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SAMMENDRAG/SUMMARY:

Field trials with Norway spruce seedlings from 84 full-sib families from a factorial cross in Opsahl Seed Orchard and 11 provenances were planted at eight sites between altitudes between 600 and 900 m in Oppland County in Norway. Measurements of tree heights and assessments of stem and branch defects were made at regular intervals until 34 years from seed. Data from measurements made in nursery trials and from artificial freezing trials were also available. The families from the seed orchard had on average 12 % better height growth than the provenances. For volume growth per hectare, measured in two of the trials 30 years after planting, the families had a superiority of more than 30 %. A large variation among families was present for height growth and additive genetic variation was the main genetic factor. For the maternal half-sib families, the ranking of families for height was stable after 15 years from seed, and the five best families selected for height at that age were at age 34 years 6 % taller and produced 13 % more volume per hectare compared with the mean of all families. Weak relationships were present between traits measured in the nursery trial, the freezing test and the field trials. Assessments were made of cone production at age 20 years after planting and showed variation among families for the frequency of trees with cones.

Feltforsøk med granplanter fra 84 fullsøsken familier fra en faktoriell krysning og 11 provenienser ble plantet på åtte lokaliteter mellom 600 og 900 m i Oppland. Måling av trehøyde og bedømmelse av feil på stamme og kvistsetting ble gjort med faste intervall inntil 34 år fra frø. Data fra målinger i forsøk i planteskolen og fra fryseforsøk var også tilgjengelig. Familiene fra frøplantasjen hadde i

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gjennomsnitt 12 % bedre høydevekst enn trærne fra proveniensene. For stående volum per hektar, målt i to av forsøkene 30 år etter planting, var familiene mer enn 30 % bedre enn proveniensene. Det var stor variasjon mellom familiene for høydevekst, og additiv genetisk variasjon var hovedårsaken. For halvsøsken familiene fra 21 mødre var rangeringen for høyde stabil etter alder 15 år fra frø, og de fem beste familiene ved den alder var etter 34 år 6 % høyere og produserte 13 % mer volum per hektar sammenlignet med totale middel av familiene. Svake sammenhenger var til stede mellom egenskaper målt i planteskoleforsøket, i fryseforsøket og i feltforsøkene. Frekvensen av trær med kongler 20 år etter planting varierte betydelig mellom familiene.

LAND/COUNTRY:	Norway
FYLKE/COUNTY:	Innlandet
KOMMUNE/MUNICIPALITY:	
STED/LOKALITET:	

GODKJENT /APPROVED	PROSJEKTLEDER /PROJECT LEADER
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Innhold

1 Introduction

The early steps in tree breeding of Norway spruce in Norway were based on seed production in seed orchards where plus trees selected in natural populations were grafted. The plus trees were selected based on their superior phenotypic performance. It was soon recognized that information from progeny tests with off-spring of the plus trees planted at several sites were necessary to evaluate the genetic value of the selected trees. Such tests were also important for providing information about genetic variation and inheritance patterns of different traits and their relationships.

Opsahl Seed Orchard (latitude 61°26’, longitude 10°14’, altitude 200 m) was established by Oppland Skogselskap in 1961 when rootstocks were planted. From 1965, 71 clones originating from natural populations of Norway spruce between altitudes 450 and 880 m in southern Norway were grafted in the orchard. The intention was to produce seeds for the same areas. Flowering occurred in the orchard as early as in 1970 and controlled crosses were made to produce families for progeny testing. After seedling production in a nursery, plants from these families and control provenances were planted in trials at several sites at altitudes between 600 and 900 m in Oppland County. The trials have been measured during a 30-year period. The intention with this report is to present the variation in mortality, height growth and stem and branch damage among and within the trials and relationships between traits. In addition, the performance in the field trials of a subset of the families will be related to their injury scores in an early freezing test.

2 Materials and methods

2.1 Families, provenances and field trials

The controlled crosses in Opsahl Seed Orchard in 1970 were made between clones originating from altitudes between 450 and 880 m in southern Norway. Twenty-one clones were used as maternal parents and were each pollinated with pollen from four paternal parents in a 21 x 4 factorial design (Dietrichson and Haug 1976). Thus, 84 full-sib families were generated. The seed lots were germinated in Biri Nursery in 1971 and the seedlings were transplanted in nursery beds after two growing seasons. The four-year-old seedlings from the full-sib families and from ten control provenances produced in the same nursery were planted in nine long-term field trials in the spring of 1975 (Table 2). One of the trials was later terminated due to high mortality. Some of the families could not be planted at all sites due to a small number of seedlings. At each site, the seedlings were deployed in the following way: One seedling from each genetic entry was collected in a bundle. At planting, the seedlings in each bundle were randomly distributed in one or two adjacent rows, making up one block. Twenty blocks were planted at each site. In the statistical analyses this layout will be treated as a single tree plot design with 20 replicates.

The ten provenances (seed collection zones in natural forest) were from altitudes between 100 and 850 m in southern Norway (Table 2). They were grouped in three altitude regions.

Table 1. Provenances from ten seed collection zones (Skogfrøverket 1995) grouped in three altitude provenance regions based on altitude.

Altitude region	Seed collection zones
1: 0 – 350 m	B 1, C 1, E 1, B 3
2: 351 – 650 m	A 5, A 6, B 6
3: 651 – 850 m	A 7, B7, B 8

Measurements of tree heights were made in the field trials in 1975, 1979, 1984, 1989 and 1995. In two of the trials (Østre Slidre and Ringebu) heigh and diameter were also measured in 2004 and wood specimens for wood density analyses were then collected from trees in a subset of the families. Results from this study was published by Steffenrem et al. (2009). When heights were measured, assessments were also made of stem and branch defects (double stems or leaders, ramicorn branches) that had occurred during the last five years period. Results from 1984, 1989 and 1995 will be reported here. During the summer of 1995 flowering occurred in some trials and in the autumn each tree was scored in two classes: fewer than five and five or more cones. In three of the trials the timing of bud flush was scored based on the Krutzsch scale (Krutzsch 1973) during the second week of June 1986 (Strandbakke 1987). In the nursery at age four years, seedling heights were measured and scorings were made of the frequency of seedlings with lammas shoots in four family plots of 25 seedlings with the following scale: 0=no lammas shoots, 1=less than 20%, 2=20 – 60 %, 3=more than 60%, but less than 100 %, 4= 100 % of seedlings with lammas shoots. Mean family heights and lammas shoot scores are available from the nursery trial (Dietrichson and Haug 1976).

Table 2. Long-term field trials planted 1975 with full-sib families from Opsahl Seed Orchard and control provenances. Mean heights 2004 at Østre Slidre and Ringebu and 1995 at the other sites. The two first sites had mean heights 502 and 523 cm in 1995. Double stems and ramicorn branches are means of the percentages from the assessments made in 1989 and 1995. Percentages are presented of trees alive in 1995 assessed with no damage in any of the years 1984, 1989 or 1995.

Trials	Latitude	Altitude m	Mortality 1975 %	Mortality 1979 %	Mortality 1995 %	Height 2004/ 1995 cm	Double stems %	Ramicorn branches %	Trees without damage %
Østre Slidre	61° 08′	600	12	14	17	944	14	15	55
Ringebu	61° 34′	720	10	25	38	911	29	29	29
Vardal	60° 49′	600	3	16	30	405	38	16	20
Østre Toten	60° 36′	600	25	37	43	418	13	7	68
Sør-Fron	61° 34′	780	4	14	31	309	32	26	20
Vågå	61° 49′	750	7	22	26	351	11	14	62
Vestre Slidre	61° 02′	900	25	40	42	316	28	16	34
Sør-Aurdal	60° 40′	800	24	39	54	256	31	24	21

In 1989, a second set of crosses were made in Opsahl Seed Orchard. Selection had been made of five of the maternal parents with superior half-sib family means for height and five with lower heights, based on the 1984 measurements. These ten maternal parents were pollinated with the same four pollen parents that were used in the crosses in 1970, and a 10 x 4 factorial crossing design was generated.

Seed lots of the 40 full-sib families were germinated at Hogsmark Experimental Farm, Ås, in May 1990, and seedlings were cultivated in the greenhouse by standard routines. In the first week of October seedlings were freeze tested in three separate tests down to -14°C in two of the tests and to -16°C in the third, following the procedures described by Johnsen (1989) and Johnsen et al. (1996). Each test was made in three freezing chambers with two seedlings per plot and family in four blocks. After the freezing, the seedlings were placed in a greenhouse under humid conditions and injuries on needles were assessed on individual plants three weeks after freezing in classes 0-11; 0=no visible damage, 1-10 = ten percent intervals of brown or discoloured needles; 11= all needles completely brown.

Increment cores were collected in 2004 for a sub-sample of 180 trees from the full-sib families. The results from this study were published in Steffenrem et al. (2009). In 2008, a new sample were collected from the provenance groups (full-sib families, 0-350 m, 351 – 850 m) at Ringebu to evaluate the realized change in density considering the differences in growth between the materials.

2.2 Statistical analyses

Statistical analyses were made by SAS (SAS Institute 2003).

For each trial, calculations were made of percentage values for each full-sib family and provenance of the following traits: mortality in 1975, 1979, 1984, 1989 and 1995; trees assessed with double stems and with ramicorn branches in 1989 and 1995; trees without stem, branch and leader shoot damage assessed in 1984, 1989 or 1995 and trees with more than four cones. Before analyses of variance were made across sites individual tree values (damage or not damaged) were transformed to normal scores within each site.

In the analyses of variance for height and diameter by proc GLM in SAS, the following factors were included in the model: site, mother, father, mother x father, site x mother, site x father. All factors, except sites, were treated as random. These analyses were made of heights measured in 1995 at all eight trials and for height and diameter measured in 2004 at Ringebu and Østre Slidre. Estimates of narrow sense heritability were based on variance components estimated by proc VARCOMP in SAS.

Volume of standing trees was calculated for all trees at Ringebu and Østre Slidre based on the measurements of height and diameter in 2004. The calculations were made by the functions developed by Vestjordet (1967). The total standing volume of each of the maternal half-sib families and provenance regions were then calculated expressed in volume per hectare, based on the area of all trees planted of each family and provenance region.

Wood density was measured for a sub-sample of the trees within each provenance group at Ringebu in 2008. Increment cores were collected from breast height and scanned with a CT-scanner to estimate the density from the Dicom-values as described in Steffenrem et al. (2009).

Injury scores from the freezing tests were transformed to normal scores within each freezing chamber. These values were analysed by a similar model as used for height, replacing site with freezing test as fixed, and freezing chamber and blocks with chamber as random.

Pearson correlation coefficients were calculated between maternal half-sib family means of traits measured in the nursery, in the freezing tests and in the field trials.

3 Results

3.1 Variation in field trials

A high mortality occurred in three of the trials (Østre Toten, Vestre Slidre, Sør-Aurdal) the first summer after planting (Table 2). This was to a substantial extent due to draught and grazing by sheep. The mortality continued to increase at these sites. The percentages of trees with stem and branch defects were lowest at three sites at 600 m, but was also low at Vågå, 750 m. The trials above altitude 750 m had the lowest tree heights.

Minor differences were present among means of families and provenance groups for mortality and stem and branch defects across all sites (Figure 1). The full-sib families were significantly taller (12 %) than the provenances for height across all sites in 1995 and for height and diameter (13 %) in 2004 at Østre Slidre and Ringebu ($p<0.001$). The mean volume of the half-sib families was 57, 36 and 31 % higher than for the provenances from regions 1, 2 and 3, respectively. The wood density of the full-sib families and the provenance group 351 – 850 m differed with 7 kg/m^3 but were not significantly different ($p<0.05$). However, the density was considerably higher for the low-elevation group. From Figure 2, it is clear that the annual radial increment of the families and the provenances from 351-850 m were higher than the increment of the low elevation provenances. The ring width and density fluctuates, probably also due to experimental errors, but the general trend is that the families and the provenances from 351-850 m perform similarly. It is worth to notice that the families seem to respond differently in the year of 2002 and 2006.

The provenances from the highest altitude had a slightly earlier bud flush than the other groups, approximately three days earlier than the families. The range of variation among the maternal half-sib family means was from 2.7 to 3.7, which corresponds to five days. No relationships were present between these means and the altitude of the origin of the maternal parents.

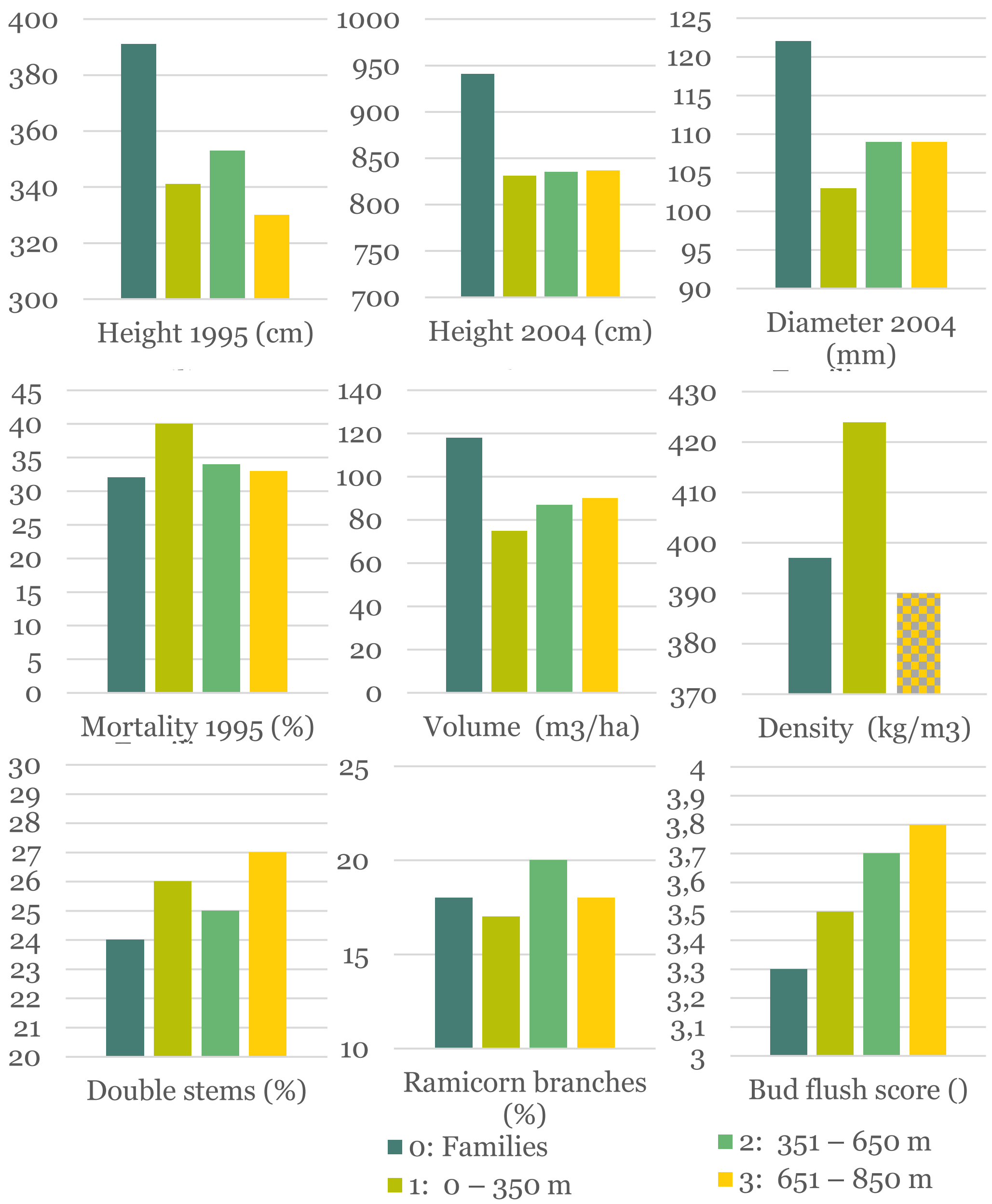

Figure 1. Mean values of full-sib families and three provenance regions for mortality, mean heights across all sites in 1995, mean heights, diameters and volume at Østre Slidre and Ringebu in 2004, wood density at Ringebu in 2008 (provenance group 351-650 and 651-850 were combined), mean percentages of double stems and ramicorn branches in 1989 and 1995 and mean bud flush score in 1986.

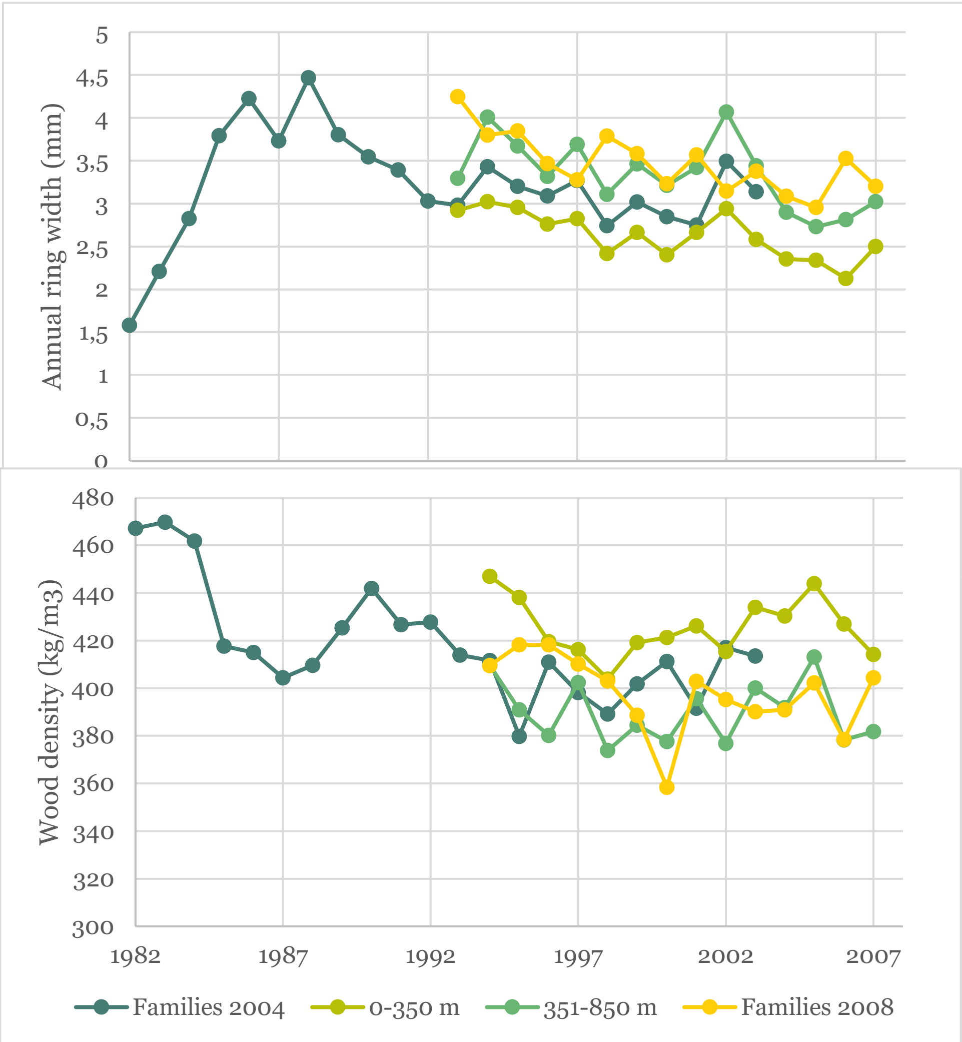

Figure 2. Average annual ring width (mm) and wood density (kg/m3) of the provenance groups and full-sib families (2004 and 2008 material) shown over year of ring formation. The material sampled in 2004 were published in Steffenrem m. fl. (2009) and only contained rings formed before that year.

Figure 3 presents mean values of mortality 1979, the percentage of trees without damage and height 1995 for families and provenance regions for each trial. It shows some interactions between the groups and sites. The families had a mortality lower or equal to the mean at all sites and their frequencies of trees without damage were also close to the sites means. The provenances from 351 – 650 m were slightly taller than the families in two of the trials with high mortality (Østre Toten and Sør-Aurdal). At the other sites, the families had the highest means. The percentage of trees without damage showed large variation among the trials and less variation among the groups. The largest portion of damage was due to double stems and leaders and ramicorn branches.

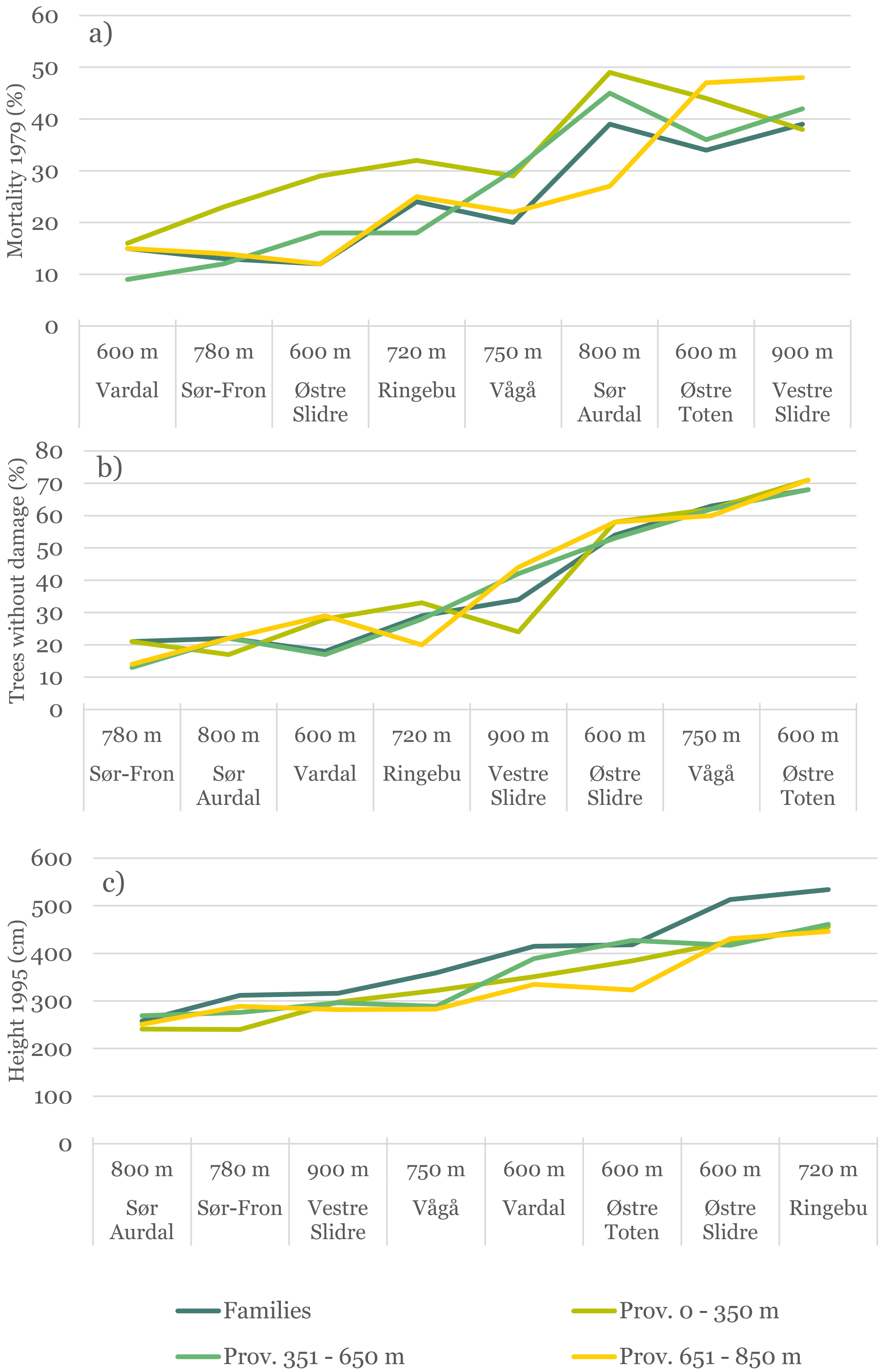

Figure 3. Mortality 1979 a), the percentage of trees without damage in the period 1984 – 1995 b) and mean tree heights for the families and three groups of provenances at each trial c).

In the analyses of heights in 1995 of the full-sib families in the factorial cross significant differences were present both among the maternal and the paternal parents (p<0.0001) and with a smaller interaction effect among the parents (p=0.02). Interaction effects were also present between sites and parents. The estimate of heritability for height in 1995 was 0.09. For the measurements in 2004 at Østre Slidre and Ringebu significant differences were present among the maternal parents for both height (p=0.04) and diameter (p=0.01), and no interactions between the maternal and paternal parents and between the families and the trials. The estimates of heritability had the same value 0.09 for both height and diameter.

Significant differences were present in 1989 among both maternal and paternal parents for double stems and ramicorn branches, but only among the maternal parents in 1995. The range of variation among the 21 maternal half-sib families, based on the mean percentages of 1989 and 1995 across all trials, were from 17.8 to 32.1 % and from 12.6 to 25.4 % for double stems and ramicorn branches, respectively. Based on estimated correlation coefficients, no relationships were found between the altitude of the origin of the parents and their half-sib family mean heights, percentages of double stems or ramicorn branches.

The two groups of selected families had mean heights 114 and 104 cm in 1984 and 406 and 365 cm in 1995. There were no differences between the two groups in mortality nor in the percentage of trees without damage. The mean altitude of the origin of the maternal parents in the two groups were 710 and 670 m.

3.2 Variation in freezing tests

The mean injury scores were 3.3, 3.6 and 4.9 in the three tests. Significant variation (p<0.001) was present among both female and male parents and for their interaction. For the 10 maternal half-sib families the mean score ranged from 2.4 to 7.7. The five families selected for superior height growth had a mean injury score of 4.5 and it was 3.3 for those selected for inferior height growth. There was a negative relationship between injury score and altitude of the maternal parents with r=-0.49. However, two of the half-sib families from low altitude deviated and had a low injury score.

3.3 Variation in cone production

In the assessments made of cone production in the autumn of 1995, cones were present at Ringebu, Sør-Fron, Vågå and Sør-Aurdal in varying frequencies (Table 5). The range of variation in percentage of trees with cones among the 21 maternal half-sib families was large within each trial. Strong relationships were present between the cone percentages at Ringebu, Sør-Fron and Vågå with correlation coefficients between 0.55 to 0.77. These three sites are located less than 60 km apart. In the analysis of variance of the transformed cone percentages of the full-sib families across the four sites significant variation was present among the female (p=0.0006) and male parents (p=0.02), but no female times male interaction (p=0.11), nor family times trial interaction (p=0.50). In three of the trials, the cone percentage was positively related to the mean height of the family in 1995 (r=0.50 – 0.56). However, there was a genetic component in the variation in cone production among the maternal parents in addition to the variation in height growth, as illustrated in the plots in Figure 4. There was no relationship between cone percentages and the altitude of the origin of the maternal parent. The provenances had cone percentages like the families at each site, with no differences among the altitude regions.

Table 3. Trials with cone production and mean percentage of trees with five or more cones in each trial, and the range of variation in cone percentages among the 21 maternal half-sib families.

Trial	Trees with cones %	Range of variation %
Ringebu	82	56 - 94
Sør-Fron	50	25 - 69
Vågå	58	13 - 82
Sør Aurdal	17	4 - 39

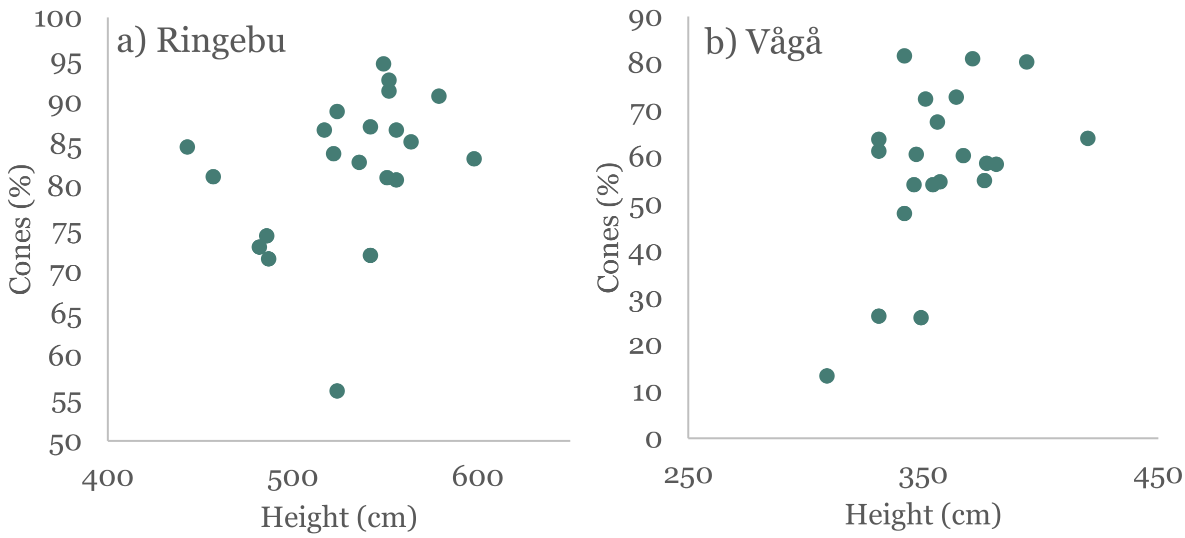

Figure 4. Plots of relationships between the mean percentage of cones and mean height 1995 for the female half-sib families at a) Ringebu and b) Vågå.

3.4 Correlation patterns

A significant correlation coefficient (r=0.66, p=0.01) was present between the mean height of the maternal half-sib families at age four years in the nursery and the mean height across all trials five years after planting (1979). For height at later ages no relationship with the four years' heights were present. No other significant correlation coefficients were found between other field trial traits and height and lammas shoot scores in the nursery.

Across the trials there was no significant relationship between freezing test injury scores and mortality. Separate analyses made for each trial showed significant correlations (r=0.64 and r=0.66) for mortality percentages in 1975 at Vågå and in 1979 at Ringebu. For stem damage traits, no relationships were present at any of the sites with the freezing test scores.

A positive relationship was present between injury scores in the freezing test and family mean heights across all trials 21 years after planting, with an estimated correlation coefficient of r=0.63 (p=0.05). For the mean height in 2004 for the two trials Østre Slidre and Ringebu the estimate was r=0.67 (p=0.03). However, the plot in Figure 5 shows that the best-growing families with mean height above 900 cm in these trials had a range in frost hardiness score the first growing season from 3.5 to 7.7. The maternal parent of the most frost hardy family with inferior height growth originated from altitude 800 m, while the range in altitude of the best-growing families was from 560 to 730 m.

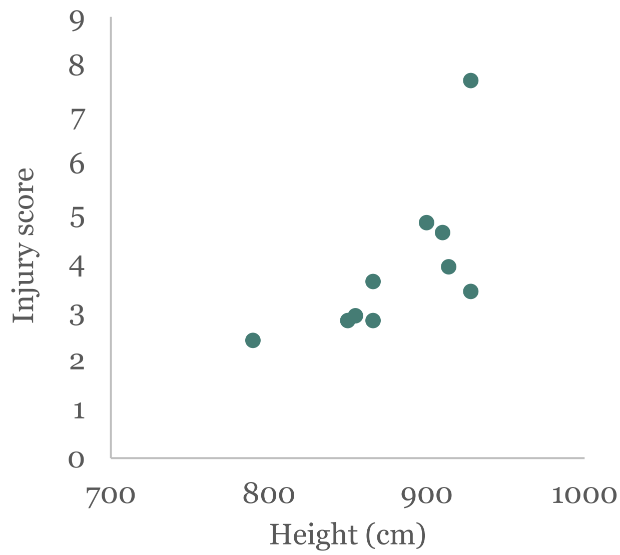

Figure 5. Relationship between mean heights 2004 at Østre Slidre and Ringebu and injury scores in the freezing test for ten half-sib families.

No significant relationships were present between the bud flush score and mean mortality percentage across all trials. In separate analyses made for each trial a slight relationship was found between early mortality (1975) and bud flush (r=0.41, p=0.07) at Østre Slidre. Between the bud flush scores and the percentages of trees with stem damages there was a significant positive relationship (r=0.49, p=0.04) only in one trial (Østre Toten). Similarly, for heights the only significant correlation with bud flush was for early height (1979, r=0.46) at Ringebu.

3.5 Implications related to an optimal age of selection

The height measurements in the years 1975, 1979, 1984, 1989, 1995, and height and diameter measurement made in 2004 at Østre Slidre and Ringebu, make it possible to study the changes in ranking of the 21 maternal half-sib families during a 30-year period in the field. It is seen from Table 4 that there were weak relationships between mean height, diameter and volume at age 34 years and the heights in the nursery and the first year after planting. At age nine years (1979) the correlation coefficients were above r=0.61 and increased to higher values five years later. The ranking of the five best families was stable after age 15 years and the five tallest families at that age were, with one exception, also the five tallest at age 34 years. The mean of these families was then 6 % above both the mean height and diameter and 13 % in volume of the mean of all families at these two sites. The percentage of trees without damage during the period 1984 to 1995 across all eight trials was 39 both for these five and for all families, and at the same level for the three provenance regions. The mean mortality of the five selected families was at the same level as the mean of all families and of the provenances from regions 2 and 3.

Table 4. Correlation coefficients between mean height of 21 maternal half-sib families at different ages at eight sites and height, diameter and volume at age 34 years in trials Østre Slidre and Ringebu.

Height at age	Height at age - years						Diameter age	Volume age
	5	9	15	20	25	34	34	34
4	0.92	0.63	0.34	0.28	0.24	0.38	0.46	0.22
5		0.69	0.40	0.29	0.25	0.37	0.41	0.31
9			0.82	0.76	0.76	0.63	0.61	0.63
15				0.95	0.91	0.75	0.67	0.73
20					0.97	0.78	0.67	0.76
25						0.75	0.60	0.77

4 Discussion

Large variation was present among the trials both for mortality and height growth. A major factor is the difference in altitude among the sites, ranging from 600 m to 900 m, implying a large variation in climatic conditions. In addition, heterogeneity in topography may cause local variation in the temperature climate. This has been shown to cause major differences in mortality between trials located within short distances and may be the reason for genotype by site interactions (Skrøppa 2021). The years 1975 and 1976 were warm and with low level of precipitation which caused at some sites a high initial mortality. Grazing by sheep also caused a high mortality the first years after planting.

The mean performance of commercial provenances from the altitude regions did not vary much based on total means across all trials. At some of the sites, the provenances from the lowest altitudes had the highest mortality. Interactions were present between trials and regions for both mortality and height. These interactions could not be predicted from the altitude of the sites and were most likely caused by local conditions at the trial site. Less interactions between trials and provenance regions were present for the percentage of trees without damage.

The families from the seed orchard had on average 12 % higher mean heights than the provenances and had the highest means in six of the eight trials. The difference found here were smaller than the 25 % superiority in height at age four years in the nursery found by Dietrichson and Haug (1976). This shows that growth performance in the nursery may not be representative for height growth at later ages in the field. One factor could be family variation in lammas growth frequencies in the nursery correlated with seedling heights (Dietrichson and Haug 1976). A low frequency of lammas growth was observed in the field trials.

Differences in height in trials at high altitudes between seed orchard families and regular stand seed provenances have earlier been shown to be more than 20 % after 12 years growth in the field (Skrøppa et al. 2007). Here, the superior growth of the seed orchard families compared with the provenances was expressed for volume production which also takes mortality into account. These differences should be considered to be “realised seed orchard gain” rather than solely genetic gain from selection of plus trees and will include the effects of inbreeding, pollen contamination and seed production in a warmer climate at a lower altitude (Haapanen et al. 2015).

The samples collected for the wood density study in 2008 were only a small sub-sample of the whole population tested. The cores collected comprised only rings in the outer part of the wood, formed from 1993. The aim of this study was to see if there were substantial differences in wood density between the different materials after observing the large differences in growth. The sub-sample might have been slightly biased as the average annual increment of the sampled family-trees and trees representing the provenances from 351-850 m were similar, and not as different as the total diameter of the whole material. However, the results indicate that the density is the same of the families from the seed orchard and relevant provenances for this elevation.

The range of variation in injury scores in the freezing test did not relate well to the variation in height growth at age 34 years, and some faster growing families seemed to have an acceptable frost resistance. There were no relationships between mortality in the field and the frequency of trees with no damage. This shows that such freezing tests do not provide good indications of family mortality and the occurrence of stem damage under field conditions.

The variation among the families from the factorial cross was to a substantial extent expressed among the female and male parents and less as an interaction among the parents. This shows that additive genetic variation was the main genetic factor. Due to the interactions among parent and sites the estimate of narrow sense heritability for height was as low as 0.09, lower than the estimate reported by Dietrichson and Haug (1976) for height at age four years. Higher levels of heritability for height at ages eight and ten years in short-term trials were reported based on families from seed orchards (Skrøppa and Steffenrem 2015) and from natural stand (Skrøppa, Solvin and Steffenrem 2022).

In these trials, a stable ranking based on height of the half-sib families occurred at age fifteen years from seed, or after nine years in the field, at mean tree heights of 1.5 m. The tallest families did not have a higher frequency of trees with stem and top damages and had the lowest mortality. The indications given here of making selection at this age is supported by recommendations given by Werner et al. (1986) who found a correlation coefficient r=0.66 between height at age ten years and volume production after age 37 years. Similar results have been presented by Nanson (1987).

The maternal parents of the five superior half-sib families were selected in different natural populations located between latitudes 60°14' and 61°09' and altitudes between 550 to 880 m in the central part of southern Norway (Vang, Vestre Slidre, Nordre Land and Fåberg). The natural populations in this region obviously contained valuable genetic materials that should be included in the breeding intended for producing improved seeds for breeding zone G3 (Skogfrøverket 2017). Selection within populations seems to be most effective as other studies have shown minor differences in height growth among provenances between altitudes 600 to 800 m in southern Norway (Dietrichson 1973, Skrøppa 2021, Skrøppa unpublished).

Large variation in flowering abundance and cone production has earlier been described among clones in Norway spruce seed orchards, e. g. Skrøppa and Tutturen (1986), Nikkanen and Routsalainen (2000). However, no studies have been found, in which variation among families in young progeny tests has been characterized. Our study shows a considerable variation among families in cone production in plantations at the age of 20 years. Cones occurred with high frequencies both in families with good and medium height growth. The shortest trees within the families had no cones. A genetic variation in cone production, partly related to the variation in height growth, seem to be present. Similar results were found in three progeny trials containing Norway spruce full-sib families where assessments were made of cone abundance, also in 1995, at age 20 and 17 years after planting (Skrøppa, unpublished).

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Cover photo: Gunnar Haug in progeny test with families from Opsahl Seed orchard. Photo: Arne Steffenrem, NIBIO/Norwegian Forest Seed Center.

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