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ERKKI LÄHDE

THE EFFECT OF SEED-SPOT SHELTERS AND COLD STRATIFICATION ON GERMINATION OF PINE (PINUS SILVERTRIS L.) SEED

KYLVÖSUOJAN JA KYLMÄSTRATIFIOINNIN VAIKUTUS MÄNNYN SIEMENEN ITÄMISEEN

1972

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Erkki Lähde

THE EFFECT OF SEED-SPOT SHELTERS AND COLD STRATIFICATION ON GERMINATION OF PINE (PINUS SILVESTRIS L.) SEED

Kylvösuojan ja kylmästratifioinnin vaikutus
männyn siemenen itämiseen

19993—73/12

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ABSTRACT

LÄHDE, ERKKI. The effect of seed-spot shelters and cold stratification on germination of pine (Pinus silvestris L.) seed. (For. Res. Inst., Rovaniemi, Finland.) Folia Forestalia 196. 1973.

The field germination could be improved considerably and the fail spot percentage reduced by covering the sowing spots with plastic shelters. The effect of the plastic shelter in the field corresponds to that of the plastic greenhouse in the nursery. The seed germination was not improved by the cold stratification method used in the study. The beneficial effect of the plastic shelter was significant regardless of the geographical locations, which included the total north-south range of Finland.

SUMMARY

This study deals with the development of the so-called shelter-sowing method for field use. Preliminary investigations were made to determine whether the method can be used on plowed reforestation areas in different parts of Finland. Also, the difference in germination was determined when using shelters of different size and model. The effect of cold stratification on germination under shelters and on uncovered controls was also studied.

The stratification method was not good since seed germination was not increased by its use. The method used consisted of soaking in water and pre-treatment of the seed for 14 days at +4 °C.

The height of the shelters used varied from 5–20 cm (page 7 and Figure 1, p. 7). The studies were carried out in the townships of Juupajoki, Rautavaara, Rovaniemi (specifically in Muurola), and in Sodankylä (specifically in Pomokaira). The sowing was done in May–June 1972, and the results were inspected in August of the same year.

Using a split-plot design, the sowing was done on the shoulder and tilt on plowed reforestation areas. The tilt, however, was not very suitable for sowing due to the model of plow used. Consequently, the difference between the shoulder and the tilt was statistically significant in that the field germination was larger and fail spot percentage smaller on the former. No definite conclusions can be made yet about the differing development of the emerged seedlings on the two placements of the sowing spots.

The air temperature and humidity during July-September was measured inside the two largest shelters and outside as the control (p. 8). These measurements were made in an experiment at the nursery of Imari in Rovaniemi township. The relative humidity was greater inside the shelters, indicating that the effect of the shelters corresponded to that of a plastic greenhouse.

The results indicated that the shelters had a significant effect on germination, increasing it on all experimental locations (Tables 2–6).

The differences between the shelters were small. Apparently the best shelter size, with respect to germination of the seed and the shelters' sensitivity to wind, corresponds to that of shelter no. 5 which was a 10 cm high truncated cone with a diameter of 9 cm at the base and a wall inclination of 60°.

The average field germination, i.e. the germination percentage of the seed in the field as a percentage of laboratory germination, under different shelters deviated from that of the control 15.1–33.4 percent units. At the northernmost location in Pomokaira the deviation the control was 29.8 percent units. Correspondingly, the fail spot percentage deviated 5.5–45.3 percent units.

SUOMENKIELINEN SELOSTUS

Tutkimuksessa käsitellään uuden nk. suojakylvön kehittämistä käytännön menetelmäksi. Alustavasti pyritään selvittämään, voidaanko menetelmää käyttää auratuilla uudistusaloilla eri osissa Suomea ja mitä eroja on männyn siemenen itämisessä erikokoisia ja -mallisia suojia käytettäessä. Samassa yhteydessä tutkitaan myös kylmästratifioinnin vaikutusta suoja- ja kontrollikylvöksissä.

Stratifiontimenetelmä ei ollut onnistunut, koska sen avulla ei pystytty nostamaan siementen itävyyttä. Stratifiointina käytettiin siementen liotusta ja esikäsittelyä +4° C:n lämpöisessä vedessä 14 vrk:n ajan.

Käytettyjen suojien korkeus vaihteli 5–20 cm:iin (sivu 7 ja kuva 1 s. 7). Tutkimuspaikkakunniksi valittiin Juupajoki, Rautavaara, Muurola Rovaniemen maalaiskunnasta ja Pomo-

kaira Sodankylän kunnasta. Kylvö tehtiin toukokesäkuun vaihteessa 1972 ja tulosten inventointi elokuun lopulla samana kesänä.

Kylvökset tehtiin split plot koejärjestelyjä käyttäen auratuille uudistusaloille sekä aurausjäljen pientareeseen että palteeseen. Tosin palle ei ollut muodostunut käytetystä piennarauramallista johtuen kunnolliseksi viljelykohdaksi. Niinpä ero pientareen ja palteen välillä muodostui kaikissa tapauksissa merkitseväksi siten, että kenttäitävyys oli suurempi ja tyhjälaikkusadannes pienempi pientareessa kuin palteessa. Syntyneiden taimien kehityksen myöhemmistä eroista ko. viljelykohdissa ei vielä voida olla varmoja.

Ilman lämpötila ja suhteellinen kosteus mitattiin heinä- syyskuun aikana kahdessa suurimmassa suojassa sekä kontrollina suojan ulkopuolella (s. 9). Nämä mittaukset tehtiin Rovaniemen maalaiskunnassa Imarin taimitarhalle perustetussa kokeessa. Ilman suhteellinen kosteus oli suurempi suojissa kuin ulkopuolella, mikä osoitti suojien vaikutuksen vastaavan muovihuoneen käyttöä taimitarhalla.

Tulokset osoittivat, että käytetyt suojat vaikuttivat merkitsevän edullisesti siementen itämiseen kaikilla tutkituilla paikkakunnilla (taulukot 2–6).

Suojien väliset erot olivat vähäisiä. Ilmeisesti siementen itämisen kannalta ja toisaalta suojien paikallaan pysymisen vuoksi suositeltavan suojan koko vastaa käytettyä suojaa n:o 5, joka oli 10 cm:n korkuinen katkaistun kartion muotoinen ja jonka pohjan läpimitta oli 9 cm ja seinän kaltevuus 60°.

Kenttäitävyydessä, jolla tarkoitetaan siementen itävyyttä ilmoitetusta itävyysprosentista, ero suojien keskimääräisen arvon ja kontrollikylvösten välillä vaihteli 15.1:sta 33.4:ään prosenttiyksikköön ollen pohjoisimmalla koekentällä Pomokairassa 29.8. Vastaavasti tyhjälaikkusadanneksessa ero vaihteli 5.5:stä 45.3:een prosenttiyksikköön.

1. INTRODUCTION

Cost comparisons of various reforestation methods indicate the desirability of increasing the proportion of Scots pine sowing in the northern parts of Finland (e.g. KELTIKANGAS and SEPPÄLÄ 1966, RIIHINEN 1966). When using sowing, certain phenomena detrimental to the seedling vigor are avoided. Such detrimental effects occur when seedlings are raised in the nursery, treated in different ways, are transported long and time-consuming distances to the field and are finally planted on the reforestation site by more or less competent crews.

Natural selection is much more intensive in sowed sapling stands, compared to planted ones. Thus, sowed stands do not seem to be as sensitive to damage as planted ones (NOROKORPI 1973). The negative effect of competing ground cover on the initial development of sowed seedlings has been largely eliminated due to the increased use of soil preparation in northern Finland. In addition, the use of modern herbicides eliminates the need to use planting stock of a larger size.

The use of sowing in northern conditions, however, may be somewhat hindered by the fact that the seedlings do not always develop far enough before the winter. It may be possible to alleviate this problem by stratifying the seed prior to sowing.

There is an obvious need to develop methods and means to promote economically feasible sowing. According to the investigation by LÄHDE and PÖYHTÄRI (1972), the success of sowing may be assured by using a cylindrical plastic shelter for the sowed seeds. This shelter speeds up germination and development of the seedlings.

In the present study the development of the so-called shelter-sowing method is continued, and investigations are made concerning the adaptability of the method for sowing on the shoulder or the tilt on plowed reforestation sites in various parts of the country. In addition, the effect of cold stratification on pine seed germination under various types of shelters, compared to control sowings without shelters, was studied.

2. MATERIALS AND METHODS

In order to elucidate the effect of geographic location, the experimental areas were selected from the following parts of Finland:

Juupajoki, N 61°50'; E 24°20'
Rautavaara, N 63°30'; E 28°40'
Muurola, N 66°25'; E 25°00'
Pomokaira, N 67°50'; E 26°40'

The sites for the experimental plots were selected on relatively moist clear-cut pine sites where the soil had been prepared by plowing. Both the shoulder and the tilt were used for sowing, even if the tilt was not always of a satisfactory quality for sowing due to the model of the shoulder plow used.

Some of the shelters used, were made from ordinary greenhouse plastic (0.2 mm thick) as a cone truncated by hand. Others were prefabricated drinking cups turned upside-down. Holes (diameter about 1.5 cm) had been burned in the bottoms (Figure 1). Those made by hand had seams secured by one or two staples.

The dimensions of the shelters were as follows:

Shelter no.		Diam. of base, cm	Height, cm	Diam. of top, cm	Inclination of wall
1	pre-	5	6	3.5	
2	fabric-	6	5	4.6	77°
3	ated	7	8	4.7	
4	hand-	5	5		
5	made	9	10	1.5	60°
6		18	20		

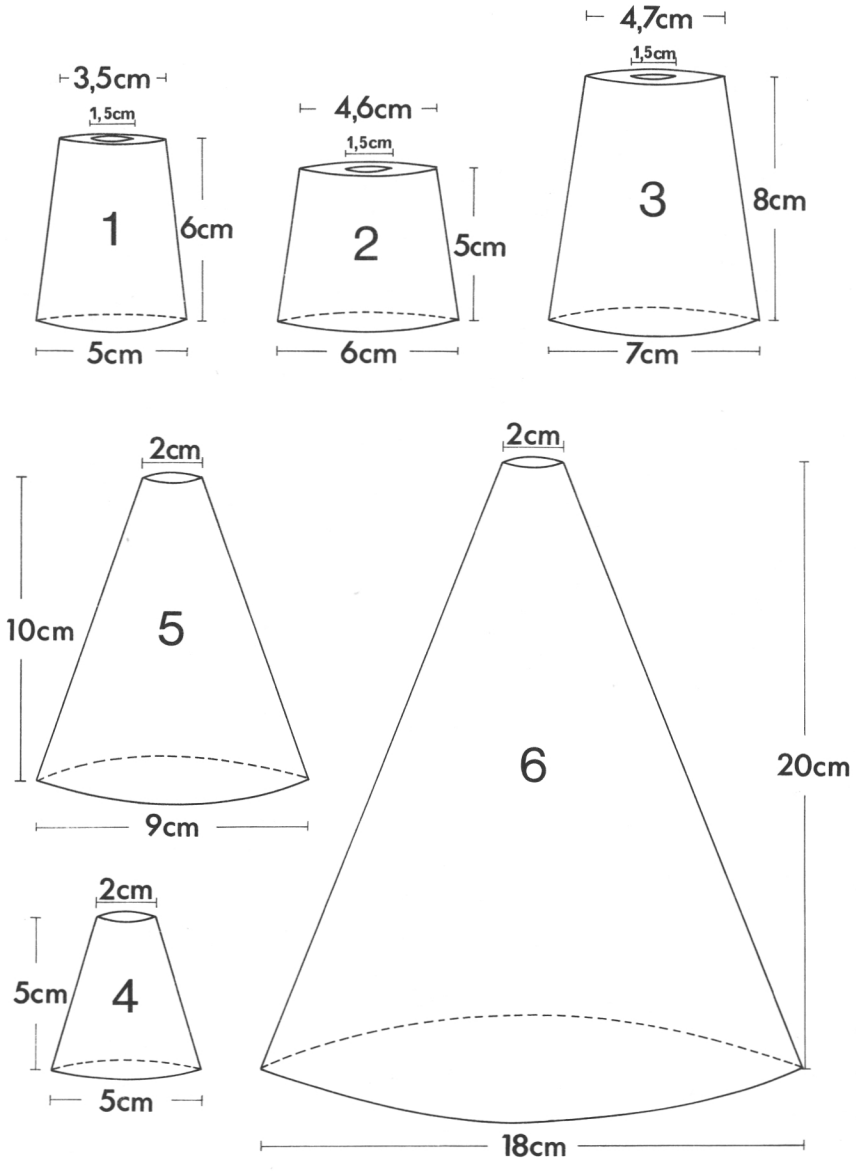

Fig. 1. Models of seed-spot shelters used in the study.
Kuva 1. Tutkimuksessa käytetyt kylvösuojamallit.

Control sowing without shelters was denoted by no. 7. The sowing was done in the spring of 1972. In order to sink the shelters into the ground, a device was made with which a hole, about one cm deep and of the size of the bottom of the shelter, was made in the ground. The seeds were also sown into this hole. If needed, some soil was added to the outside wall in order to keep the shelter in place. Into each shelter or on the control spot at least three but not four germinating seeds, based on seed germination tests, were sown. The seed was of local provenance. The following table gives exact data on the seed lots and dates of sowing:

Provenance	Percent Germination	1000-grain weight	Date of Sowing in 1972
Juupajoki	91 %	4.40 g	05–24 . . . 26
Rautavaara	83 %	4.05 g	05–29 . . . 30
Muurola	91 %	5.53 g	06–06 . . . 08
Pomokaira	58 %	3.60 g	06–12 . . . 16

Stratified and untreated seed was used for the sowing. The stratification was made as follows: First the seeds were soaked for 12 hours in water at 4°C. Subsequently, the seeds were spread evenly, forming a thin layer on a flat surface lined with a thoroughly wetted thick blotting paper covered with strips of burlap. Both the blotting paper and the burlap were kept in water during the entire treatment. The stratification was carried out at 4°C for 14 days. At the end of the treatment, the water was drained off, and the seeds were dried for one day at the same temperature. The strips of burlap were rolled up and transported at 4°C in coolers to the sowing locality. The seeds were shaken from the rolls into the sowing containers.

The experimental layout was a split plot design where the plot consisted of a 16 m long plowing track. The sowing was made at 2 m intervals on both sides of the furrow both on the shoulder and the tilt. A block consisted of 14 plots. The blocks were replicated three times, and the order of the plots was randomized separately for each block.

At the end of August the number of developed seedlings in each sowing spot was counted. The shelter was removed from the seedlings only when the number of seedlings could not be counted accurately by observation through the shelter. On the northernmost experimental areas reindeer had destroyed some shelters. Some of the largest shelters were removed by the wind from the sowing spot.

In the statistical treatment of the data the field germination (counted as percentage in the field as a percentage of laboratory germination), number of developed seedlings, and number of fail spots were used as variables. Percentage values were transformed to arc. sin. values. Analysis of variance and Tukey's t-test were applied to the data. Least significant differences at the 5% level of probability were calculated. In order to find out how the shelter influences the air temperature and humidity, measurements were made in an experiment at the Imari nursery (N 66°30', E 25°30'). Shelters 5 and 6 were put on the ground in three randomized blocks. In the walls of the shelters a slit was made through which the measurements were taken. The slit was protected by tape. The temperature and humidity measurements, both inside and outside (at a distance of 0.5 m) the shelters, were made with the Wallac Ltd. EP-400 thermo-hygrometer. The measurements were made twice a day five days a week at 08.00 and 15.00. The measurements were not started until the beginning of July due to delayed shipment of the instruments. Measurements were continued until the end of September. Results are reported as monthly means of all observations.

The manufacturer of the instrument reports that its accuracy at 20°C and 50% relative humidity is ± 2% and at 80% relative humidity, ± 3% and for temperature at -20°C... + 40°C, ± 0.6%.

3. RESULTS

3.1. Air temperature inside and outside the shelters

The average air temperature in July was about the same both in- and outside the shelters (Table 1). The relative humidity inside the largest shelter was 15% -units and in the smallest, 10% -units larger than outside these shelters. This also shows that more heat occurred inside the shelters than outside since the water vapour inside strongly bound heat. The conditions inside the shelters consequently correspond to those of a plastic greenhouse. Toward the fall the differences in humidity decreased when the temperatures dropped. At this time the temperature inside the shelters increased above that recorded outside.

3.2. Effect of the shelter on seed germination at the experimental areas

3.2.1. Juupajoki

Field germination at the southernmost area of the study, Juupajoki, rose to an average of 50.2% (54.6% inside and 23.5% outside the shelters). There were no statistically significant differences between stratified and unstratified seed (Table 2). No significant differences were found between the various types of shelters, but they all differed very significantly from the control. On an average there were 2.0 seedlings under the shelters compared to 0.9 seedlings in the controls. Statistically, there was a very significant difference between the two sowing spots. On the shoulder the germination was 59.6%, and the average number of seedlings was 2.2. On the tilt the germination was 40.8, and the average number of seedlings was 1.5.

There was no difference in percentage of fail spots between stratified and unstratified seed. Under all shelters the fail spot percentage (average 21.0%) was significantly smaller than on the controls without shelters (43.8%). On the shoulder the fail spot percentage was 13.3 and on the tilt, 35.7. The difference was statistically very significant.

3.2.2 Rautavaara

In the experiment at Rautavaara the total field germination was 46%. The controls had 47.5% germination and for stratified seed it was 46.4% (Table 3). The difference was not significant. Under all shelters the germination was significantly larger than in the controls without shelters. In addition, the field germination under shelters numbers 5, 3, and 4, in this order, was significantly larger than under the largerst shelter, no. 6.

There were an average of 1.7 seedlings under the shelters compared to 0.6 for the controls.

Table 1. Monthly averages of air temperatures (°C) and humidity (%) inside and outside the shelters (control outside).
Taulukko 1. Kuukausittaiset ilman lämpötilan (°C) ja kosteuden (%) keskiarvot suojassa ja suojan ulkopuolella kontrollissa.

Symbol of Shelters Suojan tunnus	*July*—Heinäk.		*August*—Elok.		*Sept.*—Syysk.	
	Temperature Lämpötila	*Humidity* Kosteus	*Temperature* Lämpötila	*Humidity* Kosteus	*Temperature* Lämpötila	*Humidity* Kosteus
6	21.8	70.2	19.3	69.4	10.0	76.6
5	21.8	64.4	19.2	68.3	09.7	76.9
Control Kontrolli (7)	22.0	55.6	19.0	65.6	09.4	73.7

Table 2. Field germination (%) of the seed and fail spot percentage for different sowings according to seed treatments and placement of the sowing spot in Juupajoki. Legend for shelters, see page 7.
Taulukko 2. Siemenen kenttäitävyys (%) ja tyhjälaikkusadannes erilaisissa kylvöksissä Juupajoella siemenen käsittelyn ja kylvökohdan mukaan ryhmiteltynä. Kylvötunnukset ks. s. 7.

Symbol of Shelters Kylvön tunnus	*Treatment of Seed* Siemenen käsittely: *Control* Kontrolli	*Stratified* Stratifioitu	$\bar{x}$	*Sowing Spot* Kylvökohta: *Shoulder* Piennar	*Tilt* Palle
	Field Germination — Kenttäitävyys				
4	57.2 ± 5.3	58.6 ± 7.6	57.9	68.2 ± 3.9	47.6 ± 5.3
3	53.1 ± 6.8	59.5 ± 5.1	56.3	68.2 ± 2.4	44.4 ± 3.7
5	53.5 ± 6.1	58.1 ± 5.9	55.8	67.7 ± 2.5	43.9 ± 3.3
6	57.6 ± 7.1	50.3 ± 6.6	54.0	65.4 ± 2.6	42.5 ± 6.3
1	49.8 ± 7.1	55.8 ± 1.7	52.8	60.8 ± 2.1	44.8 ± 5.2
2	51.7 ± 6.5	50.3 ± 5.0	51.0	60.4 ± 4.7	41.6 ± 3.2
$\bar{x}$ 1–6	53.8	55.4	54.6	65.1	44.1
Control (7)	27.4 ± 3.6	19.6 ± 2.2	23.5	26.5 ± 3.0	20.6 ± 3.4
$\bar{x}$ 1–7	50.1 ± 6.1	50.3 ± 4.9	50.2	59.6 ± 3.0	40.8 ± 4.3
F	0.10		23.5 xxx	95.8 xxx	
	Fail Spot Percentage — Tyhjälaikkusadannes				
5	19.8 ± 6.7	13.6 ± 4.7	16.7	5.2 ± 1.9	28.2 ± 3.9
4	16.7 ± 6.2	20.9 ± 7.2	18.8	9.4 ± 2.7	28.2 ± 7.0
3	27.1 ± 8.5	13.6 ± 4.7	20.4	7.3 ± 3.0	33.4 ± 6.0
2	21.9 ± 6.0	20.9 ± 6.6	21.4	8.4 ± 2.1	34.4 ± 2.7
1	27.1 ± 8.2	18.8 ± 3.6	23.0	13.6 ± 3.8	32.3 ± 6.1
6	24.4 ± 10.9	27.1 ± 9.4	25.8	17.1 ± 11.0	28.2 ± 7.5
$\bar{x}$ 1–6	22.8	19.2	21.0	10.2	30.8
Control (7)	39.6 ± 7.8	47.9 ± 4.7	43.8	32.3 ± 4.9	55.2 ± 3.7
$\bar{x}$ 1–7	25.2 ± 7.8	23.2 ± 5.8	24.2	13.3 ± 4.2	35.2 ± 5.3
F	0.39		5.61 xxx	66.7 xxx	

For the whole area the average was 1.6. The field germination on the shoulder (57.4%), as well as the number of seedlings (1.9), was significantly larger than on the tilt (36.4% and 1.2 seedlings).

With respect to the fail spot percentage, there was no difference between seed treatments, but all shelters differed significantly from the control. In the shelters the average percentage of fail spots was 22.3 and in the controls, 31.1. The percentage of fail spots under shelters 5, 3 and 4 was significantly smaller than under shelter 6. On the shoulder the average fail spot percentage was 19.2, and on the tilt, 43.0. The difference was very significant.

3.2.3. Muurola

In Muurola the field germination was very high, with an average of 76.8% (Table 4). There was an average of 2.8 seedlings per spot (under the shelters 2.9 and on the control 2.3). The seed used was of very good quality as indicated by the high germination (91%) and large 1000-grain weight (5.53 g). There was no difference between seed treatments. In both treatments there was the same number of seedlings (2.8) per spot. There was a significant difference between results at the different locations of the sowing spots. On the shoulder field germination was 81.5% and there was an average of

Table 3. Field germination (%) of the seed and fail spot percentage for different sowings according to seed treatments and placement of the sowing spot in Rautavaara. Legend for shelters, see page 7.
Taulukko 3. Siemenen kenttäitävyys (%) ja tyhjälaikkusadannes erilaisissa kylvöksissä Rautavaarassa siemenen käsittelyn ja kylvökohdan mukaan ryhmiteltynä. Kylvötunnukset ks. s. 7.

Symbol of Shelters Kylvön tunnus	*Treatment of Seed* Siemenen käsittely		$\bar{x}$	*Sowing Spot* Kylvökohta	
	Control Kontrolli	*Stratified* Stratifioitu		*Shoulder* Piennar	*Tilt* Palle
	Field Germination — Kenttäitävyys				
5	61.2 ± 8.0	58.2 ± 7.9	59.7	74.8 ± 3.8	44.6 ± 4.6
3	58.7 ± 8.0	54.3 ± 5.5	56.5	68.8 ± 4.6	44.1 ± 3.7
4	54.7 ± 5.6	56.2 ± 4.5	55.4	62.2 ± 3.7	47.6 ± 3.7
1	53.2 ± 6.5	47.1 ± 8.4	50.1	61.7 ± 6.2	38.6 ± 5.0
2	52.2 ± 4.9	45.1 ± 5.8	48.7	58.7 ± 2.9	38.6 ± 3.8
6	38.1 ± 6.9	41.6 ± 4.7	39.8	46.6 ± 6.1	33.1 ± 4.0
$\bar{x}$ 1–6	53.0	50.4	51.7	62.1	41.1
Control (7)	14.5 ± 3.7	22.1 ± 7.8	18.3	28.1 ± 6.3	8.5 ± 1.4
$\bar{x}$ 1–7	47.5 ± 6.2	46.4 ± 6.4	46.9	57.4 ± 4.8	36.4 ± 3.7
F	0.20		21.8 xxx	75.1 xxx	
	Fail Spot Percentage — Tyhjälaikkusadannes				
5	13.6 ± 4.7	18.8 ± 7.2	16.2	5.2 ± 1.9	27.1 ± 5.0
4	20.9 ± 6.8	15.7 ± 6.6	18.3	6.3 ± 2.3	30.2 ± 5.4
3	17.7 ± 4.7	21.9 ± 8.0	19.8	8.3 ± 2.6	31.3 ± 5.4
2	27.1 ± 6.8	29.2 ± 8.8	28.1	12.5 ± 3.2	43.8 ± 4.0
1	25.0 ± 8.4	32.4 ± 7.6	28.7	14.6 ± 5.7	42.8 ± 4.7
6	42.7 ± 7.1	42.7 ± 5.9	42.7	37.5 ± 7.0	48.0 ± 5.0
$\bar{x}$ 1–6	24.5	26.8	25.6	14.1	38.9
Control	66.7 ± 8.9	61.5 ± 9.6	64.1	50.0 ± 8.1	78.2 ± 5.5
$\bar{x}$ 1–7	30.5 ± 6.8	31.7 ± 7.7	31.1	19.2 ± 4.4	43.0 ± 5.0
F	0.09		16.6 xxx	70.0 xxx	

3.0 seedlings per spot, compared to the tilt where the corresponding figures were 72.0% and 2.6 seedlings. Shelters 6 and 5 were significantly different from the controls in terms of field germination. The average field germination for all shelters was 78.9%, compared to the control with 63.8%.

Due to the high field germination, the percentage of fail spots in Muurola was very low, 5.2%. In this respect there were no significant differences between different types of shelters or seed treatments. Under the shelters the average fail spot percentage was 4.4 compared to the clearly larger corresponding figure (9.9%) for the controls. On the shoulder the fail spot percentage was only 1.6 compared to the tilt it was 9.0. The difference was very significant.

3.2.4. Pomokaira

On the northernmost location, Pomokaira, 150 km north of the Arctic Circle, there was a significant difference in the field germination between untreated and stratified seed in that it was smaller for the stratified seed compared to the untreated seed (Table 5). Naturally, this difference was also seen in the number of seedlings per spot, 1.1 and 1.4. On the shoulder the field germination was significantly larger

Table 4. Field germination (%) of the seed and fail spot percentage for different sowings according to seed treatments and placement of the sowing spot in Muurola. Legend for shelters, see page 7.
Taulukko 4. Siemenen kenttäitävyys (%) ja tyhjälaikkusadannes erilaisissa kylvöksissä Muurolassa siemenen käsittelyn ja kylvökohdan mukaan ryhmiteltynä. Kylvötunnukset ks. s. 7.

Symbol of shelters Kylvön tunnus	*Treatment of Seed* Siemenen käsittely		$\bar{x}$	*Sowing Spot* Kylvökohta	
	Control Kontrolli	*Stratified* Stratifioitu		*Shoulder* Piennar	*Tilt* Palle
	Field Germination — Kenttäitävyys				
6	84.7 ± 4.3	82.0 ± 3.8	83.3	88.4 ± 4.0	78.3 ± 2.6
5	72.7 ± 9.6	87.0 ± 2.2	79.9	83.4 ± 2.0	76.4 ± 10.4
3	82.4 ± 3.0	77.0 ± 4.2	79.7	82.0 ± 2.5	77.4 ± 4.6
2	80.1 ± 5.7	76.9 ± 4.4	78.5	82.4 ± 4.7	74.6 ± 4.9
4	78.3 ± 4.6	78.3 ± 5.7	78.3	82.9 ± 4.6	73.7 ± 4.9
1	79.2 ± 4.3	68.2 ± 5.2	73.7	77.8 ± 6.1	69.6 ± 3.7
$\bar{x}$ 1–6	79.6	78.2	78.9	82.8	75.0
Control (7)	63.2 ± 9.6	64.5 ± 2.3	63.8	73.7 ± 5.0	54.0 ± 5.8
$\bar{x}$ 1–7	77.2 ± 5.9	76.3 ± 4.0	76.8	81.5 ± 4.1	72.0 ± 5.8
F	0.27		3.14^{xxx}	13.0^{xxx}	
	Fail Spot Percentage — Tyhjälaikkusadannes				
6	4.2 ± 2.6	1.1 ± 1.1	2.6	0.0 ± 0.0	5.2 ± 2.5
3	3.1 ± 2.1	3.2 ± 1.4	3.1	1.1 ± 1.1	5.2 ± 1.9
4	2.1 ± 1.3	6.3 ± 5.1	4.2	1.1 ± 1.1	7.3 ± 4.9
2	4.2 ± 2.1	4.2 ± 3.1	4.2	2.1 ± 2.1	6.3 ± 2.8
5	11.5 ± 6.5	0.0 ± 0.0	5.7	1.1 ± 1.1	10.4 ± 6.8
1	3.1 ± 3.1	9.7 ± 2.8	6.4	2.1 ± 1.3	10.7 ± 3.5
$\bar{x}$ 1–6	4.7	4.1	4.4	1.3	7.5
Control (7)	13.6 ± 6.7	6.3 ± 2.3	9.9	2.1 ± 1.3	17.7 ± 5.4
$\bar{x}$ 1–7	6.0 ± 3.5	4.2 ± 2.6	5.2	1.6 ± 1.3	9.0 ± 4.0
F	0.32		1.38^{xxx}	25.2^{xxx}	

(42.8%) compared to the tilt (30.0%). The field germination was significantly larger under all shelters (40.5%) compared to the controls (10.7%). There was no significant difference between the shelters.

With respect to the percentage of fail spots, there was a corresponding difference between untreated and stratified seed. The difference was significant. Between shelters there was no significant difference, but compared to the control (70.9%), the fail spot percentage was significantly smaller under all shelters (23.6%). On the shoulder the percentage of fail spots was significantly smaller (22.0%) compared to the tilt (42.1%).

3.3. Comparisons among area

Field germination was the largest and fail spot percentage the smallest in the experiment in Muurola compared to those on the other locations. In Pomokaira, the northernmost experimental location, field germination was smallest and fail spot percentage largest. The difference in field germination between Juupajoki and Rautavaara was not significant according to Tukey's t-test. With respect to fail spot percentage, the locations were ranked in the same order, but the difference between Rautavaara and Pomokaira was not significant at the 5% level of probability (Table 6). There is, of

Table 5. Field germination (%) of the seed and fail spot percentage for different sowings according to seed treatments and placement of the sowing spot in Pomokaira. Legend for shelters, see page 7.
Taulukko 5. Siemenen kenttäitävyys (%) ja tyhjälaikkusadannes erilaisissa kylvöksissä Pomokairassa siemenen käsittelyn ja kylvökohdan mukaan ryhmiteltynä. Kylvötunnukset ks. s. 7.

Symbol of shelters Kylvön tunnus	*Treatment of Seed* Siemenen käsittely		$\bar{x}$	*Sowing Spot* Kylvökohta	
	Control Kontrolli	*Stratified* Stratifioitu		*Shoulder* Piennar	*Tilt* Palle
	Field Germination — Kenttäitävyys				
4	48.3 ± 5.3	37.3 ± 2.5	42.8	45.9 ± 5.9	39.7 ± 2.7
5	43.3 ± 6.6	40.7 ± 2.7	42.0	47.6 ± 5.3	36.4 ± 3.4
6	47.4 ± 7.4	34.5 ± 3.0	40.9	50.2 ± 6.3	31.6 ± 2.2
1	44.4 ± 5.5	36.8 ± 4.4	40.6	46.9 ± 5.4	34.3 ± 3.1
3	52.4 ± 4.1	26.7 ± 5.1	39.5	47.1 ± 5.1	31.9 ± 7.7
2	40.7 ± 6.6	33.5 ± 3.4	37.1	45.5 ± 4.8	28.7 ± 3.0
$\bar{x}$ 1–6	46.1	34.9	40.5	47.2	33.8
Control (7)	8.6 ± 2.9	12.9 ± 2.8	10.7	16.2 ± 1.8	5.2 ± 1.6
$\bar{x}$ 1–7	40.7 ± 5.5	31.8 ± 3.4	36.2	42.8 ± 4.9	29.7 ± 3.4
F	22.9^{xxx}		33.6^{xxx}	64.8^{xxx}	
	Fail Spot Percentage — Tyhjälaikkusadannes				
4	15.7 ± 4.2	24.0 ± 4.7	19.8	15.6 ± 5.0	24.0 ± 3.8
5	22.9 ± 8.9	27.1 ± 2.6	25.0	18.8 ± 5.8	31.3 ± 6.3
3	12.5 ± 5.8	40.7 ± 7.0	26.6	16.7 ± 3.8	36.5 ± 5.2
6	25.0 ± 8.1	28.2 ± 5.3	26.6	14.6 ± 6.6	38.6 ± 7.8
2	26.1 ± 8.0	27.1 ± 4.2	26.6	13.6 ± 3.8	39.6 ± 3.5
1	27.1 ± 6.0	31.3 ± 5.6	29.2	21.9 ± 3.1	36.5 ± 6.1
$\bar{x}$ 1–6	21.6	29.7	25.6	16.9	34.4
Control (7)	74.0 ± 8.5	67.8 ± 8.6	70.9	53.2 ± 4.2	88.6 ± 2.5
$\bar{x}$ 1–7	29.0 ± 7.1	35.1 ± 5.4	32.1	22.0 ± 4.6	42.1 ± 5.0
F	15.1^{xxx}		31.2^{xxx}	93.8^{xxx}	

course, a definite relationship between the field germination and fail spot percentage in that the larger the field germination, the smaller the fail spot percentage.

4. DISCUSSION

It must be considered that the results are based on observations made during only one summer. The summer of 1972 was in all of Finland exceptionally warm and dry. In northern Finland degree days sum was the third largest observed in this century. Consequently, the results apply to a rather exceptional case.

The results were very similar at different lacations. The field germination, i.e. the percentage of seedlings developed from seeds germinated in the field, was highest in Muurola with 76.8% being the average for that location. It was significantly larger than that on the other locations. Obviously, this was partially due to

Table 6. Average field germination and fail spot percentage with statistical tests on different locations. Taulukko 6. Eri paikkakuntien keskimääräiset kenttäitävyys- ja tyhjälaikkuprosentit ja niiden tilastollinen tarkastelu.

Location Paikka-kunta	*Field Germination* Kenttäitävyys		*Fail Spot* Tyhjälaikku	
	%	*arc* sin.	%	*arc* sin.
Juupajoki	50.2	0.79	24.2	0.48
Rautavaara	46.9	0.75	31.1	0.55
Muurola	76.8	1.08	5.2	0.14
Pomokaira	36.2	0.63	32.1	0.58
F		85.8^{xxx}		51.5^{xxx}
$HSD_{.05}{}^{Pme}{}_{.05}$		0.10		0.08

the good seed quality used in Muurola. The germination was 91% and the 1000-grain weight was 5.53 g. Correspondingly, field germination was smallest in Rautavaara where the germination (58%) and 1000-grain weight (3.60 g) were smallest. The difference between Juupajoki and Rautavaara was small.

Correspondingly, the percentage of fail spots was smallest in Muurola (5.2%) and largest in Pomokaira (32.1%). The differences between Juupajoki and Rautavaara were not statistically significant. The percentage of fail spots could have been considerably reduced by increasing the number of seeds sowed on each spot. In general, textbooks recommend 25–30 germinating seeds per spot when using patch or row sowing. In this study, the purpose of which was to investigate the effect of various shelters on seed germination, the same number of seeds (3 germinating seeds) was used at all locations.

The stratification method which was used did not seem very good, since there were no statistically significant differences in field germination and fail spot percentage between stratified and untreated seed either under shelters or on open control spots. On the contrary, at the northernmost location in Pomokaira these characteristics were more favorable for the untreated control seed. The difference was not, however, very big; but according to the data, it was significant. The effect of the shelters on the development of the emerged seedlings is not known yet since height and other measurements of the seedlings are to be made later.

The differences both in field germination and fail spot percentage between the two positions of the sowing spot were similar on all locations and statistically very significant. During the first growing season the shoulder provided a better position for the sowing spot than did the tilt. It should be noted that the summer of 1972, as already has been pointed out, was exceptionally warm and dry and that, on the other hand, in shoulder plowing very seldom is a tilt formed which is suitable for sowing. The later development of the seedlings may be better on the tilt when it has been compressed over the years. The differences between placements of the sowing spots were similar regardless of whether shelters were used over the sowed seed or not.

On all experimental locations the field germination was considerably higher and the fail spot percentage smaller under the shelters compared to the uncovered control spots. The differences were statistically very significant except for the experiments in Muurola where only the handmade, medium sized 10 cm and the largest, 20 cm high shelters differed from the controls. The medium sized shelters were, in general, better than the others. It must be remembered that the beneficial effect of the shelters continues at least during the second growing season. Consequently, the differences in results between the shelters may later change considerably. The largest (20 cm high) shelter obviously is not recommended, since it is sensitive to wind. For instance, in Rautavaara this type of shelter was clearly less beneficial than the other ones.

The effect of the shelter is based on the microclimate in it which is more favorable for

seed germination and seedling development than on an open sowing spot. The phenomenon is similar to the effect on initial development of seedlings in a greenhouse. Based on comparative measurements, it was found that the air within the shelter was, in general, somewhat warmer and clearly more humid compared to that outside the shelter. The water vapor evaporates inside the shelter, hits the wall and is condensed to water droplets which drip back to the ground (Figure 2). Sufficient heat and, more important, enough moisture are basic requirements for efficient germination of the seed. The shelter works as a "mini-plastic greenhouse" for each sowed spot. Most likely the result is that the seedlings which develop rapidly under the shelter are more resistant to the repeated frost heaving of the soil surface in the fall and, at least with respect to their size, are more resistant to winter conditions than seedlings developed from normal sowing.

The shelter itself protects against frost heaving in the fall and against snow damage during the winter. Furthermore, the shelter protects the seed against birds, insects and small rodents. When sowing on the tilt it protects against wind erosion.

The shelter sowing technique may be mechanized easily, and a manually-operated device is easy to construct. At the present time such devices are being developed intensively. In shelter sowing there should be reasons to use less seed than in patch or row sowing. It is obvious that 10 seeds is a recommendable number. When using such a small number of seeds, the advantage compared to planting, which is achieved when sowing larger amounts of seed, may be partly lost. This disadvantage may be alleviated by increasing the number of sowing spots per unit area.

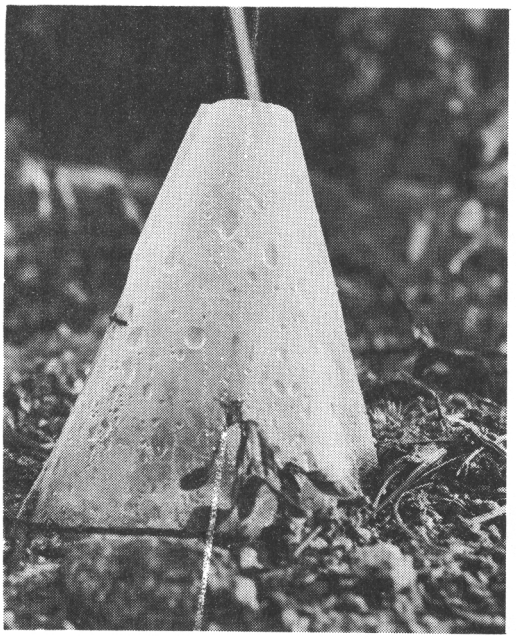

Fig. 2. Shelter no. 5 on the tilt in Juupajoki. The water vapor has condensed on the slanted wall of the shelter.
Kuva 2. Suojamalli n:o 5 palteessa Juupajoella. Vesihöyry tiivistynyt suojan kaltevaa seinää vasten.

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