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Severity Index and Transfer Effects on Survival and Volume Production of *Pinus sylvestris* in Northern Sweden

Bestämning av ett hårdhetsindex för norra Sverige med hjälp av proveniensförsök med tall

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Abstract

ODC 232.12—562: 174.7 Pinus sylvestris: 181.2

By means of results from provenance trials in northern Sweden, a map of severity index *for various latitudes and altitudes was drawn up. The severity index is defined as the expected percentage plant mortality rate in the local population during the first 20 years after establishment of the plantation. By combining transfer effects based on data from all trials, a general trend of the transfer effect was calculated. The regression obtained showed that, at constant altitude, each degree of transfer southwards meant an increase in survival of 10.8 percentage units; at constant latitude, every 100 metres of downward transfer implied an increase in survival of 3.0 percentage units.*

By means of a graph combining severity index with transfer effects, it is shown how optimum transfer can be estimated. Optimum transfer is defined as the transfer giving maximum volume yield, which equals 70—80 per cent survival.

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Contents

1 Introduction

The difficulties of obtaining satisfactory survival in plantations of Scots pine in northern Sweden are well documented, e.g. by Eiche (1966), Stefansson & Sinko (1967) and Remröd (1976). According to the detailed investigation by Eiche (1966) the damage is mainly caused by extreme weather conditions during the end of the winter and takes place at irregular intervals over several years. This damage is expressed as basal stem girdling, which eventually causes the death of the trees. Descriptions of the effect of transfers of provenances were also given in the paper quoted above. If the effect of transfer is related to the local provenance there may be some bias dependent of the genetic quality of the particular local provenance. If this provenance is a good one the benefit of transfer of the other provenances will be underestimated and vice versa if it is poor. Therefore, a method to standardize the comparison of data from one research trial to another would be of great value to circumvent such a bias. The first approach in this direction was presented by Eriksson (1975). This paper in turn was inspired by the work done by Campbell (1974), who used the data presented by Eiche (1966).

In the papers by Campbell and Eriksson the selection intensity *(i)* was used as a measure to the surviving share of the population. The selection intensity is preferred to survival percentage since the latter is insensitive when the percentage approaches zero (see also Campbell, 1974).

Eriksson (1975) calculated regressions for the data from several provenance trials with survival expressed as (*i*) as the dependent variable, and change of latitude and altitude, together with their squares and products as the five independent variables. In this way an estimate of the *i*-value for zero transfer was obtained for each trial. This *i*-value is thus dependent on all provenances tested in a certain trial. This means that the effect of transfer can be related to a calculated value for a given locality, which, in turn, means that one must no longer rely on a comparison with a particular local provenance with its good or poor genetic quality.

Furthermore, *i*-values calculated in this way constitute a description of the severity of a particular site. Since selection intensity was hardly likely to be familiar to the forest officers responsible for reforestation, it was necessary to calculate the percentage of survival to form a severity index. Before the definition of this is given, it has to be added that occurrence of plant mortality in northern Sweden continues to an age of approximately 20 years.

The severity index of a site is defined as *the expected percentage plant mortality rate in the local population during the first twenty years after establishment of the plantation.* The severity index constitutes a good means of obtaining a biological map of northern Sweden. However, the local site and climatic conditions may have influenced the severity index derived for a given trial. These factors have to be considered when such a map is being drawn up.

The severity index will only give a description of the situation as regards survival, not of the prospects of improving the survival by transferring stock. Therefore, if possible, the severity index should be combined with a regression that describes the expected improvement of the survival by transferring provenances.

The purpose of the present study can be summarized in the following way:

1. To construct a map of survival in northern

Sweden, making use of all modern provenance trials in this area. The site conditions of a test locality have to be corrected in those cases where they deviate considerably from standard conditions.

2. To derive equations (regressions), which describe the effect of plant transfer on survival, and combine them, if possible, on the map.

2 Material and Methods

This investigation comprises the experimental plantations with Scots pine provenances planted in 1952—1955 in northern Sweden by Eiche (1966). In addition, data from four experimental plantations belonging to the Institute for Forest Improvement published by Remröd (1976) are included in the present investigation. The geographical position of the plantations is shown in Figure 1 (see also Table 1).

Except for EP 51, the trials planted by Eiche in 1952—1954 have a spacing of 1.25×1.25 m and 2×2 m. In EP 51 the spacing is 2.5×2.5 m. The other plantations have a spacing of 1.5×1.5 m. The plant mortality rate at the age of 20 years was obtained from these trials, while plant mortality at the age of 17 was presented by Remröd (1976) for the other trials.

In some of Eiche's plantations provenances from northern Norway are tested. Their performance deviated from the performance of the Swedish ones to such an extent that they had to be omitted from the studies of general geographical trends in the material. The reason for the great dif-

Table 1. Geographical data on the experimental plantations and their calculated and estimated severity indices.

Experimental plantation (EP)				Severity index	
No.	Name	Latitude	Altitude	calculated separately for each EP	estimated according to regression I
11	Högståsen	61.08	365	31.5	39.8
12	Bunkris	61.45	595	54.6	62.2
13	Idre	61.90	710	92.4	75.1
14	Brämön	62.20	5	30.9	13.4
15	Vålådalen	63.17	540	—	—
16	Bispgården	63.13	470	90.0	60.5
17	Svartberget	64.23	200	47.6	41.7
18	Robertsfors	64.20	50	24.0	27.6
19	Harrsjön	64.30	360	48.1	57.0
20	Storberget	64.55	455	30.0	67.2
21	Långsjöby	65.15	465	56.4	71.6
22	Älvsbyn	65.63	60	21.6	36.0
23	Tärnaby	65.72	630	98.9	90.7
24	Kåbdalis	66.27	440	67.9	75.8
25	Korpilombolo	66.93	200	44.2	56.4
26	Linalombolo	67.23	470	97.0	84.4
27	Kiruna	67.83	360	97.0	77.2
29	Linalombolo	67.23	475	79.7	84.9
51	Nordanås	64.32	400	66.5	60.8
98	Björkvattnet	63.43	460	66.5	61.3
113	Sudok	66.23	150	73.3	47.8
115	Bäckstrand	65.07	500	80.0	74.5
116	Brattfors	64.52	310	51.2	53.5

ferences between the two types of provenances is probably due to climatic differences caused by the mountain range which separates northern Sweden from northern Norway. The consequence of the omission of Norwegian provenances from the calculations are that too few provenances were left to get reliable estimates of the effect of transfer. On the other hand, it was assumed that zero transfer was estimated with satisfactory accuracy.

The survival of all Swedish provenances at the age of 20 years was transformed to *i*-values for calculation of the stepwise regressions as outlined in the introduction. The data from Remröd (1976) for age 17 had to be transformed to the expected survival at an age of 20 years. This was done by assuming a linearly increasing mortality rate during the first 20 years. In the Eiche series separate calculations were carried out for each spacing. The mean values of wide and dense spacing for each provenance were then calculated and used for the further calculations. The *i*-values for zero transfer based on the regression from each of the trials were used as dependent variables for a stepwise regression analysis of their geographical dependence. The altitude and latitude, and their squares and products, were used as the five independent variables in this regression analysis. In Figure 2 one example of the results of the regression analysis for one trial is illustrated.

Experimental plantation EP 15 Vålådalen (lat 63°10′, long 13°04′, alt 540 m) in the Eiche series was excluded from this calculation, since this trial seems to be exposed to quite different climatic conditions than could be expected from its geographic location. It is probable that the influence from the Atlantic causes a maritime climate in this area of the western part of the province of Jämtland, where this trial is located (cf. Liljequist 1970 p. 190—191). The plant mortality is low in this trial. Moreover, the survival of provenance Vålådalen is lower than expected in all trials in which it was planted. This may be interpreted such that this provenance has adapted to another climate than that suggested by its geographic location.

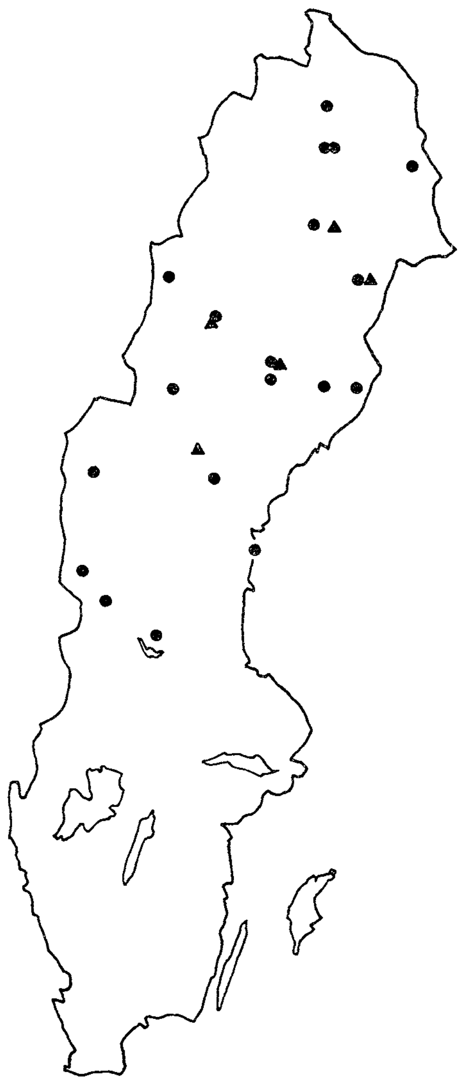

Figure 1. Map of Sweden showing the trials included in the investigation. ● = Trials belonging to the Department of Forest Genetics, College of Forestry. ▲ = Trials belonging to the Institute for Forest Improvement.

The effect of transfer on plant survival was studied by means of regression analysis. This analysis had to be carried out on data from different years for different trials. One example will help to explain this. The percentage of dead plants in 1963 and 1973

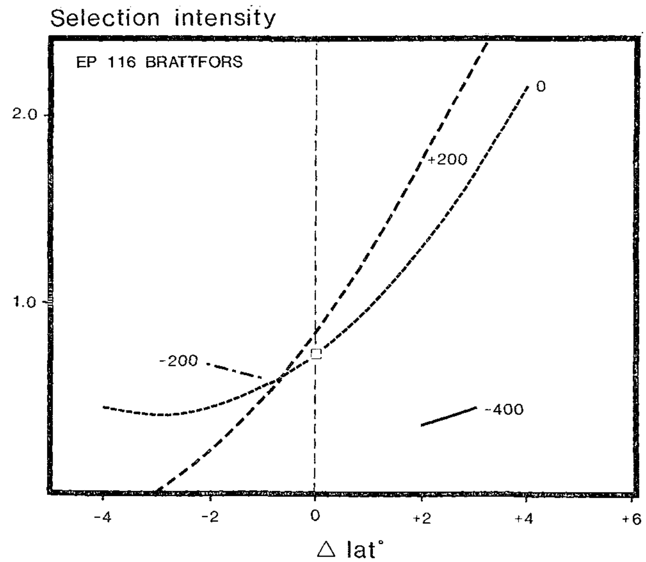

Figure 2. The effect of latitudinal transfer at constant altitude on the selection intensity at Brattfors. Plus signs indicate a transfer upwards or in a northward direction.

at EP 24 Kåbdalis (lat 66°16′, long 19°53′, alt 440 m) is shown in Figures 6a and 7. A comparison of the two diagrams reveals that two provenances approach 100 per cent mortality in 1963 whereas five provenances reach this value in 1973. The possibility to study the effect of transfer on plant survival has passed its optimum in 1973, whereas a good estimate can be obtained based on the data from 1963. Therefore, the regression analysis on the effect of transfer on plant survival was carried out on data from the first year when a provenance suffered 100 per cent mortality.

3 Results and Discussion

3.1 The effect of transfer on plant survival

The data on survival of the Swedish provenances from all trials in which at least 14 provenances were tested are illustrated in Figures 3a—13a. For the series established in 1952—1954 the figures are drawn for the years during which the effect of transfer could be studied (cf. above). For EP 51 Nordanås the percentage of dead plants during the period 1956—1973, is visualized, instead of the total percentage of dead plants in 1973. This trial was established in 1955. Shortly after the establishment an extraordinarily dry and hot summer followed, which caused severe plant losses in most of the provenances. To circumvent bias attributable to the dry season we elected to use the percentage of dead plants during the period, 1956—1973 (cf. Eriksson *et al.*, 1976), since we were interested in the damage caused by the weather condi-

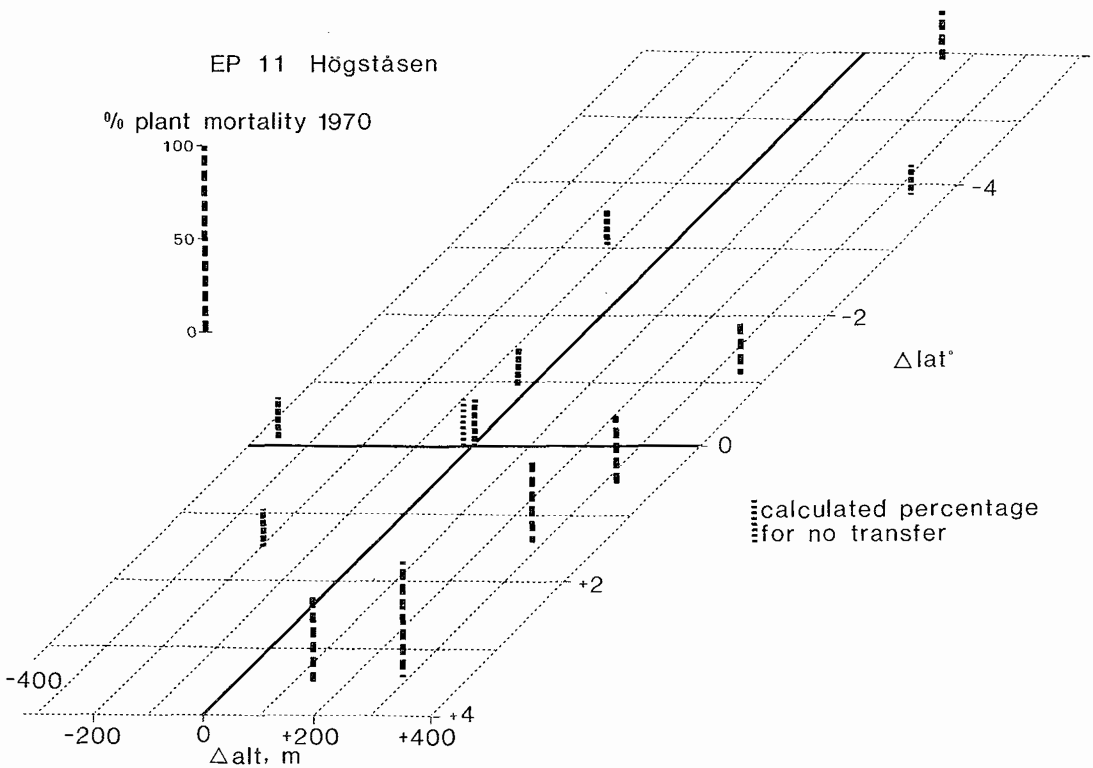

Figure 3a. The percentage of dead plants in 1970 in the populations tested at Högståsen. The location of the columns in the grid indicates the altitudinal and latitudinal transfers. Thus, columns below the horizontal line indicate populations which are moved in a northward direction. Columns to the right of the diagonal axis show provenances which were moved to a higher altitude. Two types of screen are used in the columns, one for the provenances showing a lower percentage plant mortality than that calculated for no transfer, and the other for the remaining provenances.

tions towards the end of the winter.

As may be seen in all these figures, the latitudinal transfer is significant to survival. Provenances transferred in a southern direction show the lowest percentages of plant mortality.

An altitudinal influence can also be seen in most of these figures.

Actually, the figures were carefully examined before the regression analysis was carried out. The results from the regression analysis are graphically illustrated in Figures 3b—13b. The effect of latitudinal transfer is demonstrated for constant altitudinal transfers in which plus signs indicate transfers upwards or in a northerly direction. Moreover, the curves are shown for the area of transfers that are tested in a particular trial.

There is fairly good agreement between the results from the various trials. Only EP 11 deviates to the extent that the positive effect of a transfer in a southerly direction reaches a maximum (minimum of the curves in Figure 3b). This could be attributed to provenance Korpilombolo being transferred approximately six degrees of latitude south. Such a long transfer southwards can only occur to plots situated in the southern part of the region, in which hardiness plays an important role, as in the case of EP 11. The curves in Figures 3b—13b reveal that substantial gains in survival could be obtained by an appropriate transfer.

The curves in Figures 3b—13b also reveal that the latitudinal transfer is more important than the altitudinal transfer. This is of course also evident from the results of the regression analysis.

The agreement between the regressions called for a joint analysis of the data. Therefore, a test of the fit of the data of parallel regressions was carried out. This analysis was effected in two ways: for data from all the experimental plantations shown in Figures 3a—13a, and for all the data except those from EP 11, since the regres-

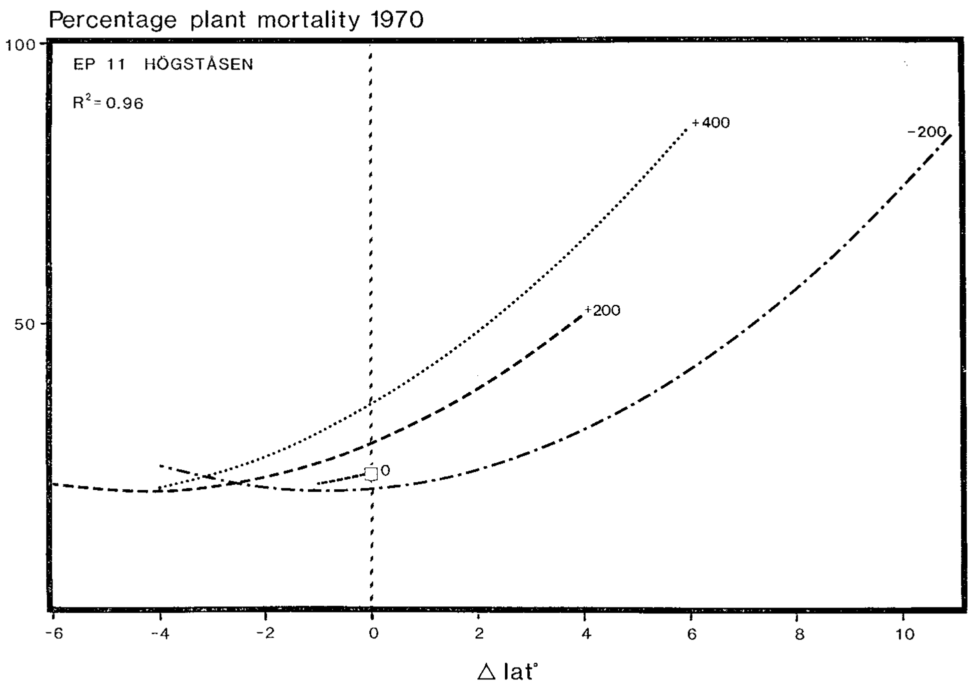

Figure 3b. The effect of latitudinal transfer at constant altitude on the percentage of dead plants at Högståsen. Plus signs indicate a transfer upwards or in a northward direction. The square of the multiple correlation coefficient is indicated.

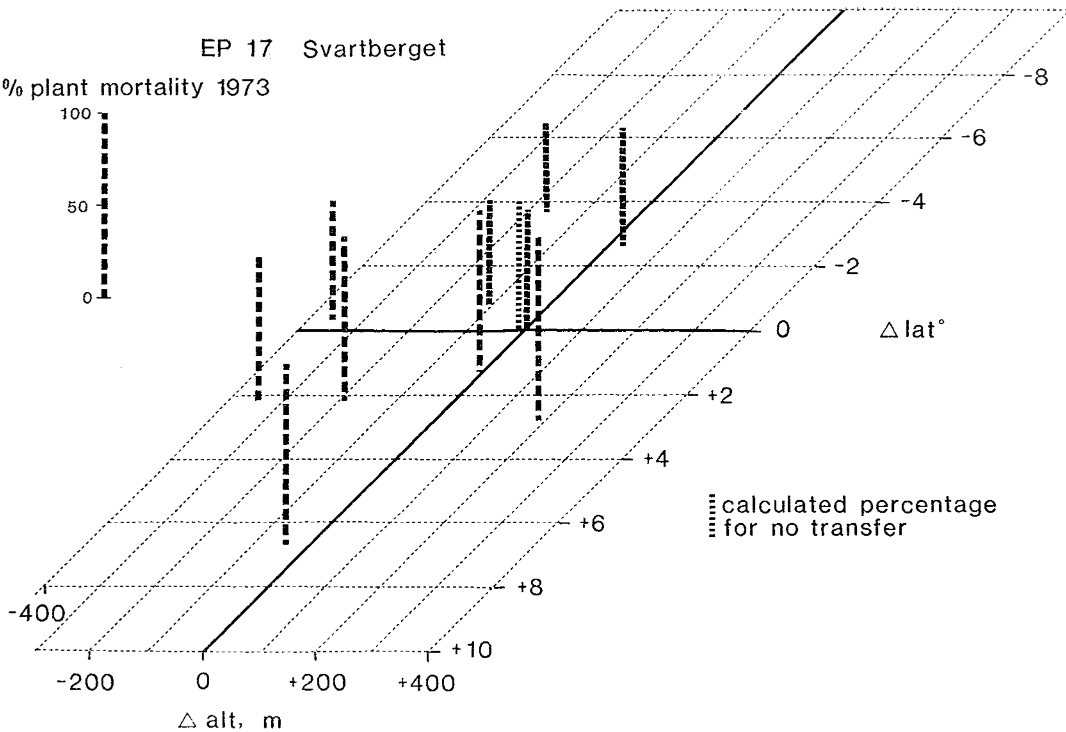

Figure 4a. The percentage of dead plants in 1973 in the populations tested at Svartberget. Legends as in Figure 3a.

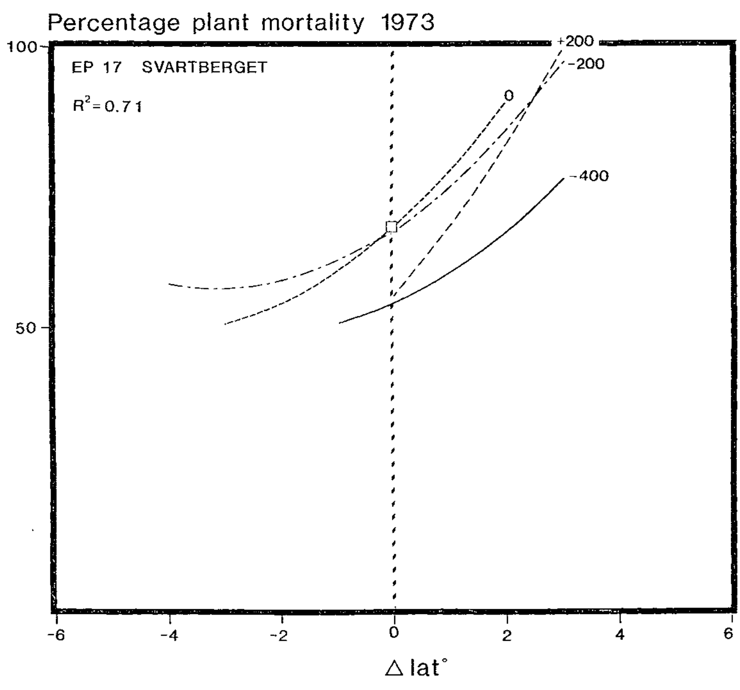

Figure 4b. The effect of latitudinal transfer at constant altitude on the percentage of dead plants at Svartberget. Legends as in Figure 3b.

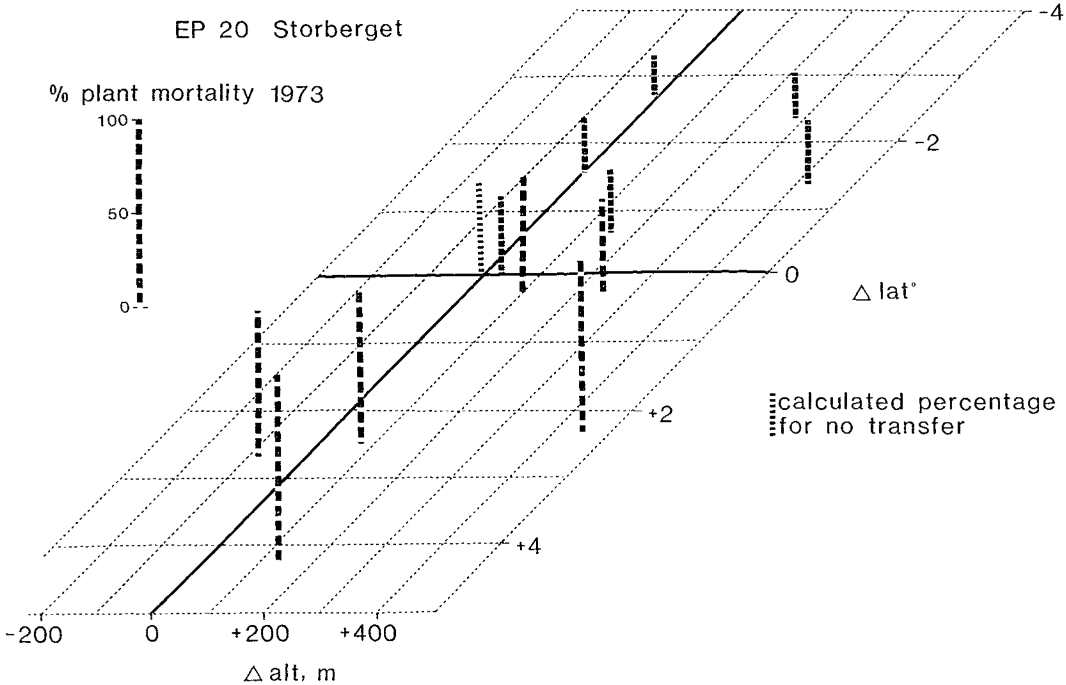

Figure 5a. The percentage of dead plants in 1973 in the populations tested at Storberget. Legends as in Figure 3a.

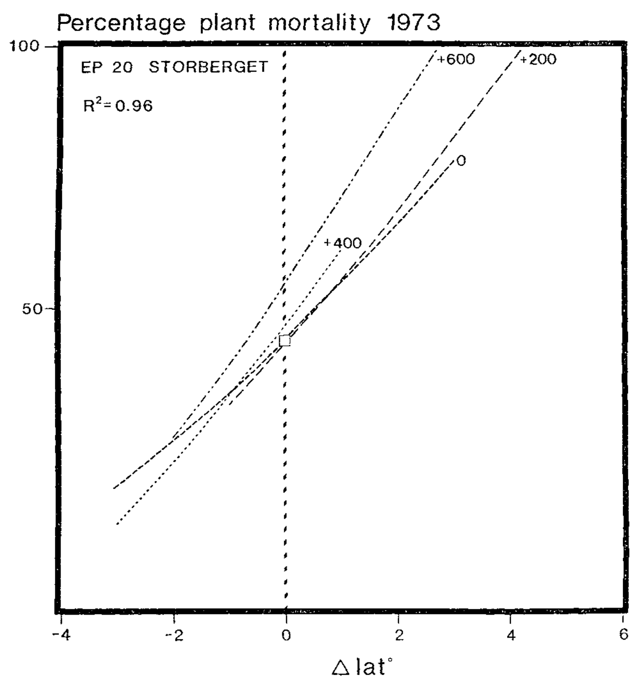

Figure 5b. The effect of latitudinal transfer at constant altitude on the percentage of dead plants at Storberget. Legends as in Figure 3b.

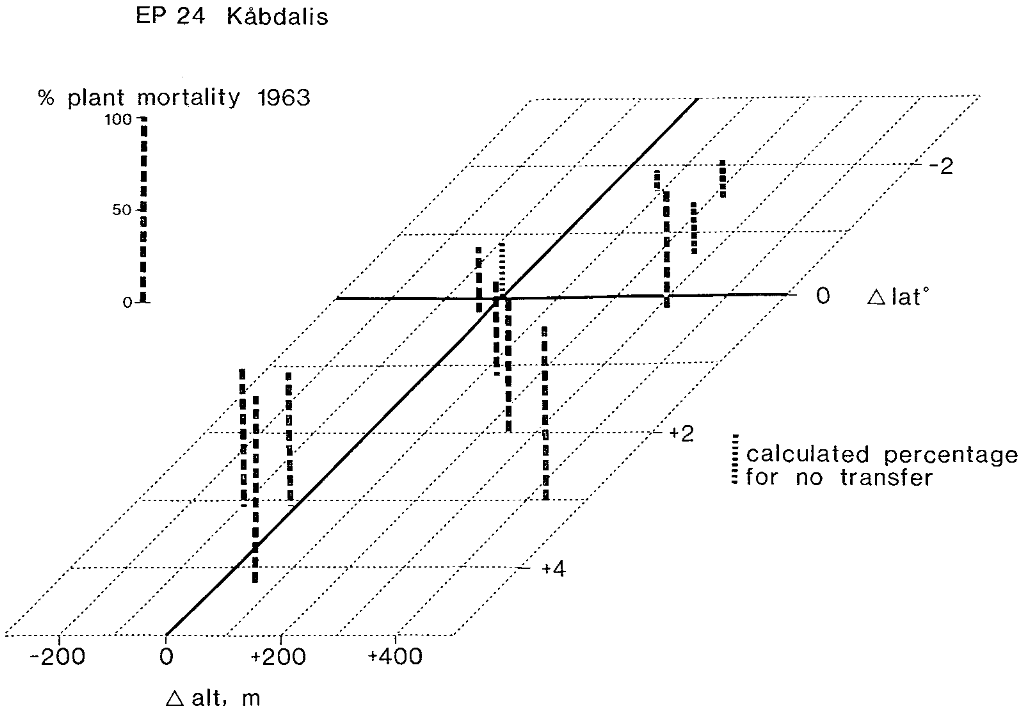

Figure 6a. The percentage of dead plants in 1963 in the populations tested at Kåbdalis. Legends as in Figure 3a.

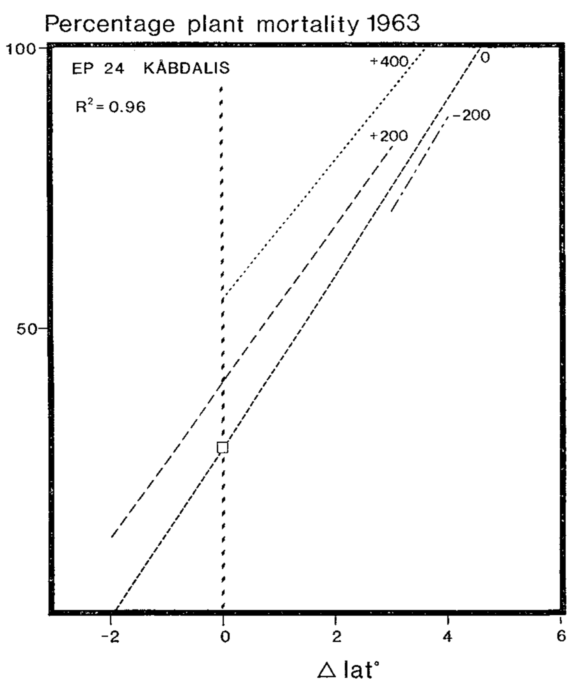

Figure 6b. The effect of latitudinal transfer at constant altitude on the percentage of dead plants at Kåbdalis. Legends as in Figure 3b.

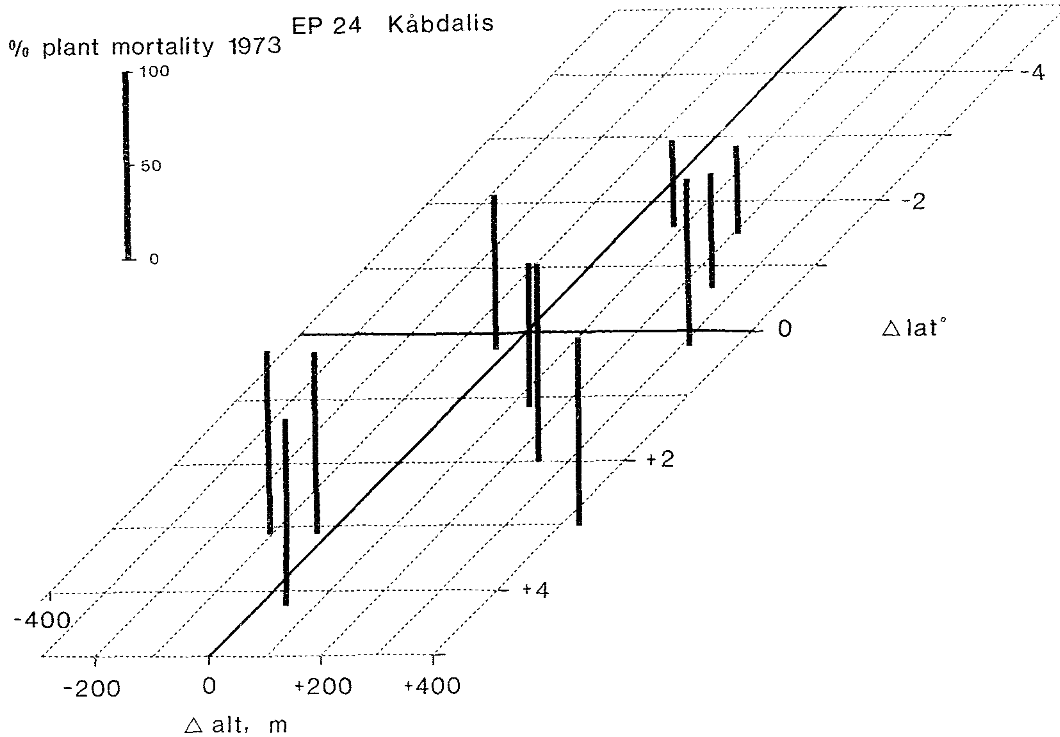

Figure 7. The percentage of dead plants in 1973 in the populations tested at Kåbdalis. Transfers as explained in Figure 3a.

sion in this case deviated from the rest of the data (as outlined above).

The R^2-values obtained from these two methods of calculating the parallel regressions amounted to 0.96 and 0.98. The high R^2-values thus confirm the visual impression of good agreement between the data from the different experimental plantations. Of the five independent variables tested, $\triangle$latitude turned out to be the most important, followed by $\triangle$altitude. The three others ($\triangle alt^2$, $\triangle lat^2$, and $\triangle alt \times \triangle lat$) gave no significant increase in the R^2-values. Thus the regressions constitute straight lines:

$$Y = k + 9.10\ \triangle lat + 2.99\ \triangle alt \quad (R^2 = 0.96)$$
$$Y = k + 10.78\ \triangle lat + 3.02\ \triangle alt \quad (R^2 = 0.98)$$

The second regression is illustrated in Figure 14.

The regressions show that every degree of transfer southwards at the same altitude implies an increase in survival by 9.1—10.8 percentage units. In the same way, every hundred metre transfer downwards at a given latitude implies an increase in survival of 3.0 percentage units. The higher value — 10.8 per cent — must be regarded as the most reliable figure for the effect of transfer by one degree latitude, since the lower figure may be biased owing to the extreme transfer to the southernmost EP of just one population, which greatly influenced the regression of this EP.

3.2 Classification into site

This classification was carried out according to the scheme worked out by Lundmark (1974). In all, twelve different characteristics were included in the examination, covering type of vegetation, moisture and soil properties.

The classification reveals that the sites for the Eiche provenance series were fairly similar.

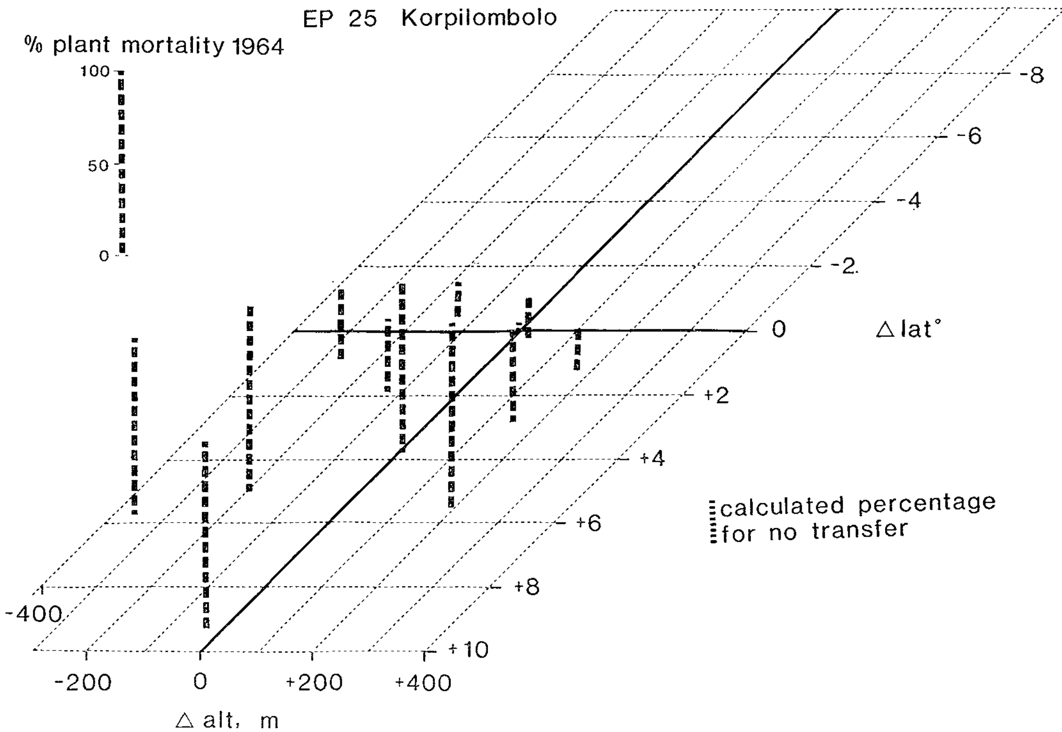

Figure 8a. The percentage of dead plants in 1964 in the populations tested at Korpilombolo. Legends as in Figure 3a.

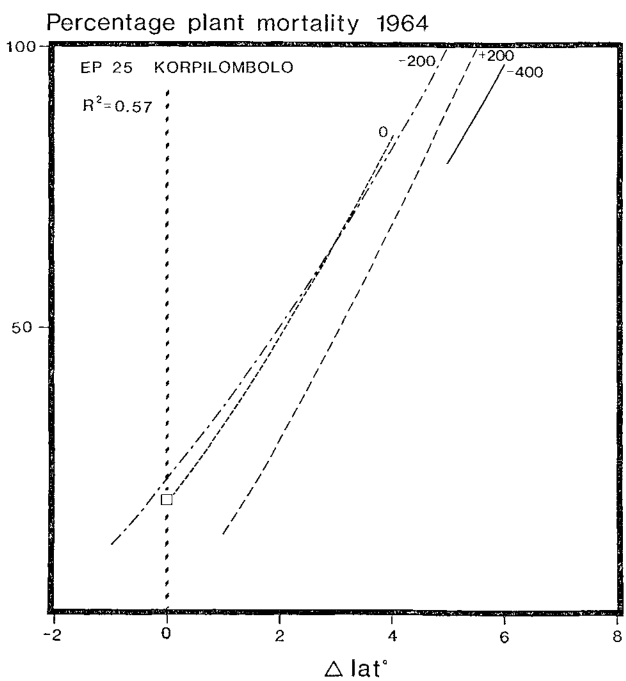

Figure 8b. The effect of latitudinal transfer at constant altitude on the percentage of dead plants at Korpilombolo. Legends as in Figure 3b.

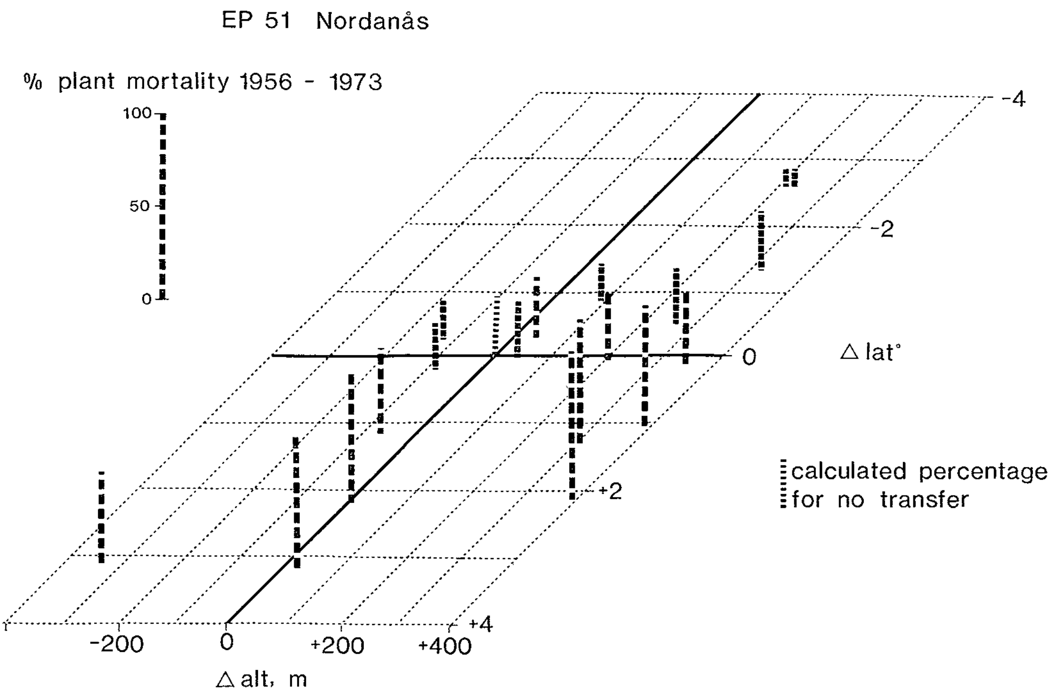

Figure 9a. The percentage of dead plants between the years 1956 and 1973 in the populations tested at Nordanås. Legends as in Figure 3a.

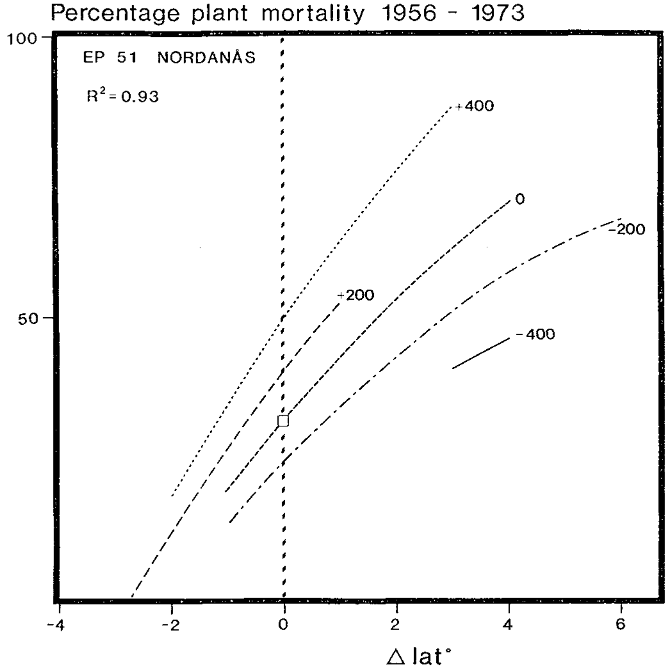

Figure 9b. The effect of latitudinal transfer at constant altitude on the percentage of dead plants at Nordanås. Legends as in Figure 3b.

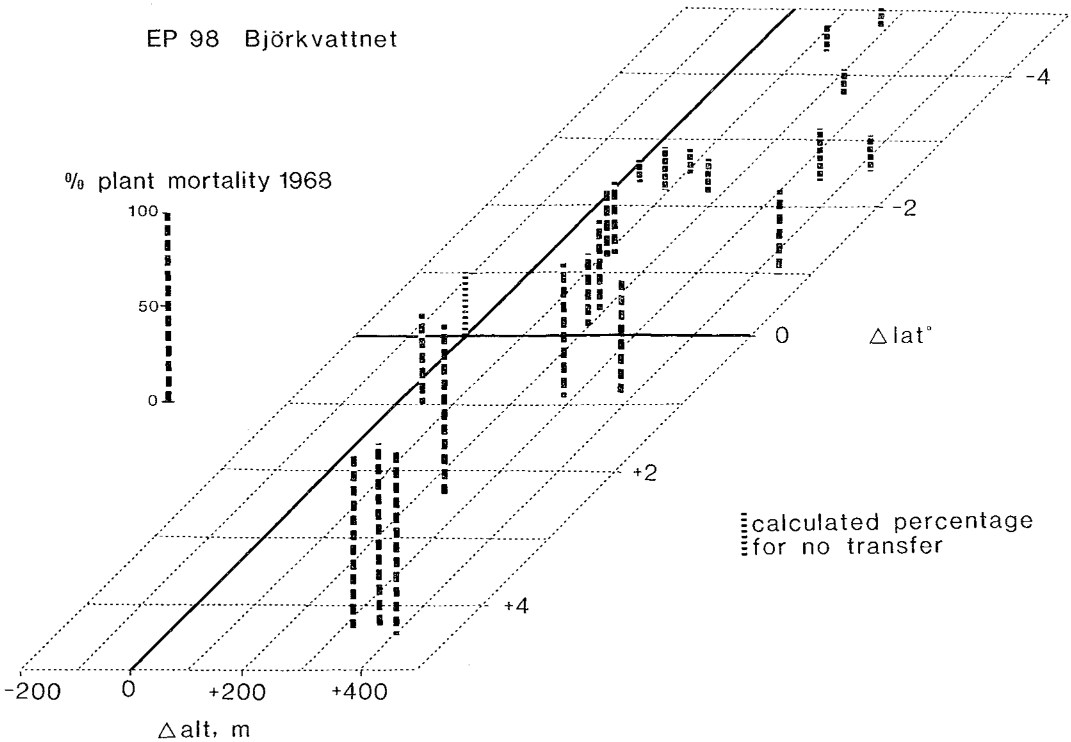

Figure 10a. The percentage of dead plants in 1968 in the populations tested at Björkvattnet. Legends as in Figure 3a.

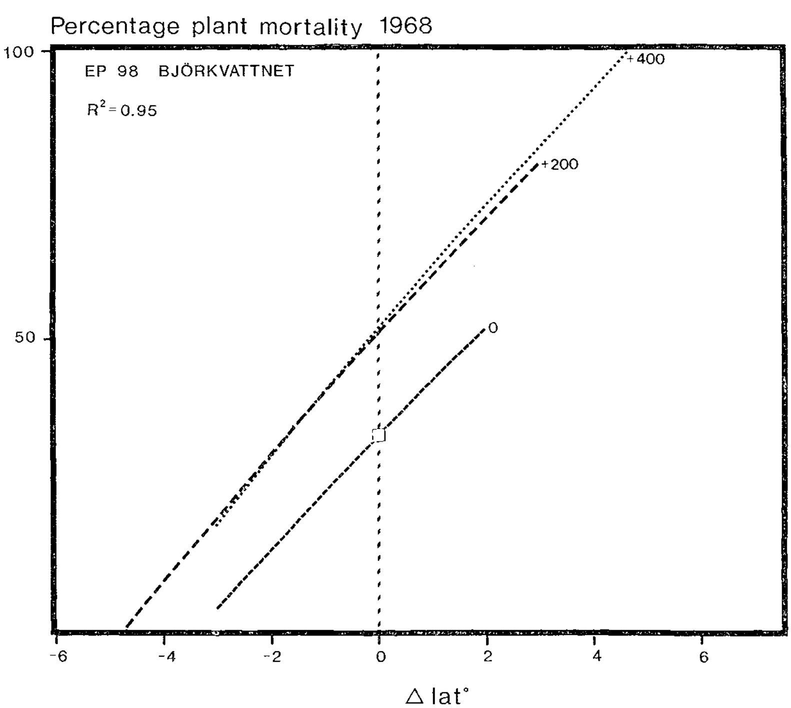

Figure 10b. The effect of latitudinal transfer at constant altitude on the percentage of dead plants at Björkvattnet. Legends as in Figure 3b.

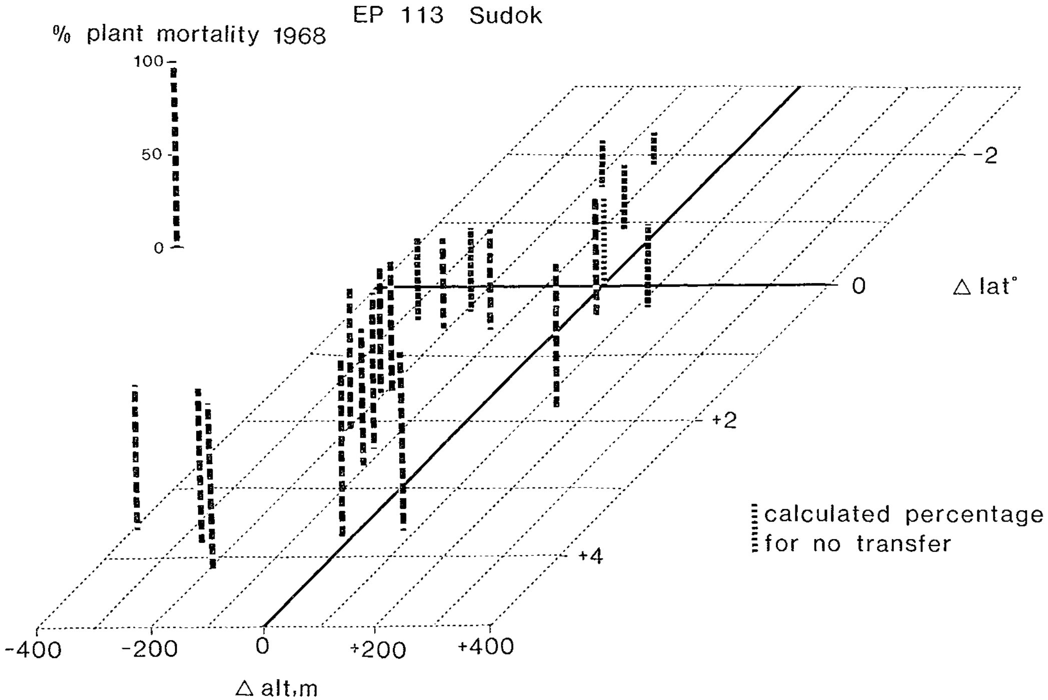

Figure 11a. The percentage of dead plants in 1968 in the populations tested at Sudok. Legends as in Figure 3a.

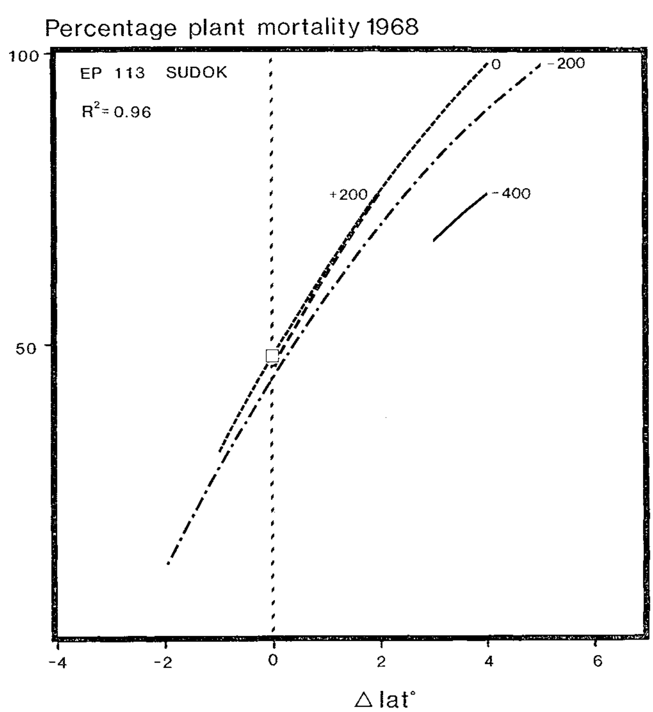

Figure 11b. The effect of latitudinal transfer at constant altitude on the percentage of dead plants at Sudok. Legends as in Figure 3b.

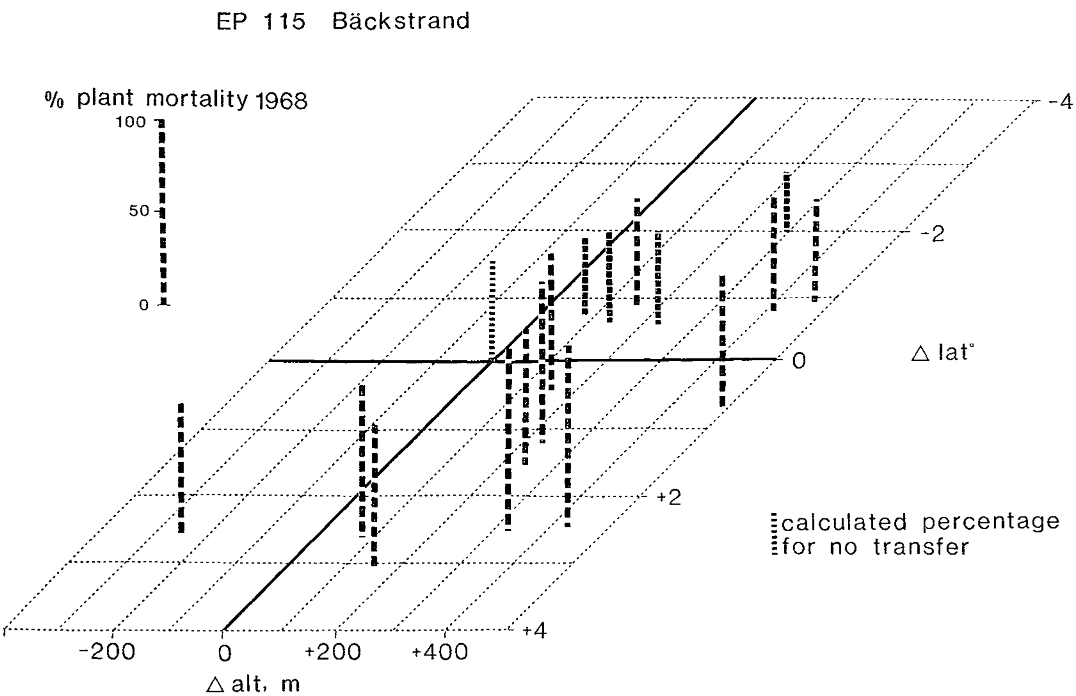

Figure 12a. The percentage of dead plants in 1968 in the populations tested at Bäckstrand. Legends as in Figure 3a.

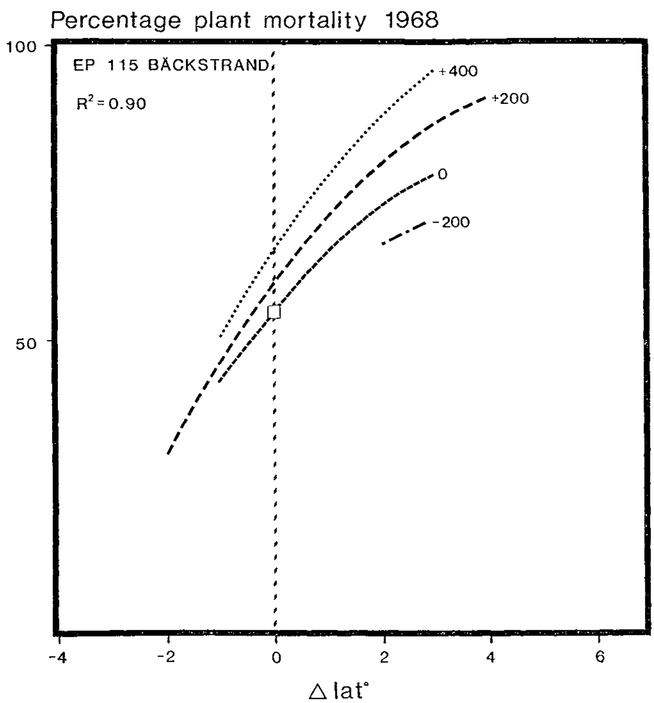

Figure 12b. The effect of latitudinal transfer at constant altitude on the percentage of dead plants at Bäckstrand. Legends as in Figure 3b.

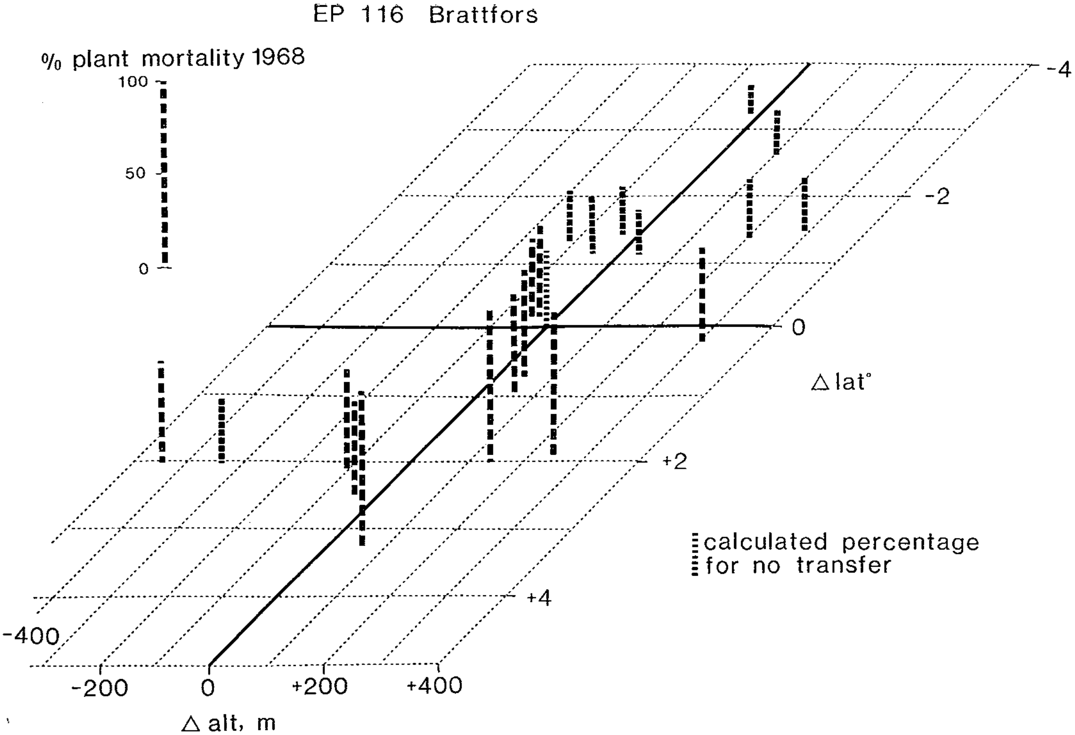

Figure 13a. The percentage of dead plants in 1968 in the populations tested at Brattfors. Legends as in Figure 3a.

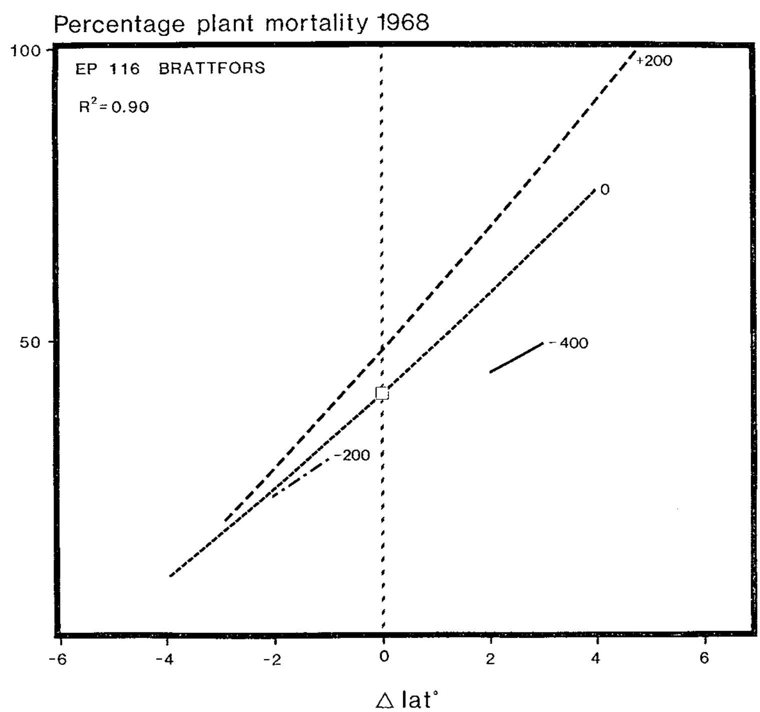

Figure 13b. The effect of latitudinal transfer at constant altitude on the percentage of dead plants at Brattfors. Legends as in Figure 3b.

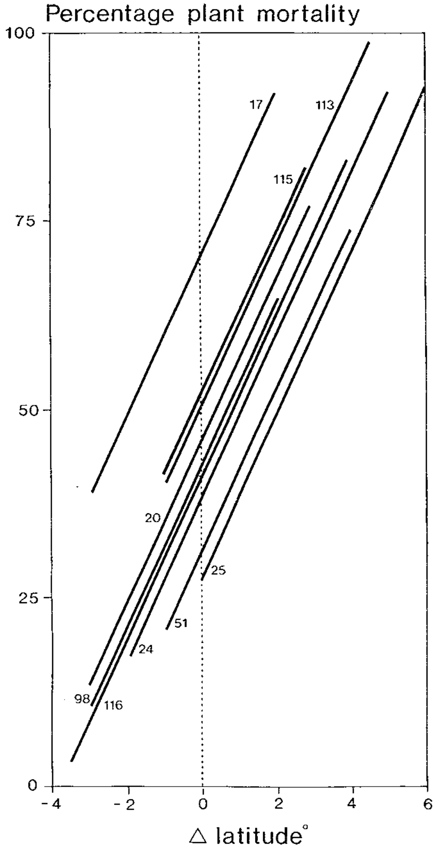

Figure 14. Illustration of parallel regressions for plant mortality at no altitudinal change; two independent variables, △altitude and △latitude are included in the regression equations. The figures indicate the EP's behind each regression.

To trace any influence of the site characteristics on the severity index of an experimental plantation, the residuals from the regression describing the severity index were compared with the site characteristics. However, no relationship could be seen. Therefore, there was no scope for improving on "the severity index map" of northern Sweden by means of the site characteristics. It has also to be remembered that the scheme worked out by Lundmark (1974) did not aim at a classification of a site with respect to plant survival but to forest tree yield.

3.3 The severity index

A detailed description of the derivation of the severity index was given in the section headed "Material and Methods". Two different regressions were calculated, one comprising all experimental plantations except EP 15 (cf. above), the other omitting EP's 16 and 20 as well. The reason for this was that their i-values deviated strongly from those to be expected on the basis of their geographical location. EP 16 showed a much greater mortality rate than expected, whereas EP 20 showed lower mortality than expected. These two EP's were examined more carefully with respect to site classification than any of the other ones in the Eiche series. However, this detailed classification did not result in any suggested explanation for the deviating pattern of plant mortality in the EP's (Lestander & Ståhl, 1980). A possible difference in the weather at the two EP's may be responsible for the results obtained. No recording of weather conditions took place, which means that we can only guess at the reasons.

The following regressions were obtained:

All EP's except EP 15

$Y = 0.14486 \text{ lat} \cdot \text{alt} + 0.03950 \text{ lat}^2 - 139.89$

$(R^2 = 0.59)$ I

All EP's except EP's 15, 16, and 20

$Y = 0.14635 \text{ lat} \cdot \text{alt} + 0.04364 \text{ lat}^2 - 157.21$
$(R^2 = 0.72)$ II

The last regression is illustrated in two different ways in Figures 15—16. Theoretically, severity index 100 should reflect the timber line. However, the scarcity of trials close to the timber line means that no exact agreement between the derived and the actual timber line can be expected.

The diagram of the severity index should be consulted before a decision is taken regarding the distribution of field trials. Thus, by the aid of Figure 16, the distribution of field trials can be done in a more efficient way than merely using the latitudes and altitudes of presumptive field trial localities.

Finally, it may be added that one can hardly expect any better agreement between observed data and the regression since the provenances tested varied from EP to EP. Moreover, the local climatic conditions may interfere with the general trends—as was probably the case for EP's 16 and 20 (cf. above).

3.4 Combining the severity index with the regression showing the effect of transfer on plant mortality

The linkage of these two factors will be achieved with the aid of Figure 17. In this figure the severity index is shown as dashed curves, and the data from the parallel regressions as straight, solid lines separated by ten percentage units. According to the parallel regressions, a transfer of one degree latitude at a given altitude causes a change in plant survival of 10.8 percentage units. An altitudinal transfer of 100 metres causes a change of three percentage units in survival.

By means of the curves and the parallel lines, it will be possible—for any point in the diagram—to estimate how to transfer material to obtain a given survival rate. Two examples will help to explain how to use the diagram.

At lat 61.0°, 333 m, the severity index is 35. To reduce plant mortality to 25 per cent at this locality the seed must be obtained from localities on the straight line passing through lat 61.9°, 333 m.

At 64.0°, 600 m, the severity index from the graph is 78. If seed is transferred to this locality from the straight solid line passing through lat 67.0°, 500 m, plant mortality will be reduced by 30 percentage units to 48 per cent.

From the diagram it is obvious that the prospects of obtaining satisfactory survival at high latitudes and altitudes by moving material are non-existent. For this region selection of especially hardy individuals may be a solution to this problem.

3.5 Volume per hectare

In the paper by Remröd (1976) it is claimed (in free translation from Swedish into English) that "Using the wide spacing as we do today, we have to rely on the survival of each plant to obtain sufficiently dense stands of *Pinus sylvestris* in the interior part of northern Sweden". This sentence pinpoints the great problems the forest officer faces in reforestation. In the previous part of this paper, figures of poor survival were shown repeatedly. Fortunately, the effect of provenance transfer on plant survival was shown to be uniform (cf. page 15). Therefore, it may seem simple to recommend a transfer for satisfactory survival, that is, a transfer southwards or downwards. However, in so doing there will be a reduction of growth at the tree level owing to different photoperiodic responses of different provenances. The northern ones show an earlier growth cessation than the southern ones. Thus, one has to find an optimum transfer as regards volume production per hectare. According to Remröd (1976) survival of 70—80 % will result in the highest yield. His conclusion was based on data from EP's 20, 51, 98, 113, 115 and 116. Besides the EP's listed in the previous sentence, the volume/ha was studied in all other EP's treated in this paper.

For the Eiche series of experimental

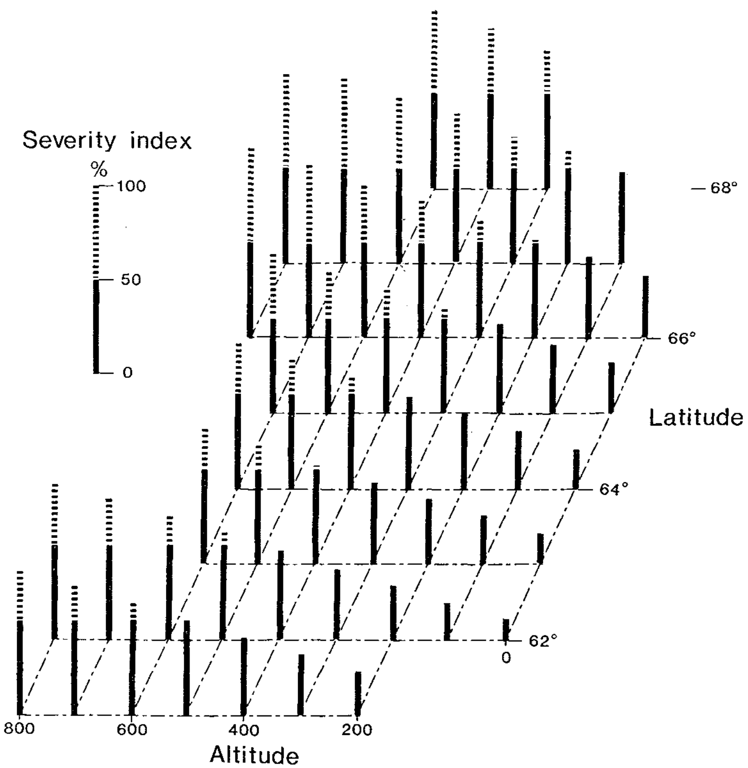

Figure 15. Severity index for different latitudes and altitudes in northern Sweden. The severity index constitutes an estimate of expected plant mortality in the local population during the first 20-year period following planting.

plantations the volume/ha of the provenances studied at EP's 11, 17, 20, 25 and 51 are shown in Figures 18—22. These were selected because they contained the highest number of provenances with satisfactory survival, thereby making a calculation of the volume/ha meaningful. As may be seen from Figures 18—22 no general trends in the effect of transfer on volume per hectare can be traced, in contrast to the situation for the effect of transfer on survival.

Our results also constitute a contrast to the uniform results obtained by Remröd (1976). Of our EP's only Nos. 20 and 51 agree with Remröd's results. The reason for the discrepancy between the results of the two investigations might be that our EP's contain too few provenances to be able to show the trends after transfer. However, the uniformity was high as regards the effect of transfer on survival. In Remröd's investigation the majority of the provenances were the same at all EP's, whereas only a few provenances were common to all test sites in the Eiche series of EP's. This may also contribute to the discrepancy. Moreover, EP 11 Högståsen is situated at the border with that part of Sweden in which no survival problems for Scots pine exist and thus a slight increase of volume per hectare is expected after transfer northwards.

A stepwise regression analysis, comprising the same five independent variables as in the calculations referred to earlier in this paper, was used to trace an effect of transfer in this case. As expected no general trends were observed in the five regressions.

Summarizing the present knowledge it may be stated that the deviations from the pattern reported by Remröd (1976) are not strong enough to cause us to suggest any other rules for transfer of provenances than those given by Remröd (1976).

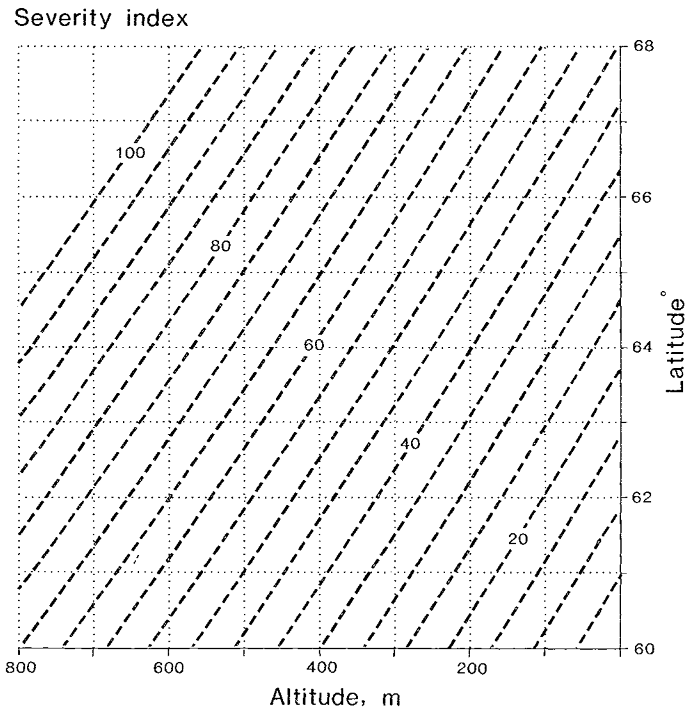

Figure 16. Curves connecting localities with the same severity index. To facilitate the visual illustration parts of the curves constituting extrapolations have not been omitted. The curve "100" constitutes an estimate of the timber line.

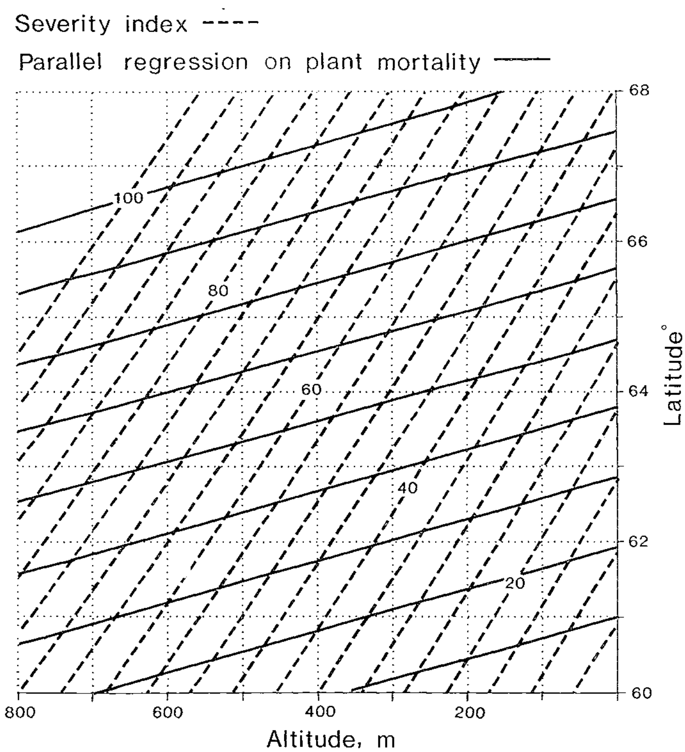

Figure 17. The combination of the severity index (dashed curves) with the parallel regression (straight, solid lines separated by ten percentage units). By the aid of the diagram it is possible to estimate how to transfer material to obtain given percentage plant survival. For details see the text.

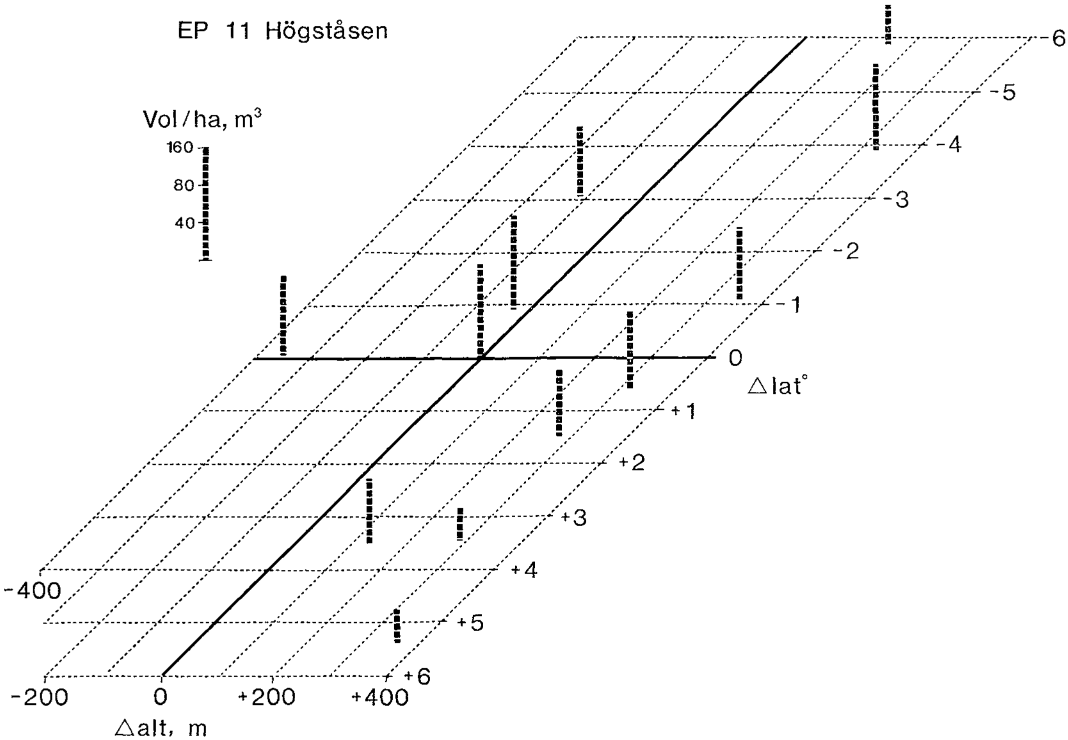

Figure 18. Volume (m³ o.b.) per hectare at an age of 20 years for populations transferred in various directions to EP 11, Högståsen. Columns below the horizontal line indicate populations which were moved in a northern direction. Columns to the right of the diagonal axis show populations which were moved to a higher altitude.

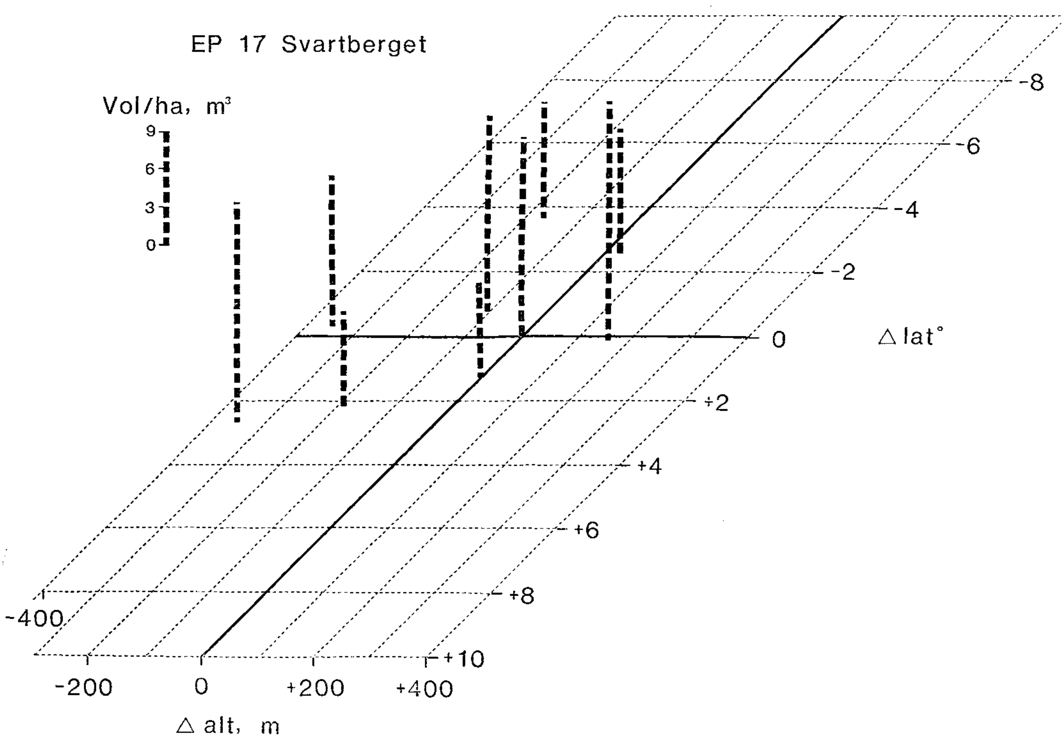

Figure 19. Volume (m³ o.b.) per hectare at an age of 20 years for populations transferred in various directions to EP 17, Svartberget. Columns below the horizontal line indicate populations which were moved in a northern direction. Columns to the right of the diagonal axis show populations which were moved to a higher altitude.

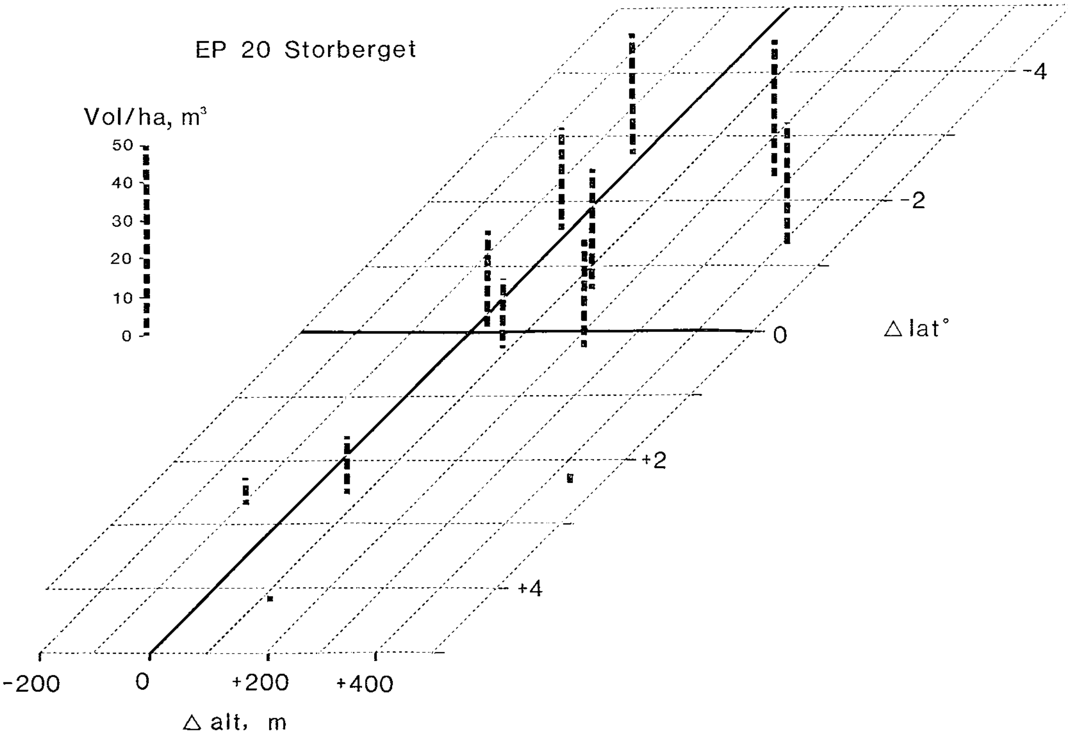

Figure 20. Volume (m3 o.b.) per hectare at an age of 20 years for populations transferred in various directions to EP 20, Storberget. Columns below the horizontal line indicate populations which were moved in a northern direction. Columns to the right of the diagonal axis show populations which were moved to a higher altitude.

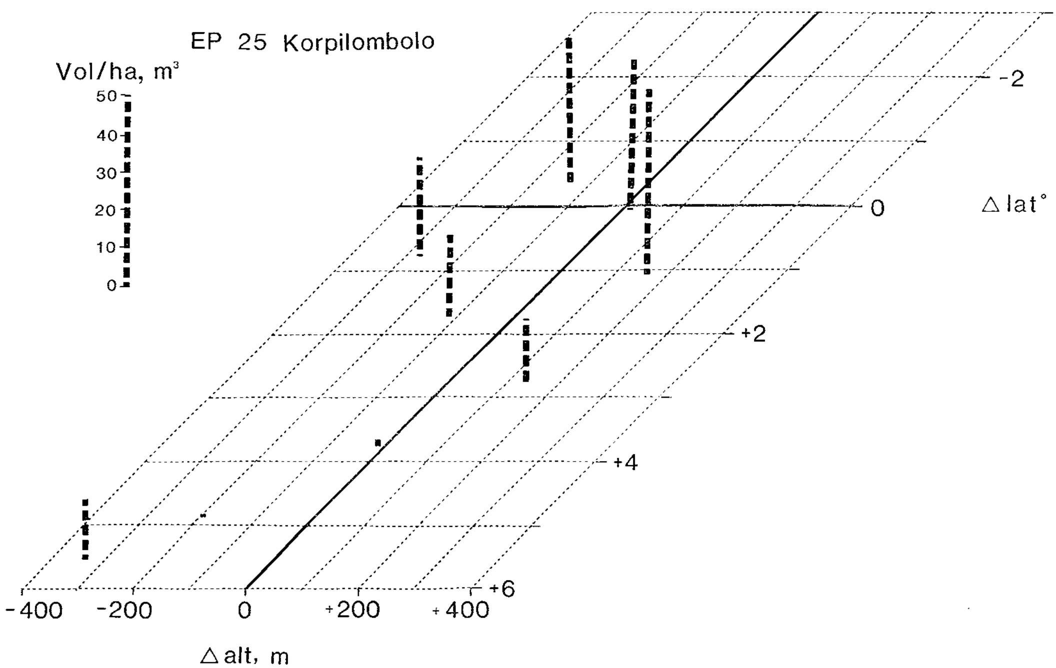

Figure 21. Volume (m3 o.b.) per hectare at an age of 20 years for populations transferred in various directions to EP 25, Korpilombolo. Columns below the horizontal line indicate populations which were moved in a northern direction. Columns to the right of the diagonal axis show populations which were moved to a higher altitude.

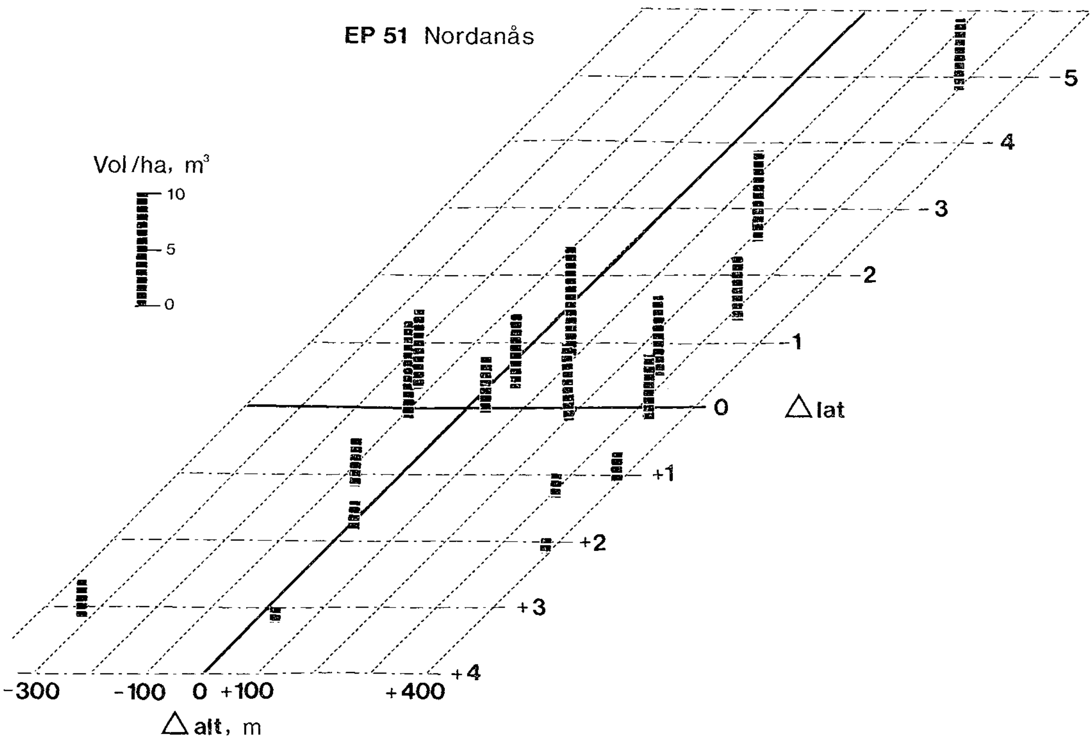

Figure 22. Volume (m3 o.b.) per hectare at an age of 20 years for populations transferred in various directions to EP 51, Nordanås. Columns below the horizontal line indicate populations which were moved in a northern direction. Columns to the right of the diagonal axis show populations which were moved to a higher altitude.

4 Acknowledgments

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6 Sammanfattning

Som en metod att standardisera jämförelser av data från olika försöksytor introducerade Eriksson (1975) begreppet hårdhetsindex. Arbetet grundade sig på Campbell (1974) som analyserat data från proveniensförsök, presenterade av Eiche (1966).

Hårdhetsindex för en lokal definieras som "den förväntade procentuella avgången hos lokalpopulationen under den första 20-års-perioden efter planteringen". Hårdhetsindex har bestämts för ett antal försökslokaler, utöver för den av Eiche (1966) beskrivna försöksserien också för försök som ingår i Remröds (1976) arbete.

Den sålunda erhållna serien av hårdhetsindex har utjämnats med hjälp av matematiska funktioner. Härigenom erhölls en biologisk karta över norra Sverige som ger lokalproveniensens förväntade avgång vid olika latitud och höjd över havet (figur 16). Det bör observeras att hårdhetsindex inte gäller för västra Jämtland, där det atlantiska inflytandet på klimatet är påtagligt.

Med syfte att om möjligt höja funktionernas förklaringsgrad har försöksytorna markklassificerats enligt en modell utarbetad av Lundmark (1974). Inget samband mellan markfaktorer och hårdhetsindex kunde dock fastställas.

För att kunna upprätta generella samband över hur förflyttningen påverkar överlevnaden har för varje försökslokal beräknats funktioner över sambandet mellan överlevnad och förflyttning i höjd och latitud. Genom god samstämmighet har de sålunda beräknade funktionerna kunnat sammanföras till parallella regressioner (figur 14). Det visade sig att införande av oberoende variabler utöver förflyttning i latitud och i höjd över havet inte förbättrade anpassningen. Funktionen visar att en grads förflyttning i sydlig riktning vid samma höjd över havet innebär en ökad överlevnad med 10,8 procentenheter. En förflyttning av hundra meter nedåt vid samma latitud innebär en ökad överlevnad med 3,0 procentenheter.

Hårdhetsindex och förflyttningseffekt har sammanställts i figur 17. Hårdhetsindex är här markerat med hjälp av streckade kurvor, medan de parallella regressionerna har framställts som räta, heldragna linjer.

Med hjälp av kurvorna och de parallella linjerna är det möjligt att för en valfri punkt i diagrammet bestämma hur man skall förflytta skogsodlingsmaterial för att uppnå en viss överlevnad.

Två exempel visar hur diagrammet skall användas: I punkten 61,0°, 333 m är hårdhetsindex 35. För att nedbringa plantavgången till 25 % på denna lokal måste frömaterialet hämtas längs den linje, som passerar punkten 61,9°, 333 m. I punkten 64,0°, 600 m kan hårdhetsindex avläsas till 78. Om frömaterialet förflyttas till denna lokal från den linje, som passerar 67,0°, 500 m, nedbringas plantavgången till 48 %. Detta motsvarar en förbättring av överlevnaden med 30 procentenheter.

Vid nordliga latituder och höga höjder över havet är det uppenbart att tillfredsställande överlevnad inte kan erhållas genom att förflytta skogsodlingsmaterial. För dessa regioner kan urval av speciellt härdiga individer vara en lösning.

En kraftig sydförflyttning innebär i genomsnitt en minskad höjdtillväxt (Remröd 1976). Enligt samma uppsats erhålls den högsta volymproduktionen vid en sydförflyttning som ger 70—80 % överlevnad. Motsvarande studie har genomförts även inom Eiches proveniensserie. Resultaten är dock något motsägande, vilket kan förklaras av att varje försök innehåller alltför få provenienser. Den enda försöksyta inom Eiche-serien som innehåller ett större antal provenienser visar resultat som överensstämmer med Remröds (Eriksson et al. 1976).

Sammanfattningsvis är avvikelserna från det mönster som Remröd (1976) konstaterat inte av sådan art att några nya förflyttningsrekommendationer behöver utarbetas. Förflyttningen bör således sikta mot att uppnå 70—80 % överlevnad.

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