SUOMEN METSÄTIETEELLINEN SEURA — FINSKA FORSTSAMFUNDET

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ACTA FORESTALIA FENNICA. Sisältää etupäässä Suomen metsätaloutta ja sen perusteita käsitteleviä tieteellisiä tutkimuksia. Ilmestyy epäsäännöllisin väliajoin niteinä, joista kukin yleensä käsittää useampia tutkimuksia.

SILVA FENNICA. Sisältää etupäässä Suomen metsätaloutta käsitteleviä kirjoitelmia ja pienehköjä tutkimuksia. Ilmestyy epäsäännöllisin väliajoin.

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EMERGENCE AND INITIAL DEVELOPMENT OF TREE SEEDLINGS ON BURNT-OVER FOREST LAND

PAAVO YLI-VAKKURI

SELOSTE:

TAIMIEN SYNTYMISESTÄ JA ALKUKEHITYKSESTÄ KULOTETUILLA ALUEILLA

HELSINKI 1961

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Introduction

Fire in the form of burning-over woodland has been subordinated to silviculture in different parts of the world, especially in the northern zone of coniferous forests, but also in the warmer zones. This method is derived from experiences with forest fires and clearing and burning-over woodland for cultivation. The method then has been further developed on the basis of both practical experience and research. In the main the method is still empirical, although the effect of fire on the forest has been studied a great deal as can be seen in the literature referred to by UGGLA (1958), YLI-VAKKURI (1958) and I. F. AHLGREN and C. E. AHLGREN (1960).

Depending on circumstances the aims of burning-over vary. In Finland burning-over is, in the first place, a method of treating the raw humus: favorable chemical, physical, and biological changes, or conditions for these changes in the soil, are sought by burning-over. At the same time seedlings and shoots of harmful trees and other vegetation as well as the slash which obstructs regeneration work are cleared away. Old slowly growing spruce stands on morainic soil with a deep raw humus layer are among the most common objects of burning-over. After burning-over these kinds of sites the species of tree is usually changed. It is often Scotch pine that is desired for a new tree generation. Usually direct seeding or planting is used, seldom natural seeding from seed trees. Some broad-leaved species, and later on Norway spruce frequently take over a burnt-over area spontaneously.

Burning-over as a silvicultural procedure has been practiced in Finland and elsewhere in Scandinavia for more than a hundred years (cf. STRÖM 1830, BLOMQVIST 1959). Only during the last decades, however, has it become established as a generally used silvicultural method. Extensive practical and educational work in this field, especially by ARVID BORG (1926, 1930) in Finland and WRETLIND (1932, 1948) in Sweden, have given it this standing. In Finland this method has been further developed particularly by KOLEHMAINEN (1951).

This method, in the course of time, has been the subject of lively discussion. It has been touched upon in many studies, as appears in the literature presented recently by UGGLA (1958) and YLI-VAKKURI (1958). Complementary data have been obtained by studying wild fires and their influences. It must be pointed out, however, that especially as regards the formation of a new tree

generation, wild burns are not exactly like burnt-over areas. It will only be necessary to consider that, in Finnish conditions, most wild fires occur on barren land and during the driest periods of the summer, when the humus burns more thoroughly than under burning-over, which is carried out on moister land and usually in early summer when the spring moisture still protects the soil. Therefore, studies of the formation of reproduction in areas burnt by wild fires are not tenable as regards regeneration problems of burnt-over areas. However, they clarify many details and provide valuable material for research; hence they are worthy of attention along with studies carried out in burnt-over areas.

The initial stages in the formation of a new tree generation succeeding shifting cultivation or burning-over and wild fires has been dealt with by e.g. HEIKINHEIMO (1915, 1931), CANNELIN (1917), ARVID BORG (1926, 1930, 1931), ENEROTH (1931), WRETLIND (1932, 1948), L. E. T. BORG (1936), SARVAS (1937, 1948), MIKOLA (1942), ARNBORG (1949), KOLEHMAINEN (1955, 1957), VAARTAJA (1949, 1950, 1954), LEHTO (1956), UGGLA (1958) and YLI-VAKKURI (1958). Also some investigations carried out elsewhere in different conditions are interesting in this connection (cf. I. F. AHLGREN and C. E. AHLGREN 1960).

The aim of this study is, by using experiments, to throw light on the initial stages in the formation of a new tree generation on burnt-over areas and some of the factors affecting such natural regeneration. The study deals mainly with Scotch pine (*Pinus silvestris* L.), Norway spruce (*Picea abies* (L.) H. KARST.) and to a lesser extent birch (*Betula verrucosa* EHRH. and *Betula pubescens* EHRH.). It is a part of a larger project the purpose of which is to clarify the regeneration of the main Finnish tree species in different conditions.

The study has been carried out at the Institute of Silviculture at the University of Helsinki. It has been sponsored by The Foundation for Research of National Resources in Finland (*Suomen luonnonvarain tutkimussäätiö*) and State Scientific Board (*Valtion luonnontieteellinen toimikunta*). The Forest Service has contributed to the study by permitting the establishment of long-time experiments on State land.

This paper was translated into English by Dr. JAAKKO LEHTO. It is also a pleasure to acknowledge the kindness of Mrs. KAY V. MALLORY and Mr. C. E. AHLGREN (U.S.A.), and other interested persons, who have read the manuscript and offered helpful suggestions.

Method of study

The main part of the material for this study consists of experimental seedings which were examined repeatedly. These seedings were established as follows: In a suitable area plots for seeding were marked out with iron stakes placed at intervals of three meters. Then by drawing lots, the sequence was determined according to which different treatments alternated (Fig. 1). Ten or twenty replications were used per each treatment. One hundred pre-bagged seeds were sown in each plot. The plots were limited by means of a portable circular frame 0.25 sq. m in area with a hole in its center for a stake marking the center of the plot (Fig. 2). Using this method the plots could quickly be established, and easily examined later when necessary. To ensure that a given plot could be found each time, a number plate was fastened to the central stake. The method used has been described more fully in a previous publication (YLI-VAKKURI 1959).

Pine and spruce seed used for experiments were collected in localities 100—300 km to the south of the study areas and obtained from the central store of the Central Forestry Association Tapio at Oitti. The origin of the seed, the year of its collection and its germinability in the laboratory was as follows:

Year of seeding experiments	Locality where seed was collected	Year of collection	Percentage of germination
	Pinus silvestris		
1956	East Häme	1954	96
1957	East Häme	1953	85
1958	Forest District of Heinola	1958	96
1959	East Häme	1956	92
1960	South Häme	1958	88
	Picea abies		
1956	Satakunta	1955	78
1957	Satakunta	1955	80
1958	North Häme	1955	93
1959	Uusimaa-Häme	1955	90
1960	Uusimaa-Häme	1955	85

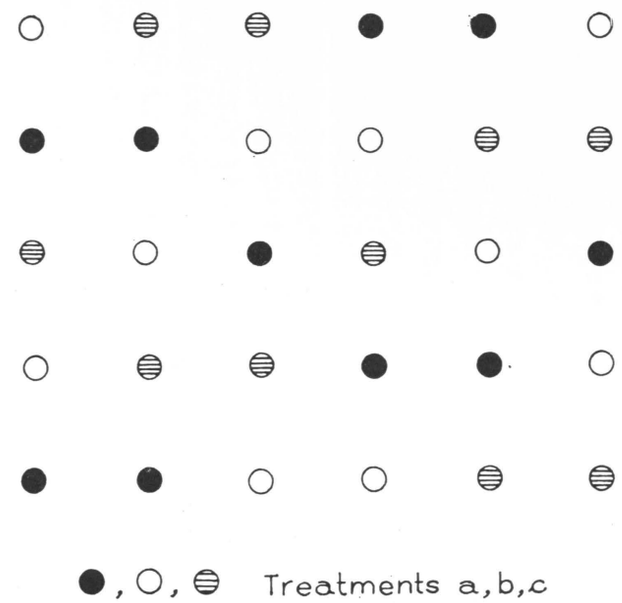

Fig. 1. Schematic illustration of the distribution of sample circles when a series of experiments (a, b, c) consisted of 10 replications.

Kuva 1. Kaavakuva näyteympyröiden sijoittumisesta, kun koesarjoihin (a, b, c) kuului 10 toistoa.

In order to have seed as homogeneous as possible, it was winnowed by strong blowing before using it in germination tests and seeding experiments. The results of the seeding experiments will be mostly given as percentages of the amount of sown seeds, not of the amount of seeds germinated in the laboratory. This was believed to be appropriate, since the principal aim of the study is to compare how seeding plots treated in different ways become stocked with seedlings, always in the same year. The origin of the seed used in different trials in different years was not quite the same each time; therefore the results from different years were not compared in detail, nor were all the results from different years made directly comparable.

In some experiments the seed was sown on burnt-over land, in others, on exposed patches of mineral soil. The patches were made a little larger than the frame itself in order to avoid the marginal effect in the area limited by the frame. As will be seen later, the seeds did not always remain where they were sown; sometimes they drifted to the edges of the patches. The results do not reflect the conditions of the mineral soil only, but those of large patches, where the edge of the patch may have an influence on the result. They were not like ordinary seeding patches, however, but five times larger. Moreover, in the experiments the seed was never covered up; in the ordinary spot-seeding and its different variations the seed is usually laid over with soil.

Additional experiments were set up to study the invasion of spruce and birch on the regeneration areas.

Experimental seedings were carried out in three consecutive summers 1956, 1957, and 1958. In addition, trial seedings were done at different dates, and experiments were conducted in 1958 to observe the effect of watering. All seedings were studied several times in the years 1956—1959. Separate experiments were arranged in 1958, 1959, and 1960 to study the destruction and loss of viability of seed sown on a burnt-over area, and the destruction of seed during burning-over. The vegetation of seeding plots was also studied at different dates by recording the species and their coverage. The development of the vegetation, however, which the author has dealt with earlier (Yli-Vakkuri 1958), is touched on here only to the extent that is necessary in describing conditions during the seeding experiments. In addition, other information was collected concerning the nature of the study areas.

The following grouping was used in examining the results of the seedings:

Pine — *Mänty*

a. Normally developed seedlings.
a. Normaalisti kehittyneet taimet.

aa. Seedlings with a radicle, hypocotyl, cotyledons, and plumule (even when just starting to unfold).
aa. Taimet, joissa sirkkajuuri, -varsi ja -lehdet sekä sirkkasilmu tai juuri aukeamassa oleva sirkkasilmu.
ab. Seedlings bearing, in addition to cotyledons, a clearly unfolded whorl of single primary needles.
ab. Taimet, joissa sirkkalehtien lisäksi selvästi puhjennut ruusuke yksittäisiä varhaisneulasia.
ac. Seedlings having a clearly visible shoot with single primary needles.
ac. Taimet, joissa on jo selvästi näkyvä, plumulasta puhjennut pääverso yksittäisine varhaisneulasineen.
ad. Seedlings having, in addition to primary needles, a main shoot with dwarf shoots and needles in pairs.
ad. Taimet, joissa varhaisneulasten lisäksi versoa kääpiöversoineen ja kaksittain olevine neulasineen.
ae. Seedlings with primary branches in addition to the main shoot.
ae. Taimet, joissa pääverson lisäksi esiintyy ensi asteen sivuhaaroja.
af. Seedlings with secondary branches.
af. Taimet, joissa esiintyy jo toisen asteen sivuhaaroja.

b. Injured and diseased seedlings.
b. Vaurioituneet ja sairaat taimet.

ba. Less than one half of the needles lost.
ba. Neulastosta poissa vähemmän kuin puolet.
bb. More than one half of the needles lost.

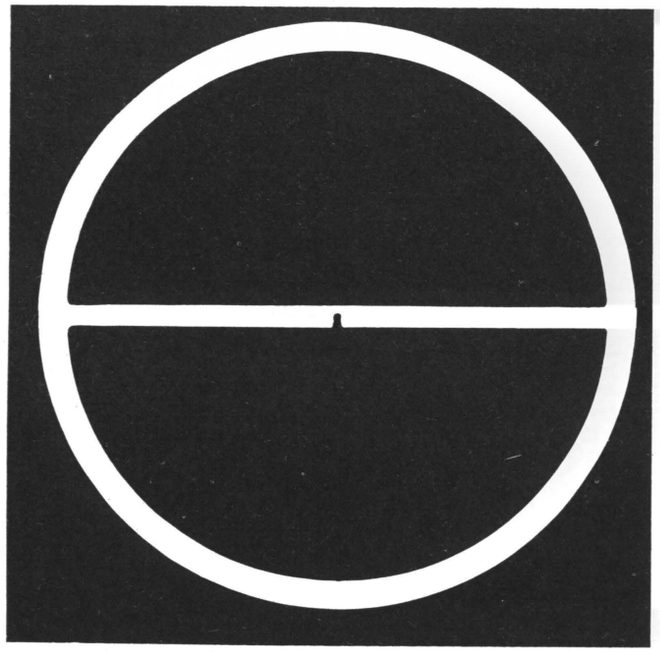

Fig. 2. A portable frame used for delimiting seeding spots.
Kuva 2. Kylvökohtien rajoittamiseen käytetty siirrettävä kehikko.

bb. Neulastosta poissa enemmän kuin puolet.
bc. Othervise diseased seedlings.
bc. Muuten sairaat taimet.

c. Dead seedlings.
c. Kuolleet taimet.

ca. Stubs, that is, seedlings incapable of development because of injury; only the hypocotyl without any plumule remains.
ca. Tyngät eli kehityskelvottomiksi vaurioituneet taimet, joiden maanpäällisistä osista on pystyssä pelkkä sirkkavarsi ilman sirkkasilmua.
cb. Seedlings killed some other way.
cb. Muuten kuolleet taimet.

Spruce — *Kuusi*

a. Normally developed seedlings.
a. Normaalisti kehittyneet taimet.

aa. As with pine.
aa. Kuten männyllä.

ab. As with pine.
ab. Kuten männyllä.
ac. Seedlings with a branchless shoot above the cotyledon.
ac. Taimet, joissa sirkkalehtien yläpuolella esiintyy haaratonta pääversoa.
ad. Seedlings with primary branches in addition to a shoot.
ad. Taimet, joissa pääverson lisäksi esiintyy ensi asteen sivuhaaroja.
ae. Seedlings with secondary branches.
ae. Taimet, joissa esiintyy jo toisen asteen sivuhaaroja.
af. Seedlings with branches of the third degree.
af. Taimet, joissa esiintyy jo kolmannen asteen sivuhaaroja.
Other classification as with pine.
Muu luokitus kuten männyllä.

The comparison of seeding results is based mainly on the occurrence of living seedlings. Tables 3—8 dealing with the results from seedings reveal the standard error of mean in addition to the mean. To facilitate drawing conclusions, the »t-test» has been used to test the significance of the differences of the mean of the seeding-results from the trials (SNEDECOR and COCHRAN 1959). The author is fully aware of the fact that the application of conventional formulae to cases in which the material is gathered as in the present study (cf. p. 7), is under discussion (cf. HASENKAMP 1954). Results of tests have been indicated as follows:

	Level of significance
significant	5 %
highly significant	1 %

Localities and material of study

The studies took place in Central Finland in the Forest Districts of Tuomarniemi and Korkeakoski. A homogeneous regeneration area of 12 hectares, where burning-over had been performed in different years, was available in the Forest District of Tuomarniemi at Ähtäri (62° 39′ N, 24° 05′ E). The average elevation above the sea level is 200 meters. The topography of the area is almost level upland. Signs of paludification were seen in some depressions. The soil is podzolised fine sandy moraine with few stones. The vegetation type of the area is primarily moist upland forest of the *Myrtillus* type (cf. CAJANDER 1949), but due to the absence or scantiness of the ground vegetation the exact forest site type in this area is difficult to identify. The regeneration area is surrounded by mature spruce and spruce-dominated stands with some admixture of birch and pine.

Before a clear cutting a mature spruce-dominated forest covered the regeneration area; the average growing stock per hectare was more than 200 cu.m. solid measure.

Fig. 3. Experiments are being started in study area 4. Forest District of Tuomarniemi, Ähtäri, June 8, 1956. Photo: Paavo Yli-Vakkuri.

Kuva 3. Kylvökokeiden alkuunpanoa tutkimusalueella 4. Tuomarniemen hoitoalue, Ähtäri 8. 6. 1956. Valok. Paavo Yli-Vakkuri.

Out of this regeneration area three subareas (Nos. 4, 5, 7) were selected as objects of study. In this paper they are called study areas.

Study area 4

The majority of the seeding experiments was performed in this area, which was clear cut in the winter of 1954—1955 and burnt-over in the same spring as the experiments were started. The area had been treated by patch seeding before the studies began, but there was still enough intact burnt-over surface. All that was left of the previous tree stand was some scorched stems of branches and tops, with a total coverage of about 5 % as estimated by eye. Charred needles

were practically everywhere on the ground indicating that the burning had not generally affected the humus layer very much; in addition to the slash, the fire had consumed the part of the vegetation of the field layer that is above the ground and the moss and lichen layer completely.

On June 8, 1956, series of seeding experiments were established in this area comprising a total of 80 circles. They consisted of pine and spruce seedings on burnt-over ground and on bared mineral soil patches; each seeding comprised 20 replications. The pine and spruce trials were arranged side by side, not alternately as in other experiments.

On June 19, 1957, a number of similar experiments, comprising a total of 60 circles in series of 10, were set up in the study area. The network of circles included control series where the plots were not seeded. The nearest tree stand was 85 meters from the seeding area. The network of these circles was located next to the experiments started the previous summer.

The experiments were carried on in the same way in 1958. A new network, consisting of a total of 110 circles, was established and seedings were done in it on May 15, June 1, June 15, and July 1. One pine and one spruce series was watered once a week, each time using an amount of water corresponding to a rainfall of 4 millimeters. In addition, the preservation of seed sown on the bared mineral soil was studied by special trials. The experiments were observed throughout the growing season and they were studied in detail at intervals of two, in some cases, three weeks.

Experiments established in the earlier years were studied usually in the latter half of the growing season, in some instances at its beginning as well. The formation of new vegetation, too, was studied repeatedly. The development of the vegetation was as follows:

When the first experiments were established in the area there was no vegetation there. It remained so practically throughout the first growing season; in the autumn only little traces of such plants as *Vaccinium vitis-idaea* L. and *Vaccinium myrtillus* L., *Deschampsia flexuosa* (L.) Trin., *Calamagrostis epigeios* L. Roth, *Pteridium aquilinum* (L.) Roth and *Rubus spp.* could be seen. In addition there were mosses characteristic of recently burnt areas, but they, too, were infrequent. The coverage of even the most abundant plant species was only fractions of one per cent. More moss appeared on the bared mineral soil, and here and there some grasses and herbs, among others *Luzula pilosa* (L.) Willd and *Rumex spp.*

The vegetation on the humus layer remained infrequent throughout the following growing season and the bare burnt-over surface was overwhelmingly dominant. A notable newcomer was *Chamaenerion angustifolium* (L.) Scop., the coverage of which, however, was insignificant, about 1 per cent. *Deschampsia flexuosa* appeared to be more vigorous. The bottom layer still consisted of infrequent mosses, mainly *Ceratodon purpureus* Brid. and species of *Polytrichum.*

Fig. 4. General view of study area 7 at the time the experiments were started in June 1956, four growing seasons after burning-over. The Forest District of Tuomarniemi, Ähtäri. Photo: Paavo Yli-Vakkuri.

Kuva 4. Yleiskuva tutkimusalueesta 7 kokeiden alottamisajankohtana kesäkuussa 1956, jolloin kulotuksesta oli kulunut neljä kasvukautta. Tuomarniemen hoitoalue, Ähtäri. Valok.Paavo Yli-Vakkuri.

The mineral soil patches, although mainly bare, grew some more mosses, some seed-borne *Calluna vulgaris* (L.) HULL, grasses and herbs.

On humus, during the third growing season *Chamaenerion* became more frequent in the field layer and mosses more frequent in the bottom layer. The coverage of the moss layer did not generally exceed 5 per cent and *Chamaenerion* 5—10 per cent.

The development was about the same during the fourth growing season. The tall *Chamaenerion* occurred quite continuously and abundantly, with a coverage of 20—30 per cent. *Deschampsia flexuosa* seemed to occupy more room too. The moss in the bottom layer became more abundant, covering about one quarter, in some places more than one half, of the ground surface.

In the mineral-soil patches mosses formed a continuous layer during the third and fourth growing season. In addition there were plenty of *Calluna* and some grasses, sedges, and solitary herbs.

There were some shoots of broad-leaved trees in this study area, as well as in the others; their seedlings appeared on the bare mineral soil. They will be described in detail later on.

Fig. 5. Study area 70 (Moisio) in early June, 1958, a few days after burning. Forest District of Korkeakoski, Juupajoki. Photo: Paavo Yli-Vakkuri.

Kuva 5. Tutkimusalue 70 (Moisio) kulotuksen jälkipäivinä kesäkuun alussa 1958. Korkeakosken hoitoalue, Juupajoki. Valok. Paavo Yli-Vakkuri.

Study area 5

The previous tree generation was removed from this area by a clear cutting in 1954. After cutting the area was cleared, burnt-over and seeded in patches in 1955. When experiments were being established on June 11, 1956, the area was practically without vegetation. Most of the existing vegetation was found in the scarified patches. In addition vigorous 1-year-old pine seedlings grew in them. There was plenty of intact burnt-over humus surface between the patches. The nearest forest, an 80-year-old spruce stand, was 100 meters to the NW. A number of charred treetops and branches were found in the area; their total coverage was estimated, by eye, to be about 5 per cent. Three series of experiments, consisting of 60 circles, were established in the area. The experiments consisted of seedings of pine and spruce on intact burnt-over humus surface, and seedings of spruce on the patches prepared the year before, where 1-year-old seedlings were already growing. The patches of spruce were closest to the stakes indicating circles on the intact humus surface.

The development of the vegetation in this area was otherwise the same as in study area 4, except that it was one growing season older. At the beginning of the experiments the vegetation was starting its second growing season.

Table 1. Data on the soil of study areas.

Taulukko 1. Maata koskevia mittaustuloksia tutkimusalueilta.

No. of study area	4	4	4	4	5	7	70	71
Tutkimusalueen n:o								
No. of series of experiments	4	6	26	29	5	7	74	71
Koesarjan n:o								
Depth index (Viro 1952), cm	25.4	25.1	28.7	27.4	24.6	23.2	20.8	23.8
Kivisyysindeksi (Viro 1952), cm								
Humus A_0, cm	3.3	3.0	2.7	4.6	1.8	2.1	3.2	4.0
Humus A_0, cm								
Leached horizon A_2, cm	16	16	12	9	9	5	14	7
Valkomaa A_2, cm								
Enriched horizon B, cm	8	8	14	14	10	11	22	15
Rikastumiskerros B, cm								
Year of burning-over	1956	1956	1956	1956	1955	1952	1958	1959
Kulotusvuosi								
Year of starting experiments	1956	1956	1957	1958	1956	1956	1958	1959
Kokeiden alottamisvuosi								

S t u d y a r e a 7

This area represented the oldest burnt-over area. The growing stock here had been removed by a clear cut in 1951. Clearing, burning-over and patch seeding for pine had been done in 1952. The nearest defined border of a forest stand was a 60-year-old spruce-dominated stand 100 meters to the SW from the place of experiments.

Three series of experiments totalling 60 circles were established in the study area on June 11, 1956. The aims of these experiments were the same as in study area 5. In addition, in area 7, spruce was seeded in old patches where 4-year-old pine seedlings already grew.

The vegetation had been developing for four growing seasons before these trial seedings. The moss covered, on the average, one-third of the ground. The dominant species in the field layer were *Chamaenerion angustifolium* and *Deschampsia flexuosa*. Dwarf-shrubs, herbs and grasses were also found. During the following years the moss cover continued to grow denser. *Deschampsia* held its ground but *Chamaenerion* lost some. *Vaccinium vitis-idaea* gained ground slowly. *Rubus idaeus* was scant.

The seeding patches had a continuous moss cover when the seeding experiments were being established. The dominating species were *Polytrichum commune* L. and *Ceratodon purpureus*. Some grasses, herbs, and dwarf-shrubs were also found. The vegetation in the scarified patches had this composition throughout the time of the experiments.

Table 2. Temperature and precipitation in the Meteorological Stations of Ähtäri and Hyytiälä, Juupajoki. The former station is situated 5 kilometers from study areas 4, 5 and 7, the latter 3 kilometers from study areas 70 and 71.

Taulukko 2. Lämpötila ja sateen määrä Ähtärin ja Juupajoen Hyytiälän säähavaintoasemilla. Edellinen asema on 5 km:n päässä tutkimusalueista 4, 5 ja 7 ja jälkimmäinen 3 km:n päässä tutkimusalueista 70 ja 71.

Month *Kuukausi*	Ähtäri										Juupajoki, Hyytiälä					
	Temperature, °C *Lämpötila, °C*						Precipitation, mm *Sade, mm*						Temperature, °C *Lämpötila, °C*			Precipitation, mm *Sade, mm*		
	Normal value *Normaaliarvo* 1921—1950	1956	1957	1958	1959	1960	Normal value *Normaaliarvo* 1921—1950	1956	1957	1958	1959	1960	1958	1959	1960	1958	1959	1960
January I	— 8.7	— 11.7	— 4.8	— 11.8	— 8.6	— 11.0	39	39	28	27	48	53	— 11.3	— 7.4	— 10.9	33	67	60
February II	— 8.9	— 15.2	— 5.2	— 11.5	— 4.2	— 10.7	30	26	39	17	25	23	— 11.0	— 3.3	— 10.1	20	18	35
March III	— 5.1	— 5.2	— 8.3	— 9.3	— 1.0	— 4.4	32	5	25	22	22	3	— 8.6	— 0.8	— 4.2	29	24	6
April IV	1.2	— 1.6	0.5	— 0.4	2.2	1.3	39	9	18	19	22	16	— 0.2	2.4	1.1	18	57	26
May V	8.0	7.8	7.1	6.7	8.0	10.4	48	43	57	79	50	18	7.0	8.1	10.2	91	45	51
June VI	12.7	14.3	10.5	12.7	13.8	15.0	68	52	62	21	29	74	12.5	13.8	15.1	34	47	65
July VII	16.2	14.6	17.2	14.2	16.6	17.3	75	63	66	84	31	91	14.3	16.9	16.8	79	30	142
August VIII	14.0	11.2	13.9	13.6	14.8	14.2	79	87	133	23	95	75	13.0	14.9	13.8	50	94	69
September IX	8.8	7.3	7.9	8.9	7.1	9.0	72	47	68	22	32	24	9.0	7.6	8.6	13	24	16
October X	2.9	2.1	3.7	4.5	3.2	0.6	62	86	75	68	55	34	4.7	3.3	1.1	42	64	37
November XI	— 1.4	— 7.5	— 1.0	1.4	— 0.7	— 2.9	47	26	53	41	47	62	1.7	0.1	— 2.4	52	61	80
December XII	— 5.4	— 4.8	— 4.4	— 9.4	— 8.5	— 3.5	38	47	71	50	29	52	— 8.9	— 8.0	2.7	58	47	76
Year — *Vuosi*	2.9	..	..	1.6	..	2.9	627	529	695	472	485	525	..	..	..	519	577	663

Study area 70

This is a burnt-over area of 4 hectares situated at Moisio, Korkeakoski, 85 km south of the locality referred to above. The topography is gently undulating. The soil is podzolised, stony, fine sandy moraine. The average elevation above the sea level is 160 meters in this and the next study area. According to an analysis before burning-over, the vegetation on the hillocks was of the *Myrtillus* type; on the slopes and in the depressions it was a little more luxuriant. The area was surrounded on many sides by narrow, moist carr dells. The neighborhood was covered mainly by old spruce-dominated forests with a mixture of pine and birch. In nearby carr depressions the growing stock was younger, and in places birch-dominated. On the west the study area bordered on a clear cut area.

Before burning-over the area was covered by an old spruce-dominated forest of high cubic contents. The area was clear cut in the winter of 1957—1958 and burnt-over successfully on June 2, 1958. In places a thin layer of humus burnt along with the slash and ground vegetation.

This area also remained practically without vegetation for two growing seasons. During the third growing season the coverage of both the field layer and the shrub layer reached about one-fifth of the area. The dominant species of the field layer were *Deschampsia flexuosa*, *Chamaenerion angustifolium*, *Vaccinium vitis-idaea*, *Maianthemum bifolium* (L.) F. W. Schmidt, *Rubus saxatilis* L. and *Luzula pilosa*.. The shrub layer consisted of luxuriant *Rubus idaeus* L. and some broadleaved tree shoots. The *Rubus idaeus* vegetation originated from seedlings, which appeared during the summer the area was burnt-over. This plant was not found there before the burning. The bottom layer of the vegetation was still so deficient in the third growing season that its coverage was under 5 per cent. The main species was *Ceratodon purpureus*.

Immediately after the burning on June 2, 1958, a series of spruce seeding experiments was begun. It consisted of a total of 58 circles in three different places. The following year, on June 3, 1959, seed was sown in the area to study its disappearance: 80 batches of pine seed were sown on the humus in rows 10 cm long at 1 meter intervals; 26 batches of spruce seed were sown in the same way. More trials were started and traps installed by the end of June to determine the causes of seed losses. The experiments were under observation throughout the summer. The viability of the recovered seed was studied by applying several tests.

Study area 71

A burnt-over area of 4 hectares at Taipaleenmaa, Korkeakoski. The topography is gently undulating and the soil is podzolised fine sandy moraine with few stones. According to the vegetation found there the area belongs in the

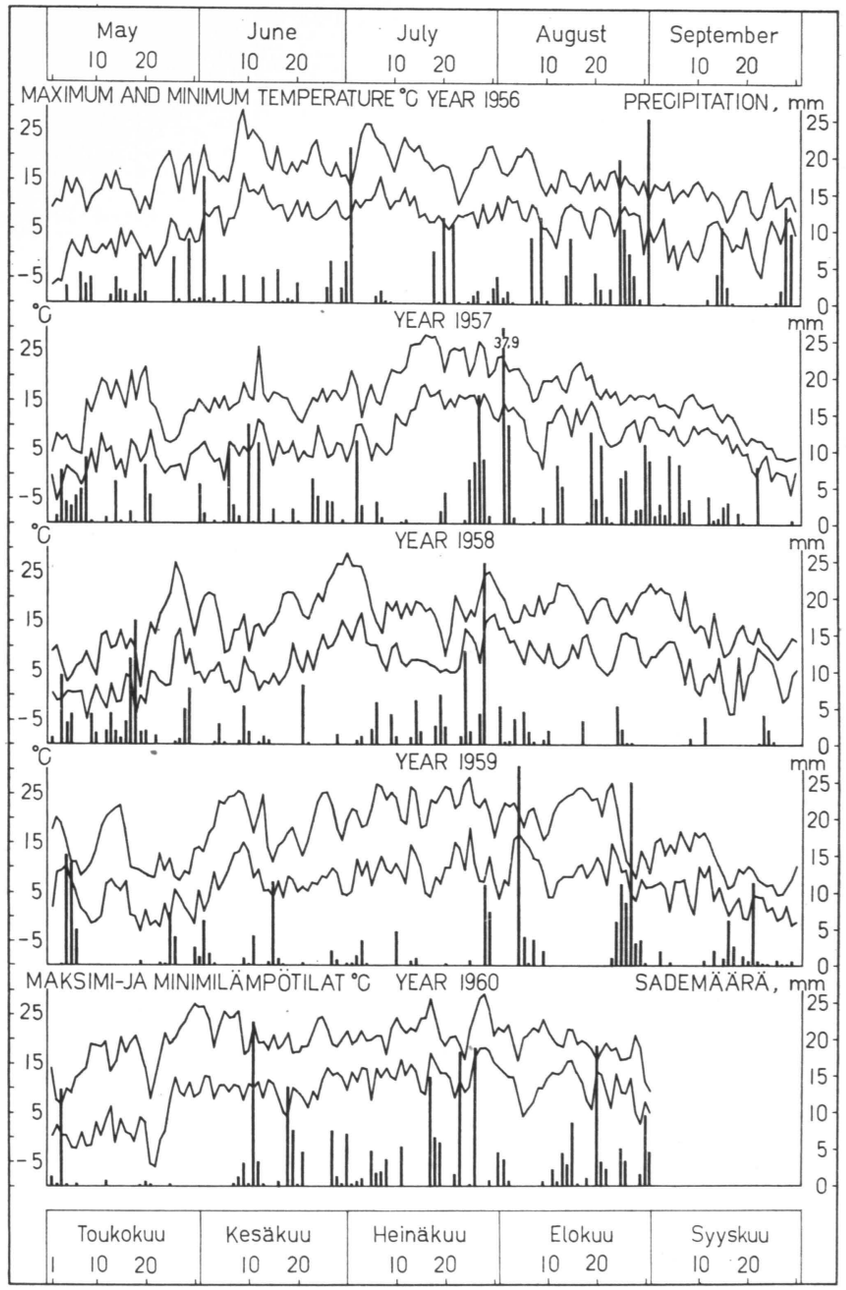

Fig. 6. Daily precipitation and minimum and maximum temperatures (2 meters above ground level) in different growing seasons. According to the Meteorological Station of Ähtäri, situated 5 kilometers from study areas 4, 5 and 7.

Kuva 6. Päivittäinen sademäärä sekä lämpötilan alin ja ylin arvo (2 m:n korkeudessa maasta) eri kasvukausina Ähtärin säähavaintoaseman mukaan, joka sijaitsee 5 km:n päässä tutkimusalueista 4, 5 ja 7.

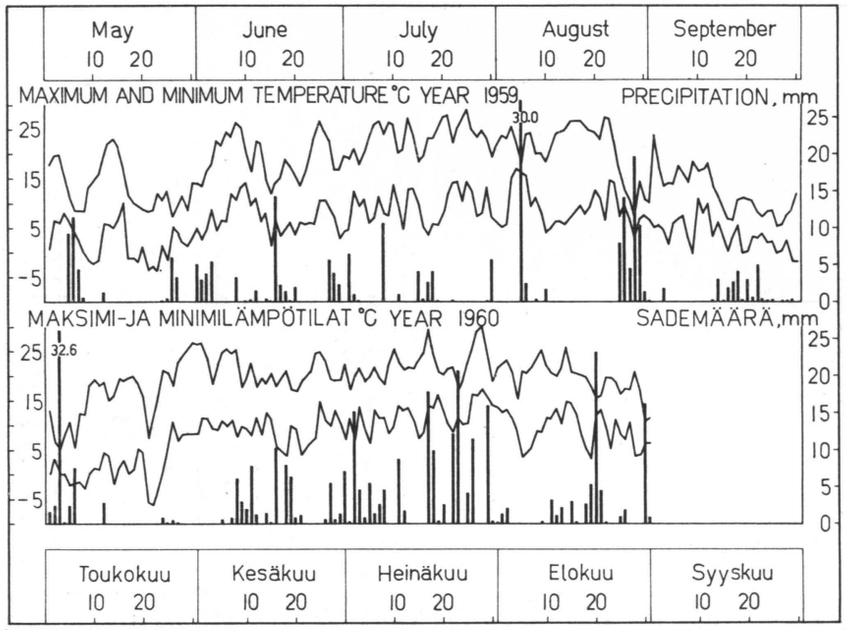

Fig. 7. Daily precipitation and maximum and minimum temperatures (2 meters above ground level) in different growing seasons. According to the Meteorological Station of Hyytiälä, Juupajoki, situated 3 kilometers from study areas 70 and 71.

Kuva 7. Päivittäinen sademäärä sekä lämpötilan alin ja ylin arvo (2 m:n korkeudessa maasta) eri kasvukausina Juupajoen Hyytiälän säähavaintoaseman mukaan, joka sijaitsee 3 km:n päässä tutkimusalueista 70 ja 71.

Myrtillus type. The area was surrounded by old spruce-dominated stands, bogs with young pine and a tract burnt-over a few years earlier.

Before burning-over the area was covered by mature spruce-dominated forest. It was clear cut in the winter of 1958—1959 and burnt-over on June 5, 1959. During the experiments the area was practically without any vegetation, because the experiments were performed during the summer of burning and the following summer.

The effect of fire on the viability of the seed was studied by placing 20 batches of 100 seeds between the moss cover and the humus layer prior to burning. To study the causes of the disappearance of the seed, 80 batches of 100 pine seeds each were sown in the area three days after burning-over. Some temperature observations were also made. The following year on May 10, 1960, experiments dealing with the disappearance of seeds were started, by sowing 40 batches of 100 pine and 100 spruce seeds on the surface of the humus. Special experiments were arranged to find out the agents causing seed losses. The viability of the recovered seeds was tested in several ways during both years.

Some data are given in the table 1 on page 16 on the soil of the study areas. Information on precipitation and temperature during the experiments is found in table 2. Special climatic features during different growing seasons are given in figures 6 and 7. The formation and disappearance of snow as well as the thawing of frozen soil in study area 4 have been reported earlier (Yli-Vakkuri 1960).

Emergence and initial development of seedlings on burnt-over humus

P i n e. Tentative trials performed in 1956 gave some hints as to the initial development of pine on a burnt-over area. Table 3 reveals that the emergence of seedlings on a recently burnt-over area and on a 1-year-old burnt-over area was almost nonexistent. At the end of the first growing season the percentage of emerged seedlings (percentage of the number of seedlings out of the number of sown seeds) was less than one. But on study area 7, that is, on a 4-year-old burnt-over area, the corresponding percentage was 4.2. A comparison based on the abundancy of living seedlings at the end of the first growing season revealed that the difference in seedling stock between the oldest and the most recent burns was statistically highly significant. For the elaboration of the causes of this result, it is worth pointing out that the oldest burn differed from the most recent ones most conspicuously as regards vegetation. The former had more vegetation already in 1956, as the following table reveals:

	Study area 4, trial series 4 A 201—239	Study area 5, trial series 5 A 301—320	Study area 7, trial series 7 A 271—290
Coverage of ground vegetation September 11, 1956, per cent			
Mosses	0	1	26
Herbs and grasses	1	1	14
Dwarf shrubs	1	1	2

As it was very probable that seeding experiments would not yield similar results in a summer with different weather conditions, the trials were continued on study area 4 in 1957. Table 4 reveals that the percentage of seedlings of seeds was still low, 2.3, but higher than the year before, although the viability of the seed used was a little lower than that of the seed used in the previous year.

It is characteristic of the trial conditions that the frozen soil thawed as late as June 5. Precipitation during the first half of the growing season was a little lower than normal, but during the latter half it was high. Ground vegetation was practically as scant as in the previous year.

The experiments reported above did not throw any light on the effect of the time of seeding on the emergence and development of seedlings. Therefore trials on these lines were continued in 1958 (Table 5). Spring was late that year, so

Table 3. Results of experimental seedings of pine and spruce on burnt-over humus on June 11, 1956. Each series of experiments comprises 20 replications of 100 seeds. Ähtäri, Forest District of Tuomarniemi.

Taulukko 3. Tulokset kulotetulle humukselle 11. 6. 1956 suoritetuista männyn ja kuusen koekylvöistä. Kuhunkin koesarjaan sisältyy 20 toistoa à 100 siementä. Ähtäri, Tuomarniemen hoitoalue.

Date of observations *Havaintojen ajankohta* Month Day Year *Kuukausi Päivä Vuosi*	Normally developed *Normaalisti kehittyneet* Stages of development *Kehitysasteet* aa	ab	ac	ad	ae	Total *Yhteensä* aa—ae	Damaged and diseased *Vaurioituneet ja sairaat* b	Living *Elävät* aa—b	Dead *Kuolleet* c	Total *Kaikkiaan* aa—c	Sample circles carrying living seedlings, % *Näyteympyröitä, joissa eläviä taimia, %*
	Average number of seedlings per sample circle *Taimia näyteympyrää kohden keskimäärin, kpl*										
Pinus silvestris											
Study area 4, burnt-over in 1956, experiment series 4 A 201—239 *Tutkimusalue 4, kulotettu 1956, koesarja 4 A 201—239*											
IX 11 1956	0.10	0.55	—	—	—	0.65	0.10	0.75 ± 0.24	0.15	0.90	30
VIII 14 1957	—	0.05	—	0.05	—	0.10	—	0.10 ± 0.07	0.15	0.25	10
VI 10 1958	—	—	0.15	—	0.05	0.20	—	0.20 ± 0.09	0.05	0.25	20
VIII 18 1958	—	—	—	0.10	0.10	0.20	—	0.20 ± 0.09	—	0.20	20
Study area 5, burnt-over in 1955, experiment series 5 A 301—320 *Tutkimusalue 5, kulotettu 1955, koesarja 5 A 301—320*											
IX 11 1956	0.10	0.15	—	—	—	0.25	—	0.25 ± 0.16	—	0.25	15
VIII 21 1957	—	0.15	0.40	0.05	—	0.60	—	0.60 ± 0.26	0.05	0.65	40
VIII 20 1958	—	—	0.05	0.20	0.20	0.45	—	0.45 ± 0.15	0.05	0.50	35
Study area 7, burnt-over 1952, experiment series 7 A 271—290 *Tutkimusalue 7, kulotettu 1952, koesarja 7 A 271—290*											
IX 11 1956	0.60	3.40	—	—	—	4.00	0.15	4.15 ± 1.49	0.05	4.20	85
VIII 22 1957	0.05	0.60	1.30	—	—	1.95	—	1.95 ± 0.97	0.05	2.00	40
VIII 19 1958	—	—	0.35	0.70	0.65	1.70	—	1.70 ± 0.60	0.45	2.15	55
Picea abies											
Study area 4, burnt-over in 1956, experiment series 6 A 361—380 *Tutkimusalue 4, kulotettu 1956, koesarja 6 A 361—380*											
IX 11 1956	0.15	—	—	—	—	0.15	0.05	0.20 ± 0.12	0.45	0.65	15
1957	—	—	—	—	—	—	—	—	—	—	—
1958											
Study area 5, burnt-over in 1955, experiment series 5 A 321—340 *Tutkimusalue 5, kulotettu 1955, koesarja 5 A 321—340*											
IX 11 1956	0.05	—	—	—	—	0.05	—	0.05 ± 0.05	0.05	0.10	5
VIII 21 1957	—	—	—	—	—	—	—	—	—	—	—
VIII 20 1958	—	—	—	0.05	—	0.05	—	0.05 ± 0.05	—	0.05	5
Study area 7, burnt-over in 1952, experiment series 7 A 61—80 *Tutkimusalue 7, kulotettu 1952, koesarja 7 A 61—80*											
IX 11 1956	0.80	0.40	—	—	—	1.20	0.10	1.30 ± 0.32	0.05	1.35	60
VIII 22 1957	0.05	—	0.05	—	—	0.10	—	0.10 ± 0.10	—	0.10	5
VIII 19 1958	—	—	0.30	0.05	0.05	0.40	—	0.40 ± 0.13	—	0.40	35

Table 4. Results of experimental seedings of pine and spruce on burnt-over humus in 1957. Each series of experiments comprises 10 replications of 100 seeds. Study area 4, burnt-over in 1956. Ähtäri, Forest District of Tuomarniemi.

Taulukko 4. Tulokset kulotetulle humukselle 1957 suoritetuista männyn ja kuusen koekylvöistä. Kuhunkin koesarjaan sisältyy 10 toistoa á 100 siementä. Tutkimusalue 4, joka on kulotettu 1956. Ähtäri, Tuomarniemen hoitoalue.

Date of observations *Havaintojen ajankohta* Month Day Year *Kuukausi Päivä Vuosi*	Normally developed *Normaalisti kehittyneet* Stages of development *Kehitysasteet* aa	ab	ac	ad	ae	Total *Yhteensä* aa—ae	Damaged and diseased *Vaurioituneet ja sairaat* b	Living *Elävät* aa—b	Dead *Kuolleet* c	Total *Kaikkiaan* aa—c	Sample circles carrying living seedlings, % *Näyteympyröitä, joissa eläviä taimia, %*
	Average number of seedlings per sample circle *Taimia näyteympyrää kohden keskimäärin, kpl*										
Pinus silvestris											
Experiment series 26 C 420—429, sown June 19, 1957 *Koesarja 26 C 420—429, kylvetty 19. 6. 1957*											
VIII 14 1957	2.10	0.20	—	—	—	2.30	—	2.30 ± 0.62	—	2.30	70
VI 11 1958	—	1.50	0.30	—	—	1.80	—	1.80 ± 0.55	0.20	2.00	70
VIII 19 1958	—	—	0.80	0.30	0.20	1.30	—	1.30 ± 0.40	0.80	2.10	60
Picea abies											
Experiment series 26 C 430—439, sown June 19, 1957 *Koesarja 26 C 430—439, kylvetty19. 6. 1957*											
VIII 14 1957	1.10	0.10	—	—	—	1.20	—	1.20 ± 1.00	—	1.20	20
VI 11 1958	—	0.10	0.40	—	—	0.50	—	0.50 ± 0.40	—	0.50	20
VIII 19 1958	0.20	0.10	0.10	0.20	—	0.60	—	0.60 ± 0.31	0.80	1.40	40

the first seeding was done early as compared with the progress of the spring. The permanent snow cover in the study area melted as late as May 7 and the frozen soil thawed on May 22. A new layer of snow, 10—15 cm deep, fell on May 18, but it melted in a few days. The surface of the humus layer had been moistened by the melting snow at the time of the first seeding; at the time of the other seedings the surface of the humus was dry.

Vegetation in the study area continued to be rather scant, as can be seen in the following table (trial series 29 C):

Coverage of ground vegetation, June 11 through 26, per cent

Mosses	7
Herbs and grasses	4
Dwarf shrubs	0

When observations of precipitation (cf. Fig. 6) are considered along with data mentioned above, it would appear that there was plenty of moisture available immediately after the first seeding, but that it was obviously too cold for

fast germination (cf. MORK 1933). Later, in June, the humus was too dry. Only the rainy period in July and in the beginning of August led to a general germination of seeds, almost regardless of the date of seeding. When the result of the earliest seeding was compared with the results of seedings on other dates, based on living seedlings on August 11, no significant differences were found. Thus under the prevailing conditions the seeding date had no influence on the result. A weekly watering of 4 millimeters each time increased little the number of seedlings obtained from the seeding on June 1, 1958. The difference as against the control was highly significant. The watering did not speed up the germination process.

Very few seedling stubs or seedlings with damaged needles were found, which indicates that agents causing such damage did not occur in these burnt-over areas. Some seedlings injured and killed by other causes were found in the first growing season.

The fact that few seedlings were found, brings forth an important question: do the seeds possibly germinate later or have they been destroyed during the first year? Since no delayed germination worth mentioning was noticed during the following years, although its occurrence was especially studied, it is reasonable to assume that the seeds have lost their viability or disappeared. This hypothesis justified special trials, the results of which will be reported later.

The inventories obtained in successive years reveal that when a notable decrease in the number of seedlings has occurred, it has generally taken place between the first and second growing seasons. An especially clear case of the loss of young seedlings was observed in an inventory in 1959. Possibly the dryness of the summer had completed the destruction that had taken place during the wintering.

The development of pine seedlings was rapid on a burnt-over humus layer. The seedlings by the end of the first growing season had generally a whorl of primary needles in addition to cotyledons. The shoot with single primary needles developed in the second growing season and in the third one the dwarf shoots appeared with needles in twos and in some cases even primary branches. The development of the seedlings during the first growing season is also reflected by the shedding of the seed coat from the tops of the cotyledons. This generally occurred during the first growing season as indicated in the following table:

Date of seeding	Date of study	Percentage of seedlings without seed coat
June 8—11, 1956	September 11, 1956	96
June 19, 1957	August 14, 1957	82
May 15—July 1, 1958[1])	July 23, 1958	..
»	» 27, »	35
»	August 11, »	88
»	September 15, »	100
»	» 29, »	100

[1]) All seeds germinated at the same time, see Table 5

Table 5. Results of pine seeding experiments on burnt-over humus in 1958. Each series of experiments comprises 10 replications of 100 seeds. Study area 4, burnt-over in 1956. Ähtäri, Forest District of Tuomarniemi.

Taulukko 5. Tulokset kulotetulle humukselle vuonna 1958 suoritetuista männyn koekylvöistä. Kuhunkin koesarjaan sisältyy 10 toistoa à 100 siementä. Tutkimusalue 4, joka on kulotettu 1956. Ähtäri, Tuomarniemen hoitoalue.

Date of observations *Havaintojen ajankohta* Month Day Year *Kuukausi Päivä Vuosi*	Normally developed *Normaalisti kehittyneet* Stages of development *Kehitysasteet* aa	ab	ac	Total *Yhteensä* aa—ac	Damaged and diseased *Vaurioituneet ja sairaat* b	Living *Elävät* aa—b	Dead *Kuolleet* c	Total *Kaikkiaan* aa—c	Sample circles carrying living seedlings, % *Näytesympyröitä, joissa eläviä taimia, %*
	Average number of seedlings per sample circle *Taimia näyteympyrää kohden keskimäärin, kpl*								
Experiment series 29 C 800—809, sown May 15, 1958 *Koesarja 29 C 800—809, kylvetty 15. 5. 1958*									
VI 23 1958	0.10	—	—	0.10	—	0.10 ± 0.10	—	0.10	10
VII 8 »	—	—	—	—	0.10	0.10 ± 0.10	—	0.10	10
VII 23 »	0.10	—	—	0.10	—	0.10 ± 0.10	—	0.10	10
VIII 11 »	6.70	—	—	6.70	—	6.70 ± 1.41	—	6.70	90
VIII 27 »	5.00	1.40	—	6.40	—	6.40 ± 1.71	0.90	7.30	90
IX 15 »	1.80	3.60	—	5.40	—	5.40 ± 1.45	0.80	6.20	90
IX 29 »	0.50	4.10	—	4.60	0.30	4.90 ± 1.32	0.80	5.70	90
VII 8 1959	—	—	—	—	—	—	4.20	4.20	—
Experiment series 29 C 820—829, sown June 1, 1958 *Koesarja 29 C 820—829, kylvetty 1. 6. 1958*									
VII 8 1958	—	—	—	—	—	—	—	—	—
VII 23 »	0.20	—	—	0.20	—	0.20 ± 0.29	—	0.20	20
VIII 11 »	5.10	0.30	—	5.40	—	5.40 ± 1.97	—	5.40	80
VIII 27 »	1.90	1.00	—	2.90	—	2.90 ± 1.63	1.30	4.20	40
IX 15 »	0.90	1.80	—	2.70	0.10	2.80 ± 1.41	1.00	3.80	50
IX 29 »	0.20	2.30	—	2.50	0.50	3.00 ± 1.56	0.40	3.40	50
VII 8 1959	—	0.10	0.10	0.20	—	0.20 ± 0.10	2.00	2.20	—
Experiment series 29 C 870—879, sown June 15, 1958 *Koesarja 29 C 870—879, kylvetty 15. 6. 1958*									
VII 23 1958	—	—	—	—	—	—	—	—	—
VIII 11 »	3.90	—	—	3.90	—	3.90 ± 1.14	0.10	4.00	80
VIII 27 »	2.80	0.60	—	3.40	—	3.40 ± 1.09	0.30	3.70	70
IX 15 »	1.30	1.90	—	3.20	—	3.20 ± 1.11	0.80	4.00	70
IX 29 »	0.40	2.10	—	2.50	0.40	2.90 ± 0.91	0.80	3.70	70
VII 8 1959	—	—	—	—	—	—	2.10	2.10	—
Experiment series 29 C 890—899, sown July 1, 1958 *Koesarja 29 C 890—899, kylvetty 1. 7. 1957*									
VII 23 1958	—	—	—	—	—	—	—	—	—
VIII 11 »	9.20	—	—	9.20	—	9.20 ± 3.34	0.10	9.30	90
VIII 27 »	6.10	2.30	—	8.40	—	8.40 ± 3.51	0.80	9.20	90
IX 15 »	2.00	6.00	—	8.00	—	8.00 ± 3.32	0.50	8.50	90
IX 29 »	0.90	6.20	—	7.10	0.30	7.40 ± 3.28	0.80	8.20	90
VII 8 1959	—	0.10	0.10	0.20	0.20	0.40 ± 0.30	5.80	6.20	30
Experiment series 29 C 830—839, sown June 1, 1958, watered weekly *Koesarja 29 C 830—839, kylvetty 1. 6. 1958, kasteltu viikottain*									
VII 7 1958	—	—	—	—	—	—	—	—	—
VII 23 »	0.50	—	—	0.50	—	0.50 ± 0.40	—	0.50	20
VIII 11 »	8.50	0.30	—	8.80	—	8.80 ± 2.19	0.10	8.90	90
VIII 27 »	4.40	3.10	—	7.50	0.10	7.60 ± 1.90	0.90	8.50	90
IX 15 »	1.50	5.80	—	7.30	0.30	7.60 ± 1.90	0.60	8.20	90
IX 29 »	0.30	6.30	—	6.60	0.30	6.90 ± 1.80	1.10	8.00	90
VII 8 1959	0.20	0.80	—	1.00	—	1.00 ± 0.33	5.70	6.70	60

The emergence of the plumule and the formation of the shoot with primary needles usually cause even the most tenaciously attached seedcoat to drop. In rare cases the seed coat may still persist.

In 1958 the development of seedlings went on as late as the last observations, that is, to the end of September, due to an unusually warm autumn.

S p r u c e. Burning-over is a suitable means of getting rid of spruce seedlings in areas where spruce is not wanted. Since it is frequently desirable from the silvicultural point of view to keep spruce away for as long as possible it is justifiable to describe the invasion of spruce of burnt-over areas.

Seedings of spruce on the humus layer in 1956 resulted in few seedlings by the end of the first growing season (Table 3), but generally spruce seedlings were almost as numerous as pine seedlings if we consider that the original viability of the spruce seed was lower than that of the pine seed. The best yield of spruce seedlings, too, was observed on the oldest burnt-over area, study area 7, where living seedlings were highly significantly more numerous than in study areas 4 and 5.

The following year the trial was repeated in study area 4 (Table 4), where the burning had been accomplished one year before the experiment was started. In this case, too, the yield was poor, 1.2 per cent of the number of seeds sown. The corresponding percentage of pine was 2.3. Thus these tentative trials gave rise to the interesting notion that there might not be any great differences between spruce and pine in this respect. Therefore extensive comparative experiments were arranged in study area 4 in 1958 (Table 6); their results with regard to pine have been given previously. If we compare with these the results of the spruce seeding trials we find some minor differences depending on the time of seeding. But, on the whole, spruce seed yielded as many seedlings as pine seed. At the end of the growing season the average percentage was, watered spots excluded, as follows:

	Pine	Spruce
Percentage of seedlings of the number of viable seeds	6	6
Percentage of dead seedlings	1	1
Total number of seeds sown	4 000	4 000

An early seeding of spruce on May 15, 1958, gave a result poorer than or similar to those of later seedings (Table 6). A comparison on the basis of the numbers of living seedlings counted on August 27 proved that the difference between the results from the sowings on May 15 and on June 1 was highly significant, but between those on May 15 and on June 15 hardly significant. On the other hand, the difference between the results from the sowings on May 15 and on July 1 was not significant. Seeds sown at different dates between May 15 and July 1, 1958 began to germinate simultaneously in early August. Thus the earliest sown spruce seeds began to germinate a little later than pine seeds sown at the same

Table 6. Results of spruce seeding experiments on burnt-over humus in 1958. Each series of experiments comprises 10 replications of 100 seeds. Study area 4, burnt-over in 1956. Ähtäri, Forest District of Tuomarniemi.

Taulukko 6. Tulokset kulotetulle humukselle vuonna 1958 suoritetuista kuusen kylvökokeista. Kuhunkin koesarjaan sisältyy 10 toistoa à 100 siementä. Tutkimusalue 4, joka on kulotettu 1956. Ähtäri, Tuomarniemen hoitoalue.

Date of observations *Havaintojen ajankohta* Month Day Year *Kuukausi Päivä Vuosi*	Normally developed *Normaalisti kehittyneet*				Damaged and diseased *Vaurioituneet ja sairaat*	Living *Elävät*	Dead *Kuolleet*	Total *Kaikkiaan*	Sample circles carrying living seedlings, % *Näyteympyröitä, joissa eläviä taimia, %*
	Stages of development *Kehitysasteet*			Total *Yhteensä*					
	aa	ab	ac	aa—ac	b	aa—b	c	aa—c	
	Average number of seedlings per sample circle *Taimia näyteympyrää kohden keskimäärin, kpl*								
Experiment series 29 C 810—819, sown May 15, 1958 *Koesarja 29 C 810—819, kylvetty 15. 5. 1958*									
VII 23 1958	—	—	—	—	—	—	—	—	—
VIII 11 »	2.70	—	—	2.70	—	2.70 ± 0.80	—	2.70	90
VIII 27 »	1.90	0.60	—	2.50	—	2.50 ± 0.84	0.60	3.10	80
IX 15 »	0.50	1.40	—	1.90	—	1.90 ± 0.71	0.90	2.80	80
IX 29 »	0.10	1.40	—	1.50	0.40	1.90 ± 0.72	0.70	2.60	60
VII 8 1959	—	—	—	—	—	—	2.00	2.00	—
Experiment series 29 C 840—849, sown June 1, 1958 *Koesarja 29 C 840—849, kylvetty 1. 6. 1958*									
VII 23 1958	—	—	—	—	—	—	—	—	—
VIII 11 »	6.10	—	—	6.10	—	6.10 ± 0.75	—	6.10	100
VIII 27 »	6.20	0.90	—	7.10	—	7.10 ± 1.43	0.90	8.00	90
IX 15 »	2.40	3.50	—	5.90	0.20	6.10 ± 1.07	1.00	7.10	100
IX 29 »	1.20	4.40	—	5.60	0.30	5.90 ± 0.97	1.00	6.90	100
VII 8 1959	—	—	0.10	0.10	0.10	0.20 ± 0.10	4.60	4.80	10
Experiment series 29 C 860—869, sown June 15, 1958 *Koesarja 29 C 860—869, kylvetty 15. 6. 1958*									
VII 23 1958	—	—	—	—	—	—	—	—	—
VIII 11 »	6.60	—	—	6.60	—	6.60 ± 2.14	—	6.60	90
VIII 27 »	6.90	1.20	—	8.10	—	8.10 ± 3.09	0.80	8.90	90
IX 15 »	3.20	3.90	—	7.10	—	7.10 ± 2.92	0.80	7.90	90
IX 29 »	1.90	4.10	—	6.00	0.40	6.40 ± 2.55	1.30	7.70	90
VII 8 1959	0.20	0.10	0.10	0.40	—	0.40 ± 0.43	4.40	4.80	20
Experiment series 29 C 880—889, sown July 1, 1958 *Koesarja 29 C 880—889, kylvetty 1. 7. 1958*									
VII 23 1958	—	—	—	—	—	—	—	—	—
VIII 11 »	6.70	—	—	6.70	—	6.70 ± 2.76	—	6.70	60
VIII 27 »	5.60	0.80	—	6.40	—	6.40 ± 2.61	0.80	7.20	60
IX 9 »	2.50	3.10	—	5.60	—	5.60 ± 2.60	1.20	6.80	60
IX 29 »	1.50	3.00	—	4.50	0.50	5.00 ± 2.43	1.30	6.30	50
VII 8 1959	0.40	0.40	0.50	1.30	—	1.30 ± 1.30	3.20	4.50	10
Experiment series 29 C 850—859, sown June 1, 1958, watered weekly *Koesarja 29 C 850—859, kylvetty 1. 6. 1958, kasteltu viikottain*									
VII 23 1958	—	—	—	—	—	—	—	—	—
VIII 11 »	9.20	—	—	9.20	—	9.20 ± 2.56	0.10	9.30	90
VIII 27 »	7.30	2.70	—	10.00	—	10.00 ± 3.44	0.50	10.50	90
IX 15 »	2.50	6.90	—	9.40	—	9.40 ± 3.17	0.90	10.30	90
IX 29 »	0.50	8.60	—	9.10	—	9.10 ± 3.24	1.50	10.60	90
VII 8 1959	—	0.10	0.10	0.20	—	0.20 ± 0.20	6.80	7.00	10

time. A weekly-repeated watering did not speed up germination but it increased a little the number of seedlings gained. The difference as against the trial series with no watering was significant.

Seedlings that emerged on the humus layer in 1956 were lost completely by the end of the following growing season in study areas 4 and 5; in area 7 their number decreased catastrophically. When a series of trials established in 1957 was studied the following spring it was found that seedlings had perished during the wintering. The larger number of seedlings observed during the second growing season suggests delayed germination. In the other series of experiments germination was low from the very beginning. On the basis of the repeated studies it seems likely that possible delayed germination has not been so significant that it has altered the poor final yield. Out of the seedlings emerged in 1958 only a small fraction was alive by the middle of the following growing season. The losses may be accounted for, apart from the wintering damage, by the drought in the summer of 1959.

In general the distribution of the types of damage between the categories distinguished was the same as with pine. During the first growing season, however, relatively more spruce seedlings died. Otherwise the development of seedlings was good and, according to observations, faster than in the nearby spruce stands. Spruce seedlings became free of their seed coat in the same manner as pine seedlings.

B i r c h. In study areas 5 and 7 no birch seedlings were found on the burnt-over humus layer, according to a study in 1958 based on 40 sample circles. In study area 4 only one birch seedling was found from 180 sample circles. Some seed had spread to the area, judging by seedlings found on the mineral soil and moist depressions between study areas.

On the other hand, birch stump shoots were found more abundantly. For example in study area 4, which was burnt-over in the spring of 1956, 193 groups of shoots per hectare were counted on July 11, 1959. However, only 30 per cent of the stumps had grown shoots after the burning-over. The groups of shoots consisted of 9 shoots on an average. The height of the shoot groups varied between 0.4—1.3 meters. The shoots had reached this stage in just under four growing seasons.

Emergence and initial development of seedlings on mineral soil

P i n e. The experiments presented on the preceding pages proved that a burnt-over humus layer of these study areas provided very poor regeneration facilities for the tree species studied. It was interesting to find out how the situation would change when the humus layer was removed.

Table 7. Results of seeding experiments with pine and spruce on exposed mineral soil in 1956 and 1957. Twenty replications were used in the series of experiments established in the former year, and 10 similar replications in the series established in the latter year. Study area 4 which was burnt-over in 1956. Ähtäri, Forest District of Tuomarniemi.

Taulukko 7. Tulokset paljastettuun kivennäismaahan vuonna 1956 ja 1957 suoritetuista männyn ja kuusen koekylvöistä. Edellisenä vuonna perustetuissa koesarjoissa oli 20, jälkimmäisenä vuonna perustetuissa 10 toistoa à 100 siementä. Tutkimusalue 4, joka on kulotettu 1956. Ähtäri, Tuomarniemen hoitoalue.

Date of observations *Havaintojen ajankohta* Month Day Year *Kuukausi Päivä Vuosi*	Normally developed *Normaalisti kehittyneet*						Damaged and diseased *Vaurioituneet ja sairaat*	Living *Elävät*	Dead *Kuolleet*	Total *Kaikkiaan*	Sample circles carrying living seedlings, % *Näyteympyröitä, joissa eläviä taimia, %*
	Stages of development *Kehitysasteet*					Total *Yhteensä*					
	aa	ab	ac	ad	ae	aa—ae	b	aa—b	c	aa—c	
	Average number of seedlings per sample circle *Taimia näyteympyrää kohden keskimäärin, kpl*										
Pinus silvestris											
Series of experiments 4 A 202 (17 sample circles), sown June 8, 1956 *Koesarja 4 A 202 (17 näyteympyrää), kylvetty 8. 6. 1956*											
IX 9 1956	—	51.76	—	—	—	51.76	1.06	52.82 ± 3.38	0.88	53.70	100
VIII 14 1957	0.35	0.41	0.53	34.83	—	36.12	0.41	36.53 ± 3.64	6.88	43.41	100
VI 10 1958	—	—	0.71	3.76	25.88	30.35	—	30.35 ± 3.25	5.47	35.82	100
VIII 19 1958	—	—	0.06	1.82	22.59	24.47	—	24.47 ± 2.55	2.47	26.94	100
Series of experiments 26 C 440—449, sown June 19, 1957 *Koesarja 26 C 440—449, kylvetty 19. 6. 1957*											
VIII 14 1957	0.60	3.20	—	—	—	3.80	0.10	3.90 ± 0.71	—	3.90	100
VI 11 1958	—	1.90	1.50	—	—	3.40	—	3.40 ± 0.60	0.10	3.50	100
VIII 19 1958	—	—	0.50	1.70	0.60	2.80	—	2.80 ± 0.36	—	2.80	100
Picea abies											
Series of experiments 26 C 400—409, sown June 19, 1957 *Koesarja 26 C 400—409, kylvetty 19. 6. 1957*											
VIII 14 1957	1.00	4.80	—	—	—	5.80	—	5.80 ± 1.16	0.10	5.90	90
VI 11 1958	—	0.70	3.10	0.20	—	4.00	—	4.00 ± 0.87	0.10	4.10	90
VIII 19 1958	—	0.10	2.40	2.20	—	4.70	—	4.70 ± 1.04	—	4.70	90

Some experiments concerning pine were performed in study area 4 (Table 7). Favorable results were expected from them on the basis of previous experience and results of studies. This expectation proved correct in 1956. The percentage of seedlings out of the number of sown seeds was as high as 54 and little damage occurred during the first growing season. The seedlings developed fast: in the first growing season a whorl of primary needles unfolded, in the second growing season dwarf shoots with double needles appeared, and in the third the primary branches. Seedlings continued to die, apparently mainly of fungus diseases,

and the number of seedlings fell during the three growing seasons and intervening winters to one half of the original.

The replication of this experiment in the following year gave an unexpectedly poor final yield. The percentage of seedlings out of the number of sown seeds was as low as 3.9. This poor result may have been caused, at least partly, by heavy rainfalls which repeatedly lashed germinating seeds and frail seedlings loose and occasionally formed puddles in the seeding patches. Those seedlings which stood the ordeal, developed as well as the seedlings of the previous year, which had emerged under propitious circumstances. Due to these obstacles in the mineral soil patches no difference in the relative number of seedlings was found between humus and mineral soil in 1957, although in the previous year the relative number of seedlings had been about 60 times greater on mineral soil than on humus. This result emphasizes the dependence of regeneration on weather and other conditions and accentuates the necessity of repeating these kinds of experiments for several years to avoid fallacies.

In study area 4 some observations were made concerning the occurrence of pine seedlings in actual seeding patches (see the following table) which had been prepared and sown by the personnel of the Forest District. The patches to be studied were taken at random and the same patches were later used for spruce seeding experiments.

	Studied		
	Autumn 1957	Spring 1958	Autumn 1958
Study area 4			
Age of seedlings, years	2	2	3
Average number of seedlings in patches	3.15	2.10	1.55
Relative number of seedlings	100	67	49
Empty patches, %	20	45	45

	Studied in autumn		
	1956	1957	1958
Study area 5			
Age of seedlings, years	2	3	4
Average number of seedlings in patches	2.10	1.60	1.25
Relative number of seedlings	100	76	60
Empty patches, %	35	35	55

	Studied in autumn		
	1956	1957	1958
Study area 7			
Age of seedlings, years	5	6	7
Average number of seedlings in patches	3.10	2.90	2.85
Relative number of seedlings	100	94	92
Empty patches, %	5	15	15

The material shows that the seeding performed in study area 7 in 1952 was successful and that the gradual decrease of seedlings slowed when the seedling stand reached the age of five years. The younger seedling stands in study areas 4 and 5 were not yet stabilized. The number of seedlings in the patches may have been small from the beginning, because the high death rate of seedlings in the first years resulted in many empty patches.

S p r u c e. In study area 4 in 1957, a seeding on exposed mineral soil yielded seedlings 5.9 per cent of the number of sown seeds which is practically of the same order that pine seeds yielded under corresponding circumstances (Table 7). Because of the heavy rains mentioned before, the growing season was so exceptional that no generally applicable conclusions can be drawn on the basis of the experiment. The seedlings that did appear developed well, better than on the humus layer, and survived the winter and the following growing season with little damage.

Burnt-over areas are frequently reforested by seeding pine in patches. Because the exposed mineral soil might offer new possibilities for the invasion of spruce, experiments to clarify this question were arranged by seeding spruce on old seeding patches (Table 8). Quite fresh patches in study area 4, seeded in 1956, and studied in 1957, yielded seedlings 1.3 per cent out of the sown seeds. The 2- and 4-year-old patches in study areas 5 and 7 yielded almost 10 per cent. In every case more seedlings emerged on mineral soil patches than on the humus layer. These differences between the numbers of living seedlings were highly significant in study areas 5 and 7 in the autumn of 1956. Thus seeding-patches facilitate the invasion of spruce on burnt-over areas.

Seedlings emerging in the patches lessened rapidly at first, apparently because of the autumn frosts, especially in 1956, and wintering damage. A number of seedlings survived and their development continued favorably. The increase in the number of seedlings during the third growing season was probably not caused by delayed germination, but by the fact that more seedlings could be distinguished in the vegetation.

As the seedlings clear themselves from the vegetation, another period of difficulties begins in their development. Apparently frosts threaten them until the pine stand in the area closes up. In 1959, when the spruce seedlings were beginning their fourth growing season, such frost damage did take place.

B i r c h. The exposed mineral soil provided a favorable germination bed for birch seeds. In the autumn of 1958, the following numbers of seedlings were counted on the mineral soil in study area 4. Because the number of seedlings was about the same in patches which had been bare for two and three growing seasons, the studies of both cases have been combined in the figures given here.

Table 8. Results of a seeding of spruce on June 11, 1956 on scarified patches prepared for pine. Each experiment series comprises 20 replications of 100 seeds.

Taulukko 8. Tulokset männyn ruutukylvölaikkuihin 11. 6. 1956 suoritetusta kuusen kylvöstä. Kuhunkin koesarjaan sisältyy 20 toistoa à 100 siementä.

Date of observations *Havaintojen ajankohta* Month Day Year *Kuukausi Päivä Vuosi*	Normally developed *Normaalisti kehittyneet* — Stages of development *Kehitysasteet* aa	ab	ac	ad	Total *Yhteensä* aa—ad	Damaged and diseased *Vaurioitu-neet ja sairaat* b	Living *Elävät* aa—b	Dead *Kuolleet* c	Total *Kaikkiaan* aa—c	Sample circles carrying living seedlings, % *Näyte-ympyröitä, joissa eläviä taimia, %*
	Average number of seedlings per sample circle *Taimia näyteympyrää kohden keskimäärin, kpl*									
Study area 4, seeding patches prepared in 1956, experiment series 6 A 381—400 *Tutkimusalue 4, laikut vuodelta 1956, koesarja 6 A 381—400*										
VIII 21 1957	—	0.60	0.35	—	0.95	—	0.95 ± 0.27	0.35	1.30	60
VI 11 1958	—	—	0.15	0.15	0.30	—	0.30 ± 0.16	—	0.30	20
VIII 19 1958	—	—	0.05	0.30	0.35	—	0.35 ± 0.21	—	0.35	20
Study area 5, seeding patches prepared in 1955, experiment series 5 A 341—360 *Tutkimusalue 5, laikut vuodelta 1955, koesarja 5 A 341—360*										
IX 11 1956	1.15	6.20	—	—	7.35	0.25	7.60 ± 1.53	1.70	9.30	95
VIII 21 1957	0.05	0.05	3.10	—	3.20	—	3.20 ± 0.87	0.15	3.35	80
VIII 20 1958	—	0.05	1.70	2.15	3.90	—	3.90 ± 1.03	0.30	4.20	75
Study area 7, seeding patches prepared in 1952, experiment series 7 A 81—100 *Tutkimusalue 7, laikut vuodelta 1952, koesarja 7 A 81—100*										
IX 11 1956	1.15	7.45	—	—	8.60	0.95	9.55 ± 1.72	—	9.55	100
VIII 22 1957	—	0.10	1.75	—	1.85	0.05	1.90 ± 0.71	0.20	2.10	40
VIII 19 1958	—	—	1.95	1.35	3.30	—	3.30 ± 1.03	—	3.30	70

Average number of seedlings in sample circles	2.9
Empty sample circles, per cent	20
Total number of sample circles	50

In 20 ordinary seeding patches examined, the number of birch seedlings was as follows:

Study area	Age of patches, growing seasons	Average number of seedlings in patches	Empty patches, per cent
4	3	0.85	65
5	4	1.25	30
7	7	0.45	65

In other ordinary seeding patches in the study areas some seedlings of *Salix spp.* and very scantily those of *Sorbus aucuparia* L. and *Populus tremula* L. were found.

These examples show how readily birch seedlings and also other broad-leaved trees intrude on the seeding patches. Such a mixed seedling stand obviously calls for early tending, because seedlings of birch and other broad-leaved trees not only complement the seedling stand, but also, being fast-growing species, can occupy too great a portion in it and thus hamper the development of pine seedlings.

Damage to seeds on the ground by fire

An experiment concerning the damage to seeds was carried out in study area 71 in the Forest District of Korkeakoski. The area was burnt-over on June 5, 1959, between 6 and 9 p.m. The weather was warm but a little windy. The last relatively heavy rainfall had occurred 3 days before, leaving the humus layer under the moss moist.

Burning-over took place as usual. On the whole, only the slash, moss, and other ground vegetation had burnt, but the humus had not burnt at all, or only superficially. In some places mosses had burnt incompletely, but died nevertheless. Similarly in places under charred needles others were found that were not burnt at all.

The seed used in the trial was sown in the central part of the area in four places just before burning-over. The seeds were placed on the humus layer under the moss. Some of the trials were performed in places cleared of slash, some in places with slash. The total number of seeds used, including a control sample, was 3 000. They had been grouped in advance in batches of 100. The seeds were recovered on June 8, and germinated in a sandbox at room temperature. The results can be seen in the following table:

Position of seed in study area	Percentage of seed developed into seedlings in sandbox, in 2 weeks	3 weeks	6 weeks	Percentage of seed destroyed in burning-over or not developed into seedlings
Slash present				
On the humus under the moss wrapped in paper	—	—	—	100
Slash removed				
On the humus under the moss wrapped in paper	12	19	20	80
Loose on the humus under the moss	7	10	10	90
Loose on the humus under the moss	26	31	32	68
Control	48	57	61	39

The experiment showed that under the conditions in question the seed partly retained its viability in places where burning was deficient because of the lack of slash. In places covered with some slash the fire was so hot that seeds on the humus burnt up or lost their viability. Some charred seeds or ones that had lost their viability partly or completely, were found also in places with no slash. Possibly all the remaining seeds were not recovered after the burning-over. Therefore the results may be a little too low.

To find out whether seed can drift in the ground vegetation as deep as they were placed in the trial conditions, some tests were performed in the Forest District of Korkeakoski using de-winged seed colored with minium. The sowing was done at the end of July in 1959, and reviewed one month later. Five batches of 100 seeds were sown in rows 15 cm long in each trial. The study showed the following results:

Number of sample plot	Forest site type	Species of tree	Age, years	Solid volume of growing stock, cubic meters per hectare	Percentile distribution of seeds found			Number of seeds found	Number of seeds lost or not recovered
					In the vegetation	On the humus layer	In the humus		
17	*Vaccinium* type	Pine	85	200	98	2	—	458	42
68	»	Opening	—	—	71	28	1	447	53
69	»	Pine	100	165	99	1	—	425	75
21	*Myrtillus* type	Spruce	85	310	52	46	2	364	136
72	*Oxalis-myrtillus* type	»	95	400	100	—	—	83	417

Under the experimental conditions most seeds remained in the ground vegetation. In two tree stands only an insignificant part of the seed sank to the surface of the humus layer. Very few seeds had gone into the humus. Judging by broken seed coats found in study areas 69 and 72, seed eaters destroyed seed, although it had been treated with minium.

When the growing stock of areas to be burnt-over is cut in the winter preceding the burning the seeds remain in cones (HEIKINHEIMO 1932 b, 1937). Cones and seeds falling from them go mainly to slash piles and obviously are for the most part lost in the fire. Some seeds may, however, end in more favorable places and survive a mild fire; this possibility at least has to be considered. In the study areas in question this possibility was very slight, as their growing stock before the burning was old and of poor growth; the seed production of this kind of forest is usually small. Moreover the seed crop of spruce was very small in 1956—1958, having been very abundant in the spring of 1955 (SARVAS 1957).

Damage caused by seed eaters on burnt-over areas

The first trials concerning the disappearance of seed were arranged in study area 4 at Ähtäri in 1958. In these trials 50 pine and 50 spruce seeds sown on mineral soil were to be observed. For this purpose five circular plots were marked out. On each of them 10 pine and 10 spruce seeds were sown on June 17, 1958. The seed spots marked with pins were under continuous observation and were studied several times during the summer. The seeds remained clearly visible for about two weeks after sowing, a period with little rain. After this the seeds were lost to sight. In many cases, however, seedlings emerged on the marked spots or elsewhere on the plot: the seed had mixed with the soil before germination. This phenomenon took place as follows: at first a thin layer of soil particles stuck to the moistened seed in the same manner as soil sticks to seedlings in nurseries. Later more soil particles accumulated on the seeds so that they finally looked like small lumps of soil and disappeared completely as the surface of the soil became smooth.

Rain drops beating the sample circles moved the seeds about before they found their places. Heavy rainfalls could cause even small puddles, where seeds floated away from their original spots, often to the fringe of the circle. The following table gives a more detailed account of the disappearance of seeds from sight and the emergence of seedlings. By the beginning of October, 44 per cent of the pine seeds and 26 per cent of the spruce seeds had developed into seedlings.

	June 17	June 25	July 2	July 25	August 14	September 5	October 1
				Pine			
Seeds	50	46	42	—	—	—	—
Seedlings ..	—	—	—	12	21	22	22
Total	50	46	42	12	21	22	22
				Spruce			
Seeds	50	49	45	3	—	—	—
Seedlings ..	—	—	—	1	8	13	13
Total	50	49	45	4	8	13	13

The disappearance of seeds from the burnt-over humus layer was studied on study areas 70 (Moisio) and 71 (Taipaleenmaa) in the Forest District of Korkeakoski in the summers of 1959 and 1960. In the trial seedings batches of one hundred seeds were sown in rows 10 cm long marked in the field at intervals of one meter. The trials comprised altogether 234 replications of one hundred seeds or a total of 23 400 seeds. The results of these trials appear in the following table:

Number of trial	Species of tree	Date of seeding	Date of study	Percentage of seed destroyed or disappeared
		Moisio, study area 70, burnt-over June 2, 1958		
70 I	Pine	June 3, 1959	June 24, 1959	88
70 II	»	»	July 15, 1959	86
74 I	Spruce	June 4, 1959	June 25, 1959	86
74 II	»	»	July 16, 1959	82
78 I	Pine	May 11, 1960	June 9, 1960	17
78 II	»	»	July 14, 1960	29
78 III	»	»	August 29, 1960	64
		Taipaleenmaa, study area 71, burnt-over June 5, 1959		
71 I	Pine	June 8, 1959	June 29, 1959	95
71 II	»	»	July 20, 1959	92
79 I	»	May 10, 1960	June 8, 1960	100
79 II	»	»	July 13, 1960	99
83 I	Spruce	»	June 8, 1960	100
83 II	»	»	July 13, 1960	99

In these trials the seeds were destroyed, or they disappeared completely, or almost completely. In the summer of 1959, the destruction had taken place in early summer, because the number of preserved seeds in the inventory in the middle of July was the same as in the inventory at the end of June. In the trials at Taipaleenmaa in 1960, the seeds were destroyed so completely that no further disappearance of seed could be studied. The result was established in a study on June 8, 1960, but more than a week earlier, the author was able to conclude that the destruction had taken place. At Moisio, only a small number of seeds disappeared in the early summer in 1960, in the third growing season after burning. Later on the portion of seed that was not found intact was considerable. Because the vegetation grew thicker at the same time, the conditions in this trial were different from the others.

In study area 71 at Taipaleenmaa the seeds sown on the humus layer were destroyed completely in 1960, but on humus cakes that were loosened from the ground with a plywood plate and iron stakes, seeds were preserved. This result suggests that the destruction may have been caused by some organisms living in the ground.

The destroyed seeds had not vanished without trace; halves and other fragments of seed coats and partly eaten seeds were seen (Fig. 9). These kinds of remains were easily discernible immediately after the destruction, but later on rain and wind could obliterate them.

To find out the agent or agents of the destruction, trials were started on the study area of Moisio on June 27, 1959. They were observed continually and terminated on September 1. The inventories of the trials showed that no significant destruction occurred that late. No particular indication of the agents of destruction was found, although birds and rodents were known to have been in the area. Thrushes (*Thurdus*) were seen frequently on the area, and occasionally a chaffinch (*Fringilla coelebs* LINNÉ), and several small insect-eating birds. Excrement of some small mammal was found in a seed batch (Fig. 8).

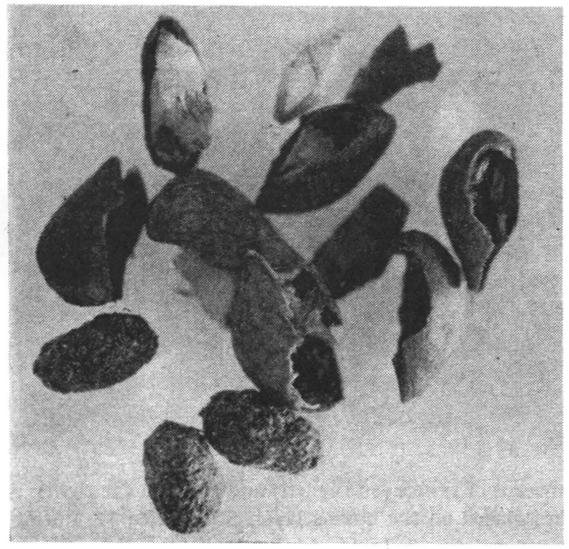

Fig. 8. Remains of spruce seeds recovered from the surface of burnt-over humus layer; damage caused presumably by small mammals. Excrement found among the seeds can be seen on lower left corner of the photo. Study area 70, Forest District of Korkeakoski, June 25, 1959.

Kuva 8. Todennäköisesti pikku nisäkkäiden kulotetulta humuspinnalta syömiä kuusen siemeniä. Kuvan vasemmassa alakulmassa näkyy siemenien seasta löydettyjä ulosteita. Tutkimusalue 70, Korkeakosken hoitoalue 25. 6. 1959.

In 1960, samples of the fauna of the burn at Taipaleenmaa in study area 71 were collected by means of decanters placed in the ground. These traps were examined every other day. Trapped insects were sorted according to species and put in glass containers with some coniferous seeds. On June 13, two mature individuals of *Pterostichus vulgaris* L. were caught. They were placed in a glass bottle with 5 pine seeds. When the bottle was examined on June 15 it appeared that 4 seeds had been eaten so that only the seed coats were left. Each specimen then was put in a separate bottle and given 5 seeds, some humus, green plants and a few drops of water. An examination on June 17 revealed that the main part of the seeds had been eaten. In a detailed study the insect was found to eat a seed within two or three minutes. Other specimens of the same insect were caught later and the test repeated, with the same results. The remains of seeds were

Fig. 9. Partly eaten seeds of spruce (on the left) and pine (on the right). No intact seeds were found in trial batches placed on the humus layer. Study area 71, Forest District of Korkeakoski, June 8, 1960.

Kuva 9. Syötyjä kuusen (vasemmanpuoleinen kuva) ja männyn (oikeanpuoleinen kuva) siemeniä. Ehjiä ei tarkastetuissa, humuksen pinnalle pannuissa, koe-erissä esiintynyt. Tutkimusalue 71, Korkeakosken hoitoalue 8. 6. 1960.

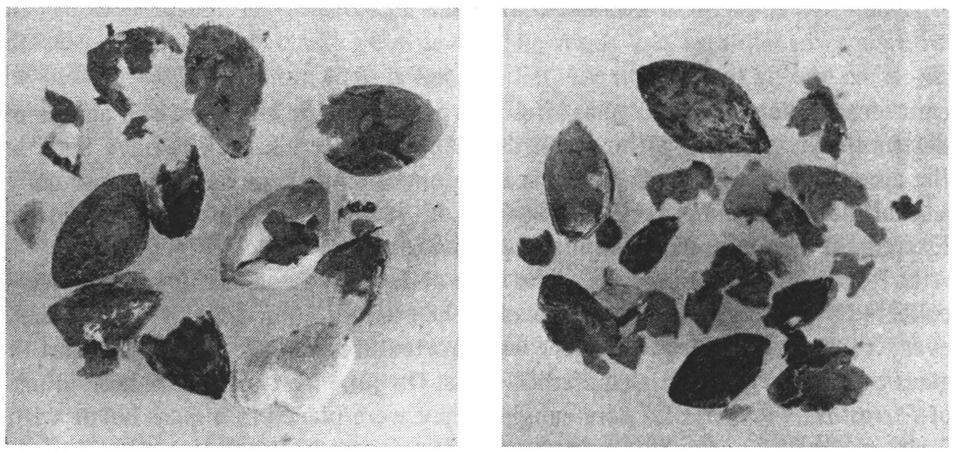

Fig. 10. Pine seeds damaged by Pterostichus vulgaris adults in captivity. These were trapped in study area 71, Forest District of Korkeakoski, June 13, 1960.

Kuva 10. Edellisessä kuvassa mainitulta kulotusalueelta 13. 6. 1960 pyydystettyjen Pterostichus vulgaris-aikuisten vankeudessa syömiä männyn siemeniä.

of the same type as were found in the field (Fig. 10). Although insects in captivity may behave differently than in nature, the observations above indicate that destrution of seed in burnt-over areas could be caused by *Pterostichus vulgaris*. But it is not certain.

The fact that *Pterostichus vulgaris* consumes plant and animal material has been mentioned by some authors (cf. LINDROTH 1945, SCHERNEY 1959). PRELL (1925) observed that in captivity it ate tree seeds. Having studied the contents of the alimentary canal of some *Carabidae* specimens, VON SKUHRAVÝ (1958) found that 9/10 of the nutrition of *Pterostichus vulgaris* originates in animals and the rest in plants. SCHERNEY (1959) assumes that many *Carabidae* species resort to vegetable nutrition, particularly when animal nutrition is lacking or under unfavorable moisture conditions.

Some other *Carabidae* species and other invertebrates were caught in the traps, but as far as was observed they did not eat tree seeds in captivity. This does not mean, however, that some other species known earlier as seed-eaters (cf. ECKSTEIN 1904, SAALAS 1917, 1924, 1949, ESCHERICH 1923, PRELL 1925, LINDROTH 1945, DAVIES 1953, SCHERNEY 1959), could not have taken part in the destruction.

Some snares were also set in the study area. Neither birds nor small mammals were caught during the summer. Nevertheless, the possible share of these animals in the destruction cannot be denied. In this connection special attention should be paid to the fact that rodents and birds may leave seed coats and partly eaten seeds in the place they have been eating and that they have been found to be seed eaters in Finland (cf. SAALAS 1924, 1949, VAARTAJA 1950, LEHTO 1956), and especially elsewhere, where this subject has been studied more (cf. HAIGH 1936, MOORE 1940, BALDWIN 1942, FORSSLUND 1944, NOVIKOV 1953, TEVIS 1953, 1956 a, b, COOPER, SCHOPMEYER and MCGREGOR 1959).

Loss of viability of seed on burnt-over areas

The capacity of seed to retain its viability was studied by germinating seeds recovered in the trials dealing with their disappearance from the burnt surface of the humus. The germination tests were made on sand at room temperature. The seed on each plot was compared in the tests with seed taken from the original batch. The table on the following page illustrates the results.

The experiments showed that the germinability of pine seed did not decrease during three weeks on the burnt humus layer, but after six weeks the loss of germinability was considerable and it increased later. The spruce seed used in the tests lost its viability under corresponding conditions faster. This kind of interpretation of the results presupposes that the average viability of the seeds remaining on the burns was the same at the beginning as that of the original sample

Number of trial	Species of tree	Date of seeding	Seeds lain on the burn before collecting, weeks	Number of seeds recovered	Germinability, when the germinability of control seed = 100	Germination percentage of control seed on sand
		Moisio, study area 70				
70 I	Pine	June 3, 1959	3	188	100	82
70 II	»	»	6	627	73	82
74 I	Spruce	June 4, 1959	3	72	86	74
74 II	»	»	6	330	59	82
78 I	Pine	May 11, 1960	4	663	85	81
78 II	»	»	9	388	18	66
78 III	»	»	16	28	0	64
		Taipaleenmaa, study area 71				
71 I	Pine	June 8, 1959	3	72	99	82
71 II	»	»	6	460	80	82
86[1]	Spruce	June 3, 1960	8	309	82	77

[1] Seeds collected from humus cakes lifted from the ground. Therefore these results are not comparable with other experiments.

batch. Because some loss of viability was also observed in these batches from which few seeds had disappeared, it can be assumed that the loss of viability was caused by the conditions that prevailed on the surface of the humus. It is not impossible, however, that seed with a germinability weaker than that of the original was unwittingly selected for the trials. In any case it can be concluded on the ground of the trials that the later the sample was taken the poorer its germinability. Pine seed recovered at the end of the growing season of 1960 did not germinate at all.

Temperature conditions on the surface of the burnt-over humus layer are generally very extreme and during the day temperature may rise to the point of tolerance of the seed. In carrying out the trials, temperature was measured on several sunny days by burying a mercury thermometer 1 cm deep in the humus. Temperatures exceeding 30° C were measured several times, in some cases even over 40° C. The highest reading was 48° C. VAARTAJA (1949) has measured temperatures above 60° C on the very surface of the humus in the same location. Several times he measured temperatures of 50° C and even higher inside seeds. Such high temperatures are detrimental to germination and may damage seeds (cf. HAACK 1912, KANGAS 1942, HERMELIN 1958) and seedlings (SCHIRLEY 1936, HAIG 1936, VAARTAJA 1954). A sudden fall in temperature considerably below 0° C during the growing season can also cause damage at least to young seedlings (cf. VAARTAJA 1954). Temperatures — 5° C (5 cm above ground) and even lower were observed in study area 4 at Ähtäri in 1957 and 1958. Also moisture conditions vary considerably on the surface of the humus as rainy

and sunny days alternate. Such variations of moisture and temperature are detrimental to the viability of the seed.

In case seeds travel into the humus layer their conditions become considerably better. This was observed when seeds were put into slits made with a knife on the surface of humus cakes loosened from the ground; the percentage of seedlings out of the number of seeds was 51 and 38, in two trials with a total of 600 seeds. Under corresponding conditions on the intact surface of the humus layer the percentage of seedlings out of the number of seeds was under one.

The development of seedlings, too, may become thwarted in their early stages (cf. KUJALA 1927) on the surface of the burnt-over humus, as an examination of the following experiment will show.

Study area 70 at Moisio, burnt-over on June 2, 1958, trial 78 III, sown May 11, 1960, studied August 29, 1960.

	Distribution, in %
Empty and unopened dead seeds	35
Opened seeds whose radicles failed to emerge	51
Seedlings died after the radicle had emerged less than 5 mm	3
Seedlings died after the radicle had emerged more than 5 mm, but had not become attached to the seedbed	1
Dead seedlings whose root had become attached to the seedbed	1
Living seedlings with roots attached to the seedbed.	9
	100
Total number of seeds	290
Living seedlings from control seed in sandbox, in %	64

When seeds that have been eaten or disappeared, as well as intact seeds that have lost their viability, are counted, the distribution of the total number of sown seeds is as follows:

	Distribution, in %
Eaten or disappeared seeds	64
Empty and dead seeds and destroyed seedlings	33
Living seedlings	3
	100
Number of seeds sown	800
Living seedlings from control seed in sandbox, in %	64

In other similar trials conducted on more recently burnt-over areas so many seeds were lost that there was not enough material for this kind of examination.

Discussion

The results of burning-over depend, to a great extent, on how and under what conditions this method is used. The observation areas of this study developed when old spruce forests with a relatively thick humus layer were clear cut and burnt-over to convert them into pine stands. As such, they represent the most common object of burning-over in Finland. The intensity of burning has been relatively low in the study areas.

In this kind of burning-over the slash, the ground vegetation and part of the humus layer are consumed. High temperatures occur, but only a thin layer of the remaining humus becomes so hot that living tissues are in danger (cf. SVINHUFVUD 1929, TKATSCHENKO 1930, BEADLE 1940, UGGLA 1957). Therefore species of the ground vegetation with underground shoots or buds can survive. Such species were observed in connection with this study; also the matter has received much attention earlier, as can be seen in the works of UGGLA (1957, 1958) and YLI-VAKKURI (1958) and the literature cited by them. In the cases studied, however, such species gained ground very slowly. New pioneer species were of greater significance at first: in the bottom layer, mosses typical of burnt areas; in the field layer, *Chamaenerion angustifolium* and in the shrub layer, *Rubus idaeus*. Seedlings of *Rubus idaeus* were seen in the summer of burning, in places where it had not occurred before burning. Thus the seeds had traveled to these places before, perhaps from quite another locality, and remained viable in the humus. Also observations by UGGLA (1957, 1958) suggest this possibility. Although the first signs of new vegetation appeared immediately after burning, the vegetation remained very scant for the first two growing seasons and became more luxuriant in only the third and fourth growing seasons.

Usually burning-over destroys spruce and pine seeds on the ground, but a portion of seeds may remain viable through at least a gentle burning. Trials by UGGLA (1958) have shown the same result. TKATSCHENKO (1930), SARVAS (1937) and KOLEHMAINEN (1957) have presented corresponding observations as regards survival of seeds in forest fires. Such survived seeds are probably not very significant, however, in the regeneration of burnt-over areas.

According to earlier observations regeneration possibilities are poor on the burnt surface of the humus layer for about two years after a burning-over (ARVID BORG 1931, SARVAS 1937). The results of this study substantiate those observations. The causes of this phenomenon have been deliberated a great deal. Many researchers have pointed out that the pH value rises after a forest fire and a burning-over (cf. SIRÉN 1955, UGGLA 1957). Some researchers (HEIKINHEIMO 1915, FABRICIUS 1929) have arrived at the conclusion that the ashes could hamper the germination of seeds; others, on the contrary, (ENEROTH 1931) believe that it has no such harmful effect. The result in each case probably depends on both the amount of ashes and the quality of the germination bed,

as for instance AALTONEN (1940, 1948) has stressed. The author obtained plenty of seedlings on peatland by seeding pine into the ashes a few hours after a burning-over (YLI-VAKKURI 1958). Since the loose ashes disappear from the ground very soon and the pH value of the substrate becomes lower (UGGLA 1957) it is unlikely that the ashes are a serious impediment, at least, in the second summer. As the establishment of reproduction continued to be poor, other causes had to be looked for.

Temperatures measured on the surface of the burnt humus in connection with this study and earlier under corresponding conditions (VAARTAJA 1949, 1950) are so high that they exceed at least the optimum temperature for germination (cf. HAACK 1912). If the highest temperatures observed are compared with those that the seed, especially the germinating seed and the growing tissue, can tolerate (HAACK 1912, BARKER 1929, MORK 1933, HAIGH 1936, SHIRLEY 1936, ISAAC 1938, KANGAS 1942, VAARTAJA 1954, BARTELS 1958, HERMELIN 1958) it will be seen that seeds may be in danger of being destroyed by too high temperatures. It is worth noticing that in trials on burnt-over peatland arranged at the same time as the trials of this study, seedlings emerged in profusion (YLI-VAKKURI 1958). Too high a temperature could not be any impediment of reproduction in this case. The chances for high temperatures may be different on peatland from that on upland soils, because moisture conditions are different. This study threw additional light on the matter when it was found that both pine seed and spruce seed retain their viability on the burnt-over humus layer for at least three weeks. Later viability weakens.

When the surface of the burnt-over humus layer becomes very warm it also dries up thoroughly. Rains moisten the surface of the humus layer, but after a rain the humus dries quickly. Many researchers (ARVID BORG 1931, HEIKINHEIMO 1931, SARVAS 1937) hold that unfavorable water conditions are the principal cause of the poor capacity of fresh burns to become stocked with seedlings. Ample evidence proving that seedlings emerge easily on burnt-over paludifying upland soils and peatlands (HEIKINHEIMO 1931, L. E. T. BORG 1936, KOLEHMAINEN 1957, YLI-VAKKURI 1958) bears out the belief that moisture conditions are significant. This is suggested also by an observation made in connection with this study that seedlings appear on the burnt-over humus layer especially during those rainy periods, when the surface of the humus is kept moist for some time. Since the number of seedlings emerged was very small even under such favorable conditions there was reason to suspect that some other serious impediments existed.

Such an impediment was found when it was observed that seed eaters can destroy seeds on the burnt-over humus layer very thoroughly and even completely. Because such seed destruction has not been observed in Finland earlier, the question needs further study to find out how generally this kind of seed-eating occurs. Also more information has to be obtained with regard to the

cause or causes of the destruction so that control measures can be worked out.

As cracks appear on the surface of the humus, seeds can be moved into them by the rainwater. The temperature and moisture conditions are more favorable in these cracks. Seedlings are frequently found in such places on burnt-over areas.

The conditions for the emergence of seedlings change considerably when the humus layer is broken so that the mineral soil is exposed. Many seedlings usually emerge from seed sown on the mineral soil, as was observed also in this study. This suggests that losses of seed are not so great on the mineral soil as they can be on the burnt-over humus layer. However, some destruction of seed has been observed on the mineral soil (cf. VAARTAJA 1950, LEHTO 1956). It was found in this study that seeds may be preserved for a long time on the bare mineral soil, although their disappearance is possible. The fact that seeds mix with soil during rains aids their preservation on the mineral soil.

Moisture and temperature conditions on the mineral soil may also be more favorable than on the burnt-over humus layer. Although temperature on the mineral soil may rise very high (VAARTAJA 1949, 1950), the chances of detrimental temperatures occurring are less than on the humus layer burnt black. Moreover, the seeds on the mineral soil become covered with a coat of protective soil, as has been pointed out. Since experience with different sowing methods (cf. HEIKINHEIMO 1932 a, ARNBORG 1947) suggests that by covering seeds, a more abundant seedling stock is obtained than when the seeds are left uncovered, the seed on the mineral soil patches of burnt-over areas should be covered at once. Thus the seeds would be in more favorable moisture and temperature conditions and seed losses reduced. In addition, seedlings would develop stronger roots and would not become detached from the substratum when big raindrops beat against the ground.

While the stocking conditions for the desired tree species, in Finland, pine on burns, become more favorable when the mineral soil is exposed, the conditions for the invasion of other species also improve. At first spruce seedlings developed more slowly in the patches than pine seedlings, suffered from frost and usually remained as undergrowth in the developing tree stand. Birch seedlings, on the contrary, developed faster than pine seedlings in the beginning. Birch may be detrimental to the further development of the seedling stand if its seed crop is abundant. In paludified places and on peatland (cf. SARVAS 1948, KOLEHMAINEN 1957, YLI-VAKKURI 1958) birch seedlings and other broad-leaved trees appear abundantly even on the humus layer. Birch and other broad-leaved trees start from shoots, since only part of the stumps lose their capacity of growing shoots (cf. SARVAS 1937, MIKOLA 1942, YLI-VAKKURI 1958). It depends, mainly on the composition of the previous tree generation, how much harm shoots may cause in a pine seedling stand.

The young seedling stock, both on the humus layer and on the mineral soil,

was vulnerable to many destructive agents. The seedling stock became well established on the mineral soil only after the fifth growing season. The same result was brought about by TIRÉN's (1952) trials. Many seedlings perished especially during the time between growing seasons. The causes of these losses were not found out in this study. Damage caused by heavy summer rains was observed on the mineral soil. Similar results have been reported earlier (SIRÉN 1948, 1952). Damage caused by seedling-eaters, although seen, was not common. Some earlier observations (FORSSLUND 1944, SIRÉN 1952) indicate that this damage is rarer in open areas than in the forest. The development of young seedlings was faster on the mineral soil than on the humus. Since more seedlings capable of development are obtained on the mineral soil than on the humus, the ground of burnt-over areas should usually be cultivated in connection with regeneration measures. This point is stressed by many researchers (HEIKINHEIMO 1931, L. E. T. BORG 1936, WRETLIND 1948, KOLEHMAINEN 1955).

Burning-over is, of course, to be examined not only as a regeneration measure; its possible later favorable or unfavorable effects have to be considered too. Although many encouraging results are known (L. E. T. BORG 1936, BLOMGREN 1952, 1953, WRETLIND 1948, KOLEHMAINEN 1955, WIBECK 1959), as yet we hardly know how and under what different conditions burning-over can be practised so that long-time favorable effects can be obtained.

Summary

In this study, by means of repeatedly studied seeding trials, the emergence and initial development of young pine and spruce as well as factors influencing them have been studied on burnt-over areas. In addition, attention has been given to the natural regeneration of broad-leaved trees, and observations have been made to clarify conditions prevailing on burns. The material was gathered in the years 1956—1960 on moist upland soils burnt-over in the usual way. The main results of the study are:

1. Part of the underground shoots of the ground vegetation survived burning-over and began to form a new plant cover very soon after burning. The burnt-over areas, however, remained almost without vegetation for about two growing seasons. After this many new pioneer species appeared, especially mosses characteristic of burnt humus, *Chamaenerion angustifolium* and *Rubus idaeus*. Seedlings of the last-named species occurred on the burns quite soon after burning-over, thus they must have emerged from seed that survived the fire.

2. On a burn which has not been tilled, conditions for the regeneration from seed of coniferous and deciduous trees are very unfavorable immediately after burning. Even an abundant seeding does not yield a plentiful seedling stock. On the other hand, shoots of deciduous trees occur soon after burning. The

emergence of both pine and spruce seedlings was infrequent. Conditions for regeneration are better on 3—5-year-old burns than on younger ones.

3. The removal of the humus layer in spots improves the regeneration on burns considerably. Different kinds of damage, however, may cause notable variation in results from year to year. Seeding patches facilitate the invasion of spruce and especially of birch. The development of spruce on burns is retarded by spring frosts. Growing slowly, however, it will remain as undergrowth in the developing tree stands. Birch and other deciduous seedlings, on the other hand, grow fast and when occurring abundantly they can retard the development of pine seedling stock. Shoots of deciduous trees have a similar and even stronger effect.

4. A continuous rainy period during the growing season improved the germination of pine and spruce seed sown on the humus layer. When a rainy period occurred in late summer, seeds sown at different dates in early summer germinated then only, almost regardless of the date of sowing. The latest sowing, July 1, led to as good or an even better result than the earlier ones. A watering of 4 mm at intervals of one week did not make the germination of seeds more rapid during a dry warm period, and when carried on throughout the summer did not increase seedling stock much. Seeds in the humus layer germinated better than those on the humus.

5. Pine and spruce seedlings on the exposed mineral soil developed more rapidly than on the humus layer. Young, especially one-year-old seedlings, were easily destroyed. On the prepared seeding patches, the seedling stock was established only by about the fifth growing season. During the time between growing seasons many seedlings were usually destroyed.

6. In a mild burning-over, which consumed the slash and the ground vegetation, part of the spruce seeds deposited on the humus layer under the moss remained viable. It was found that the vegetation greatly obstructed the movement of seeds to this depth.

7. Seed eaters destroyed the pine and spruce seeds sown on the humus layer of newly burnt-over areas completely or almost completely. The destruction usually took place mainly in spring and early summer. The cause, or causes, of the destruction was not determined with certainty, but it was found that *Pterostichus vulgaris*, trapped on the study areas, ate seeds willingly in captivity and that bits of seed coats and half-eaten seeds it left closely resembled those found in the field. The amount of seeds destroyed by small mammals and birds was not found for certain.

8. The viability of pine seed sown on the burnt-over humus layer did not decrease for three weeks. In six or more weeks, on the other hand, its viability was greatly weakened. Spruce seed used in the trials lost its viability faster than pine seed.

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Seloste:

Taimien syntymisestä ja alkukehityksestä kulotetuilla alueilla

Tutkimuksessa on kokeellisesti selvitetty männyn ja kuusen taimien syntymistä ja alkukehitystä ja siihen vaikuttavia tekijöitä kulotetuilla alueilla. Lisäksi on seurattu jonkin verran lehtipuiden luontaista uudistumista ja tehty eräitä kulotusalueilla vallitsevia olosuhteita valaisevia havaintoja. Aineisto on kerätty vuosina 1956—1960 tavanomaisesti kulotetuilta tuoreilta kangasmailta Tuomarniemen ja Korkeakosken hoitoalueista. Tutkimus on johtanut seuraaviin päätuloksiin:

1. Osa aluskasvillisuuden maansisäisistä versoista säilyi kulotuksessa ja muodosti uutta kasvillisuutta heti kulotuksen jälkeen. Kulotetut alueet pysyivät kuitenkin melkein kasvipeitteettöminä pari kasvukautta. Sen jälkeen niillä esiintyi melkoisesti uutta pioneerilajistoa varsinkin erilaisia palosammalia sekä horsmaa ja vadelmaa. Viimeksimainitun siementaimia esiintyi kulotusalueilla heti kulotuksen jälkeen, joten niiden täytyi syntyä humuksessa olleista siemenistä.

2. Kulotetuilla alueilla, jotka oli jätetty muokkaamatta, olivat olosuhteet havupuiden ja lehtipuiden siemenellisen uudistumisen kannalta hyvin epäedulliset välittömästi kulotuksen jälkeen. Runsaskaan siemennys ei tällöin johtanut pysyvän, riittävän taimiaineksen syntyyn. Vesasyntyisiä lehtipuita sen sijaan

nousi kulotetulle alueelle välittömästi kulotuksen jälkeen. Taimien syntyminen oli yhtä vähäistä männyllä kuin kuusellakin. Uudistumisolosuhteet olivat 3—5 vuotta vanhoilla kulotusaloilla paremmat kuin vereksillä.

3. Humuksen poistaminen laikuittain paransi kulotetuilla alueilla taimettumista tuntuvasti. Tuhot aiheuttivat kuitenkin huomattavaa vuosittaista vaihtelua tuloksiin. Kylvölaikut helpottivat kuusen ja etenkin koivun iskeytymistä kulotetuille alueille. Kuusen kehitystä kulotetuilla alueilla haittaavat kuitenkin keväthallat. Muutenkin hidaskasvuisena se jää alikasvokseksi syntyviin metsikköihin. Kylvölaikkuihin syntyneet koivun ja muiden lehtipuiden taimet sen sijaan kasvavat ripeästi ja saattavat runsaana esiintyessään haitata männyn kylvötaimiston kehittymistä. Samanlainen vaikutus on vesasyntyisillä lehtipuilla, joiden alkukehitys on vieläkin voimakkaampaa.

4. Kasvukauden aikana sattunut yhtäjaksoinen sadekausi edisti humusalustalle kylvettyjen männyn ja kuusen taimien itämistä. Kun sadekausi sattui kesän jälkipuoliskolle, itivät eri aikoina kesän alkupuolella kylvetyt siemenet vasta tällöin kylvöajankohdasta melkeinpä riippumatta. Myöhäisin 1. 7. suoritettu kylvö johti tällöin yhtä hyvään tai parempaan tulokseen kuin aikaisemmat. Viikon väliajoin toimitettu 4 mm:n kastelu ei nopeuttanut poutaisena aikana siemenien itämistä ja paransi koko kesän toistettuna vain vähän taimettumistulosta. Humuksen sisään joutuneet siemenet itivät huomattavasti paremmin kuin pinnalla olevat.

5. Männyn ja kuusen taimet kehittyivät paljastetussa kivennäismaassa ripeämmin kuin humusalustalla. Nuoret, varsinkin yhden kasvukauden ikäiset taimet tuhoutuivat herkästi. Ruutukylvölaikuissa havaittiin taimiaineksen vakiintuvan vasta viidennen kasvukauden tienoilla. Talvehtimisen aikana tuhoutui taimia usein runsaasti.

6. Lievässä kulotuksessa, jossa hakkuutähteet ja pintakasvillisuus kuitenkin kauttaaltaan paloivat, osa sammalen alle humuksen pintaan pannuista kuusen siemenistä säilytti itävyytensä. Kasvipeitteen havaittiin tuntuvasti estävän siementen kulkeutumista tälle syvyydelle.

7. Siemenen syöjät tuhosivat humuksen pintaan kylvetyt männyn ja kuusen siemenet vereksillä kulotusalueilla joko täydellisesti tai lähes täydellisesti. Tuho keskittyi yleensä kevääseen ja alkukesään. Tuhon aiheuttajasta tai aiheuttajista ei päästy varmuuteen, mutta havaittiin, että koealueilta pyydyksiin saatu *Pterostichus vulgaris* L. söi vangittuna halukkaasti siemeniä ja että sen syönnösjätteet, kuorenpalaset ja puoliksi syödyt siemenet, suuresti muistuttivat maastosta löydettyjä syönnösjätteitä. Pikku nisäkkäiden ja lintujen mahdollisesta osuudesta tuhoon ei saatu varmuutta.

8. Männyn siemen säilytti kulotetulla humusalustalla itävyytensä vähentymättömänä kolmen viikon ajan. Kuuden viikon aikana se sen sijaan menetti tuntuvasti itävyyttään. Kokeissa käytetty kuusen siemen menetti itävyyttään nopeammin kuin männyn siemen. Kasvukauden lopulle asti itämättömänä säilynyt männyn siemen ei itänyt enää suotuisissakaan olosuhteissa.