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Genetic evaluation of growth, external quality and phenology in two 5-year-old larch trials in southern Sweden

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Summary

Height growth and external stem quality traits in various types of larch material (inter- and intra-specific crossings between *L. kaempferi* and *L. decidua* clones, open pollinated plus-trees of *L. kaempferi* and *L. decidua,* F2-hybrid offspring and various standards) were compared in two 5-year-old progeny trials in southern Sweden.

Genetic parameters were estimated for the open pollinated plus-tree material. Most heritabilities (h^2) had high standard errors. For *L. decidua* significant h^2 values were found for height (0.41), traits related to spring and autumn phenology (0.42 to 0.61), straightness (0.41) and branchiness (0.39). Significant h^2 values for *L. kaempferi* were found for survival (0.51) and straightness (0.64). The additive coefficient of variation for height was around 10% for *L. decidua*, while it was around 5% for *L. kaempferi*. Most additive correlations were weak and not significant. However, height and the autumn phenology traits showed a strong and negative correlation for *L. decidua*, indicating that late growth termination is associated with increased growth.

Although the *L. kaempferi x L. decidua* hybrids were consistently highly ranked for growth, no significant differences among the *L. decidua*, *L. kaempferi* and *L. x eurolepis* groups of material were found. High-, intermediate- and low-ranking clones were found in the F2-*L. x eurolepis* group, indicating a high variability in the growth of this material.

Introduction

The first larch hybrid (*L. x eurolepis* Henry) in Sweden was produced in 1941 at the then "Association for breeding of forest trees" (Föreningen för växtförädling av skogsträd), now SkogForsk, in Ekebo. Its production was followed by a relatively intensive period of larch improvement activities. Nearly 30 trials and seven seed orchards of larch were established in southern Sweden by the 1960's, three of which are still active. The main objective of these trials was to study hybrid vigour and compare it to the growth of Norway spruce before possible future improvement work was started (Kiellander, 1958; 1965). However, when results from these trials were obtained, no further breeding activities were performed, due to a lack of interest in larch in the forest industry.

Today, the forest industry still has relatively little interest in larch. However, there are some sawmills and flooring manufacturers that specialise in larch wood, despite complaints that there is a lack of indigenous larch of good quality, which must therefore be imported. Nevertheless, in recent years the regeneration area of larch has increased, indicating a growing interest in it amongst the forest owners. This is probably a result of the root and butt rot and wind-throw problems affecting Norway spruce stands in southern Sweden, making forest owners look for substitute species. Hybrid larch is apparently considered to be a good alternative. In addition, the larch timber is assumed to be resistant to decay and is thus considered to be an environmentally better alternative to pressure-impregnated Scotch pine (*Pinus silvestris*) and Norway spruce.

The breeding work of larch has been very extensive since the 1970's. Thus, our genetic knowledge of the selected plus-tree material from the 1940–1960's is poor. Good genetic information on growth and straightness is only available for a few Japanese (*L. kaempferi*) and some 20 European (*L. decidua*) larch clones. The potential for improvement is substantial (e.g. Dietze, 1980; Sindelar, 1981). Activities to improve the genetic regeneration material for the southern parts of Sweden were restarted in the middle of the 1990's, when plans were made to test the selected plus-tree material from the 1940–1960's and to increase the number of clones in the breeding population.

This report presents early results from two newly established progeny tests, representing the first step towards providing southern Sweden with better larch regeneration material.

The objectives of this study were to evaluate genetic differences in growth, external stem quality and phenology, and to estimate genetic parameters and correlations among traits for different larch materials.

Material and methods

The study was based on two progeny trials (designated S21F9881314 and S21F9881315) planted with one-year-old containerised seedlings in southern Sweden in the spring of 1998 (Table 1). The material included in the two trials was divided into five main groups:

1. Partial diallell inter-specific crossings between *L. kaempferi* and *L. decidua* clones.
2. Intra-specific crossings between *L. kaempferi* and *L. decidua* clones.
3. Open pollinated offspring from selected plus-trees of *L. kaempferi* and *L. decidua*.
4. Open pollinated F2-hybrid offspring harvested from good genotypes in a *L. x eurolepis* full sib trial.
5. Standards, i.e. material of the pure species.

A detailed description of the material and the crossing scheme for the full-sib families are given in Appendices 1, 2 and 3. A maximum number of 15 trees per family were planted as single tree plots in a restricted randomised block design. Each trial was surrounded by one border row and the spacing was 2 × 2 m. Furthermore, 12 and 11 families at each site respectively were established in a 6 × 6 plot design, replicated three times for demonstration purposes, but results from these plantings are not included in this report. Since a large proportion of the seedlings were very unstable (leaning) after a year of growth many seedlings were stabilised by supporting them with bamboo sticks in spring 1999.

Total height was measured and external quality traits were classified for all living trees during the autumn of 2001, i.e. after four growing seasons in the field. Traits related to autumn and spring phenology were classified during the years 1999 and 2000, respectively. All traits included in the analysis are presented in Table 2. Trials S21F9881314 and S21F9881315 will henceforth be called F1314 and F1315, respectively.

Table 1.
Description of the two trials.

Trial number		S21F9881314	S21F9881315
Name		Tönnersjö	Storebro
County		Halland	Kalmar
Latitude		56°41'N	57°36'N
Longitude		13°06'E	15°50'E
Altitude		100 m	150 m
Spacing		2x2 m	2x2 m
Area		1.2 ha	1.1 ha
Site conditions		Site index = G30 m Thin grass type Sandy moraine Mesic ground Mobile soil water absent	Site index = G28 m Thin grass type Fine sand moraine Mesic ground Mobile soil water absent
Material	Full sibs	26 full sib families: 11 *L. x eurolepis* 6 *L. decidua x L. decidua* 9 *L. kaempferi x L. kaempferi*	8 full sib families: 2 *L. x eurolepis* 2 *L. decidua x L. decidua* 4 *L. kaempferi x L. kaempferi*
	Half sibs	55 open pollinated families: 26 *L. decidua* from the seed orchard at Hjälmshult 4 *L. decidua* from the Sudetes 20 *L. kaempferi* from the seed orchard at Klev 5 F2 *L. x eurolepis*	50 open pollinated families: 22 *L. decidua* from the seed orchard at Hjälmshult 4 *L. decidua* from the Sudetes 20 *L. kaempferi* from the seed orchard at Klev 4 F2 *L. x eurolepis*
	Others	8 standards: Seed orchard material (*L x eurolepis*) from Maglehem (Sweden) and Holbaek (Denmark) 6 *L. sibirica*	8 standards: Seed orchard material (*L x eurolepis*) from Maglehem (Sweden) and Holbaek (Denmark) 6 *L. sibirica*

Table 2.
Description of the traits analysed in the study.

Character	Abbreviation	Explanation
Height	H	Total height (cm) in the autumn of 2001, i.e. after four growing seasons in the field.
Survival	SURV	Survival in the autumn of 2001. Registered as 0 (dead) or 1(live). Presented as expected survival (%) when average survival is 80%.
Autumn phenology, trait 1	AUT1	Growth cessation in the autumn of 1999. Method 1. Scored in 10 classes based on needle discolouration in the lower half of the crown where 0 = all needles still green, 1 = 10% of the needles had turned yellow … 9 = 90% or more of the needles had turned yellow. Presented as the expected proportion of progenies with "normal" growth cessation, equal to 50% yellow needles.
Autumn phenology, trait 2	AUT2	Growth cessation in the autumn of 1999. Method 2. Scored in 10 classes based on needle discolouration in the upper half of the crown where 0 = all needles still green, 1 = 10% of the needles had turned yellow … 9 = 90% or more of the needles were yellow. Presented as the expected proportion of progenies with "normal" growth cessation, equal to 50% yellow needles.
Spring phenology, trait 1	SPR1	Growth initiation in the spring of 2000. Method 1. Scored in 9 classes based on development of the terminal buds of the upper half of the branches. The higher the class, the higher the proportion of flushing buds. Presented as the expected proportion of progenies with "normal" growth initiation, equal to classes 3–8 (50%).
Spring phenology, trait 2	SPR2	Growth initiation in spring 2000. Method 2. Scored in 9 classes based on the development of the terminal bud on the main stem. The higher the class, the higher the proportion of flushing buds. Presented as the expected proportion of progenies with "normal" growth initiation, equal to class 3–8 (50%).
Straightness	STR	Scored in 5 classes, where 1 = very crooked … 5 = completely straight. Presented as the expected proportion of progenies with acceptable straightness, equal to classes 3–5 (60%).
Apical dominance	APIC	Based on forking and leader shifting problems of the main stem. Scored in 5 classes, where 1 = substantial problems with apical dominance … 5 = no apical dominance problems at all. Presented as the expected proportion of progenies with acceptable apical dominance, equal to classes 3–5 (90%).
Branchiness	BRA	General branch quality based on thickness, number and angle of the branches. Scored in 5 classes where 1 = many, thick branches with acute angles … 5 = few, thin branches perpendicular to the stem. Presented as the expected proportion of progenies with acceptable branch quality, equal to classes 3–5 (75%).

Statistical analysis

All analyses were based on individual tree observations. Genetic parameters were estimated for the *L. kaempferi* and *L. decidua* half sib material separately. The following model was used: $y_{ijk} = \mu + b_i + f_j + e_{ijk}$ (1), where y_{ijk} = observation k, in block i for family j, μ = trial mean, b_i = fixed effect of block i, f_j = random effect of family j, $N(0,\sigma_f^2)$ and e_{ijk} = random error term for observation ijk, $N(0,\sigma_e^2)$. The variances σ_f^2 and σ_e^2 were estimated for different traits according to the REML-method (Restricted Maximum Likelihood) as performed in the ASREML software (Gilmour et al. 1999). Genetic parameters were interpreted as $\sigma_F^2 = \sigma_f^2$ and $\sigma_E^2 = \sigma_e^2 - 3\sigma_f^2$, where σ_F^2 = the family variance and σ_E^2 = the environmental variance. The individual narrow sense heritability (h^2), was calculated as: $h^2 = \sigma_A^2 / (\sigma_A^2 + \sigma_E^2)$, where the additive variance $\sigma_A^2 = 4\sigma_F^2$. The additive coefficient of variation (CV_A) was calculated as: $CV_A = 100\sigma_A / \mu$. The additive (r_A) and phenotypic (r_P) correlations between traits were estimated at the same time as the variances described above by the ASREML software as $r_A = \sigma_{A1A2} / (\sigma_{A1} \cdot \sigma_{A2})$, where σ_{A1A2} = estimated additive covariance between trait 1 and trait 2, σ_{A1}^2 and σ_{A2}^2 = estimated additive variance for trait 1 and trait 2, respectively, and as $r_P = \sigma_{P1P2} / (\sigma_{P1} \cdot \sigma_{P2})$, where σ_{P1P2} = estimated phenotypic covariance between trait 1 and trait 2, σ_{P1}^2 and σ_{P2}^2 = estimated phenotypic variance for trait 1 and trait 2, respectively.

Family values for different traits for the *L. decidua* and *L. kaempferi* half sib materials together were calculated as BLUP-estimates (Best Linear Unbiased Predictors) by Proc Mixed, SAS (1997) using model (1). In order to take into account the fact that the half sib material included different species, the family (σ_f^2) and the error (σ_e^2) variances were estimated by the REML-method (ASREML) according to the model: $y_{ijkl} = \mu + b_i + s_j + f_k + e_{ijkl}$, where y_{ijkl} = observation k, in block i for species j and family k, μ = trial mean, b_i = fixed effect of block i, s_j = fixed effect of species j, f_k = random effect of family k, $N(0,\sigma_k^2)$ and e_{ijkl} = random error term for observation ijkl, $N(0,\sigma_e^2)$. These new variances were used for the BLUP-estimations in the Proc Mixed analyses. As a measure of genotype x environment interaction, the Pearson correlation (SAS 1997) between BLUP-values from the two trials was calculated for each trait and each species separately.

It was not possible to perform any genetic analyses for the full sib material since the crossing scheme was too disconnected. Therefore, an analysis of variance using the GLM procedure and Tukey studentized range test (SAS, 1997) was carried out to test differences between families. To obtain comparable results among all the different groups of material such analysis was also carried out after dividing the material into its respective groups.

Data for all traits except height deviated from normal distributions, and so were transformed to normal score values within each block before analysis (Gianola & Norton, 1981).

Results

Half sib material

Mean height was about 2.7 m after four years of growth in the field for both species at the most southern site (F1314) and about 2.0 m at the northern site, F1315 (Table 3). Average survival was high for *L. decidua* in both trials (95% and 92%, respectively) but quite modest for *L. kaempferi* (66% and 52%, respectively).

In general the standard error of the heritabilities (h^2) was high, especially for *L. kaempferi*, which only showed high and significant h^2 values for survival and straightness in F1314 (Table 3). Significant and rather high h^2 values (greater than 0.40) for *L. decidua* were found for height (F1314), autumn phenology traits (both trials), spring phenology traits (F1314), straightness (F1315) and branchiness (F1315). As indicated by the h^2 values, the relative breeding values for height varied much more among the *L. decidua* progenies than among the *L. kaempferi* progenies (Appendices 4 and 5). The CV_A was around 10% for

L. decidua, although only significant in F1314 (Table 3). The corresponding CV_A for *L. kaempferi* was half as large, and non-significant in both trials.

Correlations were only estimated for *L. decidua*, since heritabilities for *L. kaempferi* generally had high standard errors. Most correlations were weak and not significant, with some exceptions (Table 4). Height and the autumn phenology traits showed strong and negative additive correlations (r_A). The r_A correlation between the two autumn phenology traits and between the two spring phenology traits were also strong, as was the positive r_A between apical dominance and branchiness. Straightness and branchiness showed positive and significant r_A values in F1314, while the correlation was negative and not significant in F1315. Correlations between BLUP-values of the two trials were fairly strong, positive and significant for height and the autumn phenology traits (Table 5).

Table 3.
Results from analysis of genetic parameters estimated from half sib families. All the means and the respective standard deviations are based on untransformed values while the genetic parameters for all traits except H are based on nscore-transformed values. Bold heritabilities and CV_A are significant at the $p<0.05$ level.

Table 3A.
Trial F1314 (Tönnersjö). *L. decidua*.

Trait	Mean	St dev of mean	h^2	Std err of h^2	CV_A
H (cm)	277	52.3	**0.41**	0.16	**11.7**
SURV (0–1)	0.95	0.21	0.24	0.13	
AUT1(0–9)	5.01	1.39	0.23	0.13	
AUT2(0–9)	3.26	1.47	**0.42**	0.17	
SPR1 (0–8)	2.83	0.46	0.13	0.11	
SPR2 (0–8)	2.22	0.71	**0.61**	0.20	
STR (1–5)	2.19	0.86	0.19	0.12	
APIC (1–5)	3.39	0.84	0.10	0.10	
BRA (1–5)	2.54	0.76	0.15	0.11	

Table 3B.
Trial F1315 (Storebro). *L. decidua*.

Trait	Mean	St dev of mean	h^2	Std err of h^2	CV_A
H (cm)	230	45.93	0.22	0.14	9.0
SURV (0–1)	0.92	0.27	0.14	0.12	
AUT1 (0–9)	2.32	1.23	0.29	0.15	
AUT2 (0–9)	2.11	1.19	**0.43**	0.18	
SPR1 (0–8)	3.11	0.59			
STR (1–5)	2.70	0.87	**0.41**	0.18	
APIC (1–5)	3.92	0.96	0.14	0.12	
BRA (1–5)	3.12	0.74	**0.39**	0.18	

Table 3C.
Trial F1314 (Tönnersjö). *L. kaempferi.*

Trait	Mean	St dev of mean	h^2	Std err of h^2	CV_A
H (cm)	263	44.3	0.10	0.17	5.0
SURV (0–1)	0.66	0.47	**0.51**	0.22	
AUT1 (0–9)	4.96	1.55	0.19	0.19	
AUT2 (0–9)	3.68	1.74	0.04	0.15	
SPR1 (0–8)	3.23	0.73	0.22	0.20	
SPR2 (0–8)	2.50	0.95	0.41	0.24	
STR (1–5)	2.61	1.09	**0.64**	0.29	
APIC (1–5)	3.67	0.97	0.25	0.20	
BRA (1–5)	2.70	0.97	0.22	0.20	

Table 3D.
Trial F1315 (Storebro). *L. kaempferi.*

Trait	Mean	St dev of mean	h^2	Std err of h^2	CV_A
H (cm)	188	44.54	0.08	0.20	6.5
SURV (0–1)	0.52	0.50	0.27	0.16	
AUT1 (0–9)	5.70	1.91	0.28	0.25	
AUT2 (0–9)	4.34	1.87	0.29	0.24	
SPR1 (0–8)	2.46	1.89	0.24	0.24	
STR (1–5)	2.70	0.79	0.02	0.20	
APIC (1–5)	3.25	0.82	0.18	0.26	
BRA (1–5)	3.11	0.54	0.32	0.29	

Table 4.
Additive (above the diagonal) and phenotypic (below the diagonal) correlations from the half sib families of *L.decidua* in each trial. All correlations except the one for height are based on nscore-transformed values. Bold correlations are significant at $p<0.05$.

Table 4A.
F1314 (Tönnersjö). *L. decidua*.

Trait	H	AUT1	AUT2	SPR1	SPR2	STR	APIC	BRA
H		**-0.73**	**-0.73**	**-0.92**	-0.19	-0.31	-0.27	-0.03
AUT1	**-0.18**		**0.84**	-0.22	-0.26	0.26	-0.07	0.17
AUT2	**-0.32**	**0.73**		-0.02	-0.07	0.40	0.48	-0.00
SPR1	-0.08	-0.06	-0.04		**0.81**	-0.21	0.60	-0.32
SPR2	-0.05	-0.02	-0.00	**0.51**		-0.37	0.08	-0.30
STR	**-0.15**	-0.12	-0.09	-0.11	**-0.12**		**1.05**	**0.72**
APIC	-0.06	-0.09	-0.09	0.02	0.01	**0.55**		**1.10**
BRA	-0.07	**-0.14**	**-0.16**	0.02	0.00	**0.57**	**0.56**	

Table 4B.
F1315 (Storebro). *L. decidua*.

Trait	H	AUT1	AUT2	STR	APIC	BRA
H		**-1.08**	**-1.03**	-0.27	-0.67	0.07
AUT1	**-0.18**		**0.93**	-0.06	0.52	0.00
AUT2	**-0.33**	**0.79**		0.20	0.22	0.05
STR	**-0.15**	0.05	0.10		-0.11	-0.39
APIC	**0.20**	0.05	0.08	**0.18**		**0.79**
BRA	0.03	0.09	**0.13**	**0.17**	**0.34**	

Table 5.
Pearson correlations between BLUP-values of the two trials for different traits for the half sib materials. All correlations except the one for height are based on nscore-transformed values. Bold correlations are significant at p<0.05.

Trait	*L. decidua*
H	**0.69**
SURV	0.34
AUT1	0.38
AUT2	**0.66**
SPR1	–
SPR2	–
STR	**0.40**
APIC	-0.30
BRA	0.19

Full sib families

The best full sib families for height all belonged to *L. x eurolepis* in both trials (Appendices 6 and 7). However, substantial numbers of hybrid families were of average growth. There were also hybrid families (S21H9580014, -0027, -0044) and European families (S21H9580048, -0050) that combined good growth with good stem quality. All *L. x eurolepis* progenies had higher survival rates, and all except one family had lower autumn phenology trait values, than the trial means, while values for the spring phenology traits varied around the means.

All material groups

Relative lsmean values were estimated among groups, as shown in Tables 6 and 7 for all materials. All four material groups of *L. x eurolepis* were amongst the "best growers" in both trials except for the Holbaek seed orchard material in F1315, which performed worse than average. This tendency was also found for survival. However, there were few significant differences between any of the *L. decidua*, *L. kaempferi* or *L. x eurolepis* materials. Such differences were limited to a few cases in which *L. sibirica* materials showed significantly poorer growth and lower survival rates than most of the other material groups.

Table 6.
Trial F1314 (Tönnersjö). Relative lsmean-values, rankings within brackets and Tukey-test results for the different material groups and traits. Differences between groups with Tukey-test letters in common within each trait are not significant (p<0.05).

Material / Species	**H**	**Tu**	**SURV**	**Tu**	**AUT2**	**Tu**	**SPR2**	**Tu**	**STR**	**Tu**	**APIC**	**Tu**	**BRA**	**Tu**
Full sib														
L. decidua	123 (5)	AB	79 (9)	ABC	48 (9)	AB	45 (11)	DEF	82 (6)	A	96 (6)	AB	88 (5)	A
L. kaempferi	119 (7)	AB	81 (8)	ABC	54 (6)	AB	57 (6)	DEF	66 (11)	A	94 (10)	AB	80 (9)	A
L. x eurolepis	130 (1)	A	86 (2)	AB	37 (10)	BC	30 (13)	EF	71 (8)	A	94 (9)	AB	81 (8)	A
Half sib														
L. decidua	123 (6)	AB	85 (3)	AB	50 (8)	AB	44 (12)	DEF	51 (13)	A	86 (14)	B	71 (12)	A
L. kaempferi	117 (9)	AB	70 (11)	BC	59 (5)	AB	56 (8)	DEF	66 (10)	A	92 (12)	AB	77 (10)	A
L. x eurolepis, F2	125 (4)	AB	82 (6)	ABC	54 (7)	AB	46 (10)	DEF	73 (7)	A	94 (8)	AB	85 (7)	A
Standards														
L. x eurolepis														
S.O. of Holbaek	125 (3)	AB	77 (10)	ABC	60 (4)	AB	51 (9)	DEF	70 (9)	A	97 (4)	AB	65 (14)	A
S.O. of Maglehem	128 (2)	A	87 (1)	A	77 (2)	AB	57 (7)	DEF	60 (12)	A	95 (7)	AB	75 (11)	A
L. sibirica														
S.O. of Damsjön	117 (8)	AB	85 (4)	AB	74 (3)	AB	77 (4)	BCD	50 (14)	A	93 (11)	AB	70 (13)	A
Ivanov, sukaczewii	107 (10)	B	84 (5)	AB	81 (1)	A	92 (3)	ABC	89 (4)	A	98 (3)	AB	94 (3)	A
S.O. of Imatra	37 (14)	D	47 (14)	D	1 (14)	D	24 (14)	F	98 (1)	A	100 (2)	AB	97 (1)	A
S.O. of Lassinmaa, Raivola	38 (13)	D	66 (12)	CD	2 (12)	D	70 (5)	CDE	91 (3)	A	88 (13)	B	95 (2)	A
Central, south Siberia	70 (11)	C	82 (7)	ABC	13 (11)	CD	94 (2)	AB	85 (5)	A	96 (5)	AB	93 (4)	A
S.O. of Östteg	41 (12)	D	62 (13)	CD	2 (13)	D	97 (1)	A	97 (2)	A	100 (1)	A	87 (6)	A
Mean	100		80		50		50		60		90		75	

Table 7.
Trial F1315 (Storebro). Relative lsmean-values, rankings within brackets and Tukey-test results for different material groups and traits. Differences between groups with Tukey-test letters in common within each trait are not significant (p<0.05).

Material / Species	**H**		**Tu**	**SURV**		**Tu**	**AUT2**		**Tu**	**STR**		**Tu**	**APIC**		**Tu**	**BRA**		**Tu**
Full sib																		
L. decidua	128	(4)	AB	89	(2)	A	35	(10)	DE	85	(1)	A	96	(2)	A	90	(2)	AB
L. kaempferi	110	(8)	ABC	80	(8)	ABCD	70	(6)	BCD	72	(4)	AB	79	(10)	AB	79	(5)	B
L. x eurolepis	132	(3)	AB	88	(3)	AB	42	(9)	CDE	54	(9)	AB	86	(8)	AB	66	(11)	B
Half sib																		
L. decidua	136	(2)	AB	87	(5)	ABC	33	(11)	DE	57	(7)	AB	93	(5)	AB	73	(9)	B
L. kaempferi	110	(7)	AB	68	(11)	CDEF	74	(4)	BCD	57	(8)	AB	80	(9)	AB	70	(10)	B
L. x eurolepis, F2	125	(5)	AB	86	(6)	ABC	61	(7)	BCDE	75	(3)	AB	93	(4)	A	84	(4)	B
Standards																		
L. x eurolepis																		
S.O. of Holbaek	98	(10)	BC	69	(10)	CDEF	73	(5)	BCD	83	(2)	A	94	(3)	A	85	(3)	AB
S.O. of Maglehem	145	(1)	A	88	(4)	AB	51	(8)	BCDE	37	(11)	B	87	(7)	AB	76	(8)	B
L. sibirica																		
S.O. of Damsjön	106	(9)	ABC	85	(7)	ABC	82	(3)	BC	64	(5)	AB	90	(6)	AB	78	(6)	B
Ivanov, sukaczewii	120	(6)	AB	90	(1)	A	84	(2)	AB	64	(6)	AB	97	(1)	A	98	(1)	A
S.O. of Imatra	46	(12)	CD	56	(13)	EF	2	(13)	F									
S.O. of Lassinmaa, Raivola	37	(13)	CD	43	(14)	F	2	(14)	F									
Central, south Siberia	70	(11)	CD	80	(9)	ABCD	99	(1)	A	39	(10)	B	65	(11)	B	77	(7)	B
S.O. of Östteg	37	(14)	CD	60	(12)	DEF	21	(12)	E									
Mean	100			80			50			60			90			75		

Discussion

Genetic parameters

Paques (2000) found weaker genetic variability in growth for Japanese larch than for European larch, suggesting that the potential for genetic improvement of growth was lower for *L. kaempferi*. The same tendency was detected in the present study, although it could not be statistically confirmed since all CV_A values for *L. kaempferi* were non significant.

Paques (2000) also stated that the heritable parental contribution of growth for the hybrid is equal between *L. decidua* and *L. kaempferi*, while wood traits are mostly contributed by *L. decidua* and architectural traits like stem straightness are mostly under the control of *L. kaempferi*. The latter assertion is supported by the results in this study since straightness was a highly genetically controlled trait for *L. kaempferi* in F1314 (Table 3C). On the other hand, the h^2 value for straightness was also rather high for *L. decidua* in F1315. The importance of this trait in larch has been stressed many times. Severe stem form defects can be a major problem with *Larix* species (Keiding & Olsen, 1965; Yde-Andersen, 1980). Hence it should be a target trait for both species.

Since F1315 is located in a climatically harsher region than F1314, greater genetic variation and higher h^2 values were expected in F1315 than in F1314 for *L. kaempferi*. However, high and significant h^2 values were only obtained for F1314, although the same families were included at both sites (Table 3C and 3D). As mentioned above, many of the seedlings were provided with supports a year after planting since they were leaning. This problem was more pronounced in F1315 and may have reduced the variation among progenies. Since the results are based on measurements after only four growing seasons, the findings should be interpreted with caution, and the intervention required to support the seedlings emphasises the need to treat the conclusions cautiously.

In both trials the additive correlation between height and the autumn phenology traits for *L. decidua* was negative (Table 4), indicating that late growth termination is correlated with increased growth. The correlation between height and the spring phenology traits in F1314 was negative, indicating that materials with late flushing tend to grow better. Both of these traits are related to the risk of frost damage. If growth starts too early or continues too long in the autumn there will be an increased risk of frost damage. Hence, the results indicate that either the autumns so far have been rather mild, or that the material is relatively insensitive to autumn frost. Spring frost was proposed by Wyckoff et al. (1992) to be one of the most limiting factors in larch plantations. However, autumn frosts have caused observed damage to *L. kaempferi* in Denmark (Möller, 1965) and *L. eurolepis* in the central part of southern Sweden (Larsson-Stern, 1999).

The genetic correlation between growth and straightness is often found to be negative (see, for instance, Paques, 1992a), i.e. the higher the growth rate, the more crooked the trees tend to be. This means that genetic gain will be limited when selection for both traits is carried out simultaneously. The same tendency was shown in this study, although the additive correlations (r_A) were weak and not significant (Table 4). The strong and positive r_A correlations between external stem quality traits (STR-BRA, APIC-BRA), suggests that when genetically improving one of the traits, the other trait will be improved as well. Strong r_A values were also found between the two spring phenology traits and between the two autumn phenology traits, suggesting that definitions of these traits for future classifications can be guided, to a large degree, by practical considerations. Finally, the rather strong correlations between BLUP-values for height and the autumn phenology traits of the two *L. decidua* trials indicated there was a weak genotype x site interaction for these traits (Table 5).

Comparisons of different materials

Survival of the half sib material was much poorer for *L. kaempferi* compared to *L. decidua* (Table 3). Because of its very southern and oceanic origin, *L. kaempferi* is sensitive to low temperatures, spring frost damage and drought (Paques, 2000), which might explain these results. This hypothesis is also supported by the higher mortality recorded in the climatically harsher site F1315 than in F1314, which is located close to the coast. Spring frost has been suggested to be one of the most limiting factors in larch plantations, and in a study by Wyckoff et al. (1992), *L. decidua* was found to be damaged less by frost than either *L. kaempferi* or *L. x eurolepis*. However, the phenological data (Table 3) indicate that *L. kaempferi* started growth later and ended growth earlier than *L. decidua* in F1315, which conflicts with the above remarks about the origin of the two species and their predicted responses to seasonal changes. In F1314 this tendency was reversed for growth initiation.

Hybrid vigour has been well documented in *Larix x eurolepis* (e.g. Einspahr, et al., 1984, Paques, 1989, Paques, 1992b). The hybrid generally ranks higher than its parental species for several important traits such as growth, stem form and wood mechanical properties. Higher survival rates have also been reported for the hybrid than for either parent (Miller & Thulin, 1967, Zaczek et al., 1994, Baltunis et al., 1998). Keiding (1962) suggested that part of the superiority of hybrid larch could be explained by its greater drought resistance and, in general, by its higher degree of fitness. If so, its advantage over the parental species would show up more clearly under more severe site and climatic conditions. In order to make true estimations of hybrid vigour, intra-specific crossings of the two parent species should also be included in the trial. Since such crosses were not included in this study, we can only obtain rough indications here of hybrid superiority. From the data in tables 6 and 7 we can see that the full sibs and the standards of *L. x eurolepis* all belong to the most highly ranked material groups in both trials, with the exception of the Holbaek seed orchard material in F1315. The Holbaek material is often preferred in southern Swedish plantations since the foresters find it usually grows straighter than the Maglehem seed orchard material. The superiority in straightness of the Holbaek material was noticed in trial F1315 (Table 7). On the other hand, growth and survival of the Holbaek material was poor at this site. This is probably not due to frost since the phenological data suggest that this material ceased growth earlier than the trial mean (Table 7) and renewed growth close to the trial mean (data not shown). Although the hybrids were consistently ranked near the top for growth, *L. decidua* performed well too. No significant differences among *L. decidua*, *L. kaempferi* and *L. x eurolepis* were found for growth.

From a breeder's perspective, the rankings of the individual *L. x eurolepis* full sibs are more interesting than those for *L. x eurolepis* as a whole (Appendices 6 and 7). With the exception of one family, the hybrids all belonged to the highest or intermediately ranked fullsibs in growth. In addition, some of the best growers also showed good external stem quality. This combination of good growth and good stem quality is promising for future genetic improvement of larch.

Harvesting seed from genotypically good hybrid larch clones would be a cheap way to produce hybrids. There are few reports about the performance of F2 generations of hybrid larch. However, Rohmeder and Schonbach (1959) found that F2 and backcross hybrids of *L. kaempferi* and *L. decidua* showed superiority over the pure parental species, but to a lesser degree than F1 progenies and, furthermore, the variability of the F1 and F2 progenies was comparable. Paques (2000) reported worse growth but better stem straightness, wood density (according to pilodyn measurements) and phenological performance for F2- compared to F1-progenies. Paques also stated that the family variation was much larger for the F2 generation with respect to growth and phenology, while it was about the same for wood density and lower for stem straightness in relation to the variation in the F1 generation. In the present study only five (F1314) and four (F1315) F2-hybrid families were included, making any general conclusion impossible. Furthermore, the F2's were not compared with the F1-generation but with pure *L. decidua* and *L. kaempferi* families (Appendices 4 and 5). However, from these results it can be seen that the growth of the F2's varied considerably (clones with high, intermediate and low rankings were found amongst them). For straightness all F2's were more highly ranked than the trial average.

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Appendix 1

Description of families and standards included in the two trials. S.O. = Seed Orchard.

Family Id	No of living trees F1314	F1315	Mother	Father	Country	Comments
Full sibs	***L. x eurolepis***					
S21H9580006	14	14	S08N2004	S08DK7001	SExDK	
S21H9580010	15	14	S08M3015	S08DK7004	SExDK	
S21H9580014	6		S08M3006	S08DK7007	SExDK	
S21H9580025	14		S21K9580125	S08DK7011	SExDK	
S21H9580027	8		S21K9580121	S08DK7001	SExDK	
S21H9580028	4		S21K9580121	S08N1003	SE	
S21H9580029	5		S21K9580121	S08DK7008	SExDK	
S21H9580035	6		S21K9580105	S08DK7011	SExDK	
S21H9580041	11		D02V982	S08DK7004	DK	
S21H9580044	4		D02V984	S08M2001	DK	
S21H9580078	11		D02K186	S08E2002	DKxSE	
	L. decidua					
S21H9580046	10	8	S08N2004	S08E2002	SE	
S21H9580047	10		S08M3015	S08E2002	SE	
S21H9580048	5		S08M3015	S08L2002	SE	
S21H9580050	13	15	S08M3006	S08L2002	SE	
S21H9580051	8		S08M3006	S08N2004	SE	
S21H9580057	5		S21K9580125	S08M2005	SE	
	L. kaempferi					
S21H9580061	12		S08M2001	S08DK7006	SExDK	
S21H9580062	12	5	S08M2001	S08DK7004	SExDK	
S21H9580063	10	11	S08L2005	S08DK7004	SExDK	
S21H9580065	4		S08L2005	S08DK7005	SExDK	
S21H9580070	13	13	S08DK7004	S08DK7010	DK	
S21H9580071	7		S08DK7004	S08DK7011	DK	
S21H9580075	12	10	S08DK7003	S08DK7011	DK	
S21H9580076	8		S08DK7003	S08N1003	DKxSE	
S21H9580077	6		S08DK7003	S08DK7008	DK	
Half sibs	***L. x eurolepis, F2***					
S21X9580003	15	13	S21K9580003		SE	Harvested in trial S21F78801
S21X9580004	13	15	S21K9580004		SE	Harvested in trial S21F78801
S21X9580005	12	8	S21K9580005		SE	Harvested in trial S21F78801
S21X9580006	13		S21K9580006		SE	Harvested in trial S21F78801
S21X9580007	10	12	S21K9580008		SE	Harvested in trial S21F78801
	L.decidua					
S21X9580101	15	5	S21K9580101		SE	Harvested in S.O. of Hjälmshult
S21X9580102	11	6	S21K9580102		SE	Harvested in S.O. of Hjälmshult
S21X9580103	15	9	S21K9580103		SE	Harvested in S.O. of Hjälmshult
S21X9580104	15	11	S21K9580104		SE	Harvested in S.O. of Hjälmshult
S21X9580105	15	14	S21K9580105		SE	Harvested in S.O. of Hjälmshult
S21X9580106	14	13	S21K9580106		SE	Harvested in S.O. of Hjälmshult

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Appendix 1. Continuation.

Family Id	No of living trees		Mother	Father	Country	Comments
	F1314	F1315				
	L.decidua					
S21X9580108	15	13	S21K9580108		SE	Harvested in S.O. of Hjälmshult
S21X9580109	15		S21K9580109		SE	Harvested in S.O. of Hjälmshult
S21X9580110	15	13	S21K9580110		SE	Harvested in S.O. of Hjälmshult
S21X9580111	15	12	S21K9580111		SE	Harvested in S.O. of Hjälmshult
S21X9580112	13	15	S21K9580112		SE	Harvested in S.O. of Hjälmshult
S21X9580113	15	14	S21K9580113		SE	Harvested in S.O. of Hjälmshult
S21X9580114	15	8	S21K9580114		SE	Harvested in S.O. of Hjälmshult
S21X9580115	13	14	S21K9580115		SE	Harvested in S.O. of Hjälmshult
S21X9580116	15	13	S21K9580116		SE	Harvested in S.O. of Hjälmshult
S21X9580118	15	15	S21K9580118		SE	Harvested in S.O. of Hjälmshult
S21X9580119	15	15	S21K9580119		SE	Harvested in S.O. of Hjälmshult
S21X9580122	15	15	S21K9580122		SE	Harvested in S.O. of Hjälmshult
S21X9580123	12	13	S21K9580123		SE	Harvested in S.O. of Hjälmshult
S21X9580124	13	12	S21K9580124		SE	Harvested in S.O. of Hjälmshult
S21X9580125	14	14	S21K9580125		SE	Harvested in S.O. of Hjälmshult
S21X9580126	15		S21K9580126		SE	Harvested in S.O. of Hjälmshult
S21X9580127	13	12	S21K9580127		SE	Harvested in S.O. of Hjälmshult
S21X9580128	7		S21K9580128		SE	Harvested in S.O. of Hjälmshult
S21X9580129	14	14	S21K9580129		SE	Harvested in S.O. of Hjälmshult
S21X9580130	12		S21K9580130		SE	Harvested in S.O. of Hjälmshult
S21X9580151	15	15	S21K9580131		CZE	Sudeten origin
S21X9580152	14	13	S21K9580132		CZE	Sudeten origin
S21X9580153	11	11	S21K9580133		CZE	Sudeten origin
S21X9580154	14	15	S21K9580134		CZE	Sudeten origin
	L. kaempferi					
S21X9580131	14	10	S08DK7001		DK	Harvested in S.O. of Klev
S21X9580132	13	10	S08DK7002		DK	Harvested in S.O. of Klev
S21X9580133	12	5	S08DK7003		DK	Harvested in S.O. of Klev
S21X9580134	9	5	S08DK7004		DK	Harvested in S.O. of Klev
S21X9580135	13	6	S08DK7005		DK	Harvested in S.O. of Klev
S21X9580136	10	9	S08DK7006		DK	Harvested in S.O. of Klev
S21X9580137	10	11	S08DK7007		DK	Harvested in S.O. of Klev
S21X9580138	12	7	S08DK7009		DK	Harvested in S.O. of Klev
S21X9580139	12	9	S08DK7010		DK	Harvested in S.O. of Klev
S21X9580140	11	11	S08DK7011		DK	Harvested in S.O. of Klev
S21X9580141	14	12	S08L1002		SE	Harvested in S.O. of Klev
S21X9580142	9	5	S08L1013		SE	Harvested in S.O. of Klev
S21X9580143	8	11	S08L1014		SE	Harvested in S.O. of Klev
S21X9580144	11	5	S08L2005		SE	Harvested in S.O. of Klev
S21X9580145	11	4	S08L2006		SE	Harvested in S.O. of Klev
jS21X9580146	4	7	S08L2007		SE	Harvested in S.O. of Klev
S21X9580147	5	4	S08M2002		SE	Harvested in S.O. of Klev
S21X9580148	7	7	S08N1001		SE	Harvested in S.O. of Klev
S21X9580149	5	10	S08N1002		SE	Harvested in S.O. of Klev
S21X9580150	9	7	S08N1003		SE	Harvested in S.O. of Klev

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Appendix 1. Continuation.

Family ID	No of living trees		Country	Comments
	F1314	**F1315**		
Standards	***L. x eurolepis***			
S21P9580001	15	14	SE	S.O. of Maglehem
S21A9680001	11	8	DK	S.O. of Holbaek
	L. sibirica			
S21A9680002	13	11	RU	Central south Sibiria
S21A9680003	9	2	FIN	S.O. of Lassinmaa with origin Raivola
S21A9780001	14	10	RU	Ivanov, sukaczewii
S21P7780001	14	13	SE	S.O. of Damsjön
S21P8680001	8	6	SE	S.O. of Östteg
S21P9380001	5	5	FIN	S.O. of Imatra

Appendix 2

Description of clones included in the full sib and half sib materials

Clone	Origin			Country
	Latitude	Longitude	Altitude, m	
L. kaempferi				
D02K186				DK
S08DK7001	56º32'		35	DK
S08DK7002	56º32'		35	DK
S08DK7003	56º15'		100	DK
S08DK7004	56º15'		100	DK
S08DK7005	55º50'		40	DK
S08DK7006	56º49'		90	DK
S08DK7007	56º32'		35	DK
S08DK7008	56º32'		35	DK
S08DK7009	56º32'		35	DK
S08DK7010	56º18'		90	DK
S08DK7011	55º59'		70	DK
S08L1002	56º18'		120	SE
S08L1013	56º15'	14º23'	135	SE
S08L1014	56º15'	14º23'	135	SE
S08L2005	56º20'	13º16'	130	SE
S08L2006	56º20'	13º16'	130	SE
S08L2007	56º20'	13º16'	130	SE
S08M2001	55º30'	13º25'	60	SE
S08M2002	55º30'	13º25'	60	SE
S08N1001	56º44'	13º08'	130	SE
S08N1002	56º44'	13º05'	130	SE
S08N1003	56º44'	13º08'	130	SE
L. decidua				
D02V982				DK
D02V984				DK
S08E2002	58º30'	15º50'	50	SE
S08L2002	55º54'	13º59'	100	SE
S08M2005	55º33'	13º59'	100	SE
S08M3006	58º30'	06º10'	350	SE
S08M3015	55º53'		67	SE
S08N2004	56º24'	13º00'	40	SE
S21K9580101	56º13'	12º07'	25	SE
S21K9580102	56º13'	12º07'	25	SE
S21K9580103	56º13'	12º07'	25	SE
S21K9580104	56º13'	12º07'	25	SE
S21K9580105	56º13'	12º07'	25	SE
S21K9580106	56º13'	12º07'	25	SE
S21K9580108	56º13'	12º07'	25	SE
S21K9580109	56º13'	12º07'	25	SE
S21K9580110	56º13'	12º07'	25	SE
S21K9580111	56º13'	12º07'	25	SE
S21K9580112	56º13'	12º07'	25	SE

→

Appendix 2.
Continuation.

Clone	Origin			Country
	Latitude	Longitude	Altitude, m	
S21K9580113	56º13’	12º07’	25	SE
S21K9580114	56º13’	12º07’	25	SE
S21K9580115	56º13’	12º07’	25	SE
S21K9580116	56º13’	12º07’	25	SE
S21K9580118	56º13’	12º07’	25	SE
S21K9580119	56º13’	12º07’	25	SE
S21K9580121	56º13’	12º07’	25	SE
S21K9580122	56º13’	12º07’	25	SE
S21K9580123	56º13’	12º07’	25	SE
S21K9580124	56º13’	12º07’	25	SE
S21K9580125	56º13’	12º07’	25	SE
S21K9580126	56º13’	12º07’	25	SE
S21K9580127	56º13’	12º07’	25	SE
S21K9580128	56º13’	12º07’	25	SE
S21K9580129	56º13’	12º07’	25	SE
S21K9580130	56º13’	12º07’	25	SE
S21K9580131			480	CZE
S21K9580132			480	CZE
S21K9580133			375	CZE
S21K9580134			490	CZE
***L. x eurolepis*, F2**				
S21K9580003	55º58’	13º45’	105	SE
S21K9580004	55º58’	13º45’	105	SE
S21K9580005	55º58’	13º45’	105	SE
S21K9580006	55º58’	13º45’	105	SE
S21K9580008	55º58’	13º45’	105	SE

Appendix 3

Crossing table for the full sib families included in the trials (the filled grey cells with the figures ”98”. Cells with ”X” refers to complementary crossings made in year 2000

		Fathers																
		L. kaempferi												**L. decidua**				
		M2001	DK7001	DK7006	DK7004	DK7007	DK7005	DK7002	DK7010	DK7011	N1003	DK7008	L2005	E2002	L2002	N2004	M3015	M2005
Mothers	E2002	x		x														
L. dec	L2002	x	x															
	N2004	x	98											98				
	M3015		x	x	98									98	98			
	M2005			x	x	x												
	M3006				x	98	x								98	98		
	E2009					x	x	x										
	107						x	x	x									
	126							x	x	x								
	125								x	98	x							98
	121		98							x	98	98						
	109										x	x	x					
	105									98		x	x					
	114					x							x					
	D02V981	x									x			x				x
	D02V982	x	x		98									x	x			
	D02V983		x	x											x	x		
	D02V984	98		x	x											x	x	
	E2008				x	x											x	x
L. kaemp	M2001		x	98	98													
	L2005		x	x	98		98											
	DK7006		x		x				x									
	DK7004			x					98	98	x							
	D02K186				x	x								98				
	DK7008					x	x	x										
	DK7003							x		98	98	98						

Appendix 4

Relative breeding values (BLUP) and rankings within brackets for clones based on the half sib material in trial F1314 (Tönnersjö). Standard error for relative height (H) is 7

Clone	H	SURV	AUT2	SPR2	STR	APIC	BRA
L. kaempferi							
S08DK7001	105 (14)	86 (23)	54 (18)	52 (23)	43 (43)	85 (46)	63 (50)
S08DK7002	94 (44)	83 (29)	57 (14)	91 (1)	69 (16)	93 (12)	85 (4)
S08DK7003	91 (49)	77 (41)	53 (21)	44 (31)	79 (6)	89 (33)	77 (18)
S08DK7004	96 (34)	63 (49)	57 (10)	82 (2)	36 (53)	90 (27)	64 (48)
S08DK7005	98 (28)	82 (32)	42 (44)	66 (14)	85 (4)	96 (2)	87 (3)
S08DK7006	96 (36)	68 (46)	59 (9)	63 (16)	55 (33)	87 (42)	73 (32)
S08DK7007	89 (51)	67 (47)	62 (6)	68 (11)	88 (2)	95 (4)	85 (6)
S08DK7009	97 (31)	78 (35)	42 (45)	44 (30)	65 (19)	93 (13)	71 (39)
S08DK7010	93 (46)	78 (37)	56 (16)	75 (7)	65 (20)	89 (32)	72 (36)
S08DK7011	95 (41)	74 (42)	49 (33)	42 (34)	92 (1)	96 (3)	84 (11)
S08L1002	99 (27)	86 (21)	57 (13)	80 (4)	60 (26)	92 (16)	71 (40)
S08L1013	91 (50)	64 (48)	52 (27)	60 (17)	47 (39)	85 (50)	66 (47)
S08L1014	107 (11)	55 (51)	47 (36)	49 (25)	48 (37)	90 (24)	74 (30)
S08L2005	103 (19)	73 (43)	57 (11)	37 (40)	61 (24)	86 (44)	74 (28)
S08L2006	98 (30)	72 (44)	60 (7)	37 (41)	79 (8)	92 (17)	85 (5)
S08L2007	82 (55)	31 (55)	63 (4)	54 (21)	78 (9)	90 (22)	84 (10)
S08M2002	101 (20)	38 (54)	52 (26)	65 (15)	79 (7)	93 (10)	75 (23)
S08N1001	98 (29)	50 (52)	48 (34)	29 (50)	51 (36)	91 (19)	72 (35)
S08N1002	95 38)	38 (53)	44 (41)	33 (46)	69 (15)	91 (18)	77 (19)
S08N1003	92 (47)	61 (50)	70 (2)	79 (5)	74 (12)	94 (5)	84 (9)
L. decidua							
S21K9580101	101 (23)	88 (3)	56 (15)	36 (42)	35 (54)	85 (49)	61 (52)
S21K9580102	113 (7)	87 (19)	32 (55)	32 (47)	58 (30)	86 (43)	76 (22)
S21K9580103	99 (26)	88 (3)	47 (35)	67 (12)	39 (51)	82 (53)	59 (54)
S21K9580104	104 (18)	88 (3)	53 (22)	70 (9)	53 (35)	86 (45)	64 (49)
S21K9580105	85 (54)	89 (1)	53 (19)	35 (44)	65 (18)	90 (23)	74 (27)
S21K9580106	95 (39)	85 (26)	68 (3)	28 (52)	48 (38)	89 (31)	70 (42)
S21K9580108	97 (32)	88 (3)	52 (24)	55 (18)	73 (13)	94 (8)	84 (12)
S21K9580109	95 (37)	88 (3)	40 (47)	66 (13)	61 (25)	90 (26)	85 (8)
S21K9580110	105 (17)	88 (3)	50 (32)	43 (32)	46 (41)	90 (25)	75 (24)
S21K9580111	96 (35)	88 (3)	59 (8)	52 (24)	37 (52)	81 (54)	60 (53)
S21K9580112	88 (52)	82 (31)	70 (1)	38 (39)	68 (17)	93 (9)	76 (21)
S21K9580113	117 (4)	88 (3)	33 (52)	9 (55)	59 (28)	87 (41)	72 (38)
S21K9580114	101 (21)	88 (3)	47 (37)	54 (20)	46 (40)	89 (34)	79 (14)
S21K9580115	101 (22)	82 (34)	56 (17)	34 (45)	54 (34)	87 (40)	73 (31)
S21K9580116	113 (6)	88 (3)	45 (38)	39 (38)	58 (29)	91 (21)	78 (16)
S21K9580118	105 (15)	88 (3)	43 (43)	73 (8)	62 (23)	89 (35)	72 (37)
S21K9580119	107 (13)	88 (3)	34 (51)	40 (36)	63 (21)	91 (20)	74 (25)
S21K9580122	95 (42)	89 (1)	62 (5)	28 (51)	56 (31)	85 (48)	67 (46)
S21K9580123	114 (5)	78 (38)	44 (40)	49 (26)	46 (42)	88 (36)	67 (45)
S21K9580124	95 (40)	85 (28)	50 (29)	46 (28)	43 (46)	82 (52)	69 (43)
S21K9580125	105 (16)	85 (24)	43 (42)	26 (53)	55 (32)	90 (29)	74 (26)
S21K9580126	94 (43)	88 (3)	51 (28)	30 (49)	75 (11)	90 (28)	77 (20)
S21K9580127	122 (1)	88 (18)	33 (53)	44 (29)	41 (48)	87 (39)	69 (44)
S21K9580128	100 (24)	85 (25)	52 (23)	36 (43)	42 (47)	88 (38)	79 (15)
S21K9580129	99 (25)	86 (20)	37 (50)	31 (48)	43 (44)	81 (55)	73 (33)
S21K9580130	107 (12)	78 (39)	50 (30)	46 (27)	60 (27)	92 (15)	74 (29)
S21K9580131	110 (8)	88 (3)	45 (39)	69 (10)	32 (55)	83 (51)	59 (55)
S21K9580132	117 (2)	85 (27)	38 (49)	39 (37)	43 (45)	88 (37)	78 (17)
S21K9580133	91 (48)	72 (45)	39 (48)	82 (3)	40 (49)	92 (14)	72 (34)
S21K9580134	93 (45)	86 (22)	32 (54)	43 (33)	40 (50)	85 (47)	62 (51)
L. x eurolepis, F2							
S21K9580003	109 (9)	88 (3)	42 (46)	23 (54)	63 (22)	89 (30)	71 (41)
S21K9580004	117 (3)	82 (33)	53 (20)	40 (35)	88 (3)	96 (1)	88 (1)
S21K9580005	85 (53)	77 (40)	50 (31)	53 (22)	77 (10)	94 (7)	84 (13)
S21K9580006	108 (10)	82 (30)	57 (12)	55 (19)	71 (14)	94 (6)	85 (7)
S21K9580008	97 (33)	78 (36)	52 (25)	77 (6)	80 (5)	93 (11)	87 (2)
Mean	100	80	50	50	60	90	75

Appendix 5

Relative breeding values (BLUP) and rankings within brackets for clones based on the half sib material in trial F1315 (Storebro). Standard error for relative height (H) is 7

Clone	H		SURV		AUT2		STR		APIC		BRA	
L. kaempferi												
S08DK7001	85	(50)	76	(33)	84	(4)	43	(48)	81	(50)	58	(46)
S08DK7002	92	(43)	76	(37)	72	(9)	51	(39)	81	(49)	55	(48)
S08DK7003	94	(39)	56	(46)	75	(8)	63	(20)	88	(31)	79	(20)
S08DK7004	90	(44)	56	(47)	71	(10)	44	(47)	86	(44)	62	(45)
S08DK7005	92	(42)	60	(44)	85	(3)	47	(43)	88	(30)	78	(23)
S08DK7006	95	(37)	73	(38)	77	(7)	57	(31)	86	(43)	81	(15)
S08DK7007	85	(49)	79	(31)	90	(1)	56	(34)	83	(48)	68	(35)
S08DK7009	88	(47)	64	(42)	70	(13)	63	(23)	85	(45)	67	(36)
S08DK7010	87	(48)	72	(39)	71	(11)	59	(28)	87	(42)	65	(42)
S08DK7011	88	(45)	79	(29)	86	(2)	59	(26)	88	(38)	71	(32)
S08L1002	95	(34)	82	(27)	63	(16)	45	(45)	85	(46)	66	(40)
S08L1013	95	(35)	56	(48)	63	(15)	59	(27)	87	(41)	75	(27)
S08L1014	94	(40)	79	(30)	70	(12)	49	(41)	83	(47)	65	(41)
S08L2005	102	(22)	56	(45)	59	(23)	71	(7)	91	(23)	81	(14)
S08L2006	96	(32)	51	(49)	59	(22)	56	(32)	88	(33)	65	(43)
S08L2007	94	(38)	65	(40)	62	(19)	65	(16)	88	(39)	81	(16)
S08M2002	95	(36)	51	(50)	62	(17)	64	(19)	89	(27)	69	(34)
S08N1001	95	(33)	65	(40)	60	(20)	62	(24)	92	(14)	74	(29)
S08N1002	99	(26)	76	(34)	62	(18)	52	(38)	87	(40)	69	(33)
S08N1003	93	(41)	64	(43)	78	(5)	63	(21)	88	(34)	82	(12)
L. decidua												
S21K9580101	103	(19)	87	(15)	51	(27)	47	(44)	92	(15)	79	(22)
S21K9580102	111	(6)	88	(12)	22	(45)	52	(37)	92	(17)	53	(49)
S21K9580103	112	(5)	89	(1)	21	(46)	71	(8)	93	(7)	84	(9)
S21K9580104	101	(23)	89	(1)	53	(26)	70	(10)	91	(19)	83	(11)
S21K9580105	98	(28)	87	(17)	32	(35)	75	(4)	88	(36)	57	(47)
S21K9580106	105	(15)	85	(25)	37	(32)	76	(2)	95	(2)	80	(18)
S21K9580108	103	(18)	85	(23)	23	(43)	65	(17)	91	(20)	80	(19)
S21K9580110	110	(8)	85	(24)	24	(42)	57	(30)	92	(13)	91	(1)
S21K9580111	105	(16)	82	(28)	32	(36)	63	(22)	94	(4)	80	(17)
S21K9580112	96	(31)	89	(1)	54	(25)	65	(15)	88	(32)	66	(38)
S21K9580113	117	(1)	87	(14)	16	(50)	64	(18)	91	(24)	77	(24)
S21K9580114	97	(30)	76	(35)	40	(31)	70	(9)	94	(5)	84	(8)
S21K9580115	98	(27)	87	(13)	59	(21)	76	(3)	93	(6)	66	(37)
S21K9580116	103	(20)	87	(19)	35	(33)	50	(40)	92	(12)	79	(21)
S21K9580118	109	(10)	89	(1)	23	(44)	74	(6)	89	(28)	66	(39)
S21K9580119	105	(14)	89	(1)	26	(41)	66	(14)	90	(26)	83	(10)
S21K9580122	110	(7)	89	(1)	35	(34)	57	(29)	92	(11)	72	(31)
S21K9580123	109	(9)	85	(20)	27	(39)	53	(36)	95	(1)	86	(5)
S21K9580124	106	(12)	84	(26)	43	(29)	56	(35)	93	(8)	85	(6)
S21K9580125	105	(13)	87	(18)	41	(30)	42	(49)	91	(21)	75	(26)
S21K9580127	114	(4)	88	(10)	17	(49)	56	(33)	92	(10)	81	(13)
S21K9580129	100	(25)	87	(15)	20	(47)	62	(25)	94	(3)	77	(25)
S21K9580131	116	(2)	89	(1)	19	(48)	67	(13)	88	(37)	48	(50)
S21K9580132	114	(3)	85	(22)	26	(40)	48	(42)	91	(22)	88	(2)
S21K9580133	104	(17)	79	(32)	29	(37)	44	(46)	88	(35)	74	(28)
S21K9580134	98	(29)	89	(1)	28	(38)	39	(50)	91	(25)	64	(44)
***L. x eurolepis*, F2**												
S21K9580003	106	(11)	85	(21)	64	(14)	78	(1)	93	(9)	85	(7)
S21K9580004	102	(21)	89	(1)	54	(24)	70	(11)	92	(18)	87	(4)
S21K9580005	100	(24)	76	(36)	48	(28)	74	(5)	92	(16)	88	(3)
S21K9580008	88	(46)	88	(10)	77	(6)	68	(12)	89	(29)	72	(30)
Mean	100		80		50		60		90		75	

Relative lsmean-values and rankings within brackets for the full sib families in trial F1314 (Tönnersjö). Standard error for relative height (H) is 6%

Family	H		SURV		AUT2		SPR2		STR		APIC		BRA	
L. kaempferi														
S21H9580061	92	(23)	78	(21)	25	(22)	59	(9)	61	(20)	96	(10)	83	(15)
S21H9580062	93	(22)	84	(14)	72	(4)	50	(12)	66	(19)	95	(12)	78	(20)
S21H9580063	104	(7)	84	(15)	40	(14)	50	(13)	59	(21)	94	(14)	72	(23)
S21H9580065	103	(11)	76	(24)	87	(2)	60	(6)	83	(6)	96	(9)	97	(1)
S21H9580070	84	(26)	81	(16)	43	(13)	41	(16)	78	(13)	91	(23)	85	(12)
S21H9580071	103	(10)	85	(12)	24	(23)	53	(11)	70	(16)	93	(18)	82	(18)
S21H9580075	93	(21)	78	(22)	49	(9)	71	(3)	83	(7)	95	(13)	83	(17)
S21H9580076	99	(15)	81	(18)	70	(6)	80	(1)	45	(24)	93	(20)	68	(24)
S21H9580077	94	(20)	79	(20)	94	(1)	63	(4)	34	(26)	87	(24)	77	(21)
L. decidua														
S21H9580046	85	(25)	80	(19)	13	(26)	59	(8)	94	(1)	97	(2)	95	(2)
S21H9580047	99	(14)	88	(1)	18	(24)	47	(15)	78	(12)	92	(21)	85	(11)
S21H9580048	108	(5)	70	(26)	69	(7)	34	(19)	74	(14)	91	(22)	83	(16)
S21H9580050	103	(9)	81	(17)	83	(3)	40	(17)	79	(10)	97	(5)	86	(9)
S21H9580051	98	(16)	75	(25)	70	(5)	28	(20)	84	(4)	97	(6)	86	(8)
S21H9580057	104	(6)	78	(23)	26	(21)	62	(5)	67	(18)	96	(8)	90	(6)
L. x eurolepis														
S21H9580006	103	(8)	84	(13)	15	(25)	15	(24)	79	(11)	97	(3)	91	(5)
S21H9580010	112	(3)	87	(4)	35	(16)	22	(23)	44	(25)	93	(16)	68	(25)
S21H9580014	109	(4)	86	(9)	34	(18)	36	(18)	73	(15)	95	(11)	82	(19)
S21H9580025	102	(12)	87	(5)	34	(17)	28	(21)	69	(17)	93	(19)	76	(22)
S21H9580027	115	(1)	86	(6)	33	(19)	50	(14)	80	(8)	97	(4)	84	(14)
S21H9580028	97	(19)	86	(7)	46	(11)	72	(2)	47	(23)	77	(26)	85	(13)
S21H9580029	97	(17)	86	(11)	45	(12)	12	(26)	91	(2)	99	(1)	93	(4)
S21H9580035	91	(24)	86	(9)	31	(20)	54	(10)	89	(3)	96	(7)	89	(7)
S21H9580041	97	(18)	88	(2)	62	(8)	24	(22)	53	(22)	80	(25)	54	(26)
S21H9580044	113	(2)	86	(7)	48	(10)	14	(25)	79	(9)	93	(17)	94	(3)
S21H9580078	99	(13)	88	(2)	38	(15)	60	(7)	84	(5)	94	(15)	86	(10)
Mean	100		80		50		50		60		90		75	

Appendix 7

Relative lsmean-values and rankings within brackets for the full sib families in trial F1315 Storebro). Standard error for relative height H) is 7%

Family	H		SURV		AUT2		STR		APIC		BRA	
L. kaempferi												
S21H9580062	87	(8)	66	(8)	74	(2)	54	(7)	67	(8)	62	(7)
S21H9580063	90	(7)	87	(4)	78	(1)	81	(2)	89	(3)	85	(3)
S21H9580070	99	(4)	85	(6)	58	(4)	68	(4)	77	(7)	75	(6)
S21H9580075	90	(6)	77	(7)	70	(3)	59	(6)	77	(6)	83	(4)
L. decidua												
S21H9580046	98	(5)	86	(5)	23	(8)	76	(3)	96	(1)	93	(1)
S21H9580050	113	(2)	90	(1)	38	(6)	83	(1)	96	(2)	86	(2)
L. x eurolepis												
S21H9580006	102	(3)	88	(2)	46	(5)	61	(5)	87	(4)	82	(5)
S21H9580010	122	(1)	88	(3)	37	(7)	47	(8)	84	(5)	44	(8)
Mean	100		80		50		60		90		75	