Upper Austria; Austria	-0.49
36	Bohemian Upland, Lower Austria; Czech Republic, Austria	0.40
37	West Bohemia; Czech Republic	0.29
38	Central Bohemia; Czech Republic	0.37
39	Sudetes (Krkonose, Tafelgebirge); Czech Republic	0.70
40	South Bohemia; Czech Republic	0.59
41	Bohemia; Czech Republic	0.73
42	South Bohemia, Moravia; Czech Republic	0.29
43	Moravia 1; Czech Republic	0.63
44	Moravia 2; Czech Republic	0.31
45	Moravia 3; Czech Republic	0.55
46	Velka Fatra, Mala Fatra, Slovakia	0.41
47	Nizke Tatry; Slovakia	1.04
48	Tatras; Slovakia, Poland	0.57

No	Provenance	1978
49	East Slovakia (Spis); Slovakia	0.90
50	Slovenske Rudohorie; Slovakia	1.14
51	Stiavnicke Pohorie; Slovakia	1.36
52	West Hungary; Hungary	0.68
53	North Hungary; Hungary	0.47
54	Dalmatia; Croatia	-0.60
55	Montenegro; Yugoslavia	-1.38
56	Rhodope Mts; Bulgaria	-0.55
57	Southern Carpathians, Transylvanian Upland; Romania	-0.86
58	Bihor Mts,Transylvanian; Romania	1.27
59	East Carpathians; Romania	1.20
60	East Beskids (Tarnawa); Poland	1.50
61	Little Poland Upland; Poland	0.75
62	Babia Góra, Beskid Sądecki; Poland	-0.07
63	Beskid Śląski, Beskid Żywiecki;Poland	1.19
64	Kłodzko Valley; Poland	0.03
65	Silesian Lowland, Great poland Lowland; Poland	0.67
66	West-Pomeranian Lakeland; Poland	0.48
67	East-Pomeranian Lakeland, Warmia, Masuria; Poland	0.44
68	Masurian Lakeland; Poland	0.87
69	Augustów Lakeland, Podlasie; Poland	1.20
70	Białowieża Primeval Forerst; Poland	0.69
71	Vilnius Lakeland, Belarus Lakeland; Lithuania, Belarus	0.59
72	Latvia, Estonia, 1	0.11
73	Latvia, Estonia, 2	-0.17
74	Latvia, Estonia, 3	0.21
75	Belarus	0.88
76	East Russia (Valdai Hills); Russia	-0.05
77	Russia 1	-1.29
78	Russia 2 (Central Russian Upland, Smolensk-Moscow Heights)	-0.32
79	Udmurtsk (Upper Kama Upland); Russia	-0.86
80	West Siberia; Russia	-1.74
81	Knusk; Russia	0.83
82	Jutland,(Denmark)	1.12
83	Bogstad (Ostland); Norway	-0.41
84	S-E Norway; Norway	-0.57
85	Central Norway; Norway	-1.70
86	Scania; Sweden	0.15
87	Gotland, Smaland (S-E Sweden); Sweden	-0.57
88	Gotland; Sweden	-0.65
89	Sondermanland (S-E Sweden); Sweden	-1.21
90	Central Sweden; Sweden	-0.70
91	Norrland; Sweden	-1.88
92	Madelpad, Angermanland; Sweden	-1.73
93	S-E Sweden Cost; Sweden	-2.62
94	South Finland; Finland	-1.17
95	Karelian; Finland, Russia	-1.74
96	Hudson, Ontario; Canada	1.97

Krutzsch regions level

Location of provenance regions of Krutzsch (1–95) after Schmidt-Vogt (1977)
Mean height of Norway spruce provenances in different years of observation.
Height is given in units of standard deviation from the block mean, IPTNS-IUFRO 1964/68, Krynica 1988

Age 25 years



$\overline{H}_{1988} \le \bar{x} - 1S$ $\overline{H}_{1988} \ge \bar{x} + 1S$

No	Provenance	1988
1	Massif Central, Dauphine; France	-0.88
2	West Alps: France	-1.08
3	Jura; France	-0.81
4	Ardennes, Vosges, Eifel; Belgium, France, Germany	0.81
5	Rheinisches Schiefergebirge, Hessian, Foothills; Germany	0.27
6	Harz Mts 1; Germany	0.60
7	Harz Mts 2 (Westerhof); Germany	0.50
8	Mecklenburg Lakeland, Schwerin, Rostock; Germany	-0.12
9	Lausitz; Germany	0.06
10	Erzgebirge; Czech Republic	0.52
11	Thuringerwald; Germany	0.08
12	Odenwald; Germany	0.34
13	Schwarzwald (Baden-Wurttemberg); Germany	-0.30
14	Breisgau; Germany	-0.81
15	West (Lepontine) Alps; Switzerland	-0.88
16	Swabian Upland (Wurttemberg); Germany	-0.18
17	Swabian Jura; Germany	-0.18
18	Franconian Jury; Germany	0.40
19	Franconia, Upper Palatinate; Germany	0.63
20	Bavarian Forest; Germany	0.22
21	Bohemian Forest; Czech Republik, Germany	-0.47
22	Swabian-BavarianUpland (Bavaria) 1; Germany	-0.15
23	Swabian-BavarianUpland (Swabia) 2; Germany	-0.08
24	Swabian-BavarianUpland (Swabia) 3; Germany	-0.11
25	Bavarian Alps; Germany	-0.34
26	East Alps; Germany	0.00
27	Tyrol; Austria	-0.73
28	Tyrol-Salzburg; Austria	-0.08
29	East Alps; Italy	-0.24
30	Niedrige Tauern, Styria; Austria	-0.10
31	Carinthia-Styria; Austria	-0.06
32	Styria (N-E) 1; Austria	0.04
33	Styria (S-E) 2; Austria	0.33
34	Styria (E) 3; Austria	-0.09
35	Upper Austria; Austria	-0.53
36	Bohemian Upland, Lower Austria; Czech Republic, Austria	0.45
37	West Bohemia; Czech Republic	0.62
38	Central Bohemia; Czech Republic	0.30
39	Sudetes (Krkonose, Tafelgebirge); Czech Republic	0.70
40	South Bohemia; Czech Republic	0.36
41	Bohemia; Czech Republic	0.63
42	South Bohemia, Moravia; Czech Republic	0.40
43	Moravia 1; Czech Republic	0.72
44	Moravia 2; Czech Republic	0.53
45	Moravia 3; Czech Republic	0.67
46	Velka Fatra, Mala Fatra, Slovakia	0.65
47	Nizke Tatry; Slovakia	0.96
48	Tatras; Slovakia, Poland	0.51

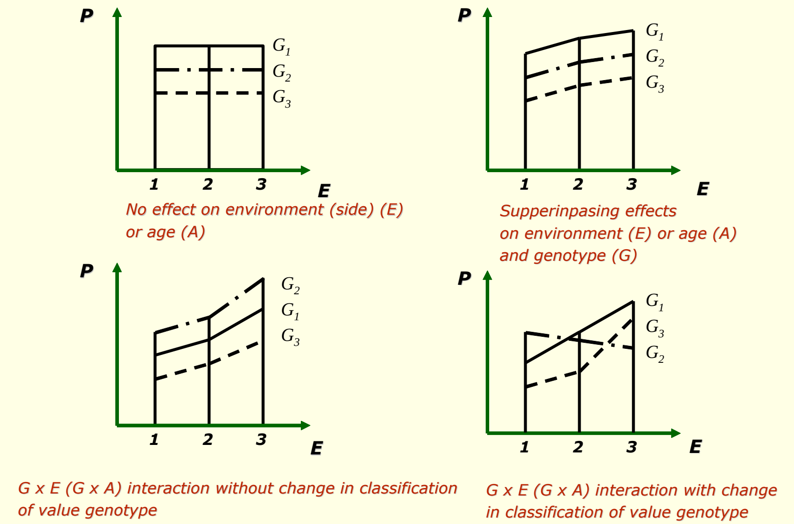
No	Provenance	1988
49	East Slovakia (Spis); Slovakia	1.11
50	Slovenske Rudohorie; Slovakia	0.92
51	Stiavnicke Pohorie; Slovakia	0.99
52	West Hungary; Hungary	0.75
53	North Hungary; Hungary	0.13
54	Dalmatia; Croatia	-1.01
55	Montenegro; Yugoslavia	-1.83
56	Rhodope Mts; Bulgaria	-0.79
57	Southern Carpathians, Transylvanian Upland; Romania	-0.60
58	Bihor Mts,Transylvanian; Romania	1.04
59	East Carpathians; Romania	1.34
60	East Beskids (Tarnawa); Poland	1.33
61	Little Poland Upland; Poland	0.29
62	Babia Góra, Beskid Sądecki; Poland	0.54
63	Beskid Śląski, Beskid Żywiecki;Poland	1.11
64	Kłodzko Valley; Poland	0.26
65	Silesian Lowland, Great poland Lowland; Poland	0.70
66	West-Pomeranian Lakeland; Poland	0.72
67	East-Pomeranian Lakeland, Warmia, Masuria; Poland	0.47
68	Masurian Lakeland; Poland	0.80
69	Augustów Lakeland, Podlasie; Poland	1.12
70	Białowieża Primeval Forerst; Poland	0.35
71	Vilnius Lakeland, Belarus Lakeland; Lithuania, Belarus	0.40
72	Latvia, Estonia, 1	0.19
73	Latvia, Estonia, 2	-0.26
74	Latvia, Estonia, 3	0.32
75	Belarus	0.31
76	East Russia (Valdai Hills); Russia	-0.36
77	Russia 1	-1.58
78	Russia 2 (Central Russian Upland, Smolensk-Moscow Heights)	-0.45
79	Udmurtsk (Upper Kama Upland); Russia	-1.64
80	West Siberia; Russia	-2.67
81	Knusk; Russia	0.55
82	Jutland,(Denmark)	0.74
83	Bogstad (Ostland); Norway	-0.61
84	S-E Norway; Norway	-0.81
85	Central Norway; Norway	-2.12
86	Scania; Sweden	0.34
87	Gotland, Smaland (S-E Sweden); Sweden	-0.55
88	Gotland; Sweden	-0.36
89	Sondermanland (S-E Sweden); Sweden	-1.36
90	Central Sweden; Sweden	-0.61
91	Norrland; Sweden	-2.28
92	Madelpad, Angermanland; Sweden	-2.31
93	S-E Sweden Cost; Sweden	-3.12
94	South Finland; Finland	-1.72
95	Karelian; Finland, Russia	-2.07
96	Hudson, Ontario; Canada	1.17

Methods of statistical analysis

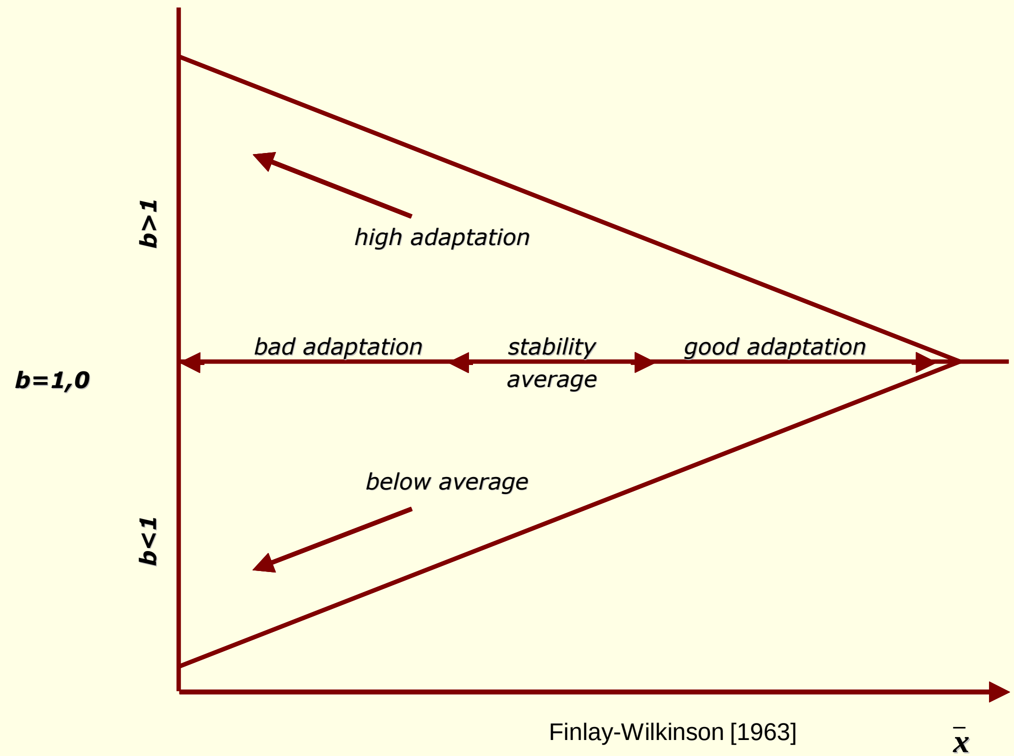
In evaluating the variability between the regions and between the years analysis of variance was applied with repetitions.

Cluster analysis with Euclidean distance was used for grouping similar provenance regions according to G x Age interaction using Finlay-Wilkinson [1963] and Mallard methods. (From Gallais [1990]).

The calculations were carried out in the STATISTICA software package.



Genotypic provenance response to environment; G_1, G_2, G_3 – genotypes; 1?3 – increasing productivity of site (E); P – value of genotype (defined by survival of trees in plantation)



Finlay-Wilkinson [1963]

Krutsch regions level

G × Age interaction

Group 1: very good height growth, no effect of G × A interaction

Group 2: average height growth, no effect of G × A interaction

Group 3: bad height growth, no effect of G × A interaction

Group 4: very bad height growth, no G × A interaction effect

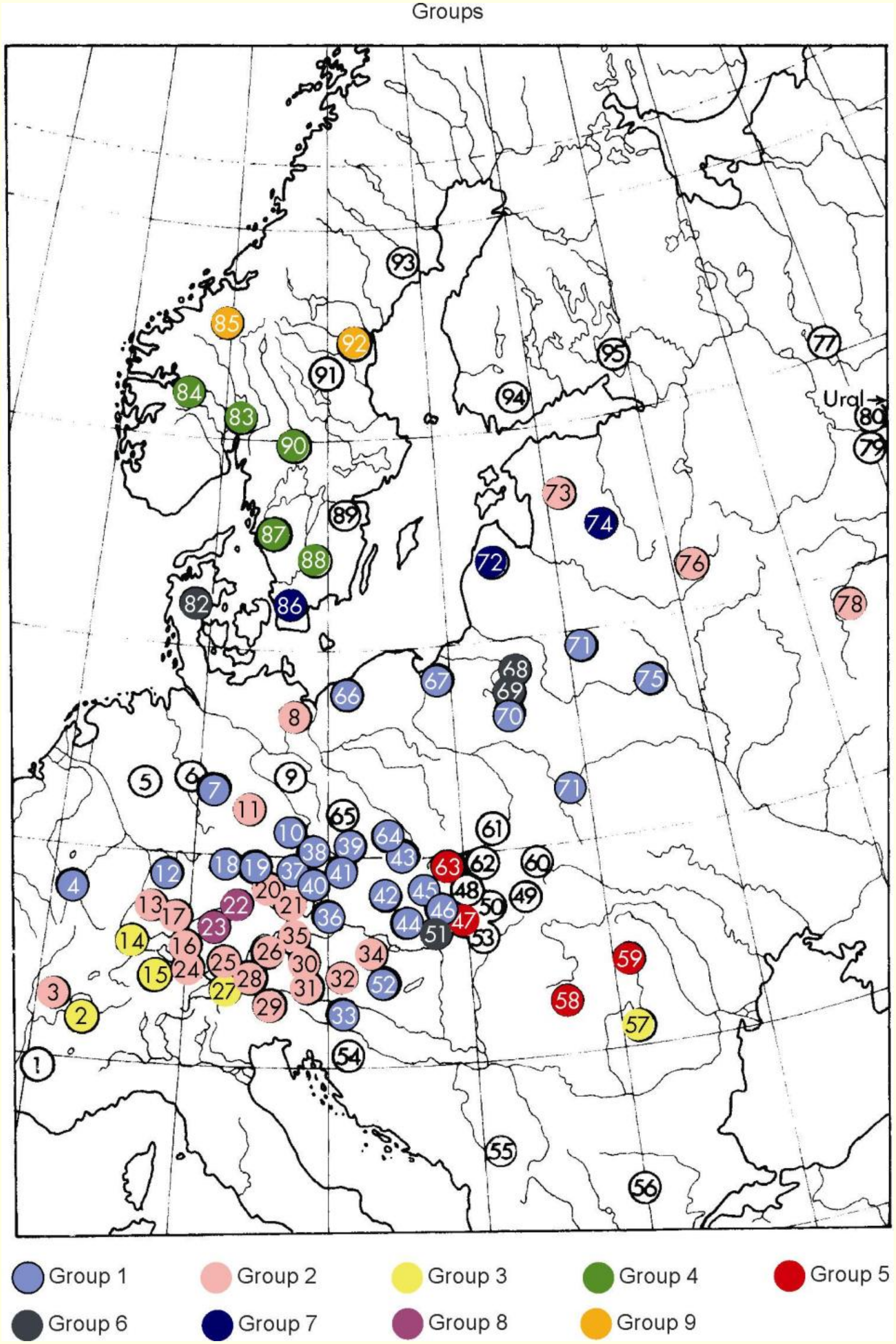
Group 5: average height growth, no G × A interaction effect

Group 6: average height growth, significant G × A interaction effect, mean height increases with age

Group 7: very bad height growth, significant G × A interaction effect, mean height increases with age

Group 8: low value of height growth, G × A interaction effect

Group 9: very low value of height growth, G × A interaction effect



Different adaptability of Norway Spruce in IUFRO Test 1964-1968. G x A in years 1969-1988 (age 6-25)

1. West, central Europe and East Baltic Krutsch regions
2. SW Europe, Russia
3. West Alps, Southern Carpathians
4. S Scandinavian Krutsch regions
5. West Carpathians (Beskid), East Carpathians; Bihor Mts, Transylvanian, Romania
6. Poland Masurian Likeland
7. Latvia, Estonia
8. Swabian Upland, Germany
9. Central Scandinavian Krutsch regions

IUFRO 1964/68 - Investigations:

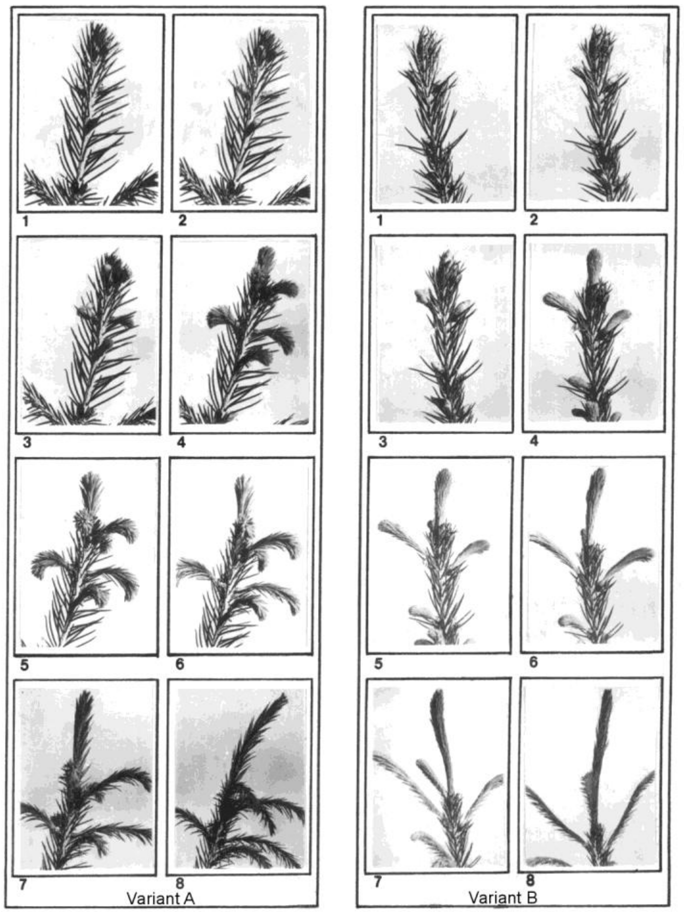
IUFRO 1964/68

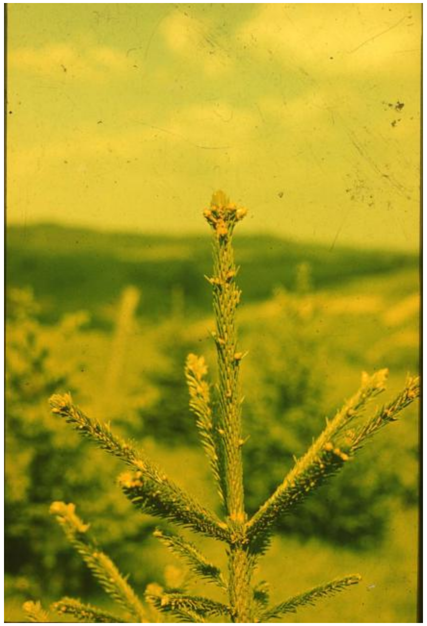
The spring flushing of Norway spruce tested at Krynica was evaluated on the basis of analyses of the degree of development of individual trees using a classification of the developmental phases of spruce worked out by Krutzsch.

Spring flushing in age 15.

Developmental phases of Norway spruce in the annual cycle of spring flushing. Variants A i B according to Krutsch.

(Krutrsch P. 1973. IUFRO S. 2.02.11 Norway spruce. Development of buds. The Royal College of Forestry, Stockholm, Sweden.

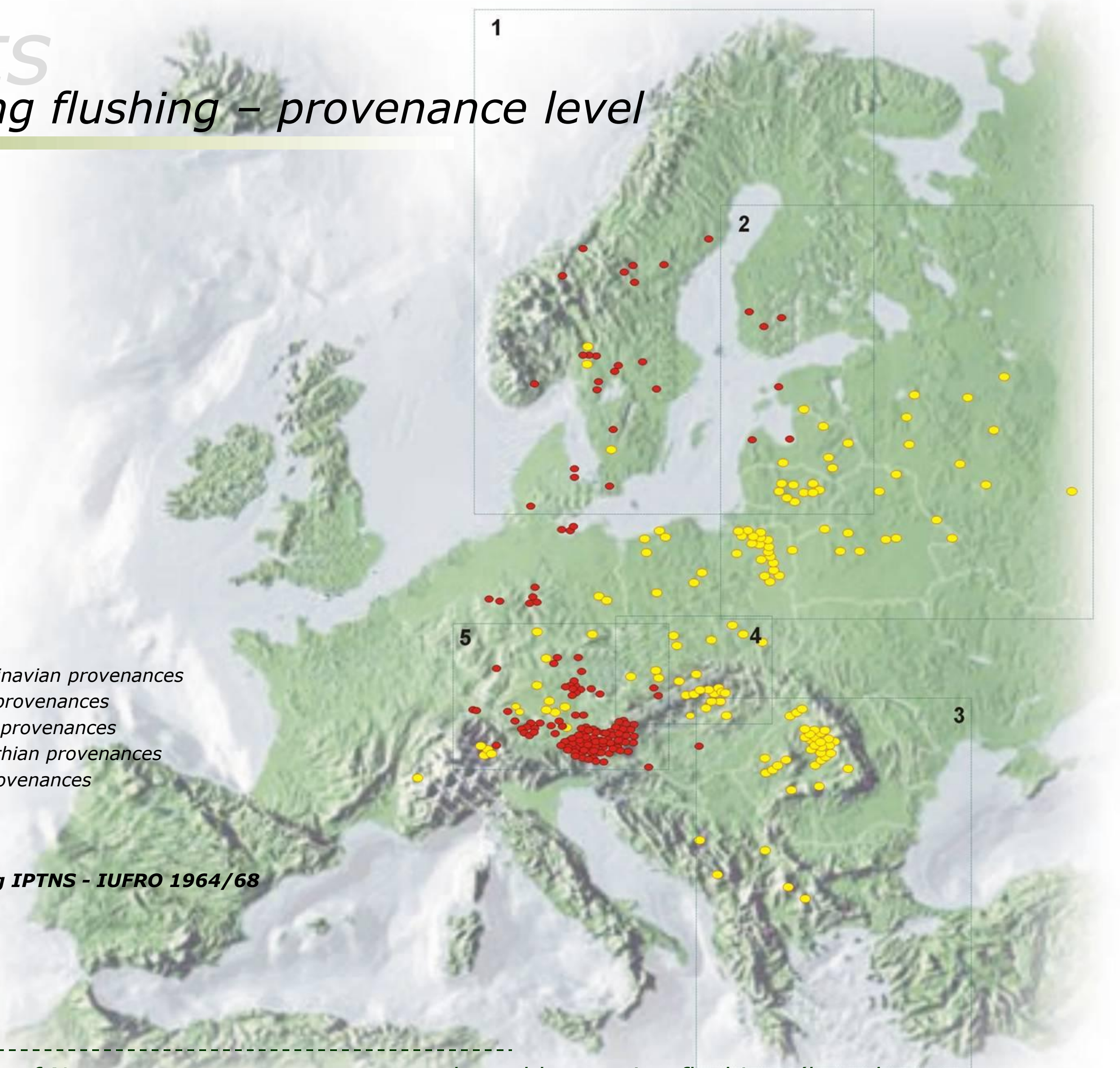




Results

Results spring flushing – provenance level



REGIONS:

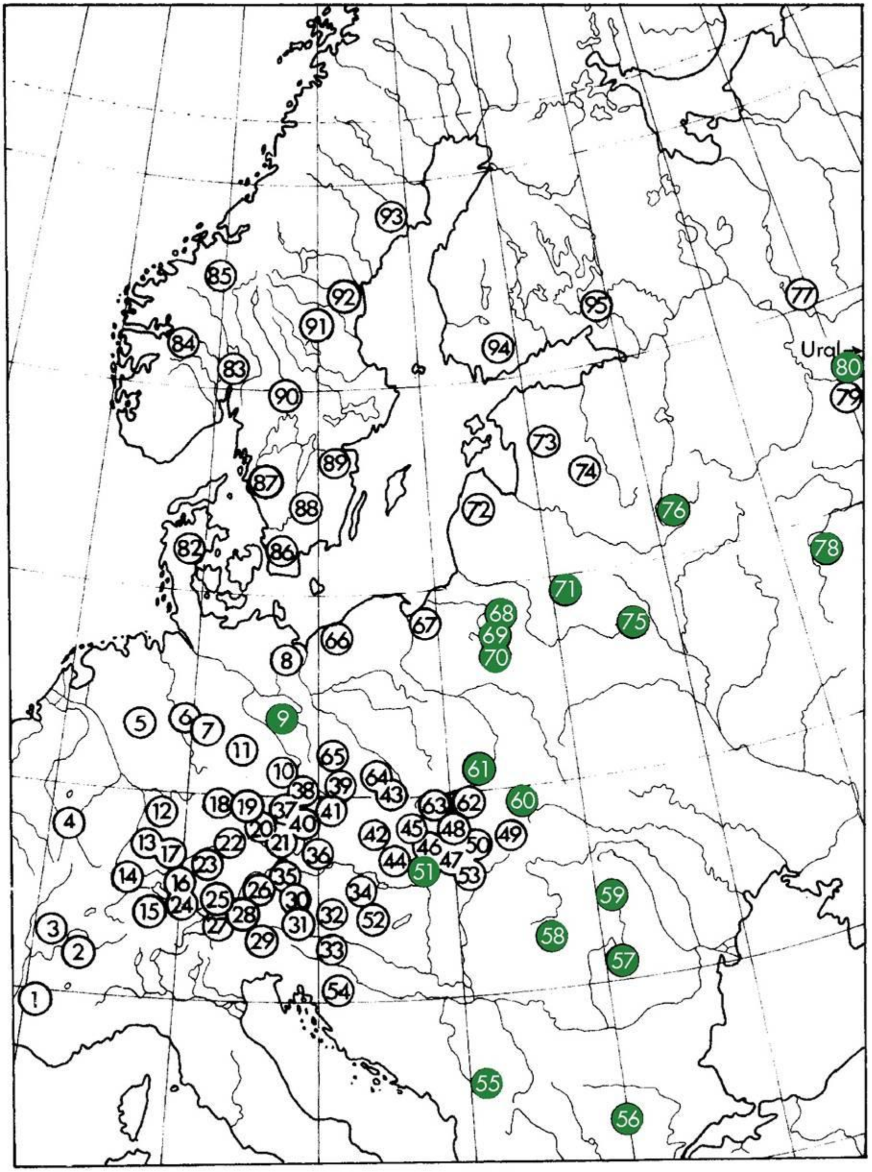
1 – Scandinavian provenances
2 – N-NE provenances
3 – South provenances
4 – Carpathian provenances
5 – Alp provenances

Numeracja pochodzeń wg IPTNS - IUFRO 1964/68

- late provenances
- early provenances

RYC.2. Distribution of Norway spruce provenances early and late spring flushing. (based on measurments of 1975). Provenance test of Norway spruce IPTNS – IUFRO 1964/68 in Krynica

Probability of occurrence of late flushing provenances in Krutzsch's regions
Fraction of provenances



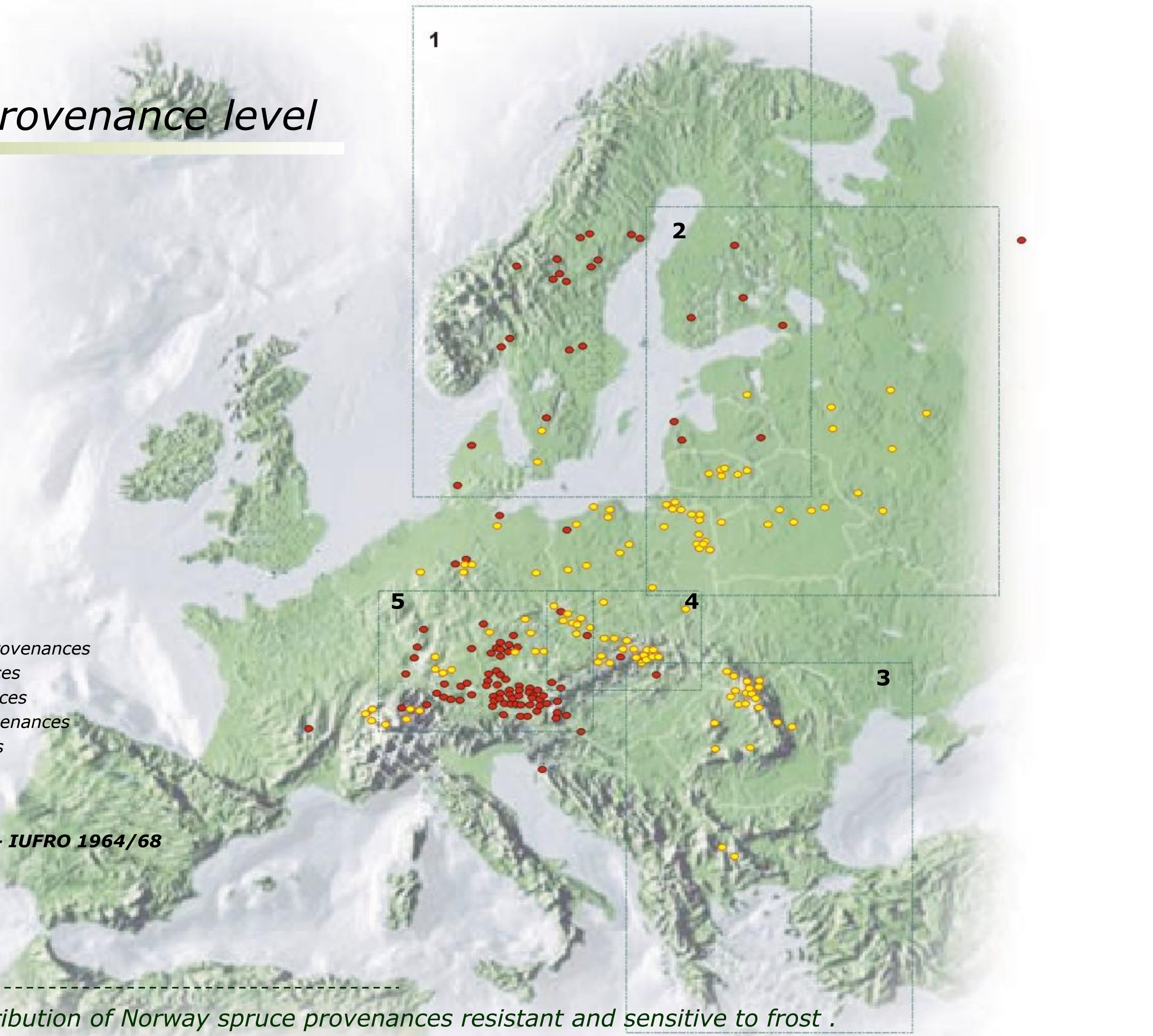
Probability ≥ 0.500

No	Provenance	late flushing
1	Massif Central, Dauphine; France	0.200
2	West Alps: France	0.077
3	Jura; France	0.000
4	Ardennes, Vosges, Eifel; Belgium, France, Germany	0.000
5	Rheinisches Schiefergebirge, Hessian, Foothills; Germany	0.000
6	Harz Mts 1; Germany	0.000
7	Harz Mts 2 (Westerhof); Germany	0.000
8	Mecklenburg Lakeland, Schwerin, Rostock; Germany	0.000
9	Lausitz; Germany	1.000
10	Erzgebirge; Czech Republic	0.091
11	Thuringerwald; Germany	0.111
12	Odenwald; Germany	0.000
13	Schwarzwald (Baden-Wurttemberg); Germany	0.000
14	Breisgau; Germany	0.000
15	West (Lepontine) Alps; Switzerland	0.235
16	Swabian Upland (Wurttemberg); Germany	0.000
17	Swabian Jura; Germany	0.000
18	Franconian Jury; Germany	0.091
19	Franconia, Upper Palatinate; Germany	0.091
20	Bavarian Forest; Germany	0.000
21	Bohemian Forest; Czech Republik, Germany	0.000
22	Swabian-Bavarian Upland (Bavaria) 1; Germany	0.194
23	Swabian-Bavarian Upland (Swabia) 2; Germany	0.059
24	Swabian-Bavarian Upland (Swabia) 3; Germany	0.000
25	Bavarian Alps; Germany	0.000
26	East Alps; Germany	0.000
27	Tyrol; Austria	0.000
28	Tyrol-Salzburg; Austria	0.000
29	East Alps; Italy	0.000
30	Niedrige Tauern, Styria; Austria	0.000
31	Carinthia-Styria; Austria	0.000
32	Styria (N-E) 1; Austria	0.000
33	Styria (S-E) 2; Austria	0.000
34	Styria (E) 3; Austria	0.000
35	Upper Austria; Austria	0.000
36	Bohemian Upland, Lower Austria; Czech Republic, Austria	0.000
37	West Bohemia; Czech Republic	0.000
38	Central Bohemia; Czech Republic	0.000
39	Sudetes (Krkonose, Tafelgebirge); Czech Republic	0.000
40	South Bohemia; Czech Republic	0.000
41	Bohemia; Czech Republic	0.000
42	South Bohemia, Moravia; Czech Republic	0.040
43	Moravia 1; Czech Republic	0.100
44	Moravia 2; Czech Republic	0.091
45	Moravia 3; Czech Republic	0.042
46	Velka Fatra, Mala Fatra, Slovakia	0.200
47	Nizke Tatry; Slovakia	0.304
48	Tatras; Slovakia, Poland	0.200

No	Provenance	late flushing
49	East Slovakia (Spis); Slovakia	0.333
50	Slovenske Rudohorie; Slovakia	0.429
51	Stiavnicke Pohorie; Slovakia	1.000
52	West Hungary; Hungary	0.000
53	North Hungary; Hungary	0.250
54	Dalmatia; Croatia	0.000
55	Montenegro; Yugoslavia	0.667
56	Rhodope Mts; Bulgaria	0.688
57	Southern Carpathians, Transylvanian Upland; Romania	0.600
58	Bihor Mts,Transylvanian; Romania	1.000
59	East Carpathians; Romania	0.880
60	East Beskids (Tarnawa); Poland	1.000
61	Little Poland Upland; Poland	0.800
62	**Babia Góra, Beskid Sądecki;** Poland	0.000
63	**Beskid Śląski, Beskid Żywiecki;**Poland	0.067
64	**Kłodzko** Valley; Poland	0.111
65	Silesian Lowland, Great poland Lowland; Poland	0.300
66	West-Pomeranian Lakeland; Poland	0.235
67	East-Pomeranian Lakeland, Warmia, Masuria; Poland	0.250
68	Masurian Lakeland; Poland	1.000
69	Augustów Lakeland, Podlasie; Poland	0.875
70	**Białowieża** Primeval Forerst; Poland	1.000
71	Vilnius Lakeland, Belarus Lakeland; Lithuania, Belarus	1.000
72	Latvia, Estonia, 1	0.000
73	Latvia, Estonia, 2	0.400
74	Latvia, Estonia, 3	0.375
75	Belarus	1.000
76	East Russia (Valdai Hills); Russia	1.000
77	Russia 1	0.400
78	Russia 2 (Central Russian Upland, Smolensk-Moscow Heights)	1.000
79	Udmurtsk (Upper Kama Upland); Russia	0.000
80	West Siberia; Russia	0.667
81	Knusk; Russia	0.667
82	Jutland,(Denmark)	0.000
83	Bogstad (Ostland); Norway	0.200
84	S-E Norway; Norway	0.000
85	Central Norway; Norway	0.000
86	Scania; Sweden	0.000
87	Gotland, Smaland (S-E Sweden); Sweden	0.000
88	Gotland; Sweden	0.125
89	Sondermanland (S-E Sweden); Sweden	0.000
90	Central Sweden; Sweden	0.000
91	Norrland; Sweden	0.000
92	Madelpad, Angermanland; Sweden	0.000
93	S-E Sweden Cost; Sweden	0.000
94	South Finland; Finland	0.000
95	Karelian; Finland, Russia	0.000
96	Hudson, Ontario; Canada	1.000

Results

Results frost – provenance level



REGIONS:

1 – Scandinavian provenances
2 – N-NE provenances
3 – South provenances
4 – Carpathian provenances
5 – Alp provenances

Numeracja pochodzeń wg IPTNS - IUFRO 1964/68

- resistant provenances
- sensitive provenances

RYC.3. Distribution of Norway spruce provenances resistant and sensitive to frost .
(based on measurments of 1977).
Provenance test of Norway spruce IPTNS – IUFRO 1964/68 in Krynica

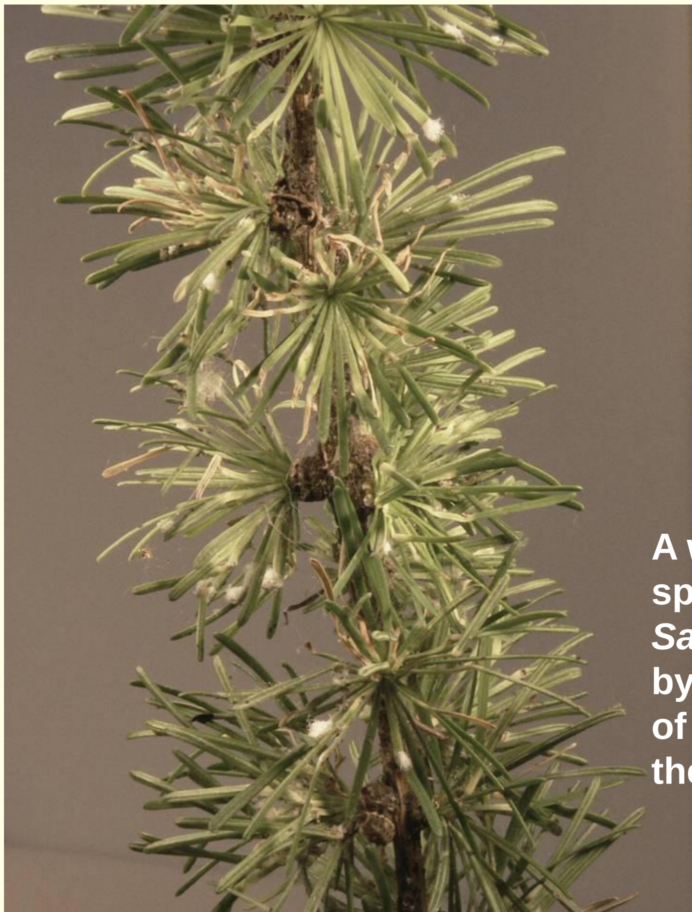
IUFRO 1964/68

IUFRO 1964/68 - Investigations:

Resistance to the infestation with Chermes viridis

Chermes viridis Ratz.
(Sacchiphantes abietis L.)

Observations were made on 11 and 12 June 1977 on all 23 843 specimens of 1095 Norway spruce provenances from the whole range of the species.

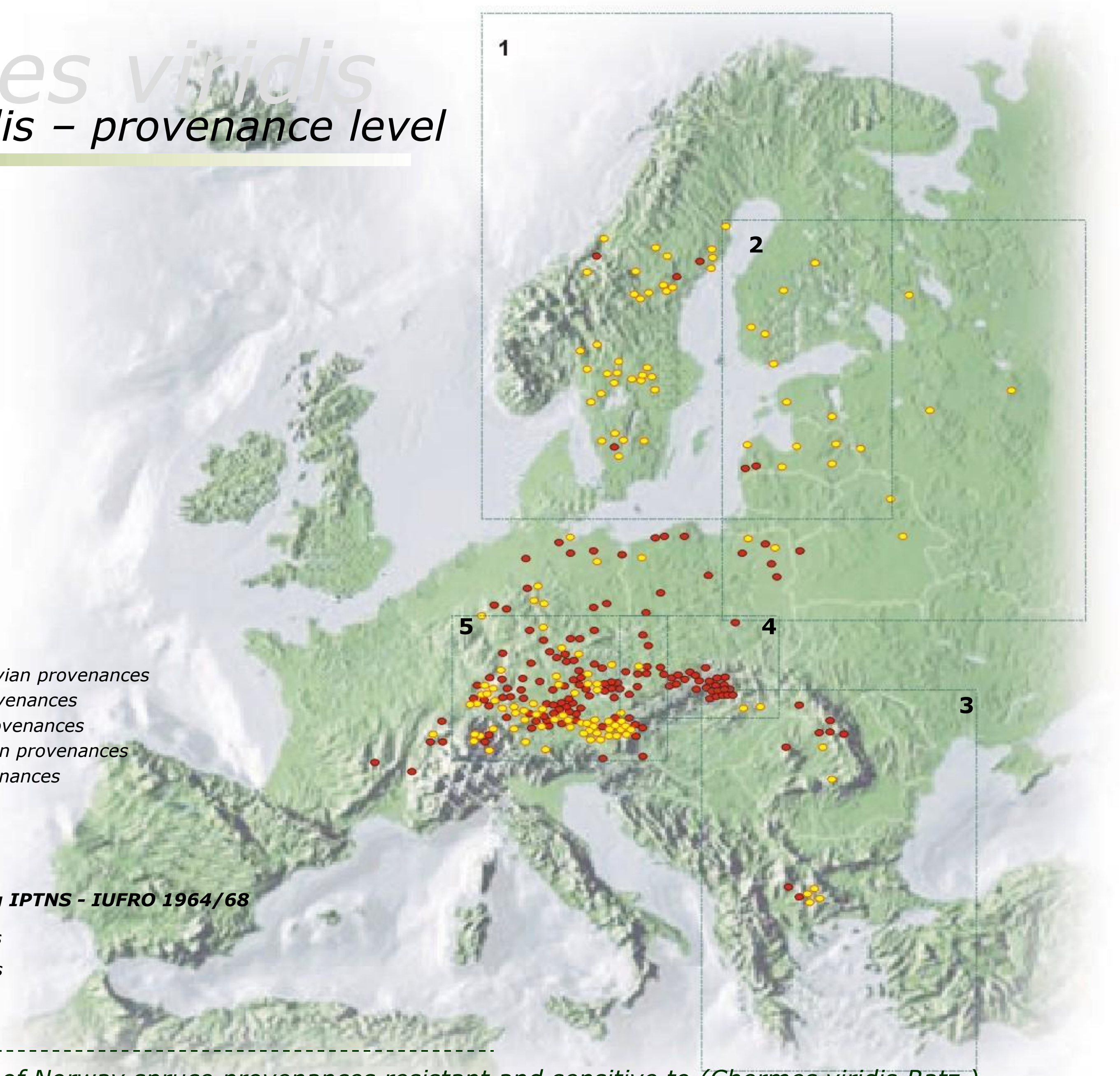


A well-known insect pest that causes much damage to Norway spruce plantations is *Chermes viridis* Ratz., called also *Sacchiphantes abietis* L. or *Adelges abietis* L. A plant infested by this aphid develops 2 – 3 cm-long excrescences at the base of young shoots, which results in their unnatural bending and the deformation of crowns in young trees.

fot. dr Robert Rosa

Chermes viridis

Chermes viridis – provenance level



REGIONS:

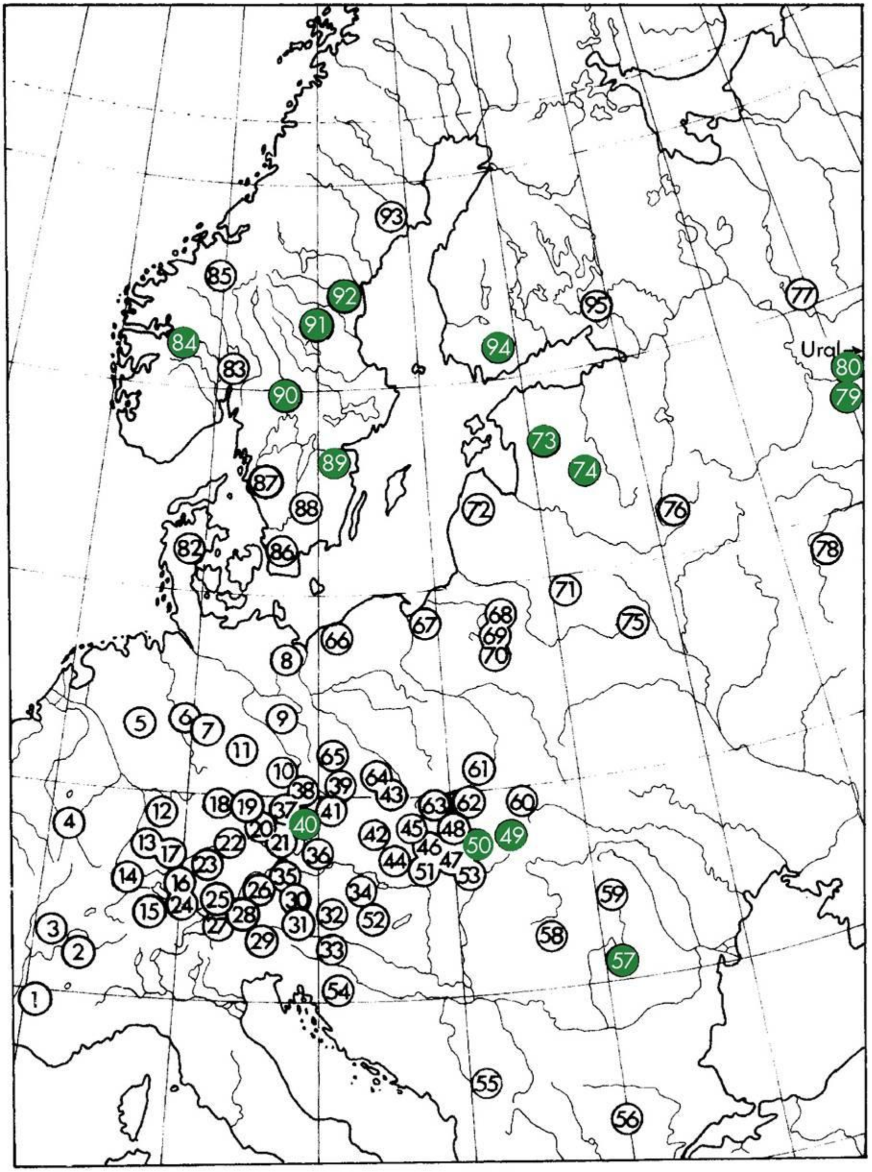
1 – Scandinavian provenances
2 – N-NE provenances
3 – South provenances
4 – Carpathian provenances
5 – Alp provenances

Numeracja pochodzeń wg IPTNS - IUFRO 1964/68

- resistant provenances
- sensitive provenances

RYC.4. Distribution of Norway spruce provenances resistant and sensitive to (Chermes viridis Ratz.).
Provenance test of Norway spruce IPTNS – IUFRO 1964/68 in Krynica

Resistance of Norway spruce provenances to *Chermes viridis* Ratz. by Krutzsch region (degree of damage from the aphid, φ (°), is expressed as arc sin $\sqrt{p}$, where *p* percentage of damaged trees)IPTNS-IUFRO 1964/68, Krynica



Degree of damage φ ≤ 40.00

No	Provenance	φ
1	Massif Central, Dauphine; France	47.117
2	West Alps: France	46.516
3	Jura; France	54.368
4	Ardennes, Vosges, Eifel; Belgium, France, Germany	40.990
5	Rheinisches Schiefergebirge, Hessian, Foothills; Germany	46.767
6	Harz Mts 1; Germany	41.595
7	Harz Mts 2 (Westerhof); Germany	50.074
8	Mecklenburg Lakeland, Schwerin, Rostock; Germany	47.997
9	Lausitz; Germany	45.660
10	Erzgebirge; Czech Republic	46.184
11	Thuringerwald; Germany	46.318
12	Odenwald; Germany	48.385
13	Schwarzwald (Baden-Wurttemberg); Germany	46.216
14	Breisgau; Germany	45.953
15	West (Lepontine) Alps; Switzerland	45.844
16	Swabian Upland (Wurttemberg); Germany	44.650
17	Swabian Jura; Germany	46.596
18	Franconian Jury; Germany	51.669
19	Franconia, Upper Palatinate; Germany	47.794
20	Bavarian Forest; Germany	43.233
21	Bohemian Forest; Czech Republik, Germany	47.880
22	Swabian-Bavarian Upland (Bavaria) 1; Germany	47.086
23	Swabian-Bavarian Upland (Swabia) 2; Germany	45.850
24	Swabian-Bavarian Upland (Swabia) 3; Germany	45.890
25	Bavarian Alps; Germany	45.720
26	East Alps; Germany	48.860
27	Tyrol; Austria	40.518
28	Tyrol-Salzburg; Austria	47.024
29	East Alps; Italy	40.598
30	Niedrige Tauern, Styria; Austria	41.770
31	Carinthia-Styria; Austria	46.182
32	Styria (N-E) 1; Austria	43.918
33	Styria (S-E) 2; Austria	53.664
34	Styria (E) 3; Austria	46.385
35	Upper Austria; Austria	46.790
36	Bohemian Upland, Lower Austria; Czech Republic, Austria	50.462
37	West Bohemia; Czech Republic	48.390
38	Central Bohemia; Czech Republic	49.857
39	Sudetes (Krkonose, Tafelgebirge); Czech Republic	52.885
40	South Bohemia; Czech Republic	39.610
41	Bohemia; Czech Republic	44.838
42	South Bohemia, Moravia; Czech Republic	45.830
43	Moravia 1; Czech Republic	47.330
44	Moravia 2; Czech Republic	47.650
45	Moravia 3; Czech Republic	47.466
46	Velka Fatra, Mala Fatra, Slovakia	52.262
47	Nizke Tatry; Slovakia	51.639
48	Tatras; Slovakia, Poland	49.700

No	Provenance	φ
49	East Slovakia (Spis); Slovakia	34.753
50	Slovenske Rudohorie; Slovakia	37.255
51	Stiavnicke Pohorie; Slovakia	57.040
52	West Hungary; Hungary	47.508
53	North Hungary; Hungary	49.000
54	Dalmatia; Croatia	58.810
55	Montenegro; Yugoslavia	52.336
56	Rhodope Mts; Bulgaria	43.950
57	Southern Carpathians, Transylvanian Upland; Romania	36.644
58	Bihor Mts,Transylvanian; Romania	48.210
59	East Carpathians; Romania	47.400
60	East Beskids (Tarnawa); Poland	49.200
61	Little Poland Upland; Poland	50.580
62	Babia Góra, Beskid Sądecki; Poland	48.752
63	Beskid Śląski, Beskid Żywiecki;Poland	48.830
64	Kłodzko Valley; Poland	48.613
65	Silesian Lowland, Great poland Lowland; Poland	46.370
66	West-Pomeranian Lakeland; Poland	53.906
67	East-Pomeranian Lakeland, Warmia, Masuria; Poland	47.220
68	Masurian Lakeland; Poland	47.440
69	Augustów Lakeland, Podlasie; Poland	48.090
70	Białowieża Primeval Forerst; Poland	54.840
71	Vilnius Lakeland, Belarus Lakeland; Lithuania, Belarus	45.770
72	Latvia, Estonia, 1	53.640
73	Latvia, Estonia, 2	37.850
74	Latvia, Estonia, 3	35.790
75	Belarus	47.350
76	East Russia (Valdai Hills); Russia	48.810
77	Russia 1	41.470
78	Russia 2 (Central Russian Upland, Smolensk-Moscow Heights)	44.100
79	Udmurtsk (Upper Kama Upland); Russia	37.860
80	West Siberia; Russia	29.290
81	Knusk; Russia	40.700
82	Jutland,(Denmark)	56.490
83	Bogstad (Ostland); Norway	44.950
84	S-E Norway; Norway	33.030
85	Central Norway; Norway	44.750
86	Scania; Sweden	48.500
87	Gotland, Smaland (S-E Sweden); Sweden	40.200
88	Gotland; Sweden	41.840
89	Sondermanland (S-E Sweden); Sweden	38.425
90	Central Sweden; Sweden	36.008
91	Norrland; Sweden	38.920
92	Madelpad, Angermanland; Sweden	36.590
93	S-E Sweden Cost; Sweden	42.405
94	South Finland; Finland	28.723
95	Karelian; Finland, Russia	40.080
96	Hudson, Ontario; Canada	31.500

IUFRO 1964/68

IUFRO 1964/68 Conclusions

1. Assessment of the height growth of Norway spruce, carried out on trees in the juvenile period (5 to 25 years) on the IUFRO trial plot in Krynica (Beskid Sądecki, Carpathian Mts), revealed that trees from the provenances representing the Krutzsch's regions in which the number of spruce provenances exceeds 10 show a significant variation both at provenance and regional level. Based on a dendrogram, six distinct provenance groups were identified differing in genetic height reactivity. The groups are as follows:

Group 1: region 48 - Tatras, Slovakia, Poland; good height growth, strong G × A interaction effect.

Group 2: regions 47 - Nízkie Tatry, Slovakia; 59- East Carpathians; Romania; 63 - Beskid Śląski, Beskid Żywiecki; very good height growth, significant G × A interaction effect, mean height increases with age.

Group 3: regions 22, 23, 24 – Swabian - Bavarian Upland (1 - Bavaria, 2, 3 - Swabia) Germany; 13 - Schwarzwald (Baden-Wurttemberg)Germany; 34 - Styria (E) 3 Austria; 25 - Bavarian Alps, Germany; 21 - Bohemian Forest, Czech Republik; 17 - Swabian Jura, Germany; 28 - Tyrol – Salzburg, Austria; 30 - Niedrige Tauren, Styria; 32 - Styria (N-E) 1 Austria; 31 – Carinthia - Styria Austria; 26 - East Alps, Germany; 16 - Swabian Upland (Wurttemberg) Germany; 8 - Meclenburg Lakeland, Schwerin, Rostock; Germany; average height growth, no G × A interaction effect.

Group 4: regions 36 - Bohemian Upland, Lower Austria; Czech Republic; Austria, 66 – West -Pomeranian Lakeland, Poland; 41 - Bohemia; Czech Republic; 19 - Franconia, Upper Palatinate; Germany; 18 - Franconian Jury, Germany; 45 - Moravia 3, Czech Republic; 10 -Erzgebirge; Czech Republic; 37 - West Bohemia, Czech Republic; 44 - Moravia 2, Czech Republic; 42 - South Bohemia, Moravia, Czech Republic; 7 - Harz Mts 2 (Westerhof), Germany; good height growth, no G × A interaction effect.

Group 5: regions 56 - Rhodope Mts; Bulgaria; 27 - Tyrol; Austria; 14 - Breisgau, Germany; 15 - West (Lepontine) Alps; Switzerland; 2 - West Alps; France; 5; poor height growth, weak G × A interaction effect.

Group 6: region 90 - Central Sweden; poor height growth, no G × A interaction effect.

As shown by an analysis of variance, the effect of study year (seedling age) and of the interaction study year (seedling age) × provenance region was significant for groups 3, 4 and 5. The provenances from the western and southern Carpathians, belonging to group 4 (fast height growth, favourable G × A interaction), and those from Bohemia, Austria and the Hartz Mts, belonging to group 4 (good height growth, no change in incremental dynamics due to interaction), can be considered the most suitable for juvenile selection.

IUFRO 1964/68 Conclusions

2. Late flushing provenances of a high spring frost resistance are those from regions **55 -61, 68-71, 75-78 and 80, i.e. the mountain regions of southern Carpathians, Bihor Mts and Rhodope Mts and the northeastern regions lying within the lowland range of spruce - from Masuria, Białowieża and central Russia**. The studies conducted so far foud a high heritability of this trait.

3. Spruces from the Bohemian provenances and a part of southern Carpathian ones are resistant to *Chermes viridis* Ratz. Those extremely late or early flushing from regions **40 South Bohemia, Czech Republic, 49 East Slovakia, 50 Slovenskie Rudohorje and 57 Southern Carpathians, Transylvanian Applend, Romania** exhibit a high resistance to the infestation by this insect species.

4. As suggested by the height of trees aged 25 years and the frost resistance (late flushing) of spruces, the provenances from regions **67 East Pomeranian Lakeland, Masuria Poland, 69 Augostów, Lakeland Poland, 50 Slovenskie Rudohorje , 75 Belarus, 96 Canada (Hudson, Ontario) and 58 Bihor Mts., Transylwania, Romania** have the greatest genetic and breeding value.

5. The current results on the variability of height and resistance traits indicate a high marketing potential of the seeds and seedlings of Norway spruce originating from the **western and southern Carpathian regions as well as from the lowland regions of Poland and Russia** lying within the northeastern range of the species.

6. Analysis of dependence between the altitudinal location of the experimental plot in Krynica, the altitudinal location of parent populations and the total height of their progeny at age of 25 which determines **the breeding success of the vertical transfer of the spruce reproduction material, was carried out distinctly showing the necessity of a strict regime in the selection of seed basis in mountainous conditions**. At age of 25 years the best growth characterized the progeny representing spruce stands of the altitudinal location similar to that of the comparative plantation. In the progeny of spruce populations from sites both lower or higher than the experimental plot decreases in height were found significant in the range of -0.95 for stands from the altitudes exceeding 1700 m above sea level to -0.26 for stands from 100 to 0 m above sea level, being proportional to differences in the altitude of the location of plantations and parent stands of the provenances tested.

Norway Spruce Symposium IUFRO WP S. 2.02.11

Stara Lesna, Wisła, Krynica

September 1 – 7, 8, 9 1997

IUFRO W.P S2 02. 11

Conference „Norway Spruce in the Conservation of Forest Ecosystems in Europe”
Warszawa – Malinówka – Białystok – Warszawa, September 3-5, 2007