Afforestation of Low-Productive Peatlands in Sweden – a Tree Species Comparison

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In 1970, five low-productive treeless peatlands in Sweden, ranging from latitudes 56°N to 67°N, were drained and fertilized for afforestation. The aim of the study was to determine the effect of four ditch spacings, varying from 7.5 to 60 m, and five NPK-fertilizer combinations, on the survival and growth of planted Scots pine (*Pinus sylvestris*), lodgepole pine (*Pinus contorta*), Norway spruce (*Picea abies*), and silver birch (*Betula pendula*) seedlings. The assessments were carried out 18–22 years after planting.

Neither silver birch, nor Norway spruce was regarded suitable for the site type. The mortality of silver birch was almost complete, and Norway spruce did not grow well in any of the study areas, however, better than Scots pine in the north. Lodgepole pine had better height and diameter growth but also higher mortality rates than Scots pine. In the two northernmost experimental areas no response to fertilization was found. In the other three areas, the response to fertilization did not differ between species. Phosphorus was the most effective of the added fertilizer elements, whereas nitrogen showed no positive effect. Broadcast fertilizer application, with three times higher amount of fertilizer per ha gave the same growth response as spot application.

Keywords afforestation, drainage, fertilization, climate, tree species, broadcast fertilization, spot fertilization, *Pinus sylvestris*, *Pinus contorta*, *Picea abies*, *Betula pendula*
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1 Introduction

Successful establishment of productive forest stands on boreal, low-productive open peatlands depend on climatic and nutrient conditions of the site, as well as the quality and intensity of the two general afforestation measures on peatlands; drainage and fertilization. When climatic, water and nutrient conditions are known, and proper measures taken, the success of an afforestation effort to a large extent relies on the selection of appropriate species of suitable provenances. How well adapted a species is to a particular site will be reflected by, initially, survival and later, growth and yield, susceptibility to damage and timber quality of the trees.

The main tree species of interest in afforestation of open peatlands in the Fenno-Scandinavian countries have been the indigenous species of Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karst.) and birch (*Betula pubescens* Ehrh. and *B. pendula* Roth). In cold, low-lying and nutrient poor sites, Scots pine is known to be superior to Norway spruce, both in terms of survival and productivity (Meshechok 1963, 1968, Holmen 1981, Kaunisto and Päivänen 1985). In more fertile sites, it is generally advised to plant Norway spruce, preferably under the cover of shelter trees, for example naturally regenerated birch (Koskela 1970, Heikurainen 1985). Downy birch (*B. pubescens*) generally has higher survival rates than silver birch (*B. pendula*) on open peatlands, but only few trials with planted birch on such sites have been carried out (Kaunisto 1973). The majority of existing birch stands on open peatlands has emerged from natural seeding.

How pine, spruce and birch trees respond to different intensities of drainage and fertilization on peatlands has been studied quite intensively, but mainly in naturally established forest stands (Börjeson 1957, Heikurainen 1959, Meshechok 1969, Braekke 1977, Kollist 1982, Valk 1982, Hånell 1984, Kaunisto and Päivänen 1985). Results from afforestation experiments including comparisons of different native species, planted or sown on the same sites, have only been reported in a few studies (Huikari and Paarlahti 1967, Meshechok 1968, Paavilainen 1970, Koskela 1970, Mannerkoski 1971, Mannerkoski and Päivänen 1974, Braekke 1984).

Exotic species to the Fenno-Scandinavian countries, like lodgepole pine (*Pinus contorta*) (Mannerkoski and Päivänen 1974, Laine 1979, Braekke 1984, Kaunisto 1985, Sundström and Holmen 1990) and various spruce species (*Picea glauca*, *P. mariana*, and *P. sitchensis*) (Person and Ganered 1981, Numminen 1983, Päivänen 1983, Braekke 1984, Arnøy 1986) have also been tested in afforestation experiments on open peatlands. Sitka spruce and lodgepole pine have been planted on large areas in Ireland and Scotland for the afforestation of open peatlands (McCarthy and Keogh 1984, Farrell 1990), often using lodgepole pine as a nurse tree to sitka spruce (Taylor 1985, Pyatt 1990).

Most comparative species studies reported earlier have dealt with species growing on different site types. The objective of this study was to compare effects of drainage intensity, fertilization and climatic variation on the establishment and growth of planted Norway spruce, Scots pine, lodgepole pine and silver birch seedlings in a series of identically designed experiments on similar site types.

2 Materials and Methods

2.1 Experimental sites

The experiment was established in 1969 on five open peatland areas. They covered a climatic range from latitude 56°N, at the South west coast of Sweden, to latitude 67°N, 50 km north of the Arctic circle, and altitudes ranging from 100 to 325 m a.s.l. (Table 1). The mean temperature sum (threshold value +5 °C, Odin et al. 1983) varied between 830 and 1400 day degrees (d.d.). Annual precipitation was 500–600 mm, except for the southernmost area that received nearly

Table 1. Basic information on the experimental areas.

Experiment	Lat. / Long.	Altitude m.a.s.l.	Temp.sum. dd >5°C	Precipitation mm yr^{-1}	Peat depth m
E1 Hillesjömossen	56°45’N/13°22’E	165	1400	985	3.1– >4
E2 Myckelmossen	59°54’N/16°15’E	95	1275	604	1.1– >4
E3 Stormyren	62°27’N/16°50’E	325	950	530	1.1– >4
E4 Totjärnmyren	64°52’N/19°34’E	320	850	580	1.1– >4
E5 Suolavuoma	66°58’N/23°26’E	180	825	520	1.8– >4

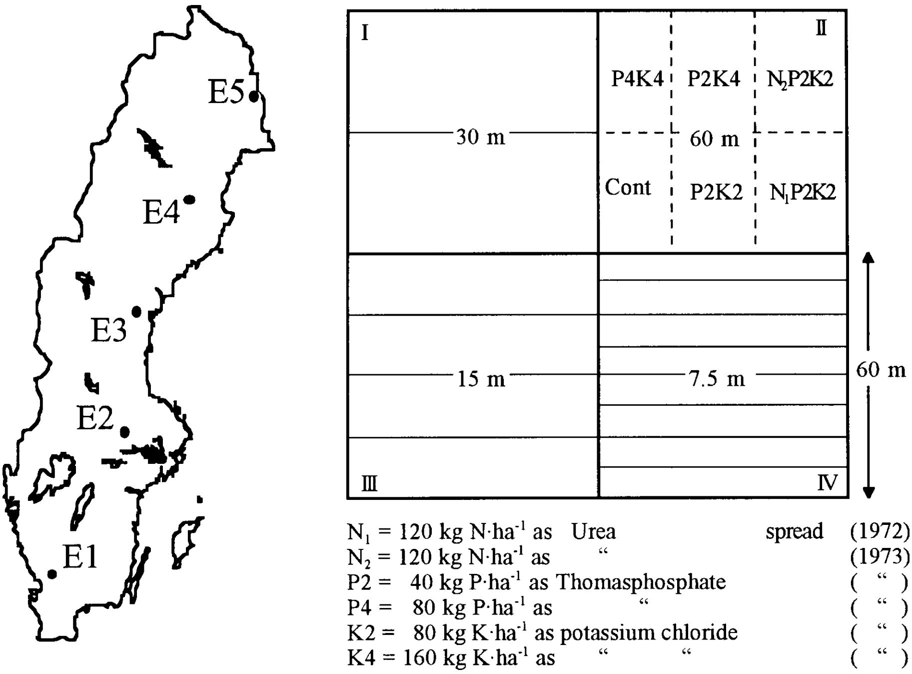

Fig. 1. Location of experimental sites (E1–E5), layout of a block with the four ditch spacings (7.5, 15, 30 and 60 m) and key to symbols of fertilizer combinations.

1000 mm. All sites were treeless, nutrient poor bogs and before drainage classified as either *Eriophorum vaginatum*/low sedge or *Calluna vulgaris*/Marsh–Andromeda-cranberry types (Hånell 1984). The peat depth exceeded 1 m on all sites. Analyses of the upper 20 cm peat layer, sampled before drainage in areas E2 and E3, showed total concentrations of N, P, K, and Ca of 0.9–1.3, 0.037–0.041, 0.062–0.067, and 0.4 % of dry matter, respectively. Total concentrations of N, P, K and Ca in peat sampled 20 years after drainage from all five areas (0–20 cm, control plots with 60 m ditch spacing), were for the same two areas (E2 and E3), 2.1–2.2, 0.070–0.082, 0.011–0.012, and 0.28–0.31 % of dry matter, respectively (Sundström 1995).

2.2 Treatments

An identical split-split-plot design was used on all experimental sites (Fig. 1). Each site was divided into four blocks (replicates). Drainage was carried out in 1970–71. Within each block, 7.5, 15, 30 and 60 m ditch spacings were randomly distributed in 60 × 60 m plots. These plots were further divided into six 20 × 30 m sub-plots. Each sub-plot received one of six, randomly distributed within blocks, different fertilizer combinations (see table in Fig. 1), including the unfertilized control. Planting of bare-rooted seedlings (2/1) , without prior site preparation, at 2 × 2 m spacing was done in 1971 (16 lines × 10 rows in each subplot). Equal proportions of Scots pine and Norway spruce (50 % each) were planted in separate plots for each species in the southernmost (E1) and the northernmost (E5) areas. The other three sites (E2–E4) were systematically planted with Scots pine (11 of 16 lines), lodgepole pine (3/16; lines 3, 9 and 11) and silver birch (2/16; lines 6 and 13). Provenances, assumed to be the most appropriate for the region, were selected for each species. Fertilization was carried out in 1972–73 in all areas, using either broadcast or spot application. Broadcast fertilization was done in all areas over all four strip widths, whereas spot fertilization was done in separate plots with the two widest strip widths only and in all but one (E2) site. In spot application, fertilizers were applied in a circular area at a distance between 20 and 60 cm from the seedling, but with only one third of the amount as in broadcast fertilization. Fertilizers used were thomasphosphate containing P in a slow-release form, potassium chloride for K, and urea for N. The N-fertilizer was applied either together with P and K in 1972 (N_1P2K2) or separately in the following year (N_2P2K2) (Fig. 1).

2.3 Measurements

All sites were inventoried in 1988, except for the spot fertilized plots in area E1, which were assessed four years later (1992). A systematic sample of 30 % of all planted trees was assessed for survival and diameter. Three rows on each subplot were selected for the assessment (every 3rd, 6th or 7th and 8th row) in order to create buffer zones and minimize edge effects. In area E5, no observations of birch were made because of difficulties in separating planted and naturally regenerated birch trees. Trees that were missing at the time of the inventory were classified as dead trees. Diameter (mm) was measured at 1.3 m breast height (DBH) and living trees below breast height were given a diameter of zero. Height was measured on every fourth sample-tree with undamaged top (birch excluded). Height increment, i.e. shoot length of the last ten internodes, was registered for pine species at all sites except for the northernmost area, where identification of whorls was impossible. Nine damage types were registered in the field assessment, i.e. basal sweep, crooked stem, forked stem, spike knot, browsing, suppressed, frost, bush type, and lying down. Trees without any of the damage types described above were registered as undamaged.

2.4 Calculations and Analyses

The analyses and species comparisons were carried out separately for areas E1 and E5 (Norway spruce and Scots pine) on one hand and for areas E2–E4 (Scots pine, lodgepole pine and silver birch) on the other. The comparisons between species in areas E2–E4 were based on broadcast fertilization and from all four ditch spacings. The comparisons in areas E1 and E5 were based on spot fertilization and from the two widest ditch spacings only (30 and 60 m). Since areas E1 and E5 were not inventoried at the same time (1992, 1988 respectively), values of mortality, diameter and height in E5 refer to a stand age of 18 years, whereas corresponding values in E1 refer to the stand age of 22 years.

For each 20×30 m sub-plot, arithmetic means of mortality, diameter, height and proportion damaged for all nine damage types were calculated for each species. Means of mortality by species were weighted by numbers of originally planted trees per species, whereas other means were weighted on the basis of sample size for each species.

Effects of the independent variables drainage intensity (D), fertilizer (F), species (S) and the random variable block (B) were analysed areawise for each of the dependent variables (Y) mortality, diameter, height and damage type, by using analyses of variance with the GLM procedure in SAS (SAS User's Guide 1985). Only four damage types, basal sweep, stem bend, forked stem and spike knot, were included in the analysis of variance due to inconsistencies in assessment procedures for the other damage types.

Multiple comparison between all main effect means, for the various treatments and species, were made using Tukey's studentized test.

The comparison between the two fertilization methods, broadcast and spot application, was done for Scots pine and lodgepole pine only, and based on survival and height values from 1988. Height of spot fertilized Scots pine in area E1, that was measured in 1992, was therefore reduced with the length of the last four internodes. Differences in the relative fertilization (F) effect compared to not fertilized plots (C) between broadcast and spot application were tested for survival (F–C) and height (F/C) with a simple factorial analysis of variance.

3 Results

3.1 Silver Birch

The mortality of silver birch was almost complete (95–99 %) in all areas except for area E3 where 56 % of the planted birch trees were still alive. Birch mortality in area E3 was twice as high on the 60 m ditch spacing compared with the 7.5 m spacing and decreased by 40 % when fertilizers were applied. The mean diameter (DBH) of birch in area E3 was 27 mm in 1988 compared with 33 mm for Scots pine and 71 mm for lodgepole pine.

3.2 Survival and Damage

3.2.1 Scots Pine and Lodgepole Pine

The survival of Scots pine trees (61 %) was on average higher than that of lodgepole pine (53 %) but the difference was not consistent in all areas (Table 2). In two of the three areas, significantly more Scots pines were alive after 18 years whereas in the third area (E3), the relationship was the reverse ($p < 0.001$). Fertilization significantly improved survival of both pine species in the two southernmost areas (Fig. 2). The positive effect on survival by narrowing the distance between ditches was more prominent in the northern areas, particularly for Scots pine.

Only about 15 % of the trees of both pine species were completely free from damage (Table 2). The most common damage types in both species were spike knot and forked stem. Both were more noticeable with increasing latitude. The proportions of basal sweep and stem bend damage were positively correlated to the amount of fertilizer, and more often found in lodgepole pine than in Scots pine. Other types of damage were to a lesser degree correlated to fertilization and drainage intensity.

Table 2. Mortality and damage frequencies of Scots pine, lodgepole pine and Norway spruce planted on open peatland. Areas E1 and E5 were spot fertilized and drained with 30 and 60 m ditch spacings. Areas E2–E4 were broadcast fertilized and drained with 7.5, 15, 30 and 60 m ditch spacings.

Area/	Mortality		Undamaged		Basal sweep		Stem bend		Forked stem		Spike knot	
by species	%	St.dev.	%	St.dev.	%	St.dev.	%	St.dev.	%	St.dev.	%	St. dev.
E1 / 56°45'												
Pinus sylvestris	25	13	21	16	46	20	14	10	3	4	44	17
Picea abies	35	24	52	26	3	7	2	11	9	15	29	22
E2 / 59°54'												
Pinus sylvestris	10	8	22	17	62	22	9	6	18	10	30	12
Pinus contorta	30	20	14	19	62	29	6	9	36	23	34	20
E3 / 62°27'												
Pinus sylvestris	41	18	18	16	8	12	3	6	40	19	49	25
Pinus contorta	21	20	22	20	36	27	23	26	45	27	35	26
E4 / 64°52'												
Pinus sylvestris	61	18	9	11	21	16	14	11	66	17	82	14
Pinus contorta	87	17	9	24	33	43	32	34	60	38	75	35
E5 / 66°58'												
Pinus sylvestris	59	22	4	6	–	–	15	19	85	15	75	16
Picea abies	16	17	25	16	–	–	1	3	55	22	47	24
All areas*												
Pinus sylvestris	39	16	15	16	29	29	10	11	42	30	55	27
Pinus contorta	47	19	16	21	46	34	18	25	45	30	43	31
Picea abies	25	21	38	25	3	7	2	8	32	30	38	25

* Means for all five areas E1–E5

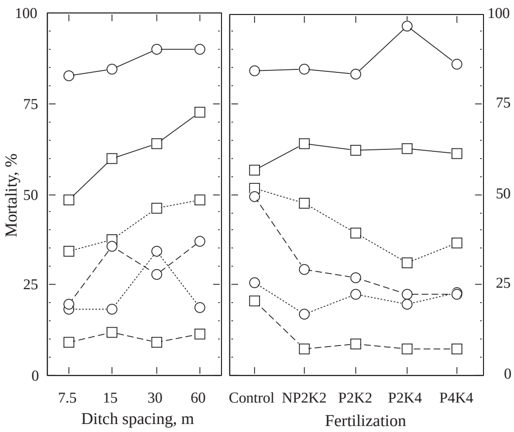

Fig. 2. Mortality in Scots pine (squares) and lodgepole pine (circles) at four ditch spacings (left) and with varying amount of fertilizer application (right) in three areas with varying latitudes: ----- = E2, Lat. 59°N, ······· = E3, Lat. 62°N, —— = E4, Lat. 64°N.

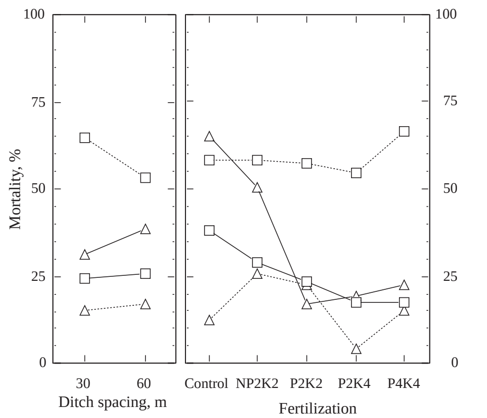

Fig. 3. Mortality in Scots pine (squares) and Norway spruce (triangles) at two ditch spacings (left) and with varying amount of fertilizer application (right) in two areas with varying latitudes. Stand age in E1 = 22 years, E5 = 18 years: —— = E1, Lat. 56°N, ······· = E5, Lat. 66°N.

3.2.2 Scots Pine and Norway Spruce

On average there were significantly ($p < 0.001$) more spruce than pine trees alive after 22 years in the northern area, E5 (Table 2). In the southern area (E1) however, the relationship was the reverse ($p < 0.005$). Fertilization with PK had a positive effect on survival in both species, but found statistically significant ($p < 0.001$) only in the southern area, E1 (Fig. 3). Denser ditch spacing, 30 compared to 60 m, did not affect survival rates significantly for the two species.

Pine trees were on average more susceptible to damage than spruce trees. Forked stems and spike knots were the most frequent damage types, especially in the northern area (Table 2). Frost damage was found on 20 % of the spruce trees whereas only 10 % of the pine trees were damaged by frost.

3.3 Height and Diameter

3.3.1 Scots Pine and Lodgepole Pine

In the southernmost area, E2, lodgepole pine trees were about 30 % larger in both height and diameter than Scots pines (Table 3). The difference in diameter was twice as big in area E3. In the northernmost area, E4, no difference in size between the two pine species was found.

The highest dose of PK-fertilizers (P4K4), increased height growth by 70 % for lodgepole pine and by 100 % for Scots pine, compared with the unfertilized control ($p < 0.001$) in the southernmost area, E2 (Fig. 4). Doubling the dose of K (P2K4) had a positive effect on the height growth of lodgepole pine, which was not found for Scots pine. Furthermore, a positive height growth effect with decreased ditch spacing was found for both pine species in those areas. The ditch spacing effect was smaller than that of fertilization, and more conspicuous for Scots pine.

In the northernmost area, E4, no effects of fertilizer and ditch spacing on height growth were found for the pine species.

3.3.2 Scots Pine and Norway Spruce

In the southern area (E1), the height and diameter of spruce trees were 42 % and 20 %, respectively, of the height and diameter of Scots pine

Table 3. Height and diameter of 18-year old Scots pine and lodgepole pine planted on drained and broadcast fertilized plots. Ditch spacings ranged from 7.5 to 60 m.

Area/ by species	Height m	St.dev.	Diameter cm	St.dev.
E2/ 59°54'				
Pinus sylvestris	4,8	1,2	5,7	2,5
Pinus contorta	6,3	1,6	7,3	3,4
E3/ 62°27'				
Pinus sylvestris	3,2	0,8	3,3	1,7
Pinus contorta	4,2	1,2	7,1	3,4
E4/ 64°52'				
Pinus sylvestris	3,0	0,7	5,7	1,4
Pinus contorta	3,0	0,9	5,4	2,7
All areas				
Pinus sylvestris	3,7	0,9	5,0	1,9
Pinus contorta	4,6	1,3	6,8	3,3

Table 4. Height and diameter of Scots pine and Norway spruce planted on spot fertilized plots with 30 and 60 m ditch spacings. Trees were 22 years old in E1 and 18 years old in E5.

Area/ by species	Height m	St.dev.	Diameter cm	St.dev.
E1 / 56°45'				
Pinus sylvestris	3,9	1,4	6,0	2,5
Picea abies	1,7	0,9	1,1	0,9
E5 / 66°58'				
Pinus sylvestris	1,5	0,3	1,6	1,0
Picea abies	1,7	0,3	1,8	0,9
Both areas				
Pinus sylvestris	2,7	0,9	3,8	1,8
Picea abies	1,7	0,6	1,5	0,9

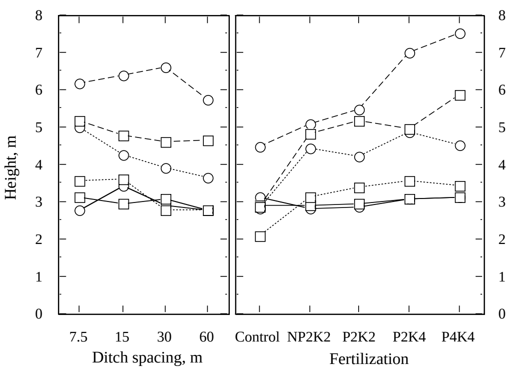

Fig. 4. Mean height in Scots pine (squares) and lodgepole pine (circles) at four ditch spacings (left) and with varying amount of fertilizer application (right) in three areas with varying latitudes: - - - - - = E2, Lat. 59°N, ······· = E3, Lat. 62°N, —— = E4, Lat. 64°N.

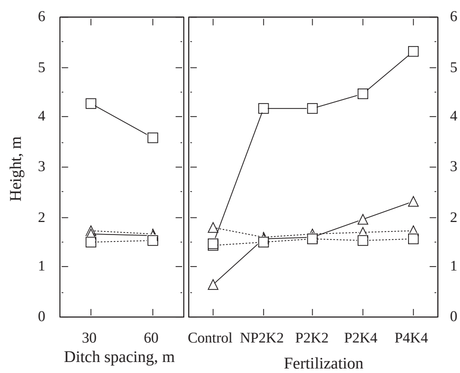

Fig. 5. Mean height in Scots pine (squares) and Norway spruce (triangles) at two ditch spacings (left) and with varying amount of fertilizer application (right) in two areas with varying latitudes. Stand age in E1 = 22 years, E5 = 18 years: —— = E1, Lat. 56°N, ······· = E5, Lat. 66°N.

(Table 4). In the northern area (E5), spruce trees were on average bigger than pines even though the size difference was smaller there. Decreased ditch spacing from 60 to 30 m had a positive effect on height growth, but only for Scots pine in the southern area, E1 (Fig. 5). Fertilization increased height growth of both spruce and pine three to four fold in the southern area ($p < 0.005$, $p < 0.001$, respectively) whereas in the northern area, no fertilization effect was found.

Table 5. Comparison of broadcast and spot fertilizer application expressed as the relative effect of fertilization (F) on survival (F–C) and height (F/C) compared with nonfertilized control (C) plots for Scots pine and lodgepole pine in four areas (E1, E3–E5).

Area/ by species	Survival, % (F–C) Broadcast	Spot	*p*	Height, m (F/C) Broadcast	Spot	*p*
E1 / 56°45'						
Pinus sylvestris	13	14	0,86	3,25	3,47	0,76
E3 / 62°27'						
Pinus sylvestris	13	28	0,09	1,82	1,33	0,30
Pinus contorta	17	12	0,70	1,15	1,98	0,17
E4 / 64°52'						
Pinus sylvestris	–10	–4	0,37	1,03	1,04	0,94
Pinus contorta	5	4	0,94	0,93	1,25	0,51
E5 / 66°58'						
Pinus sylvestris	–10	–6	0,74	1,13	1,10	0,84

3.4 Comparison of Fertilizer Application Methods

There were no significant differences in survival and height between broadcast and spot fertilization in any of the four areas (Table 5). Annual height growth in area E3 for Scots pine and lodgepole pine did not differ between the two application methods, but lodgepole pine was superior to Scots pine in both (Fig. 6).

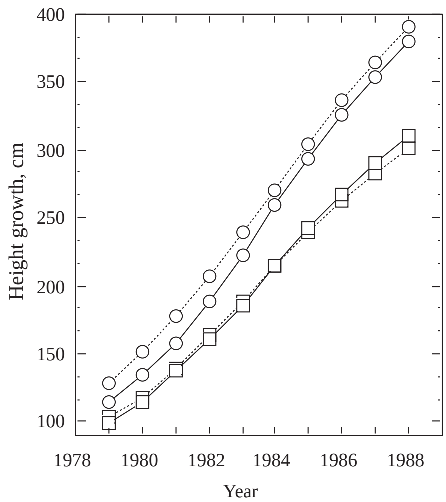

Fig. 6. Accumulated height growth in the area E3 for Scots pine (squares) and lodgepole pine (circles) with two different fertilizer application methods: —— = Spot fert., ······· = Broadcast fert.

4 Discussion

Trees of different species grow differently depending on the variation in quality of the peatland site types, i.e. spruces do better on rich sites whereas pines better can utilize the poor sites. This study was focused on low-productive peatland site types represented by study areas distributed over a climatic range. The purpose of the study was to find out whether planted trees of lodgepole pine, Norway spruce and silver birch responded to drainage and fertilization treatments as the Scots pine trees did (Sundström 1995), or whether there are any species specific differences regarding survival and growth.

The almost complete mortality of the planted silver birch in four of the five areas is consistent with findings from earlier studies in Finland (Mannerkoski and Päivänen 1974, Kaunisto and Päivänen 1985). Kaunisto (1985) however, found that the height growth of surviving silver birches, was superior to both spruce and pine. In the only area in this study (E3) where more than half of the planted silver birch trees survived, the mean diameter of birch was smaller than that of the pine species. Downy birch is generally better adapted and more natural to wet organic soils than silver birch and is therefore the recommended birch species in peatland afforestation (Kaunisto and Päivänen 1985).

Since the site type in this study is low-productive and considered most suitable for pine, it is not surprising that the results support earlier findings that Scots pine is performing much better than spruce, at least in the southern areas (Meshechok 1968, Kaunisto and Päivänen 1985, Arnøy 1986). Fertilization with P and K was needed, however, to achieve successful results even with pine. Fertilization reduced mortality and increased height growth threefold in southern Sweden. Fertilizing in northern areas on the other hand, seemed to be a total waste of resources since no effect of the fertilizer could be found for any of the species tested. The very poor height growth in northern Sweden, less than two meters in 18 years, cannot justify afforestation efforts there, even though spruce trees had significantly higher survival and were less susceptible to damage than pines.

Lodgepole pine, as an alternative to Scots pine, has been found to produce about 30 % more than Scots pine on mineral soils in Sweden (Norgren 1995). At a stand age of 18 years in this study, height and diameter was 26 and 37 % higher, respectively for lodgepole pine than for Scots pine, which is equivalent to 100 % increase in volume per tree. Mortality of lodgepole pine was on average 20 % higher than of Scots pine, however not consistently so since more Scots pines trees had died in one of the areas (E3). In western and northern Norway, survival and growth of lodgepole pine were strongly dependent on provenance choice, and it tolerated badly drained and nutrient poor peatlands better than other tree species (Braekke 1984, Arnøy 1986). Caution was advised in areas with dense moose population, and also much snow, due to the risk of browsing and poor stability. Laine (1979) also suggested that lodgepole pine did not require the same intensity of drainage and fertilization as Scots pine. In this study, fertilizing resulted in lower mortality and better height growth for both Scots and lodgepole pine in the two southern areas, E2 and E3. In the northern area, E4, there were no differences in mortality and growth between the two species, and no effect of fertilizer was found. Based on the results from this study, lodgepole pine might be an alternative species to Scots pine in afforestation of open low-productive peatlands due to its higher growth, in spite of its higher mortality and damage risk. No signs of competition or interaction effects between the two pines species were found at this stage. Because of the relatively short time since establishment, 18 years, and the limited knowledge about provenance selection of lodgepole pine for wet organic soils, continuous research is needed before safe recommendations can be made.

Intensified drainage improved survival of both pine species and more so in the north (E3–E4), whereas the impact on height was more obvious in the south (E2–E3). Fertilization with P and K improved the performance of both pine species substantially, but only in central and southern Sweden. The results also showed that doubling the dose of phosphorus improved the response even more in the southernmost area (E2). The significance of P as the single most important element on these site types has also been reported by Meshechok (1968), Mannerkoski and Seppälä (1970) and Laine and Mannerkoski (1980). On plots fertilized with the doubled K-dose (P2K4), there were indications of improved height growth for lodgepole pine, which was not found for Scots pine. This indication, that lodgepole pine would utilize available potassium more efficiently than Scots pine, is not generally known and should therefore be further investigated.

The adding of nitrogen to the PK-fertilization had no extra effect on survival and growth. This means that nitrogen is probably not the limiting element on these sites, indicated by the relatively high N-contents of surface peat, or that an initial response to added nitrogen actually did occur, however not found 18 years later.

Initially, spot fertilization with a small dose of P directly in or near the planting hole gives a better response than full broadcast fertilization (Meshechok 1968, Kaunisto and Päivänen 1985). Broadcast application with the full dose should follow, 3–6 years later, to keep up the good start and prevent a decline because of nutrient deficiences. Spot fertilized trees in this study were never refertilized with the full dose in a broadcast application but still responded as well as broadcast fertilized trees after 18 years. Comparative results from annual height growth (length of internodes) in the central area, E3, gave no indication that the smaller amount of fertilizer used in spot application lead to a decrease in height growth later on. Thus, there is reason to believe that the initial fertilizer amount in peatland afforestation can be reduced and that broadcast refertilization can be carried out at a later stage than earlier thought.

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