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The interest in growing hybrid larch (*Larix* × *eurolepis* A. Henry) in Sweden has increased during the past few decades. This is mainly due to expectations concerning rapid growth, resistance to butt rot and durability of the wood. A yield study in hybrid larch was conducted based on 28 plots in southern Sweden. The plots were established on fertile sites in stands managed in practical forestry. A growth model was developed, including regression functions for basal area increment, stand form-height development and initial basal area. Top height growth curves from a Norwegian study were also included in the model. A yield table was calculated for the age span 15–45 yrs. The calculations showed that the yield of hybrid larch in southern Sweden compared with Norway spruce was slightly higher and especially more rapid when young. On fertile sites the mean annual volume growth peaked at an age of 35 yrs, at a level of 13 m^3 ha^{-1}. *Key words: Growth model, growth simulator, yield study.*

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INTRODUCTION

The interest in growing hybrid larch (*Larix* × *eurolepis* A. Henry) in Sweden began about 30 yrs ago and has increased ever since. The recognition of hybrid larch as a potentially valuable tree species was mainly due to its assumed resistance to root and butt rot [*Heterobasidion annosum* (Fr.) Bref.] compared with Norway spruce [*Picea abies* (L.) Karst]. The hybrid was also believed to have inherited several valuable properties from its parent species: rapid growth and resistance to larch cancer (*Lachnellula willkommii* Carr.) from Japanese larch (*L. kaempferi* Lamb.) and good stem form from European larch (*L. decidua* Mill.). In general, hybrid larch has been considered to grow rapidly, especially when young, and its timber is expected to be durable in external constructions. At present the timber prices are high, even for small log dimensions. These assumptions and facts will yield a high calculated land expectation value for hybrid larch, compared with other larch species and spruce (Larsson-Stern 2003).

As yet, there is insufficient scientific evidence to assess the degree to which these positive properties really exist. However, in the case of root and butt rot, it has been shown that hybrid larch is at least as susceptible as Norway spruce (Vollbrecht & Stenlid 1999, Rönnberg & Vollbrecht 1999).

The growth and yield of hybrid larch have been studied previously in Denmark (Keiding 1980), France (Ferrand & Bastien 1985), Belgium (Nanson & Sacré 1978), England (Hamilton & Christie 1971) and Germany (Braun & Hering 1987, Gothe 1987). Most of these studies were conducted on young stands.

The Swedish University of Agricultural Sciences has established a series of hybrid larch single plots, with the intention of long-term monitoring of growth and yield. However, to date, only one of these plots has been observed for more than 10 yrs. In 1990 the University also established a thinning experiment in hybrid larch.

The increasing interest in hybrid larch necessitates the estimation of its expected average growth and yield in southern Sweden. Currently, the scientific data available from Sweden are insufficient for a yield study. Therefore, data from practically managed stands in southern Sweden were required for the analysis. The objective of this study was to examine the growth pattern of hybrid larch grown in forestry plantations in southern Sweden and to calculate a yield table well represented in data. The calculations

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had to be restricted to average conditions since the variation in site conditions, stand structure and applied silviculture is quite restricted in practical forestry and hence in the collected data.

MATERIALS AND METHODS

Data collection

Forest managers in southern Sweden were asked to identify well-managed stands of hybrid larch. From 100 suggestions, 28 stands (Table 1) were selected according to the following criteria: the stands should have a size of at least 0.25 ha and be growing on mineral soils, hybrid larch should account for at least 90% of the total growing stock, the total age should be known and should be at least 10 yrs, and the stands should have been managed according to standard practice, i.e. frequent and relatively heavy thinnings. It was considered advantageous, in addition, to know the stand history and the seed origin. The selected stands were concentrated in the south-western part of Sweden (Fig. 1). The latitude ranged from 55°36′ to 58°01′ N and the altitude from 25 to 190 m a.s.l.

Data were collected in the autumns of 1991 and 1997, from circular sample plots with a radius of 10 m. A single plot was established in stands with a density of more than 2000 trees ha^{-1} [diameter at breast height (dbh) $>$ 5 cm] and two plots in stands with a lower density. The plot centres were chosen at random, but with the constraint that the plots had to be surrounded by a buffer zone with a width at least the half of the average tree height. Plots and trees were permanently marked.

Measurements

The site data collected for each stand were soil moisture, surface/subsurface water flow, vegetation type, soil texture and soil depth, which were classified according to Hägglund & Lundmark (1977, 1982*a*). The site index (SI) for Norway spruce, H_{100} (top height, averaged for the 100 largest trees ha^{-1}, at the total age of 100 yrs), was estimated on the basis of the site properties, i.e. vegetation type, soil moisture, latitude, etc. (Hägglund & Lundmark 1982*b*).

The dbh was measured for all trees in the sample plots. For the other parameters, an average of 28 sample trees per plot was selected; the five trees with the greatest dbh were always included and the remainder were chosen at random. The tree height, height to first living branch and bark thickness at breast height of the sample trees were measured.

Cores were extracted at breast height from trees outside the sample plots, to determine the relation between total age and age at breast height.

During the 6 yr observation period (1991–1997) 16 of the stands were thinned, three of them twice. On these occasions the dbh of all trees, including the removed ones, was measured. However, in four of the stands the trees had already been harvested. Where this had happened, the dbh of the thinned trees was estimated from the relationship between dbh and diameter at stump height. The relationship was assessed with a simple regression approach, using data from the remaining trees.

Data processing

Stem volume on bark for sample trees was estimated using volume functions for Japanese larch (Carbonnier, Ch., Royal College of Forestry Stockholm, 1954, unpubl.). Plotwise secondary volume functions were calculated from the sample tree data, i.e. volume was regressed on dbh. These functions were used to assign volumes to the trees for which only dbh was measured.

SI for Japanese larch was used to classify the site fertility. H_{40} (top height at 40 yrs in breast height) was estimated using height growth curves from Norway (Wielgolaski 1993).

For each stand, top height, volume, basal area, number of stems and average diameter were calculated at the start and at the end of the observation period, as well as for thinnings carried out during the period. Basal area increment and volume increment were then calculated from these data. (The calculations were made plotwise and averaged for stands)

Stand and site data

The age at the beginning of the observation period ranged from 13 to 35 yrs, and averaged 24 yrs (Table 1). The average SI (H_{40}) for Japanese larch was 27.7 m (range 24.1–33.5 m) and the average SI (H_{100}) for Norway spruce was 33.7 m (29–36 m). There was no field vegetation in 47% of the stands. In the remaining stands, 21% were dominated by grasses and 32% by herbs. The soil moisture was classified as mesic in 79% and dry in 21% of the stands. In 86% of the stands the soil type was moraine, and the remaining 14% were sediments.

The number of thinnings in the stands before 1991 ranged from none to five. The first thinning was on

Table 1. *Stand data at the start of the observation period (1991), thinning history and increment in height and volume during the 6 yr observation period (1991–1997)*

			Stand data 1991						Thinnings			Annual increment	
Stand	P[a]	Site index[b] (m)	Total age	Top height (m)	No. of stems (ha^{-1})	dbh[c] (cm)	Basal area (m^2 ha^{-1})	Volume (m^3 ha^{-1})	No. of thinnings before 1991	Year[d]	Harvested volume (m^3 ha^{-1})	Top height (dm)	Volume (m^3 ha^{-1})
1	M	26.4	16	12.6	2196	11.2	21.5	113				6.0	15.3
2	M	24.1	22	14.9	1209	14.5	20.0	132				5.8	13.4
3		33.5	24	22.3	566	22.8	23.2	244	2			5.8	16.9
4		27.8	15	12.7	1446	14.2	22.8	128				8.9	18.9
5		26.9	14	11.4	2037	11.7	21.8	117				3.0	20.0
6	M	26.9	15	12.2	2132	13.0	28.5	161		1993	23	10.9	21.6
7		28.1	27	20.3	716	21.4	25.7	241	1	1991	45	5.3	15.1
8	M	26.4	24	17.6	557	27.6	33.3	265	1			5.8	15.2
9		26.0	31	20.8	605	23.4	26.0	258	2	1995	52	5.0	13.6
10		28.5	33	23.7	605	26.2	32.6	361	2			5.2	20.8
11		29.1	23	18.7	796	20.7	26.8	225	2			6.5	15.8
12		26.2	33	21.9	382	26.9	21.8	231	2	1993	45	4.3	13.4
13	H	25.6	23	16.5	1098	19.1	31.6	243	2	1996	73	4.9	11.2
14		26.1	31	20.9	637	23.2	26.9	274	2	1994	77	4.5	11.0
15	M	28.3	16	13.7	1719	14.7	29.3	174	1			7.9	17.6
16	Dk	27.9	20	16.1	1146	18.6	31.0	226	1			6.6	16.9
17	M	29.4	19	16.4	859	21.6	31.6	230	2	1993	52	5.9	14.8
18		26.1	29	19.9	446	26.5	24.6	218	3	1991.95	32, 49	4.1	9.4
19		30.2	13	12.2	1878	13.6	27.3	149		1992.94	36, 36	7.7	16.4
20		29.5	35	25.5	286	29.2	19.1	232	5	1996	71	3.2	7.2
21		25.8	25	17.7	525	22.7	21.2	173	5	1994	26	5.4	12.6
22		27.4	25	18.8	477	25.0	23.4	206	5	1994	28	3.5	13.2
23	M	26.8	25	18.4	987	18.3	26.0	214	2	1992.96	45, 45	5.1	12.0
24		26.9	25	18.4	382	22.5	15.2	135	5			5.7	12.7
25	H	26.0	21	15.6	955	19.0	27.1	197	2	1996	25	6.1	14.3
26	H	28.5	22	17.8	732	22.8	30.0	244	2	1992	93	2.9	9.2
27	M	31.8	21	19.2	637	23.8	28.3	247	1			6.6	16.4
28		28.5	33	23.7	461	23.5	20.0	235	2	1992	95	3.2	9.9
Mean		27.7	24	17.9	945	20.6	25.6	210				5.6	14.5
Min.		24.1	13	11.4	286	11.2	15.2	113				2.9	7.2
Max.		33.5	35	25.5	2196	29.2	33.3	361				10.9	21.6

[a] Provenance: M: Maglehem, Sw; H: Holbæk, Dk; (others not known).
[b] H_{40} for Japanese larch (Wielgolaski 1993).
[c] Quadratic mean diameter.
[d] Thinning 1992, thinning during winter 1992/93, etc.

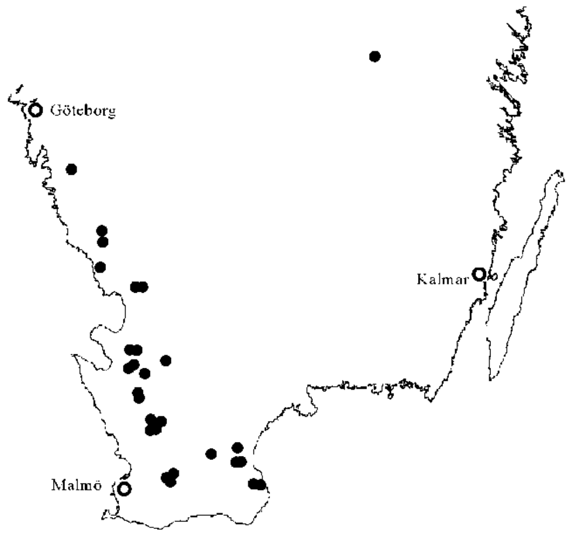

Fig. 1. The study stands in southern Sweden. The latitude ranged from 55°36′ to 58°01′ N.

average conducted at an age of 17 yrs (11–24 yrs) and the average interval between thinnings was 5 yrs (1–11 yrs). The average volume harvested during thinnings within the observation period was 50 m^3 ha^{-1} (23–95 m^3 ha^{-1}) (Table 1).

The growth model

Stand models (Munro 1974) have frequently been used to produce yield tables (Fries 1974, Assman 1970, Dudek & Ek 1980, Trinkle & Shrier 1981). In this study a stand model was developed with a configuration similar to that of several others from Sweden (Eriksson 1976, Hägglund et al. 1979, Ekö 1985, Agestam 1985). Calculations were based on basal area increment, mainly because it is more accurately assessed than the volume increment (Eriksson 1976).

The model includes regression functions for the estimation of basal area in the initial stand, for the estimation of basal area increment and for the estimation of stand form-height. The model also includes top height curves for Japanese larch in Norway (Wielgolaski 1993). Ingrowth and mortality rate are not estimated.

When calculating yield tables, the simulations were made recursively for 5 yr periods, starting at the time of the first thinning.

Estimation of the initial basal area of the stand

Only six of the stands were unthinned before the first inventory (Table 1). Therefore, an additional of 10 observations from permanent plots in hybrid larch in southern Sweden were incorporated (data not shown). Within the 16 observations the top height ranged from 11.5 to 15.5 m, with an average of 13.7 m, the number of stems ranged from 1500 to 3000 ha^{-1}, with an average of 2100 ha^{-1}, and the basal area ranged from 21.4 to 35.8 m^2 ha^{-1}, with an average of 27.5 m^2 ha^{-1}. A simple linear multiple regression model was used to estimate basal area (ba) from top height (h) and number of stems (s):

$$ba_j = c + b_1 h_j + b_2 s_j + \varepsilon_j \tag{1}$$

where ε_j is a random component N(0, ε_j) for the jth stand.

Stand form-height function

Stand volume can be expressed as the product of basal area, height and a stand form factor. The regression model chosen to estimate stand form-height (fh) (cf. Eriksson 1976, Hägglund et al. 1979) was:

$$\ln(fh_j) = c + b_1 \ln(h_j) + b_2 \ln(dbh_j) + \varepsilon_j \tag{2}$$

where dbh is the quadratic mean diameter.

An alternative approach would have been to use stand volume as the dependent variable, instead of the stand form-height, and include basal area as an independent variable in the regression. However, owing to the limited number of observations this was considered a risk, as basal area accidentally and incorrectly might be correlated to the stand form factor.

Basal area growth function

The growth model was based on the hypothesis that tree growth is determined by internal factors, including size and genetic constitution, and external factors, including competition and site fertility. In addition, it was assumed that the effects of these factors interact multiplicatively (Baule 1917). This assumption frequently underlies both stand and single tree growth models (Jonsson 1969, Hägglund et al. 1979, Ekö 1985). The specification of the model was restricted owing to the limited number of observations. The following regression model was derived:

$$\ln(iba_j) = c + b_1 SI_j + b_2 ba_j + b_3 h_j + b_4 dbh_j + b_5 th_j + \varepsilon_j \tag{3}$$

where iba is the annual basal area growth and th is a variable designed to estimate the effect of thinnings. The variable th has the form $\Sigma_{i=1}^{n} \Sigma_{t=t_a}^{t_a+p} e^{t_{0_i}-t}$

$+\Sigma_{i=1}^{k}\Sigma_{t=t_{0_i}}^{t_a+p}e^{t_{0_i}-t}$, where the first term considers the n thinnings before the observation (growth) period and the second term the k thinnings carried out during this period. In the formula t_{0_i} is the age at the time of the ith thinning, t_a is the age at the beginning of the observation period and p is the length of the observation period. The variable is designed to catch simultaneously the effect of all thinnings carried out in the stand. As already stated, it is necessary to keep the number of independent variables to a minimum; therefore, only one variable is used. Furthermore, data on the removal are not known for all thinnings, thus restricting the use of more complex variables. The impact of a thinning on growth is greatest during the first year after thinning and is then assumed to decrease rapidly. (The variable takes the value 1.58 for a thinning carried out at the start of the observation period, decreasing to 0.58, 0.21, 0.07, 0.03 and 0.01 for thinnings carried out 1–5 yrs before the period.)

The parameters in functions 1 and 3 were estimated assuming that the observations were independent. However, for the form-height function (2) data from both the beginning and the end of the observation period were used to cover as great top height interval as possible.

Calculation of a yield table

The growth model was used in a simulator to produce a yield table. The average SI and the average data relating to the initial stand were specified in the calculations. Thinning grades and thinning intervals were selected to reflect standard practice.

RESULTS

The average observed annual increment in top height was 0.6 m (range 2.9–10.9 m), the average current annual basal area increment was 1.2 m^2 ha^{-1} (0.5–2.3 m^2 ha^{-1}) and the average annual volume increment 14.5 m^3 ha^{-1} (7.2–21.6 m^3 ha^{-1}) (Table 1).

Residuals and partial relationships were used to examine the estimated regression functions (Table 2). Graphical inspection of the residuals showed that the functions fitted the data well (cf. Fig. 2). However, some of the variables contained within the functions were not significant.

The residual standard deviation about the basal area growth function (3) was 65% of the standard deviation about the mean and the regression explained 76% of the variation.

The yield table (Table 3) was calculated for $H_{40}=28$ m, which was the average SI from the data (Table 1). In the initial stand, the number of stems was set as 2000 stems ha^{-1} and the total age as 15 yrs. This corresponds to a top height of 13.0 m and to a basal area of 26.2 m^2 ha^{-1}, estimated by function (1). The simulation was continued up to a stand age of 45 yrs, 4 yrs more than the highest age in the data set. Thinnings were simulated every fifth year. The basal area after thinning was maintained at an almost constant level, varying between 17.5 and 20.8 m^2 ha^{-1}. The thinning quotient was varied from 0.90 in the first thinnings to 0.98 in the last thinning. The estimated volume removed ranged from 39 to 54 m^3 ha^{-1}.

The simulation demonstrated a rapid growth in the young stand. The annual volume increment during the first 5 yr period, age 15–20 yrs, was 16.9 m^2 ha^{-1}, compared with 11.7 during the final period, age 40–45 yrs. The mean annual increment (MAI) at the start of the simulation was 9.8 m^2 ha^{-1}; it peaked at 13.0 m^2 ha^{-1} at an age of 35 yrs. The MAI dropped only slightly during the two following periods and was 12.8 m^2 ha^{-1} in the last period. The final stand contained 330 stems, with an average dbh of 30.4 cm and an average stem volume of 0.92 m^2.

DISCUSSION

The model logic and the model specification seem reasonable and agree with other models of similar type. To preserve the logic of the model, the non-significant variables were not excluded from the functions. This will, however, not lead to biased estimates. Explanations as to why basal area and quadratic mean diameter were not significant could be that these variables are correlated to one another and to other independent variables. The variation in basal area is also quite small in the data set (Table 1). (Furthermore, the calculation of the quadratic mean diameter is based on basal area and the significance of these variables should therefore be judged simultaneously).

The available data were restricted with regard to both the number of observations and the length of the observation period. Furthermore, the material was not homogeneous concerning the genetic properties, since the seedlings originated from at least two commercial seed orchards (Table 1). A recent study found that

Table 2. *Regression functions for estimation of (a) basal area in the initial stand, (b) stand form-height, and (c) basal area increment (the constants in b and c are corrected for logarithmic bias)*

Independent variables	Coefficients	SE (% of coefficient)	p-value
(a) Dependent variable: basal area in the initial stand (m^2 ha^{-1})			
Constant	-0.9828	969	0.9194
Top height (dm)	0.1956	32	0.0081
Number of stems per ha	8.214×10^{-4}	286	0.732
R^2	0.35		
SE	3.1		
No. of observations	16		
(b) Dependent variable: ln(stand form-height) (dm)			
Constant	-2.945	9	0.0000
ln(top height) (dm)	0.8733	9	0.0000
ln(dbh [a])	0.1620	36	0.0083
R^2	0.97		
SE	0.06		
No. of observations	56		
(c) Dependent variable: ln(annual basal area increment) (m^2 ha^{-1})			
Constant	0.9020	56	0.0903
Site index (dm)	2.271×10^{-3}	81	0.2273
Basal area (m^2 ha^{-1})	3.732×10^{-3}	216	0.6473
Top height (dm)	-6.159×10^{-3}	33	0.0056
dbh [a]	-1.296×10^{-2}	112	0.3825
Thinning response variable [b]	-7.257×10^{-2}	39	0.0179
R^2	0.76		
SE	0.17		
No. of observations	28		

[a] Quadratic mean diameter.

[b] $$\sum_{i=1}^{n}\sum_{t=t_a}^{t_a+p} e^{t_{0_i}-t} + \sum_{i=1}^{k}\sum_{t=t_{0_i}}^{t_a+p} e^{t_{0_i}-t}$$

where t_{0_i} is the age at thinning, t_a is the age at the beginning of the growth period and p is the length of growth period. The first term considers the n thinnings before the thinning period and second term the k thinnings within the period.

commercially available hybrid larch seed lots often contain a substantial number of both pure European and Japanese larch seeds (Prat et al. 2000). It is obvious from field observations that there is variation among the stands in this study, in the different tree characters, particularly stem straightness.

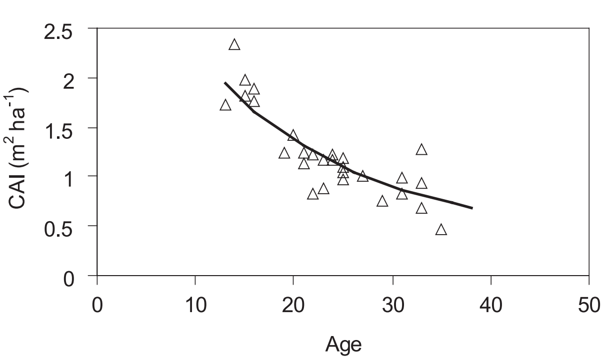

Fig. 2. Observed (triangles) and estimated (dots) current annual basal area growth (CAI) (site index $H_{40} = 28$ m).

The data suggest that there is a wide range of thinning practices, with differences in timing of the first thinning, intervals between thinnings and the thinning grade. However, from interviews with the managers of the plots, it was evident that they shared similar opinions on appropriate silvicultural practices, i.e. heavy and frequent thinning. The main difference was related to the length of the planned rotation.

The top height growth curves for Japanese larch in western Norway (Wielgolaski 1993) may not be applicable to hybrid larch in southern Sweden. If this were the case, the site classification and estimates of volume and volume increment would be biased. Therefore, the observed top height growth during the observation period was compared with the estimates from the top height growth curves produced by Wielgolaski. The height growth was slightly underestimated, 1.6% (SD 25%) ($p = 0.85$). There was no significant correlation between the residuals and top height or SI. This suggests that the top height growth curves for Japanese larch were also applicable for hybrid larch stands in southern Sweden.

Another potential source of bias was the use of functions for Japanese larch to estimate the stem volume of single trees (Carbonnier, Ch., Royal College of Forestry Stockholm, 1954, unpubl.). However, no attempt was made to study differences in stem form between Japanese and hybrid larch.

The high significances of the independent variables in the form-height function (2) may be because the observations were not independent. To study the effect of using non-independent observations in estimating the parameters of the stand form-height function (2), a recalculation was made using only observations from the first inventory. The coefficient estimates were still highly significant and differed only slightly from the original ones.

Growth was observed over a relatively short period, during which the weather may have been different to the long-term average. However, annual year ring indices were not available for the study years, so corrections to account for the current weather could not be made (Johnsson 1969, Hägglund 1981).

A comparison was made between simulations with the growth model and yield tables for Japanese and hybrid larch in Great Britain by Hamilton & Christie (1971). The table for yield class 12 was used for the comparison. SI according to Wielgolaski (1993) ($H_{40} = 22.3$ m) was determined from the top height growth in Hamilton & Christie. The forecast with the model started from the initial stand given in the yield table by Hamilton & Christie. Thinnings were simulated for intervals of 5 yrs. On every occasion the basal area was lowered, to simulate thinning, to the same value as given by the yield table, and the number of stems was lowered accordingly.

The top height growth pattern according to the models agreed well (Fig. 3). Except for the first 5 yr period, there was also good agreement in basal area growth. However, the volume estimates differ. It should be noted that the volume growth according to Hamilton & Christie refer to volume with a minimum top diameter of 7 cm. Therefore, a correction was made to include the total stem volume (Ollas 1980). This correction resulted in an increase in MAI from 12.0 to 13.1 m^2 ha^{-1}. The difference in volume estimate between the models was greatest in the first part of the simulation period, but was small in the late part. However, in total, the estimated MAI according to the growth simulator in this study was 15% lower (11.1 m^2 ha^{-1}) than estimated by Hamilton & Christie. The good agreement between Hamilton & Christie and the growth simulator, especially at older ages, indicates that reasonable

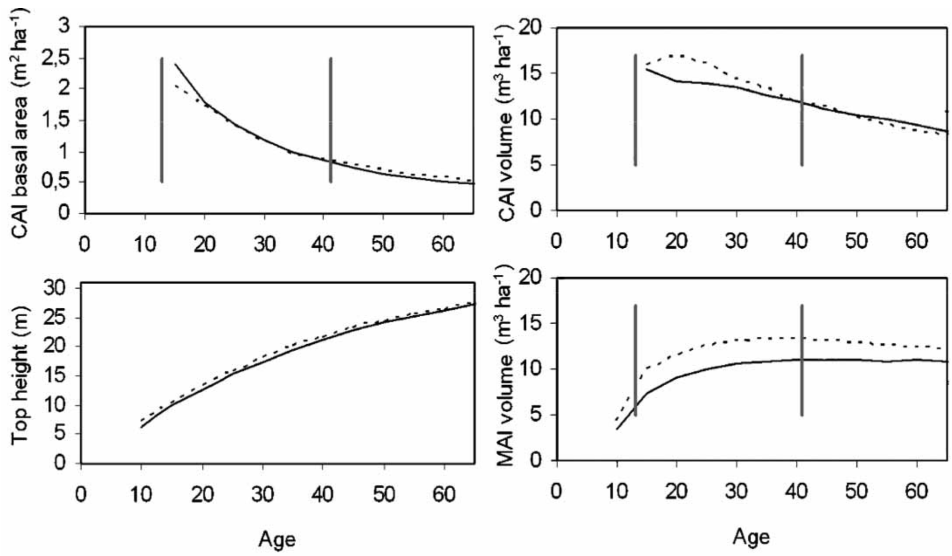

Fig. 3. Comparison between the stand development for Japanese and hybrid larch according to Hamilton & Christie (1971), yield class 12 (dotted line) and a forecast made with the growth simulator (solid line). The vertical grey lines mark the limits of the data underlying the growth simulator. CAI: current annual increment; MAI: mean annual increment.

Table 3. *Yield table for hybrid larch stands in southern Sweden, site index (H_{40}) = 28 m*

			Before thinning				Thinning						
Stand age	Age at breast height	Top height (m)	No. of stems (ha^{-1})	dbh[a] (cm)	Basal area ($m^2\ ha^{-1}$)	Volume ($m^3\ ha^{-1}$)	No. of stems per ha	dbh[a] (cm)	Basal area ($m^2\ ha^{-1}$)	Volume ($m^3\ ha^{-1}$)	CAI ($m^3\ ha^{-1}$)	MAI ($m^3\ ha^{-1}$)	Total yield ($m^3\ ha^{-1}$)
15	11	13.0	2000	12.9	26.2	146	811	11.6	8.6	47		9.8	147
20	16	16.2	1189	16.7	26.0	183	412	15.5	7.8	54	16.9	11.5	230
25	21	19.2	778	20.1	24.7	209	201	18.6	5.4	45	15.9	12.4	310
30	26	21.8	577	23.3	24.6	238	113	22.3	4.4	43	14.9	12.8	384
35	31	24.2	464	25.9	24.5	264	73	25.3	3.7	39	13.8	13.0	455
40	36	26.4	391	28.2	24.5	289	61	27.8	3.7	43	12.8	12.9	516
45	41	28.4	330	30.4	23.9	304					11.7	12.8	576

[a] Diameter corresponding to the mean stem basal area.
CAI: current annual increment; MAI: mean annual increment.

extrapolations could be made up to an age of approximately 60 yrs.

The growth model could be used in a simulator to forecast the stand development with varying SIs or thinning programmes. However, there is a risk of extrapolation errors owing to the limited data on which the model is based. Despite this, simulations were run to examine the relationship between SI and MAI. The estimated MAI was 11.8 $m^2\ ha^{-1}$ for SI 26, 13.0 $m^2\ ha^{-1}$ for SI 28 and 13.9 $m^2\ ha^{-1}$ for SI 30. It should be noted that this range of SIs corresponds to twice the SD in the data. Simulations were also run with the average basal area set either 20% higher or 20% lower than in the yield table (Table 3). The MAI was increased by 3% when using the higher average basal area and reduced by 4% with the lower one. These simulations show that the model performs logically.

This study confirmed the general belief that hybrid larch stands on fertile sites in southern Sweden had high and initially rapid growth. The traditional species alternative on the study sites is Norway spruce. The estimated average SI for Norway spruce (H_{100}) on these sites was 33.7 m, which corresponds to an MAI of 12.4 $m^2\ ha^{-1}$ (Hägglund & Lundmark 1982*a*). Thus, estimated yield was 5% higher in the hybrid larch stands. However, at an age of 35 yrs the total yield in Norway spruce (Eriksson 1976, yield table G32: 2, i.e. $H_{100} = 32$ m and four thinnings) was only about 60% of that in hybrid larch. Comparing the two species, the great difference in growth patterns, despite the same level of MAI, indicates that hybrid larch could be an economically favourable alternative to Norway spruce in commercial forestry.

For the future it is important to study the growth pattern of middle-aged and older hybrid larch stands, the relationship between SI and volume growth, and the impact of silviculture on growth and yield. However, for the near future, since there is a lack of data, conclusions must be based mainly on experience from other larch species, particularly Japanese larch.

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