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Survival and Growth in Scots Pine (*Pinus silvestris* L.)

Provenance Experiments in Northern Sweden

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Summary. Genotype — environment interaction has been investigated in Scots pine provenance experimental series, laid out during 1952—1955 in Sweden. Results obtained from six experimental plantations in the county of Norrbotten during a period of 20 years (including 1970) are the subject of discussion. The genecological variation of climatic hardiness, survival and growth — rate are shown graphically and in statistical analyses. Response of seed sources to the transfer of populations from their native habitats to the experimental sites has been analysed. The changed length of the growing season in connection with the transfer of populations is taken as the criterion of climatic differences on natural habitats and experimental sites.

1. Introduction

During the two last decades two provenance experimental series with Scots pine have attracted considerable interest in Sweden. One of them was laid out by Stefansson in 1950 and 1951, and the other by Eiche in cooperation with the staff of the Royal College of Forestry during 1952—1955. An account of Stefansson's series was rendered by Stefansson, 1965; Stefansson and Sinko, 1967; by Hagner, 1970 and by Remröd, 1973. A report on Eiche's series was made by Eiche, 1962, 1966; Langlet, 1968; Eiche and Gustafsson, 1970 and Eriksson, 1972. Data obtained from experimental plantations located in the county of Norrbotten (Fig. 1) are accounted for in the present report, which deals with Eiche's series.

2. Material and Methods

The provenance material in this series consists of 100 different provenances, originating from habitats systematically chosen in Sweden and Norway from native stands and from Germany and Holland (Fig. 1). The most northern population originates from Finnmark in Norway, 69° 55′ N. Of these 100 provenances 90 are represented by the progeny of 25—30 single trees in each population. The total number of single trees whose progenies (families) were tested in these experiments is 2200. Seeds were obtained after open pollination. Four standard populations were used throughout the whole experimental series. They are: no. 10, Korpilombolo, Norrbotten, 66° 53′ N; no. 23, Malåträsk, Västerbotten, 65° 8′ N; no. 42, Sveg, Jämtland, 62° 3′ N and no. 74, Eckersholm, Jönköping, 57° 36′ N. The experimental series was laid out during 1952—1955 on 30 localities, distributed over the main part of the country, with a total area of 36 hectares. The most northern experimental plantation (EP) is situated near Kiruna. On the EPs uniform tending of plants was carried out. During 1954 to 1962 the plants were sprayed with CaS-solution to protect them against snow-blight fungus (*Phacidium infestans* Karst.). Most of the EPs were fenced.

Experimental series described in the present report were laid out with the view of studying the climatic hardiness of the plants, their survival, growth-rate and quality, when transferring populations in meridional direction, from north to south and vice versa, or on a vertical scale, i. e. from a higher to a lower altitude and vice versa, respectively, compared with the locality of the EP. On each experimental site 7, 14 or 20 populations were tested in four replications according to modified Youden square design. One of these populations is a local strain and two are standard ones. The remaining are two plus two provenances, whose natural habitats lie to the north or to the south of the experimental locality, respectively. One of these provenances originates from a higher altitudinal range and the other from a lower one, compared with the altitude of the experimental site. In experiments with 14 (or more) populations, the additional 7 (or more) populations were transferred from more remote habitats. In all EPs each population was represented by 20 families and 13 offspring plants per family, i. e. 260 individuals per population.

Mortality and all changes in the composition of the plants were registered on all EPs north of 60° N every year, and on other EPs with an interval of a few years. A general survey of the growth-rate of the provenance material and of its quality was carried out in Norrland in 1967 and 1970, and in other parts of the country during 1968—1970. Six of the thirty EPs are laid out in Norbotten with 4-year old plants (2+2). Out of these six plantations the following five[1] plantations will be accounted for, namely:

No.	Locality	φ	H_s	Y
27	Kiruna, Kauppinen	67° 50′	360	100
29	Gällivare, Linalombolo	67° 14′	475	98
24	Kåbdalis, Rahaberget	66° 16′	440	105
25	Korpilombolo, Ohtanajärvi	66° 56′	200	113
22	Älvsbyn, Asplövberg	65° 38′	60	127

EP 29 lies near the tree limit in vertical direction, EP 27 is the most northern EP in this experimental series and the position of EP 24 is in upland near the Arctic Circle. Harsh climate is a common characteristic for these three EPs. Climatic conditions of EP 25 are more

[1] The sixth plantation (EP 26) is identical with EP 29, but is located in an extreme frost locality.

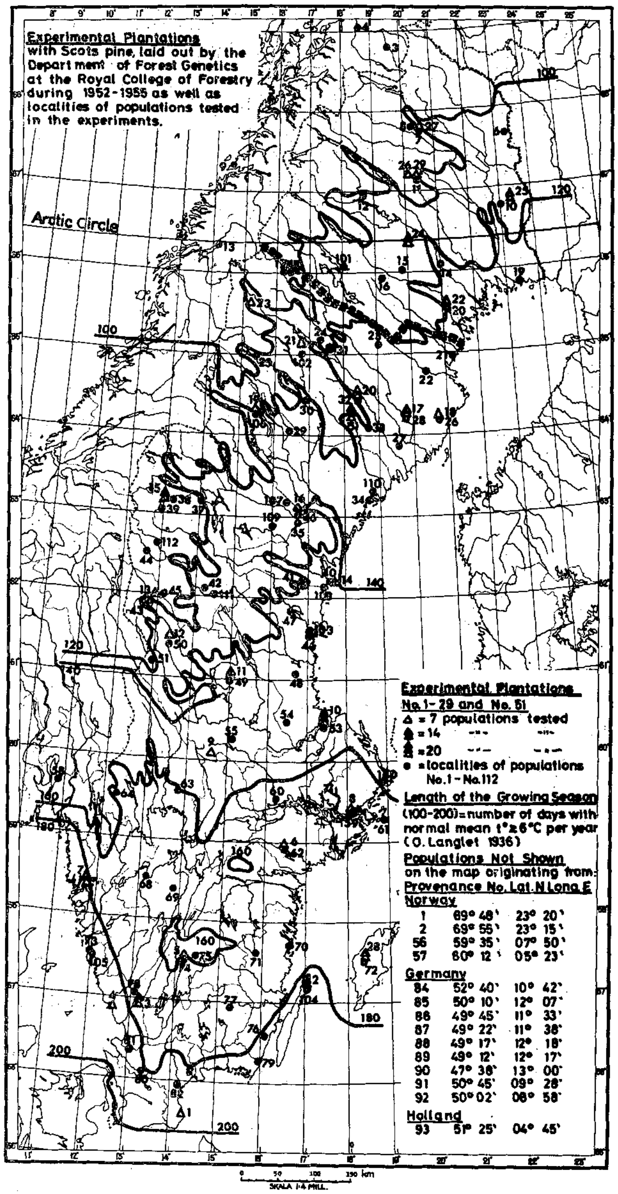

Fig. 1. Provenance trials with Scots pine (*Pinus silvestris* L.) laid out in 1952—1955. Experimental plantations are denoted by triangles and populations by black dots. Interrupted lines drawn from the Arctic Circle in NW-SE direction denote the southern border line of the county of Norrbotten, which occupies the northern part of Sweden

moderate than those of EPs 24, 27 and 29. The climate of EP 22 is the mildest of all the five EPs.

Symbols in the Table above and in Tables 1—5

PR: no. — number of population; φ — north latitude; λ — east longitude from Greenwich; H_s — altitude above the sea level in m; Y — length of growing season, i. e., the number of days with mean $t° \leq 6$ °C per year (O. Langlet, 1936).

Transfer of PR: φ — distance in meridional direction from the natural habitat of the PR to the site of EP in km, in northerly direction (+) and in southerly direction (—); H_s — distance in vertical direction in m, upward (+) and downward (—); Y — shortening (—) or lengthening (+) of the growing season.

CM (cumulative mortality): percentage of survived trees from 260, i. e., from the number of plants in the year the experiment was laid out.

Tree growth: $\bar{n}$ — mean number of trees per replication, applied in analyses of variance (mean number of plants per replication in 1954 was 65), $\bar{t}$ — unweight mean of height increment in cm in 1970, $\bar{h}$ — unweight mean of height in cm for twenty-year old trees.

3. Survival of Provenance Material

Data on the mortality rate of single provenances in each experimental plantation (EP) are shown on two types of mortality diagrams:

1. Cumulative mortality (CM) and
2. Single year mortality (SYM).

Results obtained comprise analyses carried out until the autumn of 1970.

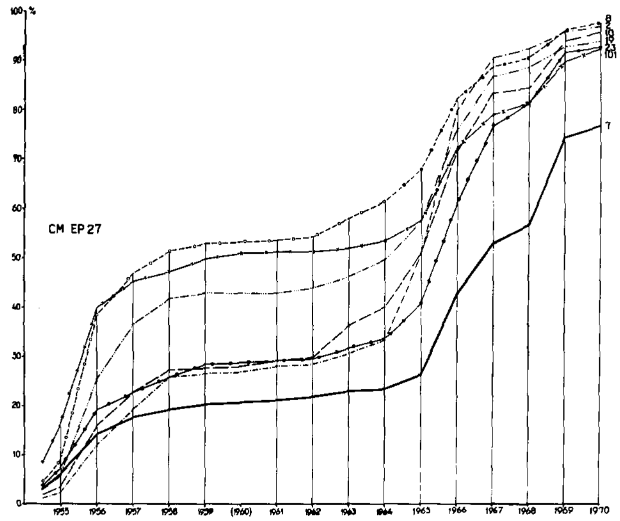

Fig. 2. Cumulative mortality (CM) in EP 27 (see Table 1)

Table 1. *Experimental plantation 27, Norrbotten, Kiruna, Kauppinen. φ: 67°50′, λ: 20°27′, H_s: 360, Y: 100*

PR					Transfer of PR			CM 1970
No	φ Locality	λ	H_s	Y	φ km	H_s m	Y	%
2	69°55′	23°15′	20	104	—232	+340	— 4	98.1
	Norway, Alta, Aronnes							
7	67°50′	20°27′	355	100	—	+ 5	—	77.7
	Norrbotten, Kiruna, Kauppinen							
8	67°50′	20°16′	480	94	—	—120	+ 6	98.9
	Norrbotten, Kiruna, Nokutosvara							
10	66°50′	23°09′	185	114	+111	+175	—14	96.9
	Norrbotten, Korpilombolo							
19	65°50′	23°18′	30	128	+223	+330	—28	95.0
	Norrbotten, Kalix, Mörträsk							
23	65°08′	18°53′	305	118	+300	+ 55	—18	93.9
	Västerbotten, Malå, Strömfors							
101	66°03′	17°57′	460	105	+198	—100	— 5	93.5
	Norrbotten, Arjeplog							

Table 2. *Experimental plantation 29, Norrbotten, Gällivare, Linalombolo.* φ: *67°14′*, λ: *20°29′*, H_s: *475*, *Y*: *98*

No	PR				Transfer of PR			CM 1970
	φ Locality	λ	H_s	Y	φ km	H_s m	Y	%
4	69°07′ Norway, Målselv, Moen, Olsberg	18°35′	100	105	−210	+375	− 7	94.2
9	67°18′ Norway, Bodö, Mulstrand	14°25′	30	119	− 7	+445	−21	99.6
10	66°50′ Norrbotten, Korpilombolo	23°09′	185	114	+ 45	+290	−16	83.5
11	67°14′ Norrbotten, Gällivare, Linalombolo	20°29′	470	98	−	+ 5	−	78.5
20	65°38′ Norrbotten, Älvsbyn, Asplövberg	21°07′	75	127	+178	+400	−29	98.5
23	65°08′ Västerbotten, Malå, Strömfors	18°53′	305	118	+234	+170	−20	96.9
32	64°34′ Västerbotten, Lycksele, Storberget	18°15′	510	111	+297	− 35	−13	99.2

The lowest mortality rate (CM) in EP 27, Kiruna, is to be found within the local population 7 (Table 1, Fig. 2) which surrounds the site. The rate of survival in 1970 was 22%. The other populations had only a few plants left intact, for instance, population 19—5%; population 10—3%; population 23—6%. Population 8 from the same neighbourhood, but with a habitat which lies 120 m higher, appeared to be the least hardy (1%). This population is a typical representative for marginal populations with a low viability.

The local population 11 in EP 29 (Table 2) lies close to the experimental site. As seen from the CM diagram (Fig. 4), the mortality curve of this population occupies the lowest position. The climatic hardiness of the local population 11 (EP 29) and the local population 7 (EP 27) is similar. On both EPs local populations distinguish themselves by a higher degree of hardiness than other populations. Among other populations in EP 29, population 10 shows a rate of survival up to 16%. The remaining populations have only a few plants intact.

Single year mortality finds its expression in a wave-like line, that is, SYM varies from year to year. Plant death was caused primarily by cold damage during some years with extreme climatic conditions. Main types of plant damage were: basal stem girdle and frost canker caused by cold during late winter in some years, and die-back of the top of plants caused by late spring frosts (Eiche, 1962, 1966; Sakai, 1968; Eiche and Gustafsson, 1970). The effect of climatic extremes on non-hardy populations is obvious. As a rule, the SYM curves show different kinds of peaks. Often a peak is caused by the delayed effect of injuries, which had arisen one or two years earlier. For instance, mortality during 1965—1968 was caused by injuries which appeared during late winter in 1965. Sometimes trouble comes much later than expected, as for example, in EP 27 (Fig. 3) and

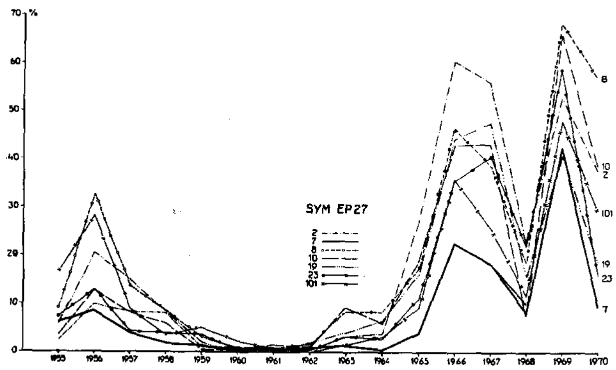

Fig. 3. Single year mortality (SYM) in EP 27 (see Table 1)

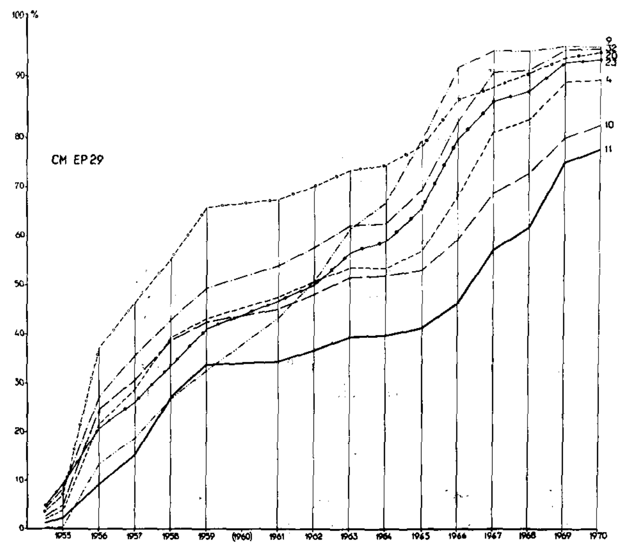

Fig. 4. Cumulative mortality (CM) in EP 29 (see Table 2)

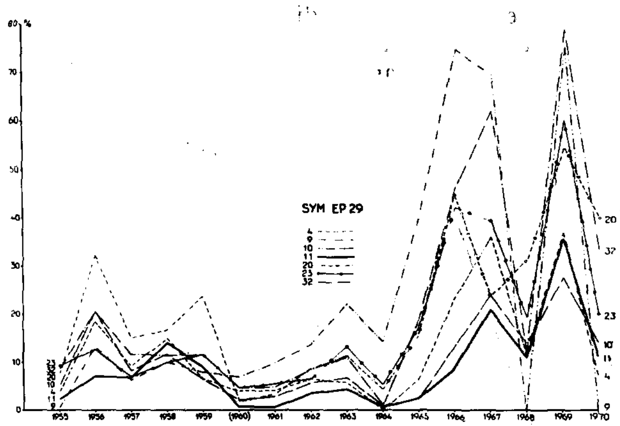

Fig. 5. Single year mortality (SYM) in EP 29 (see Table 2)

EP 29 (Fig. 5) when the plants were already 14 years old. The SYM diagrams of EP 27 and those of EP 29 are similar.

Results obtained from EP 24, Kåbdalis, are shown in Table 3 and Figs. 6 and 7. Populations 6 and 7 possess a great degree of climatic hardiness and their

Table 3. *Experimental plantation 24, Norrbotten, Kåbdalis, Rahaberget.* φ: *66°16′*, λ: *19°53′*, H_s: *440*, *Y*: *105*

No	PR φ (Locality)	PR λ	PR H_s	PR Y	Transfer of PR φ km	Transfer of PR H_s m	Transfer of PR Y	CM 1970 %	Estimated trees 1970 $\bar{n}$	Estimated trees 1970 $\bar{t}$	Estimated trees 1970 $\bar{h}$
2	69°55′	23°15′	20	104	−406	+420	+ 1	71.5	17.00	18.49	204.72
	Norway, Alta, Aronnes										
3	68°47′	19°30′	250	100	−280	+190	+ 5	91.9	5.00	17.35	191.36
	Norway, Målselv, Dividalen										
6	67°45′	23°22′	225	107	−165	+215	− 2	43.9	35.00	23.46	248.73
	Norrbotten, Kitkiöjoki										
7	67°51′	20°27′	355	100	−176	+ 85	+ 5	44.6	32.75	21.08	222.87
	Norrbotten, Kiruna, Kauppinen										
10	66°53′	23°03′	175	114	− 69	+265	−9	59.2	26.00	22.45	235.92
	Norrbotten, Korpilombolo, Smedberg										
13	66°18′	14°10′	75	123	− 4	+365	−18	83.0	10.50	17.32	197.81
	Norway, Mo i Rana, Båsmo										
14	66°05′	20°45′	130	121	+ 20	+310	−16	88.9	7.25	23.14	235.78
	Norrbotten, Spikseleå										
23	65°08′	18°53′	305	118	+126	+135	−13	79.1	12.75	23.24	243.64
	Västerbotten, Malå, Strömfors										
28	64°14′	19°43′	200	128	+226	+240	−23	95.8	2.50	16.27	182.73
	Västerbotten, Vindeln, Svartberget										
34	63°15′	18°47′	8	144	+336	+432	−39	100.0	0.25	4.25	47.50
	Västernorrland, Örnsköldsvik, Alfredshem										
38	63°10′	13°04′	540	117	+345	−100	−12	98.9	0.75	13.75	152.50
	Jämtland, Vallbogården										
42	62°03′	14°19′	385	132	+469	+ 55	−27	100.0	0.25	3.75	52.00
	Jämtland, Sveg, Malmbäcken										
101	66°03′	17°57′	460	105	+ 24	− 20	−	83.5	10.75	21.50	214.95
	Norrbotten, Arjeplog										
107	63°08′	16°39′	455	122	+349	− 15	−17	98.1	1.25	8.00	84.87
	Jämtland, Bispfors, Torresjölandet										
					± mean error (ε)				2.18	2.70	29.78

rate of survival in 1970 is 55%—56%. Both populations originate from almost the same latitude, although the habitat of population 6 lies 130 m lower than that of population 7. As regards survival they are both equal, but they differ with respect of the growth-rate. Population 6 is definitely superior to population 7 in regard to height growth. Unfortunately, the local population is not represented in this EP. Population 101 from Arjeplog is the one which comes closest to the local population. Population 42, Sveg, and population 34, Alfredshem, perished already in 1964 and 1967, respectively.

Single year mortality curves (Fig. 7) show, on the whole, the same course of development, as was the

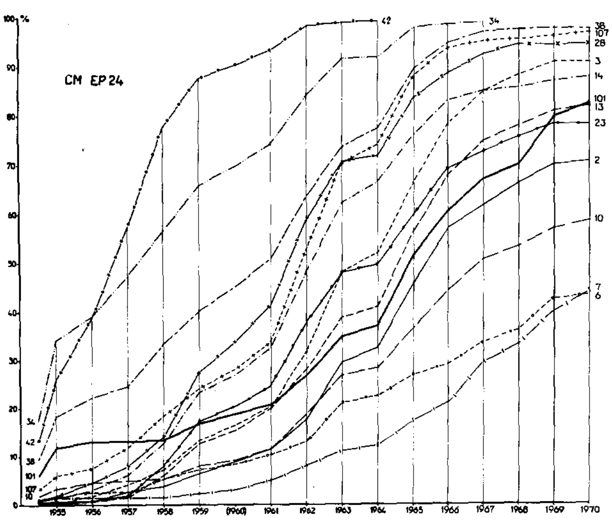

Fig. 6. Cumulative mortality (CM) in EP 24 (see Table 3)

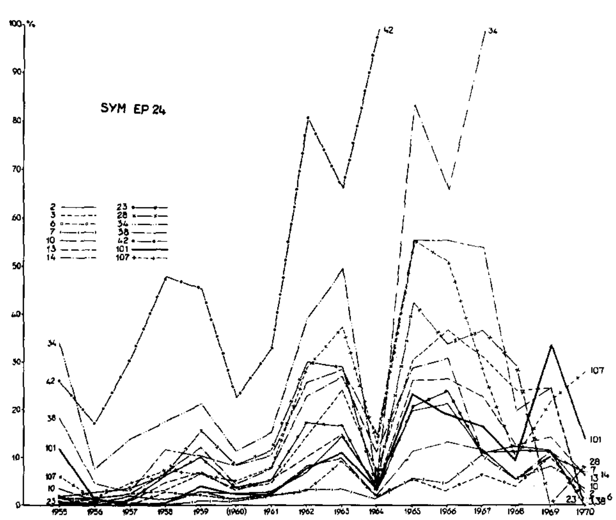

Fig. 7. Single year mortality (SYM) in EP 24 (see Table 3)

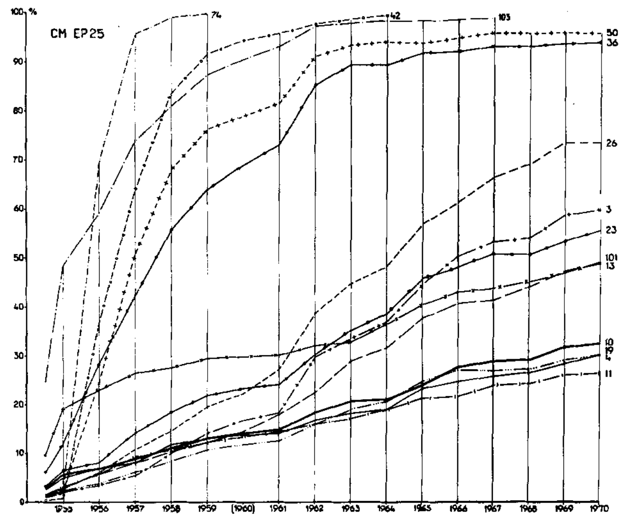

Fig. 8. Cumulative mortality (CM) in EP 25 (see Table 4)

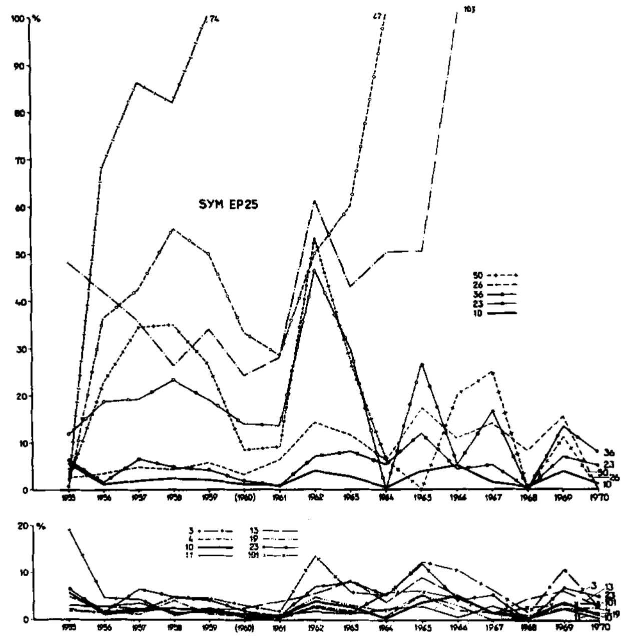

Fig. 9. Single year mortality (SYM) in EP 25 (see Table 4)

case in EPs mentioned above. However, the effect of extreme climatic conditions during the late winter in 1961 and 1965 stands out in stronger relief than in other EPs.

EP 25 is situated outside the upland region in northern Sweden. The climate is much milder on this experimental site than in EPs 24, 27 and 29. Some of the populations display a very good climatic tolerance. The adaptation of the populations to the climate in EP 25 is displayed in CM and SYM diagrams (Table 4, Figs. 8 and 9). However, most

Table 4. *Experimental plantation 25, Norrbotten, Korpilombolo, Ohtanajärvi.* φ: *66°56′*, λ: *23°11′*, H_s: *200*, *Y*: *113*

No	PR				Transfer of PR			CM 1970	Estimated trees 1970		
	φ Locality	λ	H_s	Y	φ km	H_s m	Y	%	$\bar{n}$	$\bar{t}$	$\bar{h}$
3	68°47′ Norway, Målselv, Dividalen	19°30′	250	100	−206	− 50	+13	60.8	25.50	21.55	263.55
4	69°07′ Norway, Målselv, Moen, Olsberg	18°35′	100	105	−243	+100	+ 8	30.8	43.75	20.82	268.63
10	66°50′ Norbotten, Korpilombolo	23°09′	185	114	+ 11	+ 15	− 1	33.1	43.00	25.26	291.42
11	67°09′ Norrbotten, Gällivare	20°49′	330	105	− 24	−130	+ 8	26.9	47.50	25.32	291.00
13	66°18′ Norway, Mo i Rana, Båsmo	14°10′	75	123	+ 70	+125	−10	49.6	32.00	20.59	271.64
19	65°50′ Norbotten, Kalix, Mörträsk	23°18′	30	128	+122	+170	−15	30.8	43.50	26.70	326.26
23	65°08′ Västerbotten, Malå, Strömfors	18°53′	305	118	+100	−105	− 5	56.5	27.00	22.76	283.96
26	64°12′ Västerbotten, Robertfors	20°48′	50	136	+304	+150	−23	74.6	16.00	20.10	180.57
36	63°02′ Jämtland, Bispfors	16°39′	200	134	+434	−	−21	95.4	0.00		
42	62°03′ Jämtland, Sveg, Malmbäcken	14°19′	385	132	+543	−185	−19	100.0	0.00		
50	61°27′ Kopparberg, Bunkris	13°38′	550	127	+610	−350	−14	97.3	0.00		
74	57°36′ Jönköping, Eckersholm	14°13′	225	165	+1039	− 25	−52	100.0	0.00		
101	66°03′ Norbotten, Arjeplog	17°57′	460	105	+ 98	−260	+ 8	50.0	31.75	23.96	284.33
103	61°28′ Gävleborg, Långvind	17°08′	5	154	+608	+195	−41	100.0	0.00		
						± mean error (ε)			2.73	0.86	6.23

Table 5. *Experimental plantation 22, Norrbotten, Älvsbyn, Asplövberg.* φ: *65°38′*, λ: *21°07′*, H_s: *60*, Y: *127*

No	PR φ	λ	H_s	Y	Transfer of PR φ km	H_s m	Y	CM 1970 %	Estimated trees 1970 $\bar{n}$	$\bar{t}$	$\bar{h}$
	Locality										
5	68°11′	15°35′	10	115	−284	+ 50	+12	24.2	48.00	29.77	316.42
	Norway, Tranöy										
10	66°50′	23°09′	185	114	−134	−125	+13	13.5	55.25	41.85	388.32
	Norrbotten, Korpilombolo										
11	67°09′	20°49′	330	105	−169	−270	+22	19.2	52.25	38.86	376.16
	Norrbotten, Gällivare										
20	65°38′	21°07′	75	127	—	− 15	—	25.8	48.00	43.47	427.32
	Norrbotten, Älvsbyn, Asplövberg										
23	65°08′	18°53′	305	118	+ 56	−245	+ 9	20.4	51.25	42.73	429.30
	Västerbotten, Malå, Strömfors										
34	63°15′	18°47′	8	144	+265	+ 52	−17	43.4	36.25	43.40	420.80
	Västernorrland, Örnsköldsvik, Alfredshem										
47	61°49′	15°46′	155	145	+425	− 95	−18	82.7	11.00	36.12	353.76
	Jämtland, Färila, Korskrogen										
								± mean error (ε)	3.18	1.61	16.70

southern populations show an insufficient degree of climatic hardiness. Population 74, Eckersholm, and population 103, Långvind, had already perished during the earlier years. In population 50, Bunkris, and population 36, Bispfors, only a few plants had survived. Population 3, Målselv, is an extreme marginal population, but in spite of its northern origin its progeny has a conspicuously low viability. Local population 10; population 4, Målselv; population 11, Gällivare, and population 19, Kalix, possess a pronounced capacity to adapt themselves to the climate. Population 19 is hardy, in spite of the fact that it was transferred to EP 25 from the south. Populations transferred from the more remote habitats in the south had perished, with the exception of population 26, Robertsfors. Populations 23, Malå, and 13, Mo i Rana, with a moderate range transfer from the south have survived. The rate of survival of population 101 is equal to that of population 13, although the growing season of population 101 was lengthened by eight days, due to transfer.

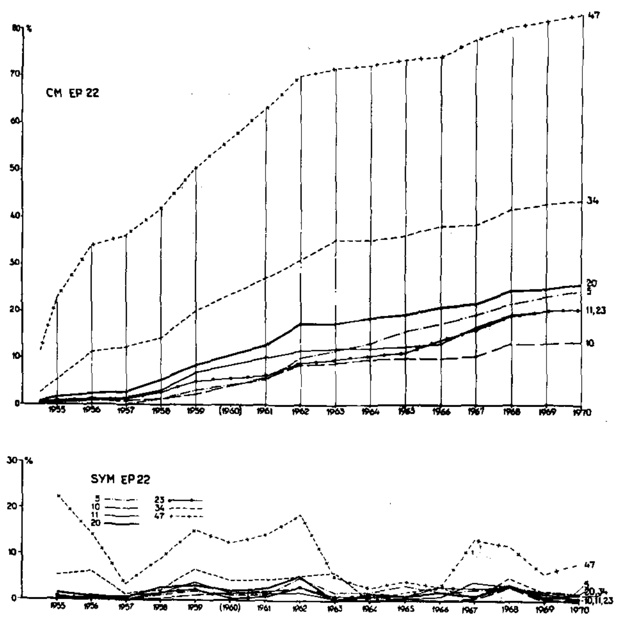

Fig. 10. Cumulative (CM) and single year mortality (SYM) in EP 22 (see Table 5)

In EP 25 (Fig. 9) single year mortality curves (SYM), with the exception of most southern populations, show a less noticeable variation.

Results obtained from EP 22 differ in some respect from those obtained from the previous four EPs. EP 22 is situated in the coastal district of the Gulf of Bothnia, in the southern part of the county of Norrbotten. As a rule the rates of survival of the plants in EP 22 are higher than those in EPs 24, 25, 27 and 29. The rate of survival in 1970 for local population 20 is 74% (Table 5). More hardy populations with a lengthened growing season (Fig. 10) have a high rate of survival, but those with shortened Y, for example 34 and 47, have only 56% and 17%, respectively. SYM diagram shows a low variation of mortality rates during 1955—1970.

4. Height Growth

The variation of growth capacity of different populations in EPs 24, 25 and 22 is shown in Table 3, Fig. 11, Table 4, Fig. 12 and Table 5, Fig. 13, respectively. Computation of survey data from the year 1970 has not yet been completed.

A positive relationship exists in EP 24 (Table 3) between height increment ($\bar{t}$), tree height ($\bar{h}$) and the number of survived trees ($\bar{n}$). However, the regression of $\bar{t}$ and $\bar{h}$ on $\bar{n}$ is not statistically significant. Populations 23, Malå; 101, Arjeplog, and 14, Spikseleå, are an exception. Their growth parameters have a strong deviation about regression. The few survived trees in these three populations have a good height growth. Thus, the genetic variation within these populations, as well as between different families in regard to climatic hardiness, is very great.

The curvilinear relationship between tree height ($\bar{h}$) in the years 1961, 1967, and 1970 and the changed length of the growing season for different populations in EP 24 is revealed in polynomial regressions in Fig. 11. Regression equations for corresponding years are the following:

	Equation	R^2 %	F
1970	$\bar{h}(\Delta y) = -0.12(\Delta y)^2 + 0.25(\Delta y) + 218.09$	58.40	7.72**
1967	$\bar{h}(\Delta y) = -0.08(\Delta y)^2 + 0.15(\Delta y) + 156.58$	58.66	7.80**
1961	$\bar{h}(\Delta y) = -0.03(\Delta y)^2 - 0.04(\Delta y) + 63.69$	56.58	7.17**

Population 6, Kitkiöjoki, in EP 24 is the best in regard both to growth capacity and resistance to cold. Its length of growing season was shortened by two days, in spite of its being transferred from north to south, and at the same time owing to transfer from a lower altitude to a higher one. Populations 6 and 7 are similar as regards survival rate, but the growth-rate of the latter one is considerably lower. Climatic hardiness of population 10, Korpilombolo, is lower than that of population 6, and its growth capacity is also somewhat smaller. It occupies the third place among other populations. The more surprising is the fact that some survived trees in population 23 and population 14 occupy the 2nd and the 4th place in respect of growth capacity, despite the fact that their length of growing season was shortened by 13 and 16 days, respectively.

In the year 1970 population 6 was definitely superior ($\Delta\bar{h}$***) to populations 34, 42 and 107 and superior ($\Delta\bar{h}$*) to population 38 in regard to mean height ($\bar{h}$).

Populations moved from the north with insignificant differences between the length of the growing season on their habitats and on the EP site, possess the highest degree of hardiness and have the best survival and growth capacity.

In EP 25 (Table 4) population 19, Kalix, transferred from the south, has the best height growth, and at the same time possesses a considerable climatic hardiness. Tree height of population 11, Gällivare, is similar to that of the local population. The results obtained from EP 25 illustrate once again that the local population is not necessarily the best for silvicultural practice.

In the year 1970 local population 10 was superior ($\Delta\bar{h}$**) to populations 3 and 4 and to population 13

* Statistically significant at 5 per cent level; ** significant at 1 per cent level; *** significant at 0.1 per cent level.

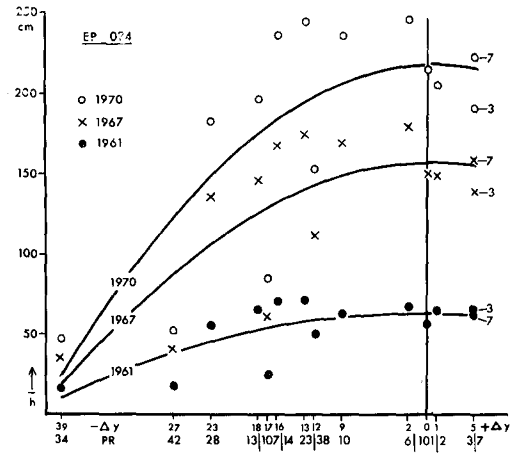

Fig. 11. Regressions of mean height ($\bar{h}$) on the changed length of the growing season (Δy) for different populations in EP 24

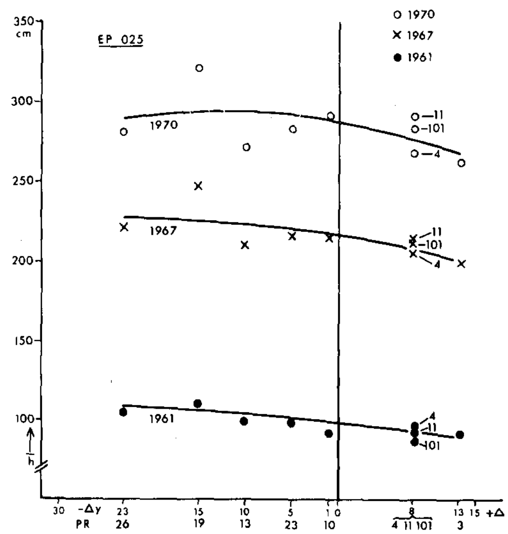

Fig. 12. Regressions of mean height ($\bar{h}$) on the changed length of the growing season (Δy) for different populations in EP 25

($\Delta\bar{h}$*) in regard to $\bar{h}$. However, as mentioned above, it was inferior to population 19 ($\Delta\bar{h}$**).

The relationship between tree height ($\bar{h}$) in the years 1961, 1967 and 1970, and the changed length of the growing season (Δy) for the populations transferred to EP 25 is expressed by slight curvilinear regressions in Fig. 12. Only the regression for the year 1961 is statistically significant. Regression equations for corresponding years are the following:

	Equation	R^2 %	F
1970	$\bar{h}(\Delta y) = -0.04(\Delta y)^2 - 0.99(\Delta y) + 288.44$	25.09	1.00
1967	$\bar{h}(\Delta y) = -0.01(\Delta y)^2 - 0.84(\Delta y) + 216.48$	44.75	2.43
1961	$\bar{h}(\Delta y) = 0.003(\Delta y)^2 - 0.44(\Delta y) + 96.39$	73.38	8.27*

In EP 22 progeny of seven populations was tested. The results obtained are shown in Table 5 and Fig. 13. In regard to $\bar{h}$ local population 20 is superior to all other populations except one—population 23, transferred from the south. Even in this case mean height ($\bar{h}$) of the two populations is almost equal. Local population 20 is strikingly superior to population 5 ($\Delta\bar{h}^{***} = 110.90 \pm 23.62$). This phenomenon is worthy of attention. It clearly illustrates the response of an inferior genotype to transfer, in this particular case to more favourable climatic conditions in EP 22. Local population 20 is also superior ($\Delta\bar{h}^{**}$) to population 47, transferred from the south, and to population 11 ($\Delta\bar{h}^{*}$), transferred from the north. Local population 20 is superior to population 10, transferred from the north, and to population 34, transferred from the south, but $\Delta\bar{h}$ is not statistically significant.

In the years 1961, 1967 and 1970 the relationship between $\bar{h}$ and Δy (Fig. 13) in EP 22 is of curvilinear character, but the regressions are not statistically significant. Thus, results obtained from EP 22, deviate in this respect from those obtained from EPs 24 and 25 and make an exception to other EPs in the whole experimental series.

Regression equations for corresponding years are as follows:

	Equation	R^2 %	F
1970	$\bar{h}(\Delta y) = -0.03(\Delta y)^2 - 0.20(\Delta y) + 396.81$	6.78	0.15
1967	$\bar{h}(\Delta y) = -0.03(\Delta y)^2 - 0.10(\Delta y) + 276.64$	9.23	0.20
1961	$\bar{h}(\Delta y) = -0.02(\Delta y)^2 + 0.18(\Delta y) + 105.77$	23.93	0.63

Climatic conditions in EPs 24, 25 and 22 are different. In these three EPs the response of the populations to changed climatic conditions in connection with transfer from their native habitats is also strikingly different. Regressions from these EPs for the years 1961, 1967 and 1970 show more or less pronounced deviations.

The results obtained convincingly show the genecological variation of climatic hardiness, capacity for survival and for growth-rate of different populations. The interaction for genotype and environment emerges here quite obviously.

5. Conclusions

The objectives of provenance experiments are to find well-adapted and highly productive populations, available for silvicultural practice. In this paper analyses of genotype — environment interaction in experimental series laid out during 1952—1955 comprise six experimental plantations located in the county of Norrbotten.

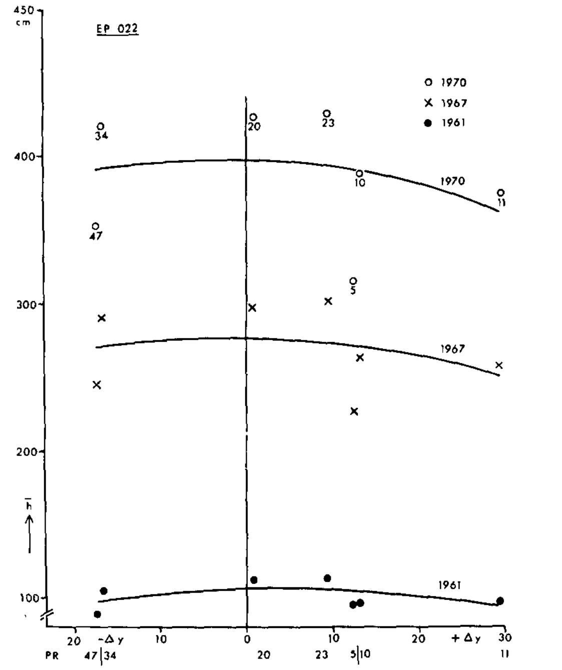

Fig. 13. Regressions of mean height ($\bar{h}$) on the changed length of the growing season (Δy) for different populations in EP 22

The response of seed sources to long or short range transfer either in northern, southern or vertical direction is analysed. The changed length of the growing season in connection with the transfer of populations is taken as the criterion of climatic differences on natural habitats and experimental sites. Short season populations, originating from northern habitats with harsh climate have, as a rule, a higher survival capacity than local populations when moderately transferred to localities with milder climate. Two marginal populations are well adapted to their local site — population 7 in EP 27 and population 11 in EP 29. On the other hand, extreme marginal populations show a considerably lower viability — population 8 in EP 27 and population 3 in EP 25.

Seed material for the cultivation of pine in Norrbotten should be taken from within the borders of the county and concentrated in the first place to districts whose provenances have a high capacity of adaptation to climate and a high growth-rate. It appears that the tested provenances originating from other districts than Norrbotten do not possess that cold resistance which is required in the harsh climate of this county.

Populations: 6, Kitkiöjoki; 10, Korpilombolo; 19, Kalix; 11, Gällivare and 7, Kiruna, distinguish themselves by both a considerable climatic hardiness and height growth. There is all reason to assume that several other populations in the geographic region from which populations 6, 7, 10, 11 and 19 were taken possess the same inherent qualities. Population 6 attracts particular attention by its stable qualities, which it retains even when transferred to remote localities in the south. Almost the same can be said about local population 20 in EP 22, which is well adapted and highly productive.

Provenance material in the experimental series is the result of natural selection during a period of twenty years. Genetic gain from this selection can be successfully used in future breeding work. Clones from survived and selected superior trees and families will be grown in specially arranged seed orchards.

Measurements and surveys of single individuals from seedling stage up to 20-year old trees were made in order to obtain their growth parameters. Studies on the relationship between certain characters, comprising different ontogenic stages are continued. Results obtained in regard to variation in the annual growth rhythm between single trees within populations, as well as variations between populations will be applied in the selection of valuable seed sources.

Genotype — environment interaction requires a more detailed statistical analysis of the results obtained. Of particular interest is the fraction of the additive variance. If the amount of the additive variance in relation to total variance in respect of different characters is high, great selection gains can be obtained by applying mass selection and crossbreeding. If the dominance variance is relatively high, selection of families and hybridisation of trees, possessing high specific combining ability, should be made use of. If heritability in the narrow sense and dominance effects (estimated from full-sib and halfsib families) are low and the interaction between environment and genotype is high, the tree improvement should be directed towards producing a separate cultivar for each ecological region. If overdominance exists, the breeding work should turn towards inbreeding, with the object of producing hybrids between unrelated inbred lines.

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