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The influence of the environment close to a snow fence on the survival and growth of pine seedlings *(Pinus silvestris L.)*

Inflytandet av miljön nära ett snöstaket på överlevnad och tillväxt hos tallplantor

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Abstract

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The natural regeneration of pine along a snow fence (3 m high) on a clear cut (1956) area on a dry site at a high altitude far north (lat. 66°44′ alt. 320 m) was studied. The density of the regeneration was ten times higher close (0—40 cm) to the fence than in the open clear cut area. The positive effect from the fence was present only up to a distance of 1.5 m. The seedlings close to the fence were 50—100 % taller than those in the open and the wounds from Dasyscypha, which were found on 48 % of the seedlings in the open area, could hardly (2 %) be detected among those along the fence. The height of the seedlings reflected a close correlation with the depth of the snow, while the density of the seedling stand did not correlate as well, although significantly.

The positive effect of snow fences as well as the micro-environment at large should be worth studying because it is obvious that great gains in regeneration results could be obtained by arrangement of suitable environments. There is reason to question the common technique for cleaning the clear cut areas, for treatment with herbicides and for thinnings in sown and planted seedling stands.

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1 Introduction

The survival of the artificial regenerations of pine in the northernmost part of Sweden (latitude 65°—67° above altitude 250 m) is very low. The provenance tests arranged in these areas in the 1950's show that the local provenance does not survive more than to 30 % at an age of twenty years (Eiche & Gustafsson 1970, Remröd 1975). If seed from a more northern place is used the survival may be somewhat increased but in these areas it is very difficult to obtain seed from the north.

In practice the regeneration results used to be less good than in tests. This is also confirmed by the results presented by Häggström (1974). At the latitudes 63°—67° the survival in regenerations established two years earlier was only 59 %. In eight out of ten plantations at latitude 65°—67° there were less than 1600 seedlings/ha and a considerable frequency of spots without seedlings.

A survey of old regenerations was carried out at the governmental forests in 1971 (Rydin 1971). Within certain districts of the interior of the "Norrbotten" (latitude 66°—67°) just 40 % of the regenerations established 1950—1965 was found to be acceptable. Frequently there were only 700 seedlings/ha left when the mean height was 2 meters.

Everyone who examines a ten-year-old plantation on level ground in these surroundings can easily see that the survival varies in a high degree from one spot to another. The pattern is obvious but it is impossible to obtain a clear view of what ground or climatic factor is the origin of the pattern. Carlquist (1972) has presented extensive material illustrating the spotwise variation in survival and growth. Andersson (1968) discussed the importance of night frosts to the differences in survival between hills and hollows.

In this paper the survival and growth of pine seedlings in the vicinity of a snow fence is presented. In this place, on a pine heath close to Nattavaara near the Arctic circle, the snow fence has drastically improved the environment of the seedlings. This location was chosen because the results was typical for many similar places where snow fences were built in clear cuts. Meteorologists, physiologists and pathologists seem to have good reasons to study these places in detail, because here it is possible to describe such important factors which enable a good regeneration to be established in spots where seedlings normally are unable to endure.

2 Material

The area described is a small part of an even pine heath. The place is situated 5 km west of Nattavaara along the road to Messaure, latitude 66°44′, longitude 20°52′E, altitude 320 m. Common plant species are Calluna vulgaris, Vaccinium vitis-idaea and Cladonia sp. There is uncut pine forest 100 m to the east but in the other directions there is clear cut area, altogether 120 ha. The ground surface is mainly even but within the studied area there are elevational differences of up to 2 meters.

The forest was cut in 1956. No seed trees were left at the studied area (the closest 35 ha) but on the remaining part of the clear cut. These seed trees were cut in 1968. Twenty randomly chosen seedlings in the regeneration were investigated as to their age. As a mean they were born in 1958, the oldest in 1952 and the youngest in 1962. The seedlings close to the snow fence (0—20 cm from the screen) were about one year older than those in the open clear cut area.

The snow fence extends in the SSW—NNE direction (209° on the compass, scale 360°). From the ground to the lowest board there is a 60 cm gap, each board is 10 cm wide and the distance between them is 6 cm. The screen is 278 cm high. The snow fence was built at a distance from the road of 20—40 m in 1945. The trees of the forest must then have been fairly widely scattered.

The regeneration, which is naturally sown pine, was studied in 1972 and the snow depth was measured in January 15th 1973. The snow depth was measured once again in March 1975. The distribution of the snow was essentially the same at the first and second instance. The presented calculations consider the first measurement of snow only.

With exception for the area close to the snow fence the regeneration has developed quite similarly on both sides of the fence. A large number of small and dead seedlings prove that the seeding has been good and the environment for germination favourable everywhere in the clear cut region. Birch (Betula sp.) is infrequent in this area.

3 Methods

The height and the size of the terminal shoot was measured on the living seedlings. Their vitality was estimated subjectively in a scale: 1 = very weak . . . 9 = excellent condition. The exact position of every seedling on the ground was recorded. This was done within three zones, extending 100 m along the fence. The closest zone was situated 0—150 cm from the screen, the second 4.0—5.0 m and the third 50.0—51.0 m out from the screen. On the eastern side only the first zone was studied.

An ocular investigation of the seedlings was performed to find out if the frequency of "basal stem girdling" by the canker Dasyscypha fuscosanguinea was the same close to the screen and in the zone 50 m from the screen.

4 Results

The density of living seedlings was ten times higher close to the screen (table 1, figures 1 and 2). On the side facing west the density began to decrease at a distance of 50 cm from the screen and at 100 cm the density was as low as out in the open area. On the opposite side the density was highest immediately close to the screen and decreased very rapidly within the first 30—60 cm. Generally the density was higher on the side turned towards the west.

The variation in density was very large along the snow fence (figure 1).

The seedling size was larger close to the screen (table 1, figures 2 and 3). The mean height close to the screen was 50 % (west side) and 100 % (east side) larger than in the open area. If a thinning had been performed among the seedlings and 800 seedlings/ha were left the mean height close to the screen would exceed the height in the open area by 3—4 times (figure 2).

The seedling vitality, judged ocularly, was considered much higher among seedlings close to the screen. The seedlings at the side facing east were thriving even more than those on the opposite side (table 1).

The pine canker (*Dasyscypha fuscosanguinea*) had formed basal stem wounds on 48 % of the seedlings in the open area, but could hardly be found (2 %) on the seedlings close to the fence (0—20 cm) (table 1).

The snow depth was smallest immediately underneath the screen and largest at a distance of 4—10 m. This corresponds well with data presented in Geiger (1971) which indicates that the wind speed is not lowered close to the screen but has a minium at a distance corresponding to 6 times the screen-height if the penetration is 50 % (figure 5). In this case the penetration is 38 %.

Table 1. Data on seedlings and snow along the snow fence.

Snow fence

East side (ESE) — Distance from fence, cm ←

West side (WNW) — → Distance from fence, cm (m)

	150	120	90	70	50	40	30	20	10	00	10	20	30	40	50	70	90	120	150	4 m	50 m
No. of trees measured	8	10	6	4	5	4	8	10	13	9	12	10	17	6	10	7	1	2		8	8
No. of surviving trees/ha, thousands	2.7	3.3	3.0	2.0	5.0	4.0	8.0	10.0	13.0	9.0	12.0	10.0	17.0	6.0	5.0	3.5	(0.3)	(0.7)		0,8	0.8
Average height of surviving trees, cm	99	116	122	150	139	121	111	118	94	95	95	69	89	109	63	81	(13)	(42)		34	61
Average height of the 800 stems/ha which are tallest, cm	130	166	177	230	195	203	175	200	233	210	190	145	200	178	103	174	–	(30)		34	61
Vitality of surviving trees, scale; 9=very good, 1= very weak	8.0	7.4	8.0	7.3	7.4	8.3	7.9	8.4	8.5	7.1	7.4	7.3	7.3	8.0	6.3	6.9	(6.0)	(7.0)		3.0	6.3
Per cent of seedlings with wounds infected by Dasyscypha										← 2 % →							← 72 % →				48 %
Depth of snow Jan. 1973, cm	40	35	28	24	22	21	20	19	19	20	23	29	35	41	50	59	67	69		70	60

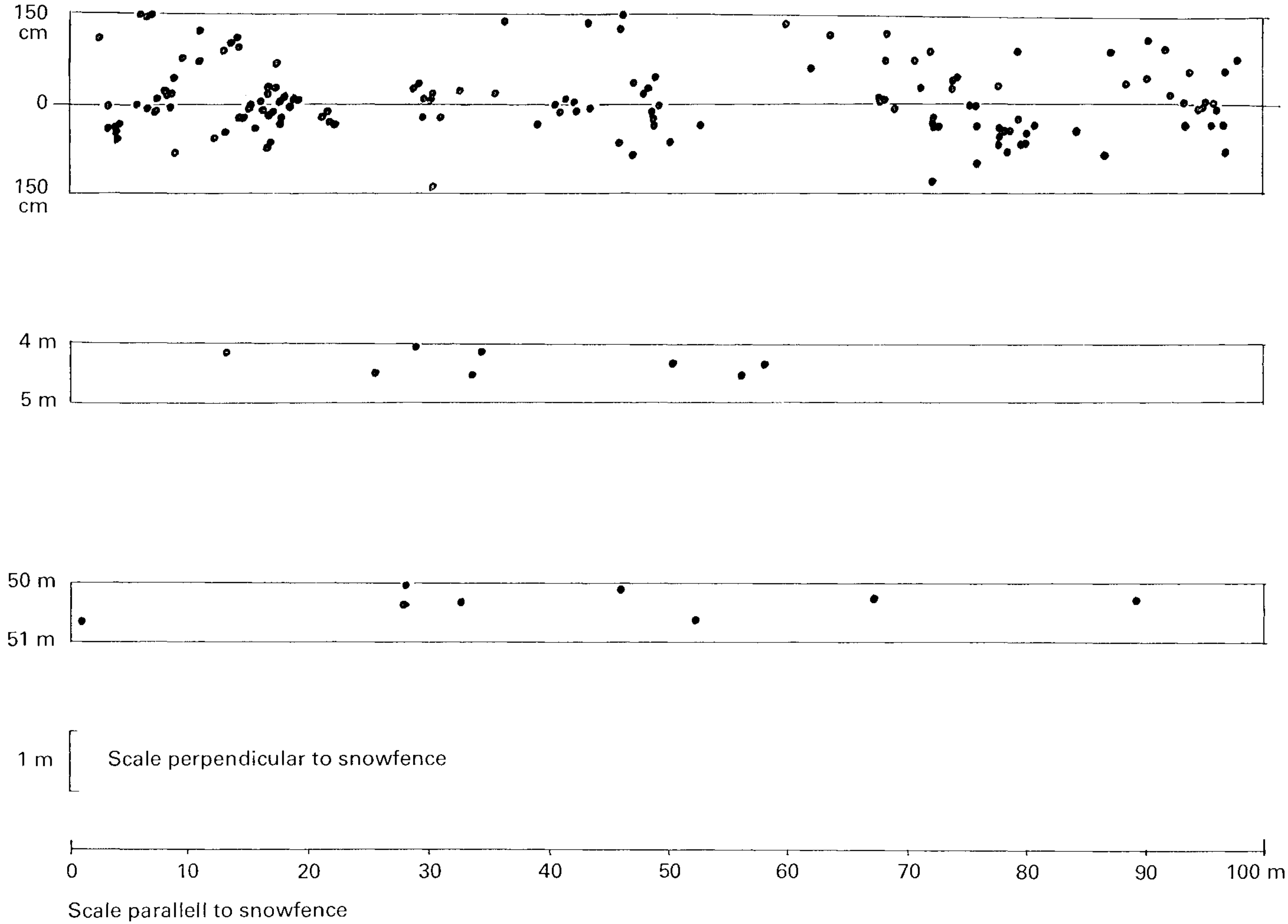


Figure 1. The position of pine seedlings along the snow fence.

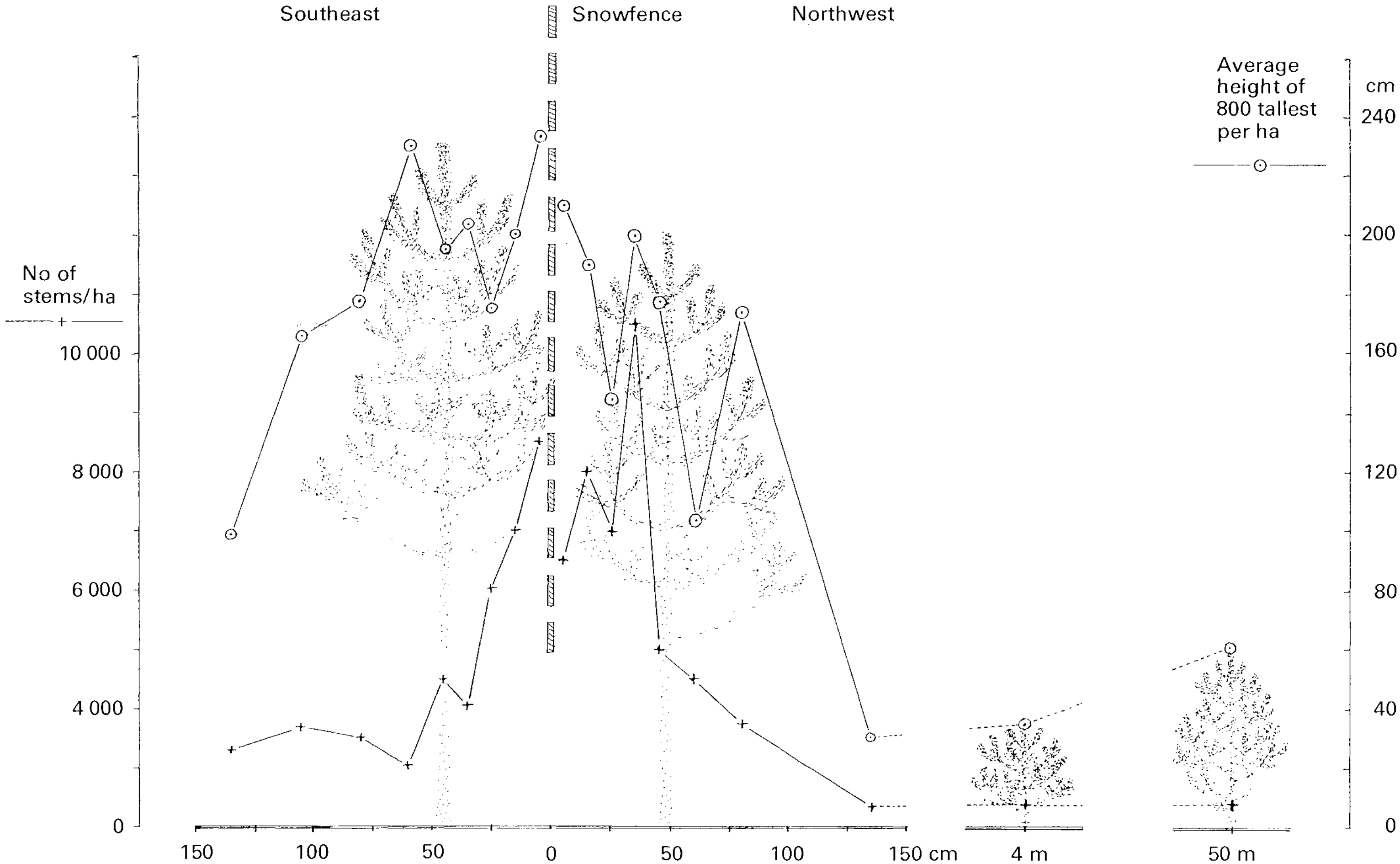


Figure 2. Number of seedlings per hectare and the height of the tallest trees (800 seedlings/ha) at various distances from the screen.

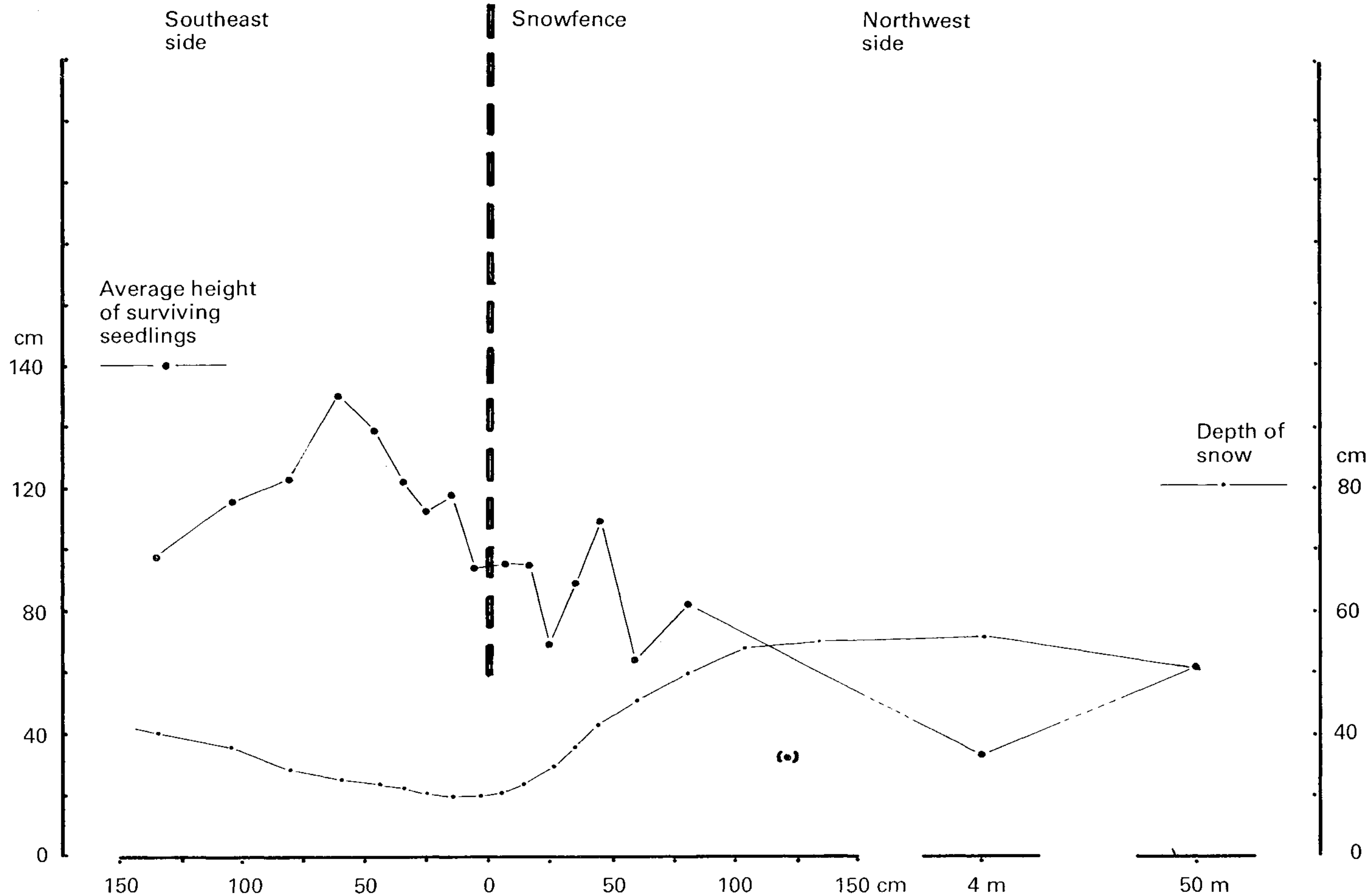


Figure 3. Average height of surviving seedlings and depth of snow at various distances from the snow fence.

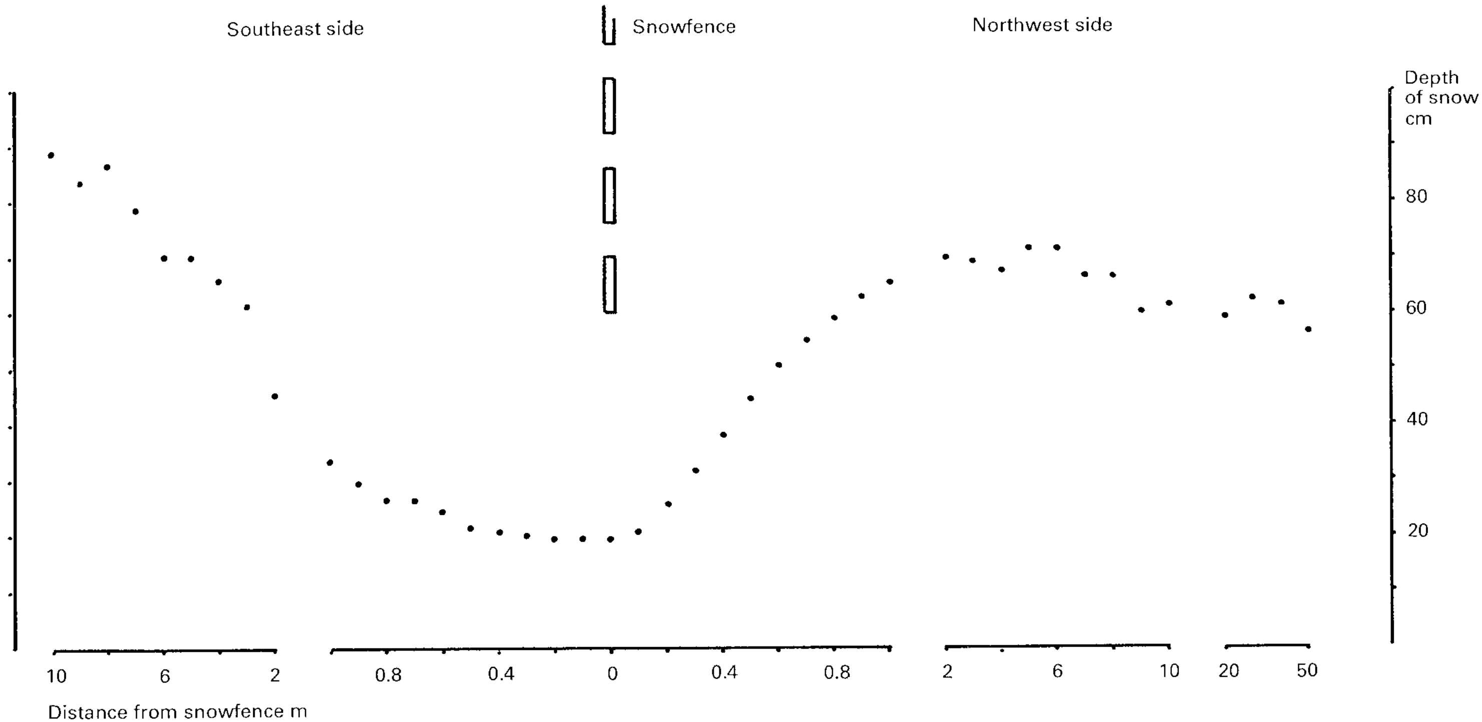


Figure 4. Depth of snow in January 1973 at various distances from the snow fence.

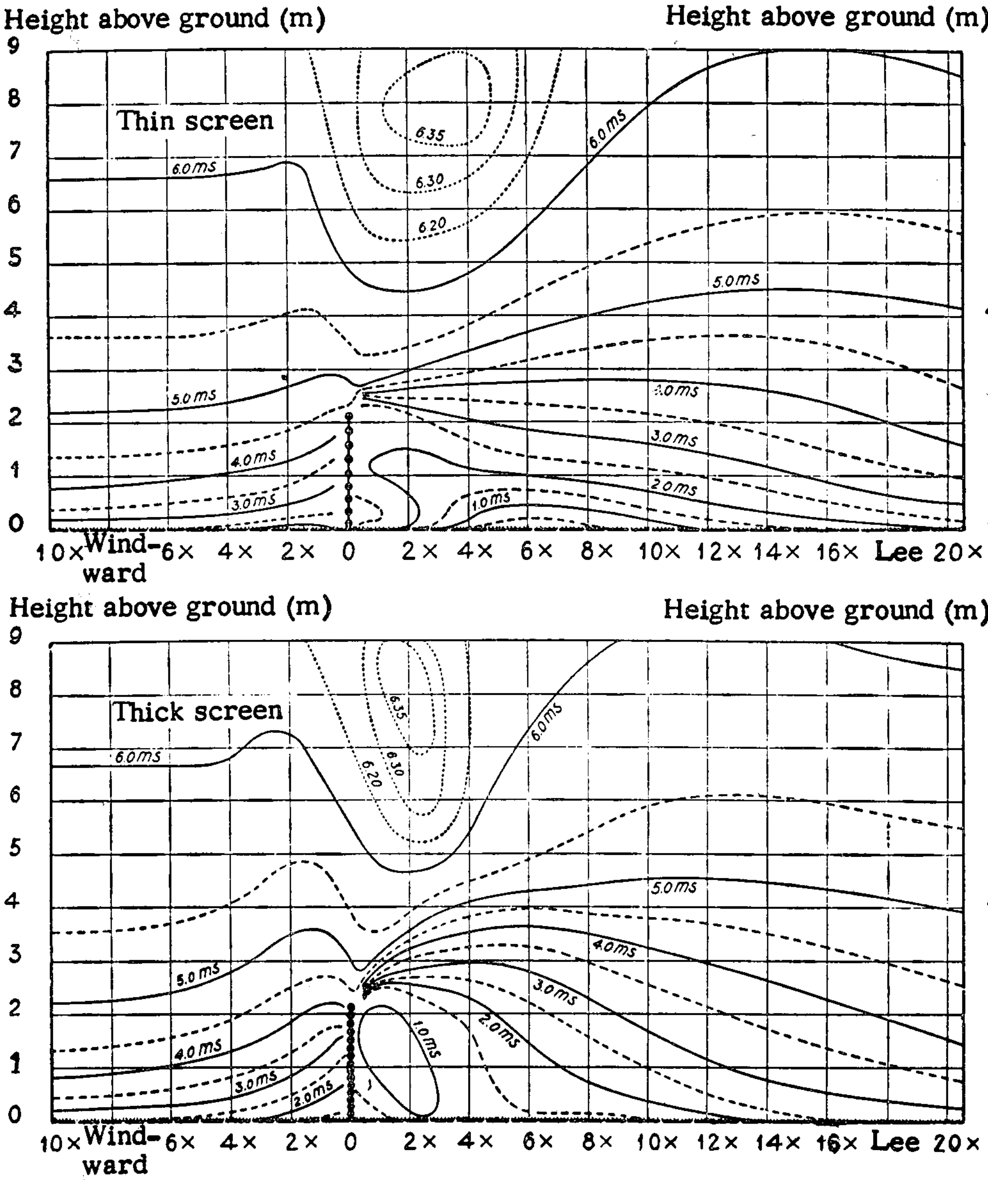


Figure 5. Wind field around two reed screens of different density (W. Nägeli in Geiger 1971).

5 Discussion

In the discussion below it is assumed that the survival is high where the seedling stand is dense. This assumption is made because an ocular investigation showed a great number of small and dead seedlings everywhere in the area. This is a generalization which may be questioned because the assumption is not founded on a regular investigation.

The growth and survival of the pine seedlings has been strongly stimulated by the environment close to the screen. However, it is evident that the survival to a certain extent is stimulated by factors other than those that are stimulating growth. The growth is best among seedlings situated 30—60 cm east of the screen while survival in this zone is fairly low (figures 2, 3, 6, 7, 8).

It was somewhat unexpected to find the growth to be largest on the eastern side. In an extensive investigation carried out in northernmost Finland (Poso & Kujala 1973) the growth of the forests in general was found to be highest in slopes turned SW—W—NW.

The growth in slopes turned WNW (which is right-angular to the screen) indicated that the general production of the forests was 36 % higher than in those turned in the opposite direction (ESE).

The practical result of a natural regeneration is best where the seedling stand is dense enough to permit an intense thinning in which the tallest seedlings can be left in an adequate spacing. A simplified version of the result from such a thinning is illustrated in figure 2 where the size of the 800 tallest seedlings per hectare is drawn. In the open area there is no need for thinning in spite of the fact that 16 years have passed since the clearance. Furthermore, the few seedlings in the open area are badly infected by Dasyscypha and most of them will die from this disease. New seedlings, developing out of seeds germinating in the future, will have even less chance of surviving. One of the reasons for this is the degeneration of the humus layer which is proceeding because the litter fall has almost ceased.

The clustering is obvious close to the fence as well as in the open area. From figure 1 it is not possible to see the clustering in the open area but this is because of the scarce material. In general, very few seedlings have been able to survive in the depressions. The clustering close to the screen proves that the environment, which in general is so favourable for survival and growth, is not present all along the screen. Obviously, in certain spots some factor is able to eliminate all the positive features of the "screen-micro-environment". There should be good reasons for studying this in detail. There is extensive material available and the pattern is clear and good results should be obtained easily.

What kind of environmental factors give such a pronounced effect on survival and growth? When discussing this it should be stressed that the favourable environment exists only within half a meter from the screen and that it is different on the two sides. The lowest board of the screen is situated 60 cm above the ground.

The wind speed underneath the screen is higher than elsewhere and the screen does not lower the wind speed considerably within the zone where the seedlings thrive (figure 5). This is obvious also from the manner in which the snow is deposited. Therefore, it is not plausible that the positive effect of the screen is its shelter against wind.

Night frosts are serious in pine heaths like this one (Andersson 1968). Probably the screen lessens the serious stratification

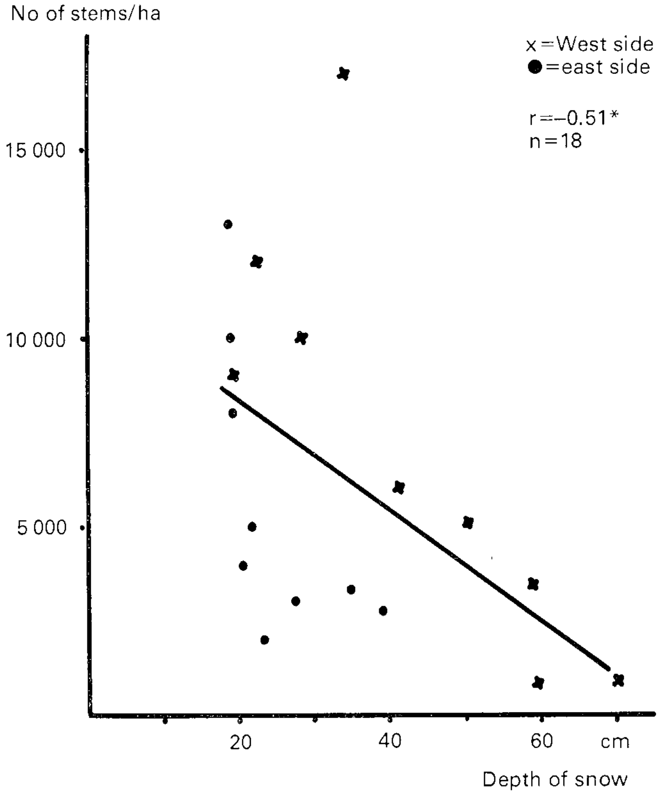


Figure 6. Covariance between number of stems/ ha and depth of snow close to the snow fence.

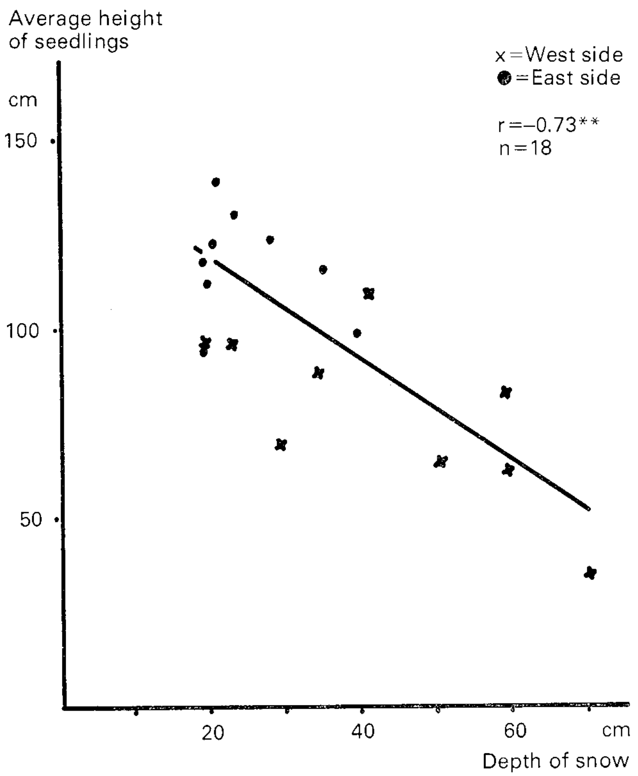


Figure 7. Covariance between average height of seedlings and depth of snow close to the snow fence.

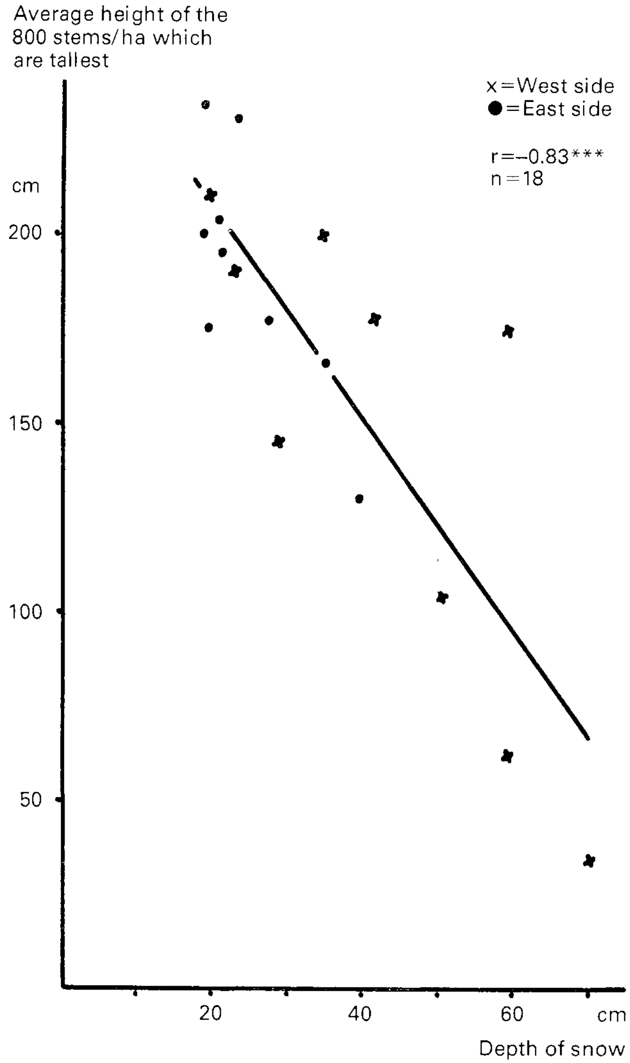


Figure 8. Covariance between average height of tallest seedlings (800 stems/ha) and depth of snow close to the snow fence.

of air during night partly because of increased wind velocity underneath the screen and partly because of turbulence caused by the heated wooden boards. These boards also reflect the heat radiation from the ground. Examining the seedlings closest to the screen one obtains the impression that the shoots are so comforted by the boards that they bend towards the wood. Some of the seedlings twine their stems back and forth between the boards.

The infestation by Dasyscypha is rare close to the screen and this may be an effect of decreased damage by night frosts. Pathologists agree that this canker is hardly a primary pathogene, but one is not certain if the infection follows primary frost injuries to the cambium, which are very common in these areas (Hagner unpublished), or if it is introduced in wounds caused by Ascocalyx (earlier named Crumenula). A third way for infection may be through the lower branches weakened from an infection by Phacidium infestans (the author's opinion). The soundness of the seedlings close to the screen may thus be an effect from decreased night frost and/or a decreased snow depth.

What kind of conclusions of practical importance may be drawn from the material presented? At first, it may be concluded that a snow fence alters the environment to such an extent that a completely doomed natural regeneration becomes successful. As it is hardly possible to build snow fences within half a meter from every seedling in a clear cut, it is necessary to speculate on what can be done with available resources.

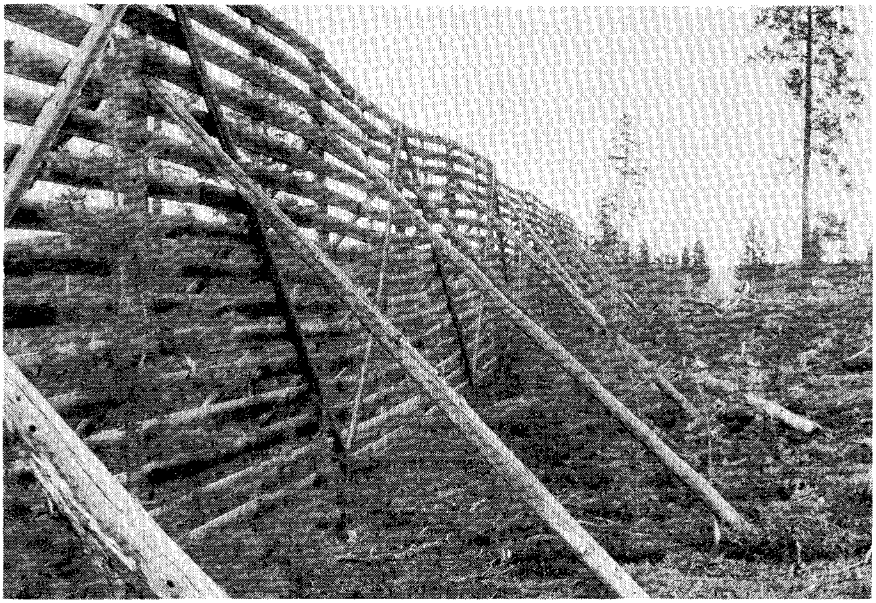
A trunk of a standing tree resembles a snow fence in many respects. The night frosts are reduced by heat reflection and turbulence. The snow depth is always much smaller close to the stem. If the tree is alive it suppresses seedlings by a competition for nutrients. However, if it is dead it still has all the favourable effects on frost and snow. If there are many low positioned branches left on the trunk the positive effect is reinforced. One is tempted to think of the fact that all virgin stands in these areas have originated in the shelter of a burnt forest in which there has been a great number of microspots with an environment similar to the one close to the snowfence. The ideal situation for the regrowth would perhaps be created by a ring-debarking of all standing trees in a forest, where the dead trees could form a suitable environment. From an economical point of view it is certainly not possible to do so, but if we aimed for a maximum shelter of the regeneration we could leave all economically indifferent trees standing plus all the shrub which is normally levelled to the ground when cleaning the clear cut area. All the taller trees must be killed because otherwise they will suppress the regrowth. Certainly there are good reasons to question the modern cleaning of the clear cut areas and the unselective spraying with herbicides.

Cleaning of clear cut areas is aimed at limiting the competition between the remaining undergrowth and the young seedlings. This could also be obtained by a debarking of the soft wood trees. A dead spruce with branches close to the ground may be an ideal shelter for a young seedling.

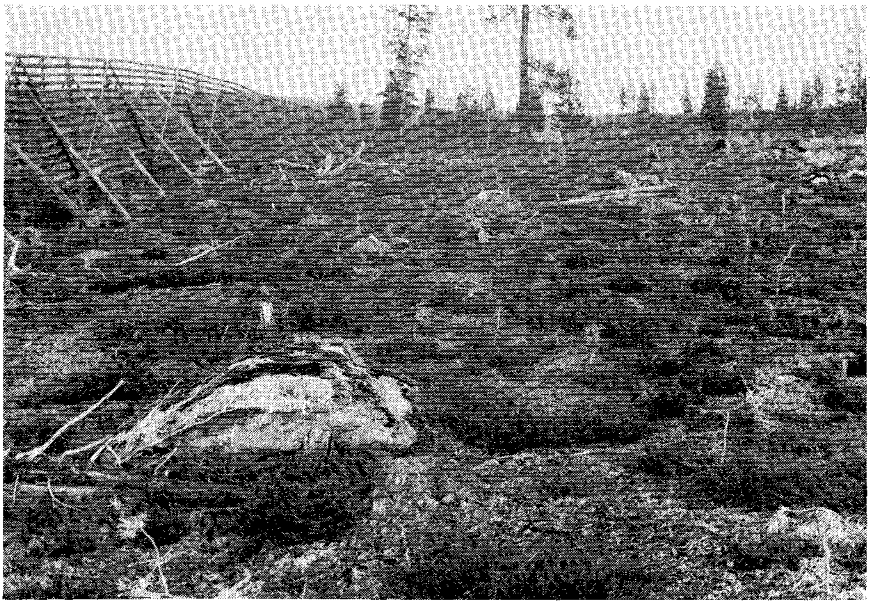
Old birches suppress effectively pine seedlings in these harsh areas. However, these birches will be very good shelters if left standing and dead after a treatment with herbicide. An unselective treatment with herbicides which also kill young birches and shrubs could be questioned. The snow depth within a cluster of slender young birches may be high but it is less immediately outside the cluster. A pine seedling situated close to such a cluster may suffer from nutritional competition but may gain from a smaller snow depth and a lower frost frequency. If the microenvironment around clusters of birches and shrubs was studied scientifically, it might be possible to design a special thinning operation by which one would diminish the negative and save the positive effects of the clusters.

The clustering of pine seedlings in this natural regeneration (figure 1) may be caused by a variation in depth of snow, topography or nutrition. However, another reason could be that seedlings gain from one another. The environment for one seedling close to another may be better than that of a free standing seedling in spite of increased competition. The heat loss from the ground will be hindered by the branches of a pine seedling and the snow depth is lower close to the stem. The increased competition among the seedlings is probably counteracted by the heavier litter fall that stimulates the activity in the humus layer. The infection by the Phacidium will be increased because of the small distance between the seedlings. If Ascocalyx and Dasyscypha are secondary and follow Phacidium these diseases will also increase within such a cluster of pine seedlings. In spite of these pathological drawbacks it is possible that the clustering is a result of an improved environment which results in increased survival.

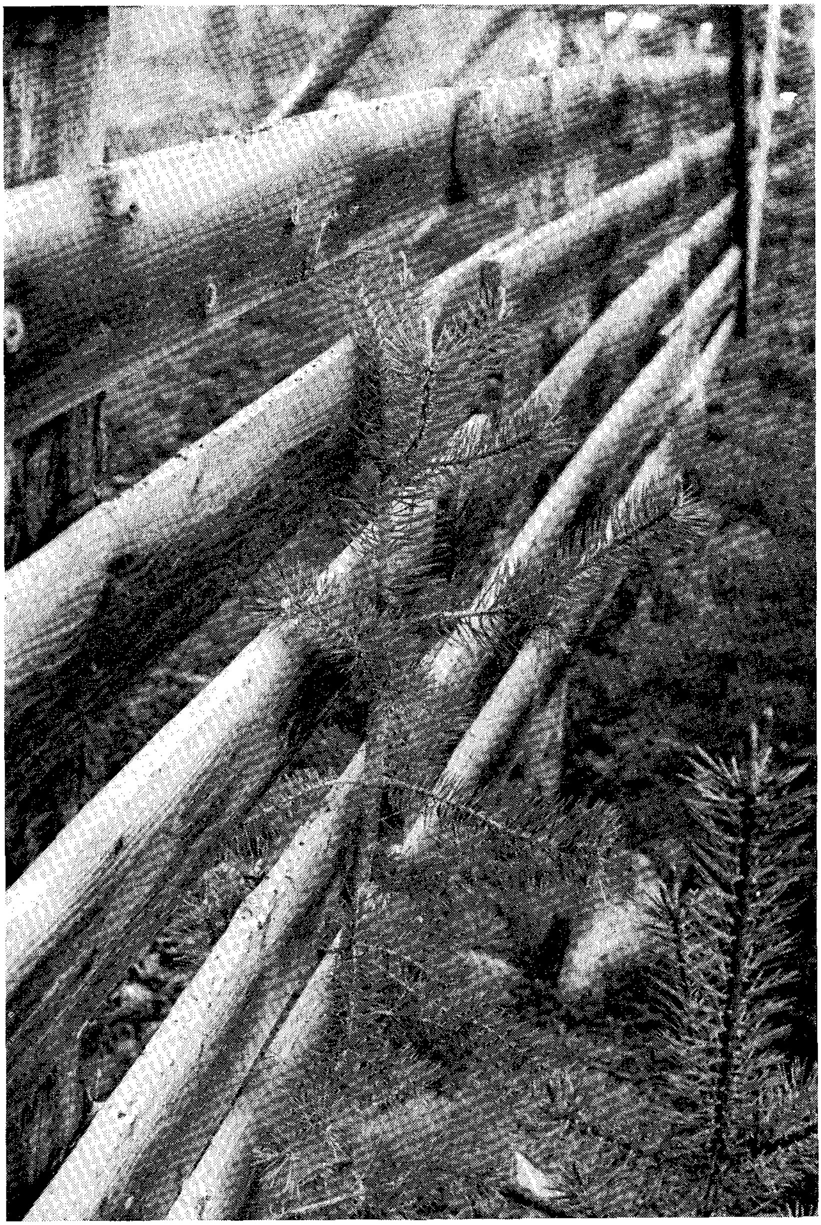
If one accepts this assumption the practical conclusion must be that an early thinning in seedling clusters, formed as a result from patch sowing, should be excluded or performed in such a way that two or more seedlings are left in each group. The thinning, normally executed when seedlings are 2—4 m high, should be carried out later in these harsh areas, because the seedlings need to be sheltered by one another.



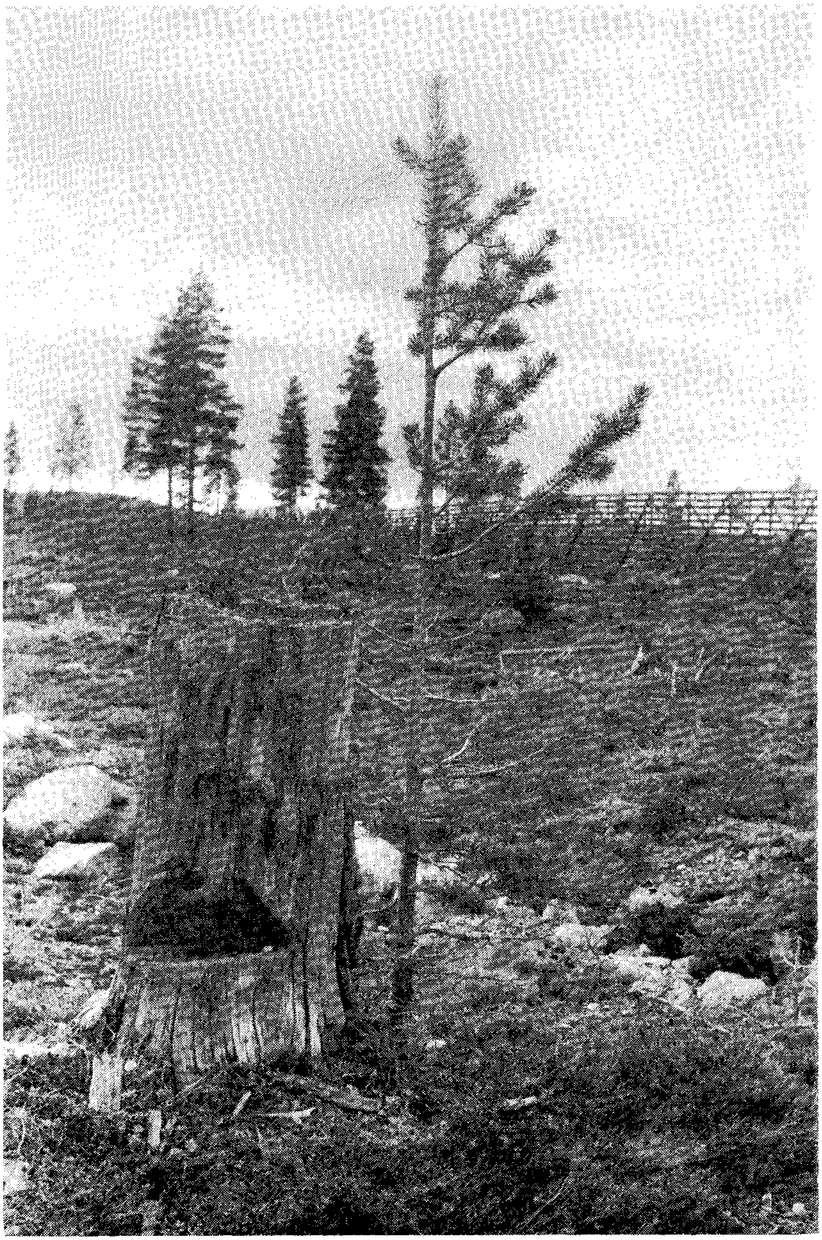
Picture 1. The natural regeneration thrives along the snow fence but the favourable environment eists only about half a meter from the screen.



Picture 2. In the area where the snow drift along the fence is deepest the regeneration is very poor.



Picture 3. The terminal shoots at the top and branches on some seedlings growing quite close to the screen are bending towards the wood. Certain pines trail back and forth among the boards.



Picture 4. One of the few well developed seedlings in the clear cut area is situated close to a very high stump.

Picture 5. Clear cut area and burnt forest at the Reivo National Park NW from Arvidsjaur, latitude 65°, altitude 450 m. Eight years after the fire most of the trees are left standing and their branches are still firm. The wind is halted and the heat flow from ground at night is decreased. This probably means that a regeneration growing in such a "natural environment" is developing under conditions which are essentially better than those in the open clear cut area.

6 Conclusions

In clear cut areas far north the survival of pine regenerations is a big problem. However, in such areas a microenvironment may be created in which pine seedlings grow and survive very well. One example of such an environment is the zone 0.5 meter wide, along the boards of a snow fence.

The presented material indicates that there are good reasons for questioning the adopted technique for cleaning of clear cut areas, for the use of herbicides and for thinnings in pine regenerations after planting and sowing. In the final cut of stands in these regions one should try to leave all trees which are economically indifferent. They should be left standing and killed. In this way one could eventually give the regeneration some of the shelter it seems to need. Regenerations should be planted or sown with a very small spacing or clustered which would enable the seedlings to shelter one another.

The effect from the snow screen upon the regeneration is quite clear and proves that the results from extensive studies of the micro-environment within established regenerations could be most useful when designing an improved technique for regrowth in these harsh areas.

7 Acknowledgement

This investigation was sponsored by Statens Råd för Skogs- och Jordbruksforskning. The field work was carried out by Doris Paulsson in Nattavaara to whom I am most indebted. The material was discussed with many research colleagues and foresters and I thank them for their valuable suggestions.

8 Sammanfattning

På en tallhed i ett nordligt höjdläge (lat. 66°44′, h.ö.h. 320 m), kalhuggen 1956, registrerades 1972 den naturliga återväxten av tall dels på det öppna hygget dels intill en 3 m hög snöskärm.

Ungskogens täthet var tio gånger större intill (0—40 cm) skärmen. Den gynnsamma effekten var i stort sett försvunnen 1,5 m från skärmen. Tallarnas medellängd var 50—100 % större intill skärmen än på hygget och tallkräfta (Dasyscypha), som angripit 48 % av tallarna ute på hygget, förekom nästan inte alls intill snöskärmen (tabell 1, figur 1, 2, 3).

Tillväxten hos plantorna korrelerade väl (negativ korrelation) med snödjupet kring skärmen, medan plantbeståndets täthet inte samvarierade lika väl, men dock signifikant, med snödjupet (figur 4, 6, 7, 8).

Tallplantornas tillväxt och överlevnad har således stimulerats kraftigt av miljön intill snöskärmen. Det är emellertid uppenbart att det delvis är olika miljöfaktorer som stimulerar tillväxt respektive överlevnad.

Tillväxten var störst på skärmens östra sida, vilket förvånar med tanke på att Poso och Kujala (1973) funnit att skogstillväxten i allmänhet på sluttningar i nordligaste Finland var störst i lutningar mot SV—V—NV.

Gruppställdheten längs skärmen visar att den för plantorna så gynnsamma miljön trots allt inte finns längs hela skärmens sträckning. Denna gruppställdhet kan ha uppstått som en följd av variation i snödjup, topografi och marknäring, men det kan också tänkas att plantorna gynnar varandra. En planta kan gynnas av den snöbrunn som bildas kring en närstående planta och omsättningen i humuslagret stimuleras av det ökade förnafallet.

I uppsatsen diskuteras vilka orsakerna kan vara till den gynnsamma utvecklingen intill skärmen; vindhastighet (figur 5), nattfroster, infektioner. Det diskuteras vidare vilka slutsatser av praktisk betydelse som kan dragas. Ett viktigt konstaterande är att en snöskärm ger en miljöförbättring inom de närmaste decimetrarna, som kan ändra resultatet i en naturlig föryngring på en mycket svår mark, från ett misslyckande till en succé. Man kan fråga sig om inte likartade gynnsamma mikrolokaler uppstår tätt intill ihjälbrända träd. Skogarna i dessa trakter har startat efter skogseld och de brända träden står kvar under många år (foto 4, 5). I framtida avverkningar kunde man kanske spara alla träd som är ekonomiskt indifferenta och låta dessa stå kvar på hygget. De måste säkert dödas då de i annat fall konkurrerar effektivt med plantorna. En del av det som brukar jämnas med marken vid hyggesrensning borde kanske lämnas stående. Uppväxande lövträd kan tänkas ha övervägande positiv effekt.

Det framlagda materialet ger anledning att ifrågasätta den vedertagna tekniken vid hyggesrensning, björkbekämpning, plantröjning i sådder och vid ungskogsröjning. Det finns skäl att pröva en selektiv avverkning där mesta möjliga träd lämnas stående, för att senare dödas. Dessa kan ge de uppväxande plantorna det nödvändiga skydd som de saknar på kallagda ytor. Ungskogar i dessa trakter skall måhända anläggas mycket täta eller i täta grupper så att plantorna kan ge varandra ett visst skydd.

Snöskärmens effekt på återväxten är slående och utgör ett gott bevis på att omfattande studier av mikromiljön inom befintliga återväxter bör kunna leda fram till en väsentligt förbättrad föryngringsteknik inom karga trakter.

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