Larch in Commercial Forestry: A Literature Review to Help Clarify the Potential of Hybrid Larch (*Larix* × *eurolepis* Henry) in Southern Sweden

Marie Larsson-Stern
Southern Swedish Forest Research Centre
Alnarp

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Summary

There are about ten larch species in the world as well as several varieties and hybrids, but larch is not native to Scandinavia.

As early as in the 18th century, Carl von Linné found larch to be fast growing and its wood to be durable, with possible uses in construction of houses and ships. Therefore he suggested that larch should be planted in Sweden. Today, the larch species used in Sweden are Japanese larch (*Larix kaempferi* (Lamb.) Carr.), European larch (*L. decidua* Mill.), Siberian larch (*L. sibirica* Ledeb. and *L. sukaczewii* Djil.) and hybrid larch (*L.* × *eurolepis* Henry). Hybrid larch refers to the hybrid between Japanese and European larch and is the most commonly used larch in southern Sweden. The total standing volume of larch amounts to less than one million m^3 (0.1% of the total standing volume) in southern Sweden (Götaland). Due to fossil findings, Siberian larch is today regarded as native to Sweden, which means that it can be used without restrictions. For other larch species, there are legal requirements to notify the County Board of Forestry about plantations larger than 0.5.

Both European and Japanese larch are hardy enough to survive spring frosts south of Limes Norrlandicus (Dalälven, lat. 60º). However, Japanese larch can suffer from autumn frosts because lignification occurs late in its young shoots, so it is recommended only on sites with a relatively mild climate in southern Sweden. As the difference between provenances and clones could be of great importance to frost resistance, the hardiness of hybrid larch depends on the origin of the parent species.

Hybrid larch seeds are produced by hybridisation in seed orchards. However, there is no guarantee that only hybrid larch seeds will be produced in these orchards. Orchards that have just one mother clone (often Japanese larch) from which the cones are gathered, and one or several father clones are less risky in these respects than orchards where cones are gathered from either of the parents.

It is impossible to distinguish hybrid larch from its parents by morphology. Methods using enzyme systems for identifying biochemical differences between the hybrid and its parents have recently been developed.

The variation among provenances and clones in the parent species could be of great importance for frost resistance, volume growth and wood properties in hybrid larch. This indicates that there is substantial scope for improvement. However, recombination of larch species is not straightforward: flowering occurs early in spring for instance and frost damage occurs frequently. Japanese and European larch clones flower disjointly and heavy flowering is irregular. Only limited amounts of seed are available in Europe. Therefore, trials have been made to produce vegetatively propagated hybrid larch from cuttings.

Larch is sensitive to shading and thinning operations should therefore start early, at the age of about 15 years, and successive thinnings are often done at intervals of

about five years. The aim of silviculture could be to produce trees with high timber quality and large dimensions, which would require a rotation period of at least 80 years. Since the growth culminates early, a shorter rotation period, of 30-50 years, could be an economically interesting alternative.

Young hybrid larch grows rapidly. Height and diameter growth of hybrid larch exceed the growth of the parent species by 10-30% up to the age of 10 years. Data presented show that the mean annual increment for hybrid larch in southern Sweden culminates at about 35 years of age at ca. 13 m^3/ha. Current annual increment peaks before the age of 20 years (*ca.* 17 m^3/ha).

Another silvicultural option for larch is to use it as a shelter in oak (*Quercus robur* L.) and beech (*Fagus sylvatica* L.) plantations, which has a long tradition. Besides acting as a shelter in such circumstances it can provide an early income.

Ungulates and rodents can severely damage larch through browsing on and fraying seedlings. However, treatment with repellents after needle fall in autumn has efficiently deterred roe deer from browsing. The pine weevil (*Hylobius abietis* L.) can cause severe damage in larch plantations. The insect not only eats the bark from the root collar upwards, but may also kill the top-shoots of larger seedlings.

Hybrid larch has high resistance to larch canker (*Lachnellula willkommii* (Hartig) Dennis). The canker can cause serious damage to European larch, but Japanese larch is considered to be more resistant. Hybrid larch and the parent species are susceptible to root and butt rot infection caused by *Heterobasidion annosum* (Fr.) Bref., which could cause heavy economic losses.

Young stands of larch are susceptible to wind throw, but older larch stands (ca. 20 m tall) are considered to be highly resistant. As larch sheds its needles in the autumn it tends to be more resistant to winter storms and snow damage than many other conifers.

In general, larch wood has higher density and hardness compared to Scots pine (*Pinus silvestris* L.) and Norway spruce (*Picea abies* L. Karst.). Annual ring width is an important predictor for wood properties of larch. Heartwood of larch is considered to be as durable as heartwood of Scots pine. High wood density and narrow ring width increase the natural durability of larch. However, major differences have been shown between different provenances, and also between individuals within provenances. The proportion of heartwood in larch is greater than in Norway spruce and Scots pine, and can account for more than 80% of the total wood volume.

Today (2003), larch timber fetches good prices in southern Sweden. The wood is used for play equipment, internal and external wall boards and for various other purposes. However, because of the high content of arabinogalactan in the wood it is not desired by the pulp industry.

Introduction

The forests in southern Sweden are dominated by Norway spruce (*Picea abies* (L.) Karst.) stands, but there is a desire to promote greater variation in tree species composition for commercial forestry in southern Sweden. Increasing the use of larch (*Larix sp.*) species could therefore be attractive in the future.

In the 1940s considerable efforts were put into studying larch and larch breeding for forestry in Sweden, but interest in these areas has been low in recent decades. However, interest in larch is growing again, both in Sweden and other parts of Europe. The EU-project “Towards a European larch wood chain” (European Commission FAIR, project no CT-98-3354) was a joint program that started in 1998 and finished in 2002, with participants in France, Great Britain, Ireland, Germany, Belgium, Austria, Italy, the Czech Republic and Sweden. It included industrial and laboratory investigations of larch wood quality, preparation of guidelines for larch stand establishment and management, a breeding program and development of efficient and economic techniques for mass-production of seedlings. As part of this project the Swedish Forest Research Institute (SkogForsk) studied vigour, vitality and wood quality of hybrid larch for use in commercial plantations in Northern Europe.

Objectives

The purpose of the study presented here was to collate knowledge from literature sources about the possibilities and problems associated with growing larch in southern Sweden. The study focused especially on the establishment and management of hybrid larch stands. Some information about larch wood properties and the use of larch wood was also acquired, and is presented here. However, the amount of scientific literature on these subjects is quite limited so handbooks and other literature have also been used.

The introduction of larch into Sweden

Larch forests essentially encircle the Northern Hemisphere (Figure 1) at mid-to-high latitudes, but natural larch forests are absent in Scandinavia (Schmidt 1995).

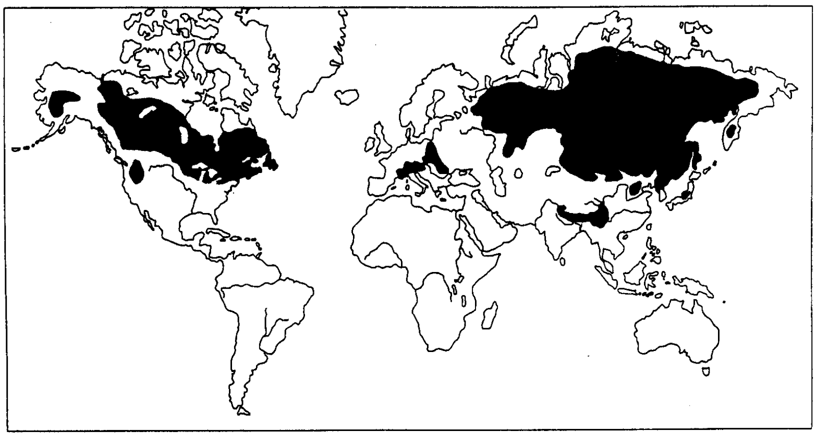

Fig. 1. The natural range of the genus *Larix* throughout the world (after Krüssmann 1985).

Fossil records of larch (*Larix sp.*) indicate that the genus has been widely distributed throughout the high latitudes of North America and north-eastern Asia for a long time, and that it reached Europe several million years ago. Larches occupy a wide range of ecological habitats including early successional forests, open-boreal forests, bogs, treeline forests (altitudinal and latitudinal), forests on fluvio-glacial soils, talus slopes, and moraines. Many of the species are adapted to a cold climate with short vegetation periods (LePage & Basinger 1995). There are about ten larch species in the world and several varieties and hybrids (Vidacovic 1991).

Cones and wood of Siberian larch (*Larix sibirica* Ledeb.) radiocarbon-dated between 8700 and 7500 BP have recently been recovered from two sites in the Scandes Mountains in Sweden, which proves that larch has occurred naturally in Sweden since shortly after the last glacial period (Kullman 1998). Climate change could be one reason that larch is not currently found in natural stands in Scandinavia. Siberian larch is adapted to continental climates with extremely cold winters. Such conditions may have been frequent during the early-Holocene in western Fennoscandia. Hemberg (1899) believed that the migration of larch was slowed by human activities as the trees could have been harvested for their valuable timber.

While the coniferous forests in Sweden are dominated by only two native conifer tree species, Scots pine (*Pinus silvestris* L.) and Norway spruce, forests in similar climatic regions in other parts of the world tend to have much greater tree species diversity. The specific circumstances during the immigration of trees into Sweden and the isolated position of the country appear to be the main reasons why the Swedish forest is so poor in the number of tree species. This situation has prompted the idea of introducing foreign tree species into Sweden (Schotte 1917).

Carl von Linné (Linnaeus 1754) suggested that foreign tree species should be planted in Sweden in the 1700s. He found larch to be fast growing and its wood to be durable, with possible uses in construction of houses and ships. Venetian turpentine was a product of larch available in pharmacies in Sweden in the 1700s

(Linnaeus 1754). In 1763 Clas Alströmer sent home two-year-old European larch (*Larix decidua* Mill.) seedlings from London that were planted on the Gåsevadholm estate in Halland in Southwest Sweden (Schotte 1917). The first plantation on a large scale was established in about 1789 at Koberg in Västergötland in southwestern Sweden with seedlings from Great Britain (Schotte 1917). During the first half of the 1800s larch was used as a forest tree with seeds mostly imported from Great Britain. Japanese larch (*Larix kaempferi* (Lamb.) Carr.) and Siberian larch were not cultivated as forest trees in Sweden before the end of the 1800s (Schotte 1917).

Today, the larch species used in commercial forestry in Sweden are Japanese larch, European larch and Siberian larch (*L. sibirica* Ledeb. and *L. sukaczewii* Djil.). The most commonly used species in southern Sweden is the hybrid between the first two of these species, the hybrid larch (*L.* × *eurolepis* Henry). Japanese larch is judged to be suitable to grow in southern Sweden, and European larch in southern and central Sweden. Siberian larch is mostly used in northern Sweden.

According to the National Forest Survey (SLU 2001) the total standing volume of larch amounts to less than one million m^3 in southern Sweden (Götaland), and 63 % of the trees have a diameter larger than 30 cm. (Table 1).

Table 1. Standing volume of larch by diameter class. Productive forest land in Sweden (SLU 2001)

Diameter class (dbh, cm)	0-9	10-14	15-19	20-24	25-29	30-34	35-44	45-	All	% of total standing volume
	(million m^3)									
Götaland (S. Sweden)	0.0	0.0	0.0	0.1	0.2	0.1	0.2	0.2	0.8	0.1
Sweden in total	0.0	0.1	0.2	0.2	0.2	0.1	0.2	0.3	1.4	0.0

The Swedish National Board of Forestry has defined tree species that have been absent since the last glacial period as foreign (Skogsstyrelsen 1994). According to the Forestry Act foreign tree species should be used only in exceptional cases. Until recently, there has been no evidence for larch being native in Scandinavia, so larch has been considered a foreign tree genus. However, as mentioned above, cones and wood of Siberian larch have been recovered from two sites in the Scandes Mountains in northern Sweden (Kullman 1998). The National Board of Forestry (Skogsstyrelsen 2000) has therefore decided that Siberian larch should be regarded as native in Sweden, which means that it can be used to any extent the forest owners want. For other larch species, the County Board of Forestry must be notified about plantations larger than 0.5 ha.

According to official statistics in Sweden about 150 ha of larch was planted in 1999 (Skogsstyrelsen 2000). This was probably an underestimate since forest nurseries have an annual production rate of 1-1.5 million seedlings (of which 600,000 are imported) per year. However, larch is often planted in small patches and nurse crops, where notification is not compulsory.

Morphology and natural distribution of larch species used in commercial forestry in Sweden today

European larch

European larch is distributed throughout the Alps, the Carpathians, Sudetern and southern and central Poland, forming various, separate ranges and races (Figure 2). European larches occur at elevations ranging from 200 to 2400 m (Vidakovic 1991) in pure and mixed stands with Norway spruce, European beech (*Fagus sylvatica* L.), *Abies sp.* and *Pinus mugo* Turra (Møller 1965).

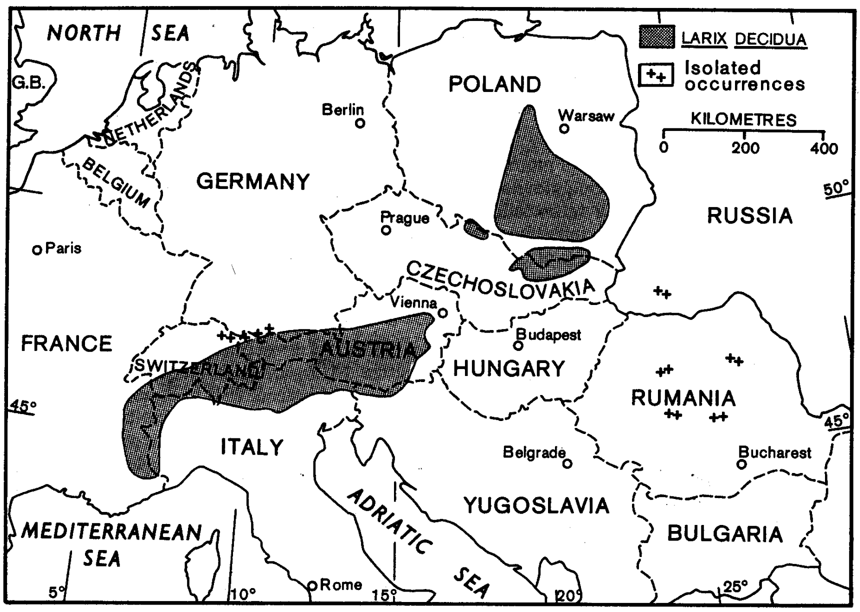

Fig. 2. Natural distribution of European larch (after Mc Comb 1955).

The European larch may reach a height of 35 m. The crown is open, thin and conical from the top but turning irregular lower. The bark is scaly and grey on young trees, while adult trees have thick, grey-brown bark. The branches are horizontal and spreading or pendulous, with ends turned upwards. The shoots are yellowish and the short shoots are black-brown. The buds are reddish-brown, and terminal buds are resinous. The needles are bright green, turn golden yellow before falling, occur in clusters of 30-40 on the short shoots, and are 1-3 cm long. Flowers appear from March to May. The cones are ovate, 2.5-4 cm long, and *ca.* 2 cm across. The European larch begins to flower frequently and abundantly at an age of 6 to 10 years. Cones for seed production are collected in September and October. The heartwood accounts for a large proportion of the wood, and is reddish to yellow-red. The sapwood is yellow (Vidakovic 1991).

Japanese larch

The natural distribution of Japanese larch is restricted to latitudes between 35° 8' and 38° 5' N. in the central part of Honshu in Central Japan (Figure 3). It occurs on the slopes of volcanic mountains, at elevations of 600 to 2500 m, most commonly between 1400 and 1800 m (Vidakovic 1991). It often grows in mixed stands with *Abies homolepis* Siebold & Zucc. at lower elevations, *Tsuga diversifolia* (Maxi.) Mast. and *Abies veitchii* Lind. at higher elevations (Møller 1965).

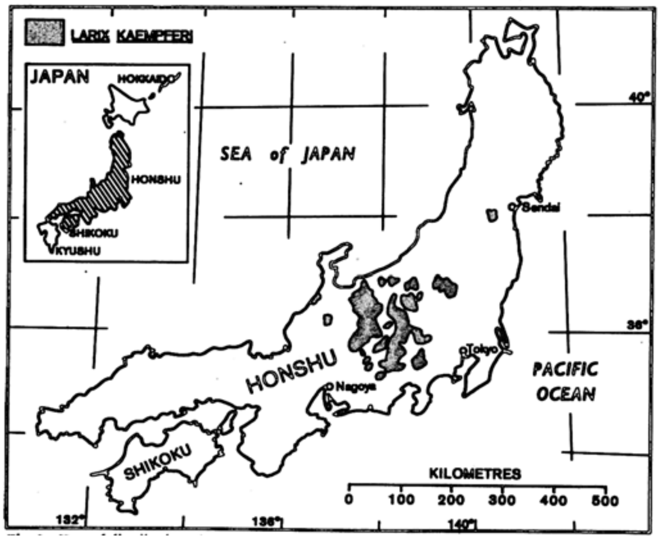

Fig. 3. Natural distribution of Japanese larch (after Katayama *et al*. 1964).

Japanese larch can reach a height of 30 m. The bark of young trees is reddish, later peeling off in small plates or narrow strips, and is reddish in places where dead bark has fallen off. The branches are short and horizontally spreading. The one-year-old shoots are reddish-brown, grooved, glabrous or slightly pubescent. The short shoots are thick, short and reddish, with 40-50 needles. The needles are 1.5-3.5 cm long, soft, glaucous-green, turning golden-yellow in autumn. Flowering occurs in March and April. The cones are ovate, 1.5-3.5 cm long, maturing in August and September. Seed is shed from September to spring. Seed of Japanese larch matures earlier in spring than that of European larch. It starts producing seed at an age of 5 to 10 years, and full seed crops are produced from an age of 15-20 years (Vidakovic 1991).

Hybrid larch

The first hybrid larch was found in Dunkeld in Scotland in the first years of the 1900s. It was the result of a spontaneous cross between a Japanese larch as the female parent and a European larch, growing next to it in the grounds of Dunkeld Castle. The growth of the hybrid was regarded as vigorous, and it was officially named by Henry & Flood (1919). Distinguishing hybrid larch from its parents is difficult. The morphological characters of the hybrid can be either intermediate between the parents, or very similar to either of the parent species (see, for instance, Delevoy 1949, Vidacovic 1991). The shape is similar to that of Japanese larch, except that it has a somewhat narrower crown. The branches have ascending tips. The shoots are yellow-brown, glabrous or slightly pubescent. The buds are red-brown and not resinous. The needles are blue-green, long and wide like those of Japanese larch, or somewhat smaller in size. The cones are small and conical (Vidakovic 1991) and intermediate in appearance compared with the parent species (Figure 4).

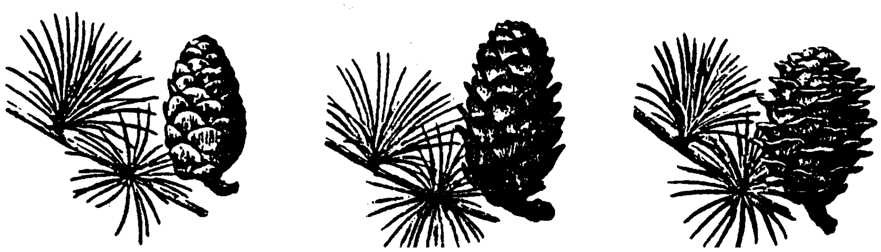

Fig. 4. Cones of *L. decidua*, *L. eurolepis* and *L. kaempferi* (after Mitchell 1974).

Siberian larch

Old Siberian larch trees can reach heights of up to 45 m, with a breast height diameter of 80-180 cm. The trunk is straight and the branches short and ascending. The bark is reddish-brown. The crown of young trees is narrow and conical. The branches on older trees are more spreading. One-year-old shoots are pale yellow and glossy, grooved and slightly pubescent at first, and later glabrous. The short shoots are densely arranged, the buds are brown, and very dark to almost black at the base. Needles, which occur in clusters of 30-50, are 3-4 cm long and up to 1 mm wide. Flowering time is in April and May. The cones are oblong-ovate and 2.5-4 cm long. They ripen from September to November, but can be collected from August to October. This species releases seed at an age of about 12 years and reaches biological maturity in 400 to 500 years (Vidakovic 1991).

Siberian larch occurs in the north-eastern parts of European Russia and western Siberia, east of Lake Baikal and north to the tundra. In its native habitat it can withstand very low temperatures, even 50 °C below zero. It tolerates a wide range of soil types and grows on various terrains, from saline steppe to distinctly moist areas, but prefers deep, moist soil (Vidakovic 1991). According to Vidakovic (1991), Djilis divided this species into two: *L. sukaczewii* Djil. occurring in the north-eastern part of European Russia, the Urals and West Siberia to the rivers Ob and Irtish, and *L. sibirica* Ledeb. occurring in the Eastern part of West Siberia. The English name Siberian larch is used for both of the species (Martinsson 1995). The natural distributions of the two species according to Abaimov *et al.* (1998) are shown in Figure 5.

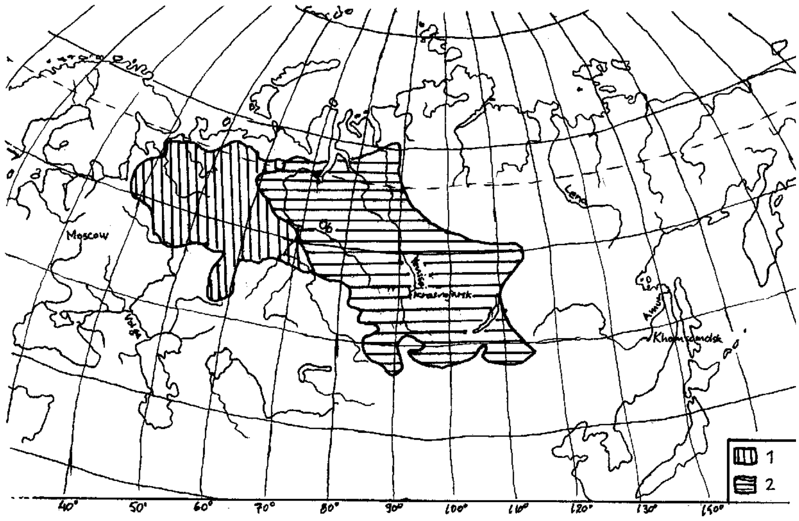

Fig. 5. Natural distributions of Sukaczewii (1) and Siberian (2) larch (after Abaimov *et al.* 1998).

Hybrid larch identification

Hybrid larch seeds are mainly produced in hybridisation seed orchards. There is, however, no guarantee that only hybrid larch seeds will be generated in them. Pure parent seeds will also be produced to some extent (Pâques 2000). Some orchards have one mother clone (often Japanese larch) from which the cones are gathered, and several father clones. Other orchards have several, mixed clones of both Japanese and European larch, and cones can be gathered from either of the parents. None of the designs will guarantee the production solely of hybrid larch seeds, but the latter strategy is more risky.

Since hybrid larches have a similar morphology to the pure species, as mentioned above, there is also no guarantee that only hybrid seedlings will be selected in the nursery. It is therefore important to find reliable methods to identify the species. Methods for identifying biochemical differences between the hybrid and its parents have been developed that distinguish the interspecific hybrid seed (embryos) from the parental species using differences in dehydrogenase (shikimate and NADH) enzyme systems (Bergmann & Ruetz 1987, Häcker & Bergmann 1991). This method is, however, not universally applicable, and can only be used in orchards where a specific allele distinguishes one of the two species.

Recently a set of mitochondrial and chloroplastic markers with interspecific polymorphism patterns has been developed which could be used for species identification. Hybrids are then identified by the maternal inheritance of the mitochondrial marker and the paternal inheritance of the chloroplastic marker. A study using this method confirmed there was a remarkably low proportion of

hybrids in commercial seed lots (2-67%) from four seed orchards in Europe (Acheré *et al*. 2002) and the proportion varies from year to year.
Scheepers *et al.* (2000) have worked with species-specific markers in European, Japanese and hybrid larch. The four RAPD primers selected in the cited study were shown to be reliable tools for the identification of different larch species.

Site requirements

Soil and water requirements

European larch grows most strongly on moderately rich soils, often giving very good results on light loams, while Japanese larch requires plenty of moisture in the soil (Vidakovic 1991). In a German study, Japanese larch proved to perform well on moist sites. For European larch, dry sites were the best. Hybrid larch showed an intermediate dependence on soil moisture (Haasemann & Tzschacksch 1986). At the end of the 19th century Höhnel maintained (according to Møller 1965) that larch consumes 5-10 times more water than other conifers, while Schubert stated (according to Kiellander 1965) that water uptake and evaporation is twice as high for larch than for Norway spruce and four times higher than for Scots pine. Unfortunately, there are no experimental data to verify these claims.

Practical experience suggests that site conditions that would be classed as intermediate (*i.e.* neither rich nor poor) for Norway spruce (SI G30-32) are most suitable for hybrid larch in southern Sweden (Larsson-Stern 1999). On richer sites, *e.g.* former agricultural land, its growth is strong, but its stem quality seems to be poor. However, hybrid larch is often used as a shelter for broad-leaved tree species on these types of sites. The best stem form is achieved on relatively light soils according to Henriksen (1988).

Light demands

Larch is a pioneer tree species with high demands for light, even compared to other pioneer tree species. According to Kiellander (1965) larch is less shade tolerant than any of the native forest tree species used in Swedish forestry.

Climatic preferences

Height increment in Denmark is completed in September for Japanese larch and in July for Norway spruce and Scots pine (Møller 1965). A factor with a strong influence on resistance to late autumn frost is the lignification of the shoots. This process is dependent on the critical night length and the minimum temperature sum. A northern transfer means that the critical night length will be reached later in the autumn. If the larch is moved too far north the minimum temperature sum may not be reached, and the young shoots will be damaged by autumn frost (Simak 1979). In a study of hybrid larch in Sävar in northern Sweden the survival was low and many trees were damaged, probably due to lack of hardiness (Jonsson 1978). According to the experience of forest managers in southern Sweden, spring frost is considered a problem for hybrid larch plantations on exposed sites (Stern 1988).

Kiellander (1958) uses climate zones defined by Ullström (1966) when describing where to grow different larch species. These climate zones were initially used for growing fruit trees. Both European and Japanese larch are hardy enough to survive spring frosts south of Limes Norrlandicus (Dalälven, lat. 60° N). European larch could be grown approximately in climate zones I-IV (Figure 6). Japanese larch is recommended only in zones I and II due to the late lignification of its young shoots. Hybrid larch is recommended in zones I-III, but its hardiness depends on the origin of the parent species.

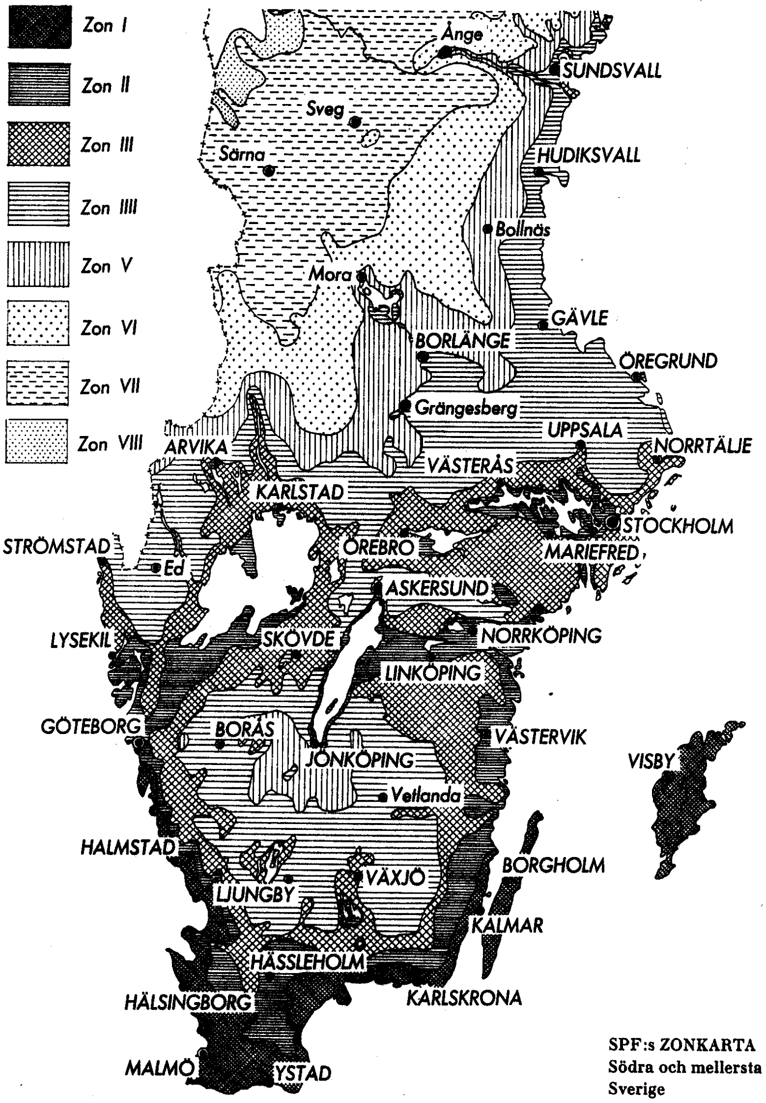

Fig. 6. Climate zones in southern and central Sweden according to the Swedish Pomological Society Scheme (Ullström 1966). Hybrid larch is recommended in zone I-III.

Seeds and seedlings

The reproductive biology is similar in all larches. Cones are normally initiated on short shoots in the summer, and overwinter as preformed buds. Pollination occurs in late winter or early spring of the second year. Fertilisation occurs about six weeks later, then embryos and cones mature in late summer. Cone production is periodic, and the ratio of filled seeds per cone is generally low (Owens 1995).

Causes of low seed set include insufficient pollination and embryo abortion (Owens 1995, Pâques 2000).

Most of the hybrid larch seedlings grown in Sweden originate from the Maglehem seed orchard in southern Sweden, which consists of one Japanese larch clone, called M 2001, and nine European larch clones selected from Swedish forest stands (Hannerz *et al*. 1993). After a progeny test one European clone was removed in 1979 to improve the stem quality. Materials from orchards in Denmark, especially Fp 203 in Holbæk, have also been used in Sweden for a long time.

For a long time there has been a scarcity of hybrid larch seeds in different parts of Europe. Using seed from genotypically superior hybrid larch clones (F_2) could provide a viable way to meet the demand for hybrid larch seeds. Pâques (2000) found that the F_2 generation tended to be much less vigorous than the F_1 generation, but was better in terms of stem straightness and phenology, and displayed considerable family variation. Brandt (1977) does not recommend collecting seeds from hybrid larch stands for production of planting material as the progeny will be a mix of high and low quality seeds.

Vegetative propagation

Vegetative propagation studies started in the 1950s and there is still a need for mass-production of planting stock (Harrison *et al*. 2002). So far no hybrid larch cuttings have been produced for commercial use in Sweden.

Seed supplies from untested random-mating seed orchards met at most 20% of the annual demand in Great Britain at the time of a study by Mason & Gill (1986) and similar limitations have been (and are) seen in other European countries. Rooted cuttings could be used to fill this shortage. Mason (1989) investigated the rooting performance of winter cuttings of hybrid larch collected from two-year-old parents. High levels of rooting, 89-96%, were obtained. The best rooting medium was a peat:bark mixture. Pâques (1992) obtained a similar rooting percentage, 87% (range, 37-100%) in France. In a study by Morgan (1992) the rates of growth of hybrid larch cuttings were equivalent to those of good quality transplants. Bare-root winter cuttings were recommended rather than summer cuttings since they had a lower predisposition to plagiotropism. Nowadays, juvenile individuals (1-4 yrs old) from entire selected families are propagated rather than individual selected clones. Rooting is kept on average at about 70% and cumulated numbers of rooted cuttings/stockplants over four years can exceed 600 plantlets (Le Pichon *et al*. 2001). Plagiotropy is not entirely absent, but is much less frequent, severe and prolonged. A reasonable economic alternative could be to produce vegetatively propagated hybrid larch from cuttings, provided that the percentage of rooted cuttings is high enough (Harrison *et al*. 2002). The expected threshold for economic viability seems to be 60% rooting. Hardwood tip cuttings rooted in a free-draining substrate at 80% relative humidity is proving to be most successful. The cuttings can be produced at between 2 and 2.5 times the cost of seed-propagated material.

Breeding

There are differences between provenances and clones regarding frost resistance, volume growth and wood properties (*cf.* Lines 1987; Martinsson 1991; Schober 1981), indicating that there is substantial potential for improvement.

Recombination of larch species is, according to Pâques (2000), one of the most stringent constraints in the breeding process, especially in artificial crossings. Flowering occurs early in spring, so frost damage frequently occurs. Japanese and European larch clones flower disjointly and heavy flowering is irregular. Pollen yield is low and the proportion of filled seed is about 30% or lower. Extraction of seeds is difficult, and the seed viability deteriorates rapidly, even when the seeds are stored at low temperatures (–20 ºC).

European larch has a broad genetic variability. According to Pâques (2000), Central European populations (Central Poland, Sudetan Mountains) have broad ecological adaptability, good resistance to larch canker (*Lachnellula willkommii* (Hartig) Dennis) and high vigour, but display poor stem form in France. Japanese larch shows very little genetic variability at the between-population level (Pâques 2000, Thormann & Madsen 1998), so genetic improvement of Japanese larch appears to have a more limited potential. When crossing the Japanese larch with the European larch complementary gains should occur as well as increases in genetic variability. Hybrid vigour has been recently shown in a study by Pâques (2002) and proved not only to be very variable from family to family, but also to be site-dependant.

In the 1940s and 1950s considerable effort was put into selecting larch clones with superior qualities in Sweden. This resulted in the establishment of 21 seed orchards with different larch species, less than a third of which remain today. The total seed harvest has so far been low, except from the hybrid larch seed orchard in Maglehem (Hannerz *et al*. 1993). Breeding work in larch has been infrequent since the 1970s (Boije Malm & Stener 2002), thus knowledge of the selected plus-tree material from the 1940s - 1960s is poor. Efforts to improve the genetic material for the southern parts of Sweden were restarted in the middle of the 1990s, when plans were made to test the selected plus-tree material and to increase the number of clones in the breeding population. Various interesting results have emerged from two 5-year-old progeny trials associated with this Swedish breeding program, for instance that there appears to be high variability in the growth of the hybrid larch material, and that there is a correlation between late seasonal growth and high rates of growth in European larch (Boije Malm & Stener 2002). On the other hand, according to Nørgård Nielsen & Larsen (1997), Spindler mentions that high growth rates are correlated with early termination of seasonal growth in hybrid larch material in Denmark.

Silviculture of larch

Practical experiences related to the establishment and management of hybrid larch stands in Sweden has been compiled in interview studies (Stern 1988, Larsson-Stern 1999). According to the interviewees, soil scarification favours establishment and larch should be planted early as it starts growing earlier in spring and finishes growth later in autumn than Norway spruce and Scots pine. Plant spacings between 1.5 and 2.5 m are normally used. Hybrid larch seems to be as sensitive to pine weevil (*Hylobius abietis* L.) damage and competition from vegetation as Norway spruce. Height increment in undamaged hybrid larch plantations is considered to be high. Sometimes larch seedlings grow faster than competing hardwood tree species, so cleaning is not always needed. Intensive management with early and heavy thinnings at short intervals is, according to the interviewees, also required.

In addition, Kiellander (1958) recommends a plant spacing of 1.5 m, while Aldentun (1987) suggests 2 m. Henriksen (1988) recommends a plant spacing as wide as 2 m to make the future stand less susceptible to wind throw.

Larch is a suitable species to prune (Kiellander 1965, Nagoda 1987, Stern 1988). The period of healing over differs between species, but the time required for the process in larch is in the same range as in Norway spruce and oak (*Quercus robur* L.) (Nylinder 1952). The risk of rot damage due to pruning is relatively low in larch (Arvidsson 1987).

Larch is extremely sensitive to shading (Kiellander 1965), and the management of larch stands should therefore be intensive. Kiellander (1958) recommends that the first thinning should be delayed a little, and then the stands should be thinned every 2nd or 3rd year. Later, many and heavy thinnings are recommended by Møller (1965) and Wielgolaski *et al.* 1993). Møller (1965) suggests the first thinning should be done at an age of 10 to 15 years and that successive thinnings should be relatively strong and frequent.

According to a yield study by Larsson-Stern *et al.* (submitted 2003) the first thinning in hybrid larch is often carried out, in practice, at an age of 15 years and successive thinnings are done at intervals of 5 years. In the yield model developed in this study, 1200 stems per hectare are left after the first thinning. The remaining number of stems, at an age of 35 years, after five thinnings, is on average 330 per hectare according to the yield model.

Schotte (1917) suggests the first thinning should be carried out in early years as a combination of crown thinning and thinning from below. If an understorey has been planted in the older larch stand, the last thinning should be quite heavy and done from below.

The rotation period could be short in hybrid larch stands given the early culmination of its volume growth. Møller (1965) suggests 30-40 years. However, to ensure the trees have large dimensions and provide good quality timber, the rotation period could be prolonged. In Denmark in the 1960s the recommended rotation period for European larch was 80-100 years and for Japanese larch 50 years. Henriksen (1988) recommended final felling at an average *brh* diameter of 60-70 cm.

Volume growth and yield

Young hybrid larch can grow rapidly and give high yields in Sweden, as shown by authors such as Kiellander (1958) and Aldentun (1987). The mean annual increment for hybrid larch in southern Sweden on fertile sites culminates at about 35 years of age at approximately 13 m^3/ha (Larsson-Stern *et al.* submitted 2003). Current annual increment peaks before the age of 20 years (*ca.* 17 m^3/ha).

Height and diameter growth of hybrid larch can exceed the growth of the parent species by 10-30% up to the age of 10 years (Keiding 1980). Henriksen (1988) refers to German and Danish studies on Japanese and hybrid larch, in which height growth and volume increment were superior for hybrid larch up to 10 years. Between 10 and 20 years the differences seemed to level out. Nørgård Nielsen & Larsen (1997) believe that the superiority will continue as the stands age. The superiority in growth of the hybrid compared to its parents in early years has also been found in other European countries: including France (Ferrand & Bastien 1985), Belgium (Nanson & Sacré 1978) and Germany (Braun & Hering 1987, Gothe 1987). Similar results have been found in North America (Holst 1974, Zavitkovski & Strong 1984, Carter & Selin 1987). The cited studies are mostly comparisons of hybrid progenies with non-related pure parental species material. However, there are also similar indications in progenies of controlled crossings, showing superiority in growth in the hybrid up to an age of 10 years (Schneck *et al*. 2002) or even 40 years (Hering 2002). Pâques (2002) presents evidence suggesting that heterosis in growth exists in first-generation inter-specific hybrid larch up to six years.

High volume growth and yield in Siberian larch in northern Sweden was found by Edlund (1966), Remröd & Strömberg (1977) and Martinsson (1995).

Larch in mixed stands

As hybrid larch is fast growing, especially in the first 8-10 years (see, for instance, Keiding 1980), there could be advantages in using larch for beeting up compared to other tree species. However, potential damage by browsing makes the results of its use in this way uncertain (Gemmel 1988).

Larch could be used as shelter for other tree species (Brandt 1977, Nørgård Nielsen & Larsen 1997). Hybrid larch, with its light crowns, has been used as an overstorey in oak and beech plantations in Sweden (Stern 1988). It can also provide an early income from these types of plantation (Kiellander 1965, Møller 1965). At the beginning of the 1900s mixed stands with larch and Scots pine were common (Schotte 1917). Larch has been used in mixed stands with various species, for example oak, beech, Scots pine and alder (*Alnus sp.*) in Germany. It has, for instance, been planted at a wide spacing (4 x 4 m) with alder as an understorey, which can improve the wood quality of the larch (von der Schulenburg 1958). Lüpke (1982) tested the possibility of planting European larch and oak in natural regeneration of beech, in groups with at least 20 x 25 m spacing. After the first four years both tree species had proven to be sufficiently shade tolerant for this purpose. Advantages with this strategy were better quality and protection against late frosts. However, there were also disadvantages, including reduced diameter and height growth and higher costs for protection against damage by animals. Guericke (2002) considered various silvicultural scenarios for the treatment of 35-year-old mixed stands of beech and European larch, with percentages of larch ranging from 0-25%. He demonstrated the influence and importance of early and strong thinnings in larch stands for the production of high value timber in periods of less than 140 years.

Damage

Animals

Roe deer, moose, hare, capercaillie, rabbit, squirrel and rodents can all severely damage larch (Kiellander 1965) through browsing on leaders and branches, fraying and gnawing. According to Henriksen (1988) fraying by deer causes considerable damage to hybrid larch seedlings. However, treatment with repellents after needle fall in autumn has efficiently deterred roe deer from browsing (Stern 1988).

Yield and effects of competition on growth of different tree species in beeted up stands were analysed by Gemmel (1988). Amongst hybrid larch seedlings, 80% were dead or severely damaged six years after beeting. The main causes of damage were fraying and browsing by moose and roe deer. Corresponding figures for Scots pine and Lodgepole pine (*Pinus contorta* Douglas) were 50% and 70%, respectively.

Voles can cause great damage. *Microtus agrestis* L. may kill larch seedlings by gnawing the bark during winter on the lower part of the seedlings. *Chlethrionomys glareolus* Schreber also eats bark, but further up and may destroy the shoots four metres above ground (Eidmann 1959).

Insects

About 150 different species of insects can affect larch in Europe, and 25% of them are exclusively dependent on larch (Eidmann 1965).

The pine weevil (*Hylobius abietis* L.) can cause severe damage to larch plantations. It not only eats the bark from the root collar upwards, but may also cut the top-shoots. Trees more than 2 m in height may also be affected by gnawing (Eidmann 1959).

Coleophora laricella Hübner occurs in most places where larch grows, but heavy attacks are rare. The insects hollow out the needles, where they also overwinter. They seldom attack trees younger than seven years old, and most of the damage is found in the lower parts of the crown. Heavy attacks can result in growth reduction (Eidmann 1958).

Argyresthia laevigatella Heydenreich causes damage to the current shoots. The larvae eat and overwinter in the shoot. The damage is not visible until springtime, when the dead shoots are found. Heavy attacks are rare and lasting defects are seldom of economic importance (Eidmann & Klingström 1990).

Pristiphora erichsonii Hartig and *P. wesmaeli* Tischbein are two species that often occur at the same time on larch. They eat needles, mostly in the first part of August, often in the same tree, and they can cause a total loss of needles (Eidmann 1959).

Fungi

Different larch species differ in their susceptibility to larch canker (*Lachnellula willkommii* (Hartig) Dennis). It has caused severe damage in European larch (Schotte 1917, Vidakovic 1991, Kurkela 1983, Phillips & Burdekin 1982). Buczacki (1973) studied European larch and found that the most vigorous trees were the most affected. However, there was a generally positive correlation between growth vigour and incidence of canker healing. According to Kurkela (1983), the disease occurs naturally in Japan on Japanese larch. Larch canker has also been found on Japanese larch in Europe, but the effects are normally negligible according to Phillips and Burdekin (1982). They also note that it has occasionally caused some loss in hybrid larch. Keiding (1980) mentions resistance to larch canker as being one of the most important properties of hybrid larch. Sylvestre-Guinot *et al*. (1999) have confirmed the very low susceptibility of hybrid larch to the canker, in experiments in which they inoculated different hybrid larch families (3-4 years old). After 18 months, the infection rate was 27.9% and most (80-90%) of the experimental clones were found to be receptive. After 39 months, nearly all infected sites had recovered and the final infection rate was 2.2%. Sylvestre-Guinot & Delatour (2002) have also confirmed that there are inter-specific differences in susceptibility, European larch being the most susceptible (Central European provenances less so), then Japanese larch, and hybrid larch the least susceptible.

It has been known for a long time that European and Japanese larch are susceptible to root and butt rot infection caused by *Heterobasidion annosum* (Fr.) Bref. (*cf.* Vollbrecht *et al.* 1995). One of the reasons for planting hybrid larch in the 1960s was that it had a reputation for being much less susceptible to root and butt rot infections than Norway spruce (Larsson-Stern 1999). Wagn (1987) found indications that hybrid larch was resistant to root and butt rot infection caused by *H. annosum* in observations (registration of dead trees) taken over 23 years in an infection experiment in field trials. Nine out of 74 species, including hybrid larch, were not attacked at all by the fungus. The most conspicuous differences were between the heavily attacked Japanese larch and the healthy hybrid larch. However, Gladman & Low (1963) recorded heavy root and butt rot infections in a 34-year-old thinning experiment, affecting 40%, 25% and 50% of hybrid larch, European larch and Douglas fir (*Pseudotsuga menziesii* (Mirbel) Franco), respectively. In a 20-year-old stand of hybrid larch in southern Sweden 38-57% of the thinned trees were infected by root and butt rot, while only 5% of Norway spruce trees nearby were affected (Vollbrecht & Stenlid 1999). Rönnberg & Vollbrecht (1999) examined three young hybrid larch plantations in southern Sweden established after clear cutting Norway spruce stands that were heavily infected by *H. annosum*. The incidence of the fungus was 7%, 33% and 70% respectively in the 2-, 3- and 5-year-old plantations. The conclusion was that hybrid larch planted on sandy soils after clear felling of heavily infected Norway spruce is very susceptible to infection.

A survey of the incidence of root and butt rot in 18 newly thinned hybrid larch stands aged 21-47 years in southern Sweden was carried out by Stener & Ahlberg (2002). The incidence of infection varied substantially among sites, but in six of them more than 10% of the surveyed stumps were infected. Stener *et al.* (2002) found no significant difference among families in the spread of *H. annosum* mycelia in the wood of hybrid larch. However, there are indications that different families react differently to artificial infection by *H. annosum* with respect to the size and spread of reaction zones (Stener *et al.* 2002). This variation could be useful for producing plant material with greater resistance to *H. annosum*.

Young stands of larch can be damaged by honey fungus (*Armillaria sp.*) (Møller 1965).

Frost, drought, wind and air pollution

Hybrid larch seems to be intermediate to the parent species in many respects, for example frost resistance (Henry & Flood 1919, Kiellander 1967). As the Japanese larch has a tendency to continue growing late in the autumn it can be damaged by frost, but seldom seriously (Møller 1965). According to Kiellander (1966) Japanese larch, Siberian larch and European larch have poor, good and intermediate autumn frost resistance, respectively. On sites with frequent spring frost hybrid larch seedlings could be severely damaged (Stern 1988). Larch flushes early, which makes it liable to frost damage and makes the tree vulnerable to diseases (Taylor 1964). Having Siberian larch as one of the parents seems to give resulting hybrids more frost resistance than other hybrids, and various hybrids, including hybrid larch, seem to be hardier than the parent species (Nilsson 1959).

Hybrid larch seems to resist drought better than Japanese larch, but it is still sensitive to late summer drought (Brandt 1977, Henriksen 1988). Lundberg (1987) has recorded serious drought damage in larch plantations compared to Norway spruce and lodgepole pine on former agricultural land.

Young stands of larch are susceptible to storms (Møller 1965, Henriksen 1988). The problem seems to be most serious up to the age of 10 years (Kiellander 1965), and old larch stands are considered to have high resistance to wind throw (Møller 1965, Henriksen 1988, Fodgaard 2001). European larch has a deep rooting system and is fairly wind-firm, but has poor ability to withstand strong winds (Taylor 1964). For good performance in this respect a sheltered site is to be preferred. As larch sheds its needles in the autumn it tends to be more resistant to winter storms and snow damage than many other conifers. Crook and Ennos (1996) studied the anchorage of 16-year-old hybrid larch in Great Britain, combining winching tests with analyses of strain around the base of the trunk and root system, and mechanical tests on individual roots. On waterlogged soils the vertical orientation of the root system of larch was found to be more efficient than the plate system formed by Sitka spruce. The relatively high wind resistance of larch stands is based on the mechanical-physical properties of larch wood, which has higher tensile and bending strength than spruce (Vicena 1998). Rooting also provides a firm anchorage in the soil as the larch has a robust root core. Larch admixture in forest stands enhanced the wind resistance of other tree species in a Czechoslovakian study (Vicena 1998). On the other hand there are indications that admixture of larch with other conifers will make the stands more liable to storm damage (Fodgaard 2001). For example, in the summer larch can give shelter to spruce when they are mixed, but as larch sheds its needles in the autumn the spruce will be more exposed to storms in the winter.

Crookedness, which is quite common among larches, is often influenced by genetic factors, but it may also be caused by environmental factors such as frost damage, wind and snow pressure (Karlman 1998). Bastien & Pâques (2002) found that stem crookedness after two years of fast growth was significantly related to stem crookedness at the age of 16. They also found that most bending defects appeared at the end of the growing season in the upper part of the shoot. A discrepancy between the times at which the rates of growth and liginification peaked was found in crooked genotypes.

Larch trees at Czechoslovakian research sites heavily damaged by industrial emissions, particularly sulphur dioxide, have shown considerable mortality rates and slow growth. However, individuals that have survived the first few years show satisfactory growth in comparison with other species used and generally have a good state of health (Sindelar 1987). According to literature compiled by Bialobok & Fabijanowski (1984) European and Japanese larch trees are mostly moderately sensitive or sensitive to sulphur dioxide and ozone (*i.e.* they are not classed as tolerant).

Impact of larch on soil conditions

Larch stands generally produce a more acid throughfall than Norway spruce (*Picea spp.*) and Scots pine (*Pinus spp.*) stands according to Hornung *et al*. (1986).

Larch litter has been shown to release nitrogen more readily than spruce litter (Carlyle & Malcolm 1986). However, the amount of nitrogen contained in larch litter seems too low to be of significance. Nitrogen and potassium concentrations in freshly fallen spruce and larch litter were similar, while phosphorous concentrations were found to be considerably greater in larch than in spruce litter in a study by Carlyle & Malcolm (1986).

In a Swedish study, Japanese larch and silver fir (*Abies alba* Miller) stands were found to contain higher amounts of calcium, magnesium, potassium and nitrogen in the topsoil, but less in the biomass than grand fir (*Abies grandis* Lamb.) and Norway spruce stands. Japanese larch stands had 35% more organic matter in the 0-horizon than stands of the other species tested (Eriksson & Rosén 1994). Indications were found that species differed with respect to nutrient input (deposition, weathering), output (leaching) or both. The choice of tree species may therefore affect the nutrient budget of Swedish forest soils, even when rates of stem-wood biomass production are similar (Alriksson & Eriksson 1998).

Larch wood properties

The wood of *Larix* species is anatomically almost identical to that of *Picea* species. The differences are barely detectable under the microscope. However, the late wood zone is wider, accounting for about 25-35% of the annual ring width (Nevalainen & Hosia 1969). Larch wood generally has higher density and hardness compared to Scots pine and Norway spruce wood (Thunell & Perem 1952). The strength of larch wood does not decrease much with increasing ring width (Collinder & Borgstrand 1929). According to Jonsson & Lindström (1991), larch wood is about 25% more dense than wood of Norway spruce. Grabner *et al.* (2002) showed there were close correlations among earlywood width, latewood percentage, wood density, compression strength and hot-water soluble extractives in larch. Ring width seemed to be an important predictor for wood properties of larch.

The amount of cellulose, lignin and hemicellulose in Siberian larch is almost the same as for Norway spruce and Scots pine (Sjöström 1981). However, larch wood contains 5-30% arabinogalactan (a water soluble hemicellulose), according to the literature, while the corresponding figure for other conifers is about 1% (Malmqvist & Woxblom 1991).

High density, hardness and resin content make larch difficult to saw. Air drying seems to be the best treatment for sawn larch wood to prevent skewing of the resulting boards, which could be a problem, especially if the drying process is too rapid (Rosell 1988).

Wood from *Larix* species has long been considered resistant to rot. Carl von Linné (1754) mentions that larch is probably more durable than any other tree species. Timber quality in larch is of the best quality according to Schotte (1917), who notes that larch has very high timber quality compared to other conifers, and even better than oak timber in many respects.

Later research findings have made scientists question the supposed superiority of larch wood hardiness. Heartwood of larch seems to be as durable as heartwood of Scots pine (Björkman 1944). The relatively high rot resistance in larch heartwood could be due to its high amounts of resin (Boutelje & Rydell 1986). However, researchers differ in their opinions about the durability of larch timber (Martinsson 1996, Nilsson & Edlund 1996). Nilsson & Edlund (1996) have classified heartwood of larch for use in soil as “not durable”, while Boutelje & Rydell (1986) refer it to as “moderately durable” with a permanency of 10-15 years. Jacques *et al*. (2002) inoculated wood samples from different provenances and individuals of European, Japanese and hybrid larch with two fungi: *Poria placenta* (Fr.) Cke. and *Coniophora puteana* (Schum.ex Fr.). Their study showed that natural durability appears to depend on the species involved, with Japanese larch being more durable than European larch. However, there were also major differences between different provenances and also between individuals within provenances. With *Poria* 30 % of trees were moderately durable or durable; with *Coniophora*, 2/3 were moderately durable or better and 1/3 were slightly durable. High wood density and narrow ring width seemed to increase the natural durability of larch, but even for wood with low density, high variability in natural durability has been observed.

Gierlinger *et al.* (2002) concluded that a high amount of heartwood extractives are related to natural durability in larch. FT-NIR spectroscopy seemed to be a reliable, accurate and rapid method for the determination of larch heartwood extractives.

It is important to use only the heartwood when durable wood is required, since the sapwood does not have lasting qualities. However, larch wood in old trees is dominated by the reddish brown heartwood, which can account for more than 80% of the total wood volume (Rosell 1988). Heartwood formation in European larch starts at an age of 10-12 years compared to 30-36 years in Norway spruce and more than 40 years in Scots pine (Kiellander 1965). The proportion of heartwood is correlated to diameter. In a study from southern Sweden, top and bottom diameters of 3m logs from Japanese and hybrid larch stems (17-38 years old) were examined. It was found that heartwood accounted for about 4 cm and 18 cm of the diameter, when the total stem diameter was 10 cm and 25 cm, respectively (Jacobsson & Olsson 1992).

Malmqvist & Woxblom (1991) compiled more literature on larch wood properties.

Applications of larch wood

According to Linné (1754), larch timber was used for building houses and ships in Venezia. Well-preserved parts of a bridge built of larch timber in Donau 1700 years earlier were found in 1858, and Schotte observed buildings constructed with larch timber in good condition in Switzerland that were 200-300 years old, or even older (Schotte 1917). One of the buildings was 800 years old.

The timber market for larch timber is growing (Rapp 2001). The Hökön Sawmill in southern Sweden produces 4,000 cubic metres of sawn larch timber per year. Half of the timber used comes from southern Sweden and the rest from Denmark. The wood is used for balcony floors, play equipment, internal and external wall boards and various other purposes. In southern Europe larch timber is widely used for furniture, window frames *etc.* (Rosell 1988). In Russia larch is also used in plywood and glued joint constructions (Kewenter 1988).

As mentioned above, larch wood contains large amounts of arabinogalactan. This hemicellulose is water-soluble and is therefore lost when producing pulp, and its loss may decrease the yield by up to 5% (Rosell 1988). Larch is therefore not wanted in large amounts in the Swedish pulp industry (Larsson-Stern 1999). However, a Finnish study showed that a hectare of Siberian larch could yield more chemical pulp than a hectare of pine or spruce (Nevalainen & Hosia 1969). In Canada, hybrid larch and jack pine (*Pinus banksiana* Lamb.) kraft pulps were found to be similar in many respects and differences were relatively minor. Based on these findings, plantation of hybrid larch was started (Gagnon 1999).

Conclusions

Hybrid larch is the most commonly planted larch species in southern Sweden. However, of the total standing volume in southern Sweden (Götaland) not more than 0.1% of the growing stock (one million m^3) consists of hybrid larch. Hybrid larch is well suited to be grown in large areas in southern Sweden, but relatively harsh climate zones (> III, Figure 6) should be avoided.

Fertile to medium fertile sites, where the recommendation is to grow Norway spruce, can also be recommended for hybrid larch. The experience of growing hybrid larch on less fertile sites is limited.

There are few commercially available seed sources. However, evidence of great variation in the plant material has been observed in different quality traits, especially stem straightness. Breeding and choice of plant material are therefore important issues.

Hybrid larch seedlings can be established in almost the same way as Norway spruce seedlings, *i.e.* with soil scarification and 2 x 2 m spacing. Protection against pine weevil is essential. Ungulates and rodents can cause severe damage to the seedlings. Cleaning is not always necessary as hybrid larch grows rapidly in its early years.

Management of hybrid larch stands has to be intensive. As it is less shade tolerant than many other tree species thinning operations have to start early, at about 15 years, and then be repeated at intervals of about five years. The silvicultural aims could vary. Production of high quality timber with large dimensions requires a long rotation period. However, as the growth in young stands is high and peaks early, short rotations could offer economically competitive alternatives.

It should be noted that root and butt rot damage caused by *H. annosum* in hybrid larch occurs frequently, and could cause severe economic losses. Wind throw could also cause losses and is, according to experience, most likely to appear in young and middle aged stands.

My general judgement is that hybrid larch can be recommended as a complementary tree species to Norway spruce in southern Sweden. It is easy to establish, its growth rate is high, and the market for its timber market seems to be stable. However, there is a need for more knowledge about aspects such as the risks and impact of damage, durability of the wood in outdoor-constructions, the adaptability of the plant material to different site conditions and timber quality.

References

Abaimov, A.P., Lesinski, J.A., Martinsson, O. & Milyntin, L.I. 1998. Variability and ecology of Siberian larch species. SLU. Department of silviculture. Report, No. 43, 123 pp. ISSN 0348-8969.

Acheré, V., Faivre Rampant, P., Benoît, V., Leplé, J-C., Pâques, L.E. & Prat, D. 2002. Characterization of hybrids between *Larix decidua* and *L. kaempferi* by molecular markers. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality. Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, pp 176-186.

Aldentun, A. 1987. Hybridlärkens tillväxt och produktion i ungdomen. SLU. Institutionen för skogsskötsel. Examensarbete 1987-12, 23 pp. ISSN 0349-2923. (In Swedish.)

Alriksson, A. & Eriksson, H.M. 1998. Variations in mineral nutrient and C distribution in the soil and vegetation compartments of five temperate tree species in NE Sweden. Forest Ecology and Management, No. 108, pp 261-273.

Arvidsson, A. 1987. Stamkvistning – för bättre framtida virkeskvalitet. Kvalitetsskog. Sågverkens råvaruförening, pp 55-61. (In Swedish.)

Bastien, C. & Pâques, L.E. 2002. Early prediction of stem form in hybrid larch. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality. Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, p 154.

Bergmann, F. & Ruetz, W. 1987. Identifizierung von Hybridlärchensaatgut aus Samenplantagen mit Hilfe eines Isoenzym-Markers. Silvae Genetica, Vol. 36, No. 2, pp 102-105. (In German with English summary.)

Bialobok, S. & Fabijanowski, J. (Ed.) 1984. Concepts of forest management in industrial regions. Contributors: Adamczyk, B., Bialobok, S., Fabijanowski, J., Greszta, J., Lesinski, J.A., Oleksyn, J. & Rachwal, L. 8.1. Forest functions in industrial regions. Ecological Studies No. 49, pp 231-267.

Björkman, E. 1944. Om röthärdigheten hos lärkvirke. Norrlands Skogsvårdsförbunds Tidskrift, No. 1, 45 pp. (In Swedish with English summary.)

Boije Malm, M. & Stener, L-G. 2002. Genetic evaluation of growth, external quality and phenology in two 5-year-old larch trials in southern Sweden. SkogForsk. Arbetsrapport No 522, 28 pp.

Boutelje, J. & Rydell, R. 1986. Träfakta - 44 träslag i ord och bild. Träteknikcentrum, p 47. ISBN 91-970513-3-0. (In Swedish.)

Brandt, K. 1977. Hybridlærk i hedeskovbruget. Hedeselskabets Tidskrift, vol 98, pp 155-160 and 169-172. (In Danish.)

Braun, H. & Hering, S. 1987. Wachstumsverlauf von Hybridlärchen (*Larix eurolepis* Henry). Beitrage für die Forstwirtschaft, No. 21:4, pp 164-168. (In German with English summary.)

Buczacki, S.T. 1973. Some aspects of the relationships between growth vigour, canker and dieback of European larch. Forestry, Vol. 46, No. 1, pp 71-79.

Carlyle, J.C. & Malcolm, D.C. 1986. Larch litter and nitrogen availability in mixed larch-spruce stands. II. A comparison of larch and spruce litters as a nitrogen source for Sitka spruce seedlings. Canadian Jorunal of Forest Research, No. 16:2, pp 327-329.

Carter, K.K. & Selin, L.O. 1987. Larch plantation management in the northeast. Northern Journal of Applied Forestry, No. 4:1, pp 18-20.

Collinder, S. & Borgstrand, C.A. 1929. Om lärkvirkets tekniska egenskaper. Skogsvårdsföreningens Tidskrift, pp 374-395. ISSN 0039-730X. (In Swedish.)

Crook, M.J. & Ennos, A.R. 1996. The anchorage mechanics of deep rooted larch, *Larix europea* x *L. japonica*. Journal of Experimental Botany, vol. 47, No. 303, pp 1509-1517.

Delevoy, G. 1949. *Larix eurolepis*. Bull. de la Soc. Centr. Forest. de Belgique, pp 178-194. (In French.)

Edlund, E. 1966. Den sibiriska lärken i Norrland och Dalarna som skogsträd och industriråvara. Sveriges Skogsvårdsförbunds Tidskrift, No 5-6, pp 461-560. ISSN 0371-2907. (In Swedish.)

Eidmann, H. 1958. Lärkträdsmalen (*Coleophora laricella* HBN). Statens skogsforskningsinstitut. Uppsatser, No 61. Svenska Skogsvårdsföreningens Tidskrift, No 4, pp 399-418. ISSN 0562-7605. (In Swedish with German summary.)

Eidmann, H. 1959. Skadedjur på lärkträd. Skogen, Vol. 46, No. 8, pp 180-181. (In Swedish.)

Eidmann, H. 1965. Lärchenschädlinge in Schweden und ihre Verbreitung. Zeitschrift f. angewandte Entomologie, No. 55:4, pp 377-388. (In German.)

Eidmann, H.H. & Klingström, A. 1990. Skadegörare i skogen. LTs förlag, Stockholm. ISBN 91-36-02004-4. (In Swedish.)

Eriksson, H.M. & Rosén, K. 1994. Nutrient distribution in a Swedish tree species experiment. Plant and Soil, No. 164, pp 51-59.

Ferrand, J. Ch. & Bastien, J. Ch. 1985. Bilan à 26 ans d'une plantation camparative de mélèzes. Revue Forestiere Francaise, No. 37:6, pp 441-448. (In French.)

Fodgaard, S. 2001. Erfaringer om stormfasthed. Skoven, No 2, pp 61-65. (In Danish.)

Gagnon, P.F. 1999. Determination of the papermaking potential of hybrid larch: lab-scale and mill trials. 84th Annual meeting of the Techical Section, CPPA, Montreal, QC, Canada, 26-30 January 1998. Pulp-and-Paper-Canada. No 100:3, pp 62-66.

Gemmel, P. 1988. Beeting in *Picea abies* (L.) Karst. Growth and damage in a field experiment. Scandinavian Journal of Forest Research, No. 3, pp 201-212.

Gierlinger, N., Jacques, D., Marchal, M., Wimmer, R., Schwanninger, M. & Pâques, L.E. 2002. Heartwood extractives and durability of larch – relationships and their prediction by FT-NIR spectroscopy. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality. Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, pp 414-421.

Gladman, R.J. & Low, J.D. 1963. Conifer heart rots in Scotland. Forestry, No. 36(2), pp 239-240.

Gothe, H. 1987. Ein Kreuzungsversuch mit *Larix europaea* D.C., Herkunft Schlitz, und *Larix leptolepis* Gord. 7. Mitteilung. Allgemeine-Forst-und-Jagdzeitung, No. 158, pp 1-3. (In German with English summary.)

Grabner, M., Gierlinger, N., Rosner, S., Wimmer, R., Gindl, W., Schwanninger, M. & Pâques, L.E. 2002. Effects of ring-width on wood properties of larch. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality. Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, pp 380-387.

Guericke, M. 2002. Modelling of silvicultural scenarios. Investigations in beech-larch mixed stands as an example to evaluate effects of alternative silvicultural strategies. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality. Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, pp 332-339.

Haasemann, W. & Tzschacksch, O. 1986. Untersuchungen zur Ökologie der Europäerlärche, Japanerlärche und ihrer Hybriden im Nass-Trockenfeld. Beiträge fur die Forstwirtschaft, vol. 20:4, pp 184-188. (In German with English summary.)

Hannerz, M., Hajek, J., Stener L-G & Werner, M. 1993. Lärkfröplantager i Sverige. SkogForsk. Resultat, No. 8, 4 pp. (In Swedish with English summary.)

Harrison, A.J., Hoffmann, D., Kannenberg, N., Lelu, M-A., Verger, M., Le Pichon, C., Bourlon, V. & Thompson, D. 2002. Developments in hybrid larch (*Larix* × *eurolepis* Henry) vegetative propagation in north western Europe. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality. Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, pp 250-265.

Hemberg, E. 1899. Sibiriska lärkträdet. Tidskrift för skogshushållning, No 2, pp 83-106. (In Swedish.)

Henriksen, H.A. 1988. Skoven og dens dyrkning. Dansk Skovforening. Nyt Nordisk forlag, Arnold Busck. Copenhagen. ISBN 87-17-05937-2. (In Danish.)

Henry, A. & Flood, M.G. 1919. The history of the Dunkeld hybrid larch, *Larix eurolepis*, with notes on other hybrid conifers. Proc. of the Royal Irish Academy, sect. B, No. 35:4, pp 55-66.

Hering, S. 2002. Breeding and silvicultural treatment of larch stands in Saxony under changed silvicultural objectives. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality. Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, pp 187-193.

Holst, M.J. 1974. Performance of Japanese larch and the Dunkeld hybrid larch at the Petawawa Forest Experiment Station. Forestry Chronicle, No. 50:3, pp 109-110.

Hornung, M., Stevens, P.A. & Reynolds, B. 1986. The effects of forestry on soils, soil water and surface water chemistry. - Environmental aspects of plantation forestry in Wales. ITE Symp., No 22. ITE, Bangor Research Station, pp 25-36.

Häcker, M. & Bergmann, F. 1991. The proportion of hybrids in seed from a seed orchard composed of two larch species (*L. europaea* and *L. leptolepis*). Annales des Sciences Forestieres, No 48, pp 631-640.

Jacobsson, Ö. & Olsson, P. 1992. Kärnvedsandel i lärk. SLU. Södra Skogsinstitutet. Examensarbete, No. 171, 27 pp. (In Swedish.)

Jaques, D., Curnel, Y., Jourez, B. & Pâques, L.E. 2002. Among and within provenance variability for decay resistance of larch wood to fungi. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality. Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, pp 405-413.

Jonsson, R. & Lindström, H. 1991. Planteringsförbandets inflytande på hybridlärkens kvalitet och produktion. SLU. Institutionen för skogsskötsel. Examensarbete, No. 6, pp 37. (In Swedish.)

Jonsson, S. 1978. Lärkhybrider i Norrland. Institutet för Skogsförbättring. Skogsträdsförädling, No. 9, 4 pp. (In Swedish with English summary.)

Karlman, L. 1998. Stem quality of larch. Stem shape and heartwood content of six different larch species tested in Central and Northern Sweden. SLU. Institutionen för skogsskötsel. Examensarbete, No. 5, pp 35. ISSN 0349-2923.

Katayama, M., Kurata, S., Matsubara, S., Oda, S., Tsuji, R., Yokose, M. (Eds.) 1964. Illustrated important forest trees of Japan. Chikyu Shuppan Co., Ltd. Tokyo, pp 217.

Kewenter, P. 1998. Import of larch timber and sawmill products from Russia to Sweden. SLU. Instititutionen för skogsskötsel. Examensarbete, No. 4, 56 pp. ISSN 0349-2923.

Keiding, H. 1980. Hybridlærkens vækst og tilpasningsevne i forhold til de rene arter. Dansk Skovforenings tidsskrift, No. 65, pp 204-234. ISSN 0011-6475. (In Danish with English summary.)

Kiellander, C.L. 1958. Hybridlärk och lärkhybrider. Svenska Skogsvårdsföreningens Tidskrift, No. 4, pp 371-398. ISSN 0562-7605. (In Swedish.)

Kiellander, C.L. 1965. Om lärkträdens egenskaper och användning med särskild hänsyn till europeisk och japansk lärk. Föreningen Skogsträdsförädling, årsbok, pp 65-99. ISSN 0430-8468. (In Swedish with English summary.)

Kiellander, C.L. 1966. Främmande barrträd I: Hybridlärken. Skogen No. 11, 2 pp. (In Swedish with English summary.)

Kiellander, C.L. 1967. Främmande barrträd II: Hybridlärken. Skogen No. 5, pp 132-134. (In Swedish with English summary.)

Krüssmann, G. 1985. Manual of cultivated conifers. Timber press, Portland, OR, pp 157-163.

Kullman, L. 1998. Palaeoecological, biogeographical and palaeoclimatological implications of early Holocene immigration of *Larix sibirica* Ledeb. into the Scandes Mountains, Sweden. Global Ecology and Biogeography Letters, No. 7, pp 181-188.

Kurkela, T. 1983. European larch canker – its biology, hosts, site relationships, implications to forestry and the microbiology of cankers. European larch canker workshop. Canadian Forestry Service. MFRC Workshop proceedings, No. 3, pp 28-34.

Larsson-Stern, M. 1999. Hybridlärk – ett lämpligt trädslag för Sydsverige? Skog & Forskning, No. 3, pp 44-51. ISSN 1101-9506. (In Swedish.)

Larsson-Stern, M., Ekö, P.M. & Albrektson, A. 2003. Growth and yield of hybrid larch (*Larix* × *eurolepis*) in southern Sweden. (Submitted.)

LePage, B.A. & Basinger, J.F. 1995. The evolutionary history of the genus Larix (Pinaceae). Ecology and management of *Larix* forests: A look ahead. Proceedings of an international symposium. United States Department of Agriculture, Forest Service, pp 19-27.

Le Pichon C., Verger M., Brando J. & Le Bouler H. 2001. Itinéraires techniques pour la multiplication végétative en vrac du Mélèze hybride (*Larix* × *eurolepis* Henry). Forêt-Entreprise. Rev. For. Fr. Llll, No. 2, pp 111-124. (In French with English summary.)

Lines, R. 1987. Choice of seed origins for the main forest species in Britain. Forestry Commission Bulletin, Vol 66, pp 28-31.

Linnaeus, C. 1754. Tankar om nyttiga växters planterande på de lappska fjällen. Kungliga Vetenskapsakademiens handlingar, pp 182-189. (In Swedish.)

Lundberg, J. 1987. Plantningsforsøg på marginal landbrugsjord. Vækst, vol. 108, pp 15-23. (In Danish.)

Lüpke, B.v. 1982. Versuche zur Einbringung von Lärche und Eiche in Buchenbestände. Schriften aus der Forstlichen Fakultät der Universität Göttingen und der Niedersächsischen Forstlichen Versuchsanstalt, Vol. 74, pp 109-113. (In German with English summary.)

Malmqvist, C. & Woxblom, L. 1991. Trädslag för beskogning av åkermark – kustgran och lärk. Del II: Lärk. SLU. Institutionen för Skog-Industri-Marknad Studier. Serien utredningar, No. 11, 54 pp. ISSN 0284-3803. (In Swedish.)

Martinsson, O. 1991. Proveniensval av japansk lärk för södra Sverige. Höjdutveckling, överlevnad, stamkvalitet och produktion 30 år efter plantering. SLU. Institutionen för skogsskötsel. Arbetsrapporter, No. 59, pp 29. ISSN 0281-7292. (In Swedish.)

Martinsson, O. 1995. Yield of *Larix sukaczewii* Dyl. in Northern Sweden. SLU. Studia Forestalia Suecica, No 196, 20 pp. ISSN 0039-3150.

Martinsson, O. 1996. Angående SLU's trovärdighet. SLU Just Nu, december, pp 13-14. (In Swedish.)

Mason, W.L. 1989. Vegetative propagation of hybrid larch (*Larix* × *eurolepis* Henry) using winter cuttings. Forestry Supplement, No. 62, pp 189-198.

Mason, W.L. & Gill, J.G.S. 1986. Vegetative propagation of conifers as a mean of intensifying wood production in Britain. Forestry, Vol. 59, No. 2, pp 155-172.

Mc Comb, A.L. 1955. The European larch: its races, site requirements and characteristics. Forest Science No 1 (4), pp 298-318.

Mitchell, A. 1974. A field guide to the trees of Britain and northern Europe. Collins repr., London. ISBN 0-00-212035-6.

Morgan, J.L. 1992. Forest performance of hybrid larch cuttings. Research Information Note, No. 227, 4 pp. Forestry Commission Res. Div.

Møller, C.M. 1965. Vore skovtræarter og deres dyrkning. Dansk Skovforening, Copenhagen, pp 175-187. (In Danish.)

Nagoda, L. 1987. Lerkevirkets egenskaper og anvendelse. Norsk Skogbruk, No. 10, pp 4-5. (In Norwegian.)

Nanson, A. & Sacré, E. 1978. À propos de l'hétérosis de *Larix* × *eurolepis*, en particullier pour les propriétés du bois. Bullentin des recherches agronomiques de Gembloux, No. 13(4), pp 323-336. (In French with English summary.)

Nevalainen, K. & Hosia, M. 1969. The suitability of larch as fibre raw material. Papper och Trä, No. 6, pp 503-510.

Nilsson, B. 1959. Om lärkfrö och lärkhybrider för mellansverige. Föreningen för växtförädling av skogsträd. Årsberättelse 1958, pp 43-58. (In Swedish.)

Nilsson, T. & Edlund M-L. 1996. Lärkvirkets beständighet mot rötangrepp – inte bättre än furu. SLU. Fakta Skog, No. 24. (In Swedish.)

Nylinder, 1952. Om kvistning. Meddelanden från Statens Skogsforskningsinstitut. Serien uppsatser, No. 26. Norrlands Skogsvårdsförbunds Tidskrift, No. 2, pp 1-13. (In Swedish.)

Nørgård Nielsen, C. & Larsen J. B. 1997. Lærk. Europeisk lærk, Japansk lærk og hybridlærk – arts- og proveniensvariation, forædling og frøkildevalg. In Larsen, J.B. (ed.) Træarts- og proveniensvalget i et bæredygtigt skovbrug. Dansk Skovbrugs Tidsskrift, vol. 82:1, pp. 214-225.

Owens, J.N. 1995. Reproductive biology of larch. Ecology and management of *Larix* forests. Proceedings of an international symposium. United States Department of Agriculture, Forest Service, pp 97-109.

Pâques, L.E. 1992. Inheritance and estimated genetic gains in a clonal test of hybrid larch (*Larix* × *eurolepis*). Scandinavian Journal of Forest Research, No. 7, pp 355-365.

Pâques, L.E. 2000. Interspecific hybridisation in larch: The long way to get outstanding varieties. Hybrid breeding and genetics of forest trees. Proceedings of QFRI/CRC-SPF Symposium, 9-14 April 2000, Noosa, Queensland, Australia. Department of Primary Industries, Brisbane.

Pâques, L.E. 2002. Heterosis in interspecific hybrids between European and Japanese larch. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality. Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, pp 155-163.

Phillips, D.H. & Burdekin D.A. 1982. Diseases of forest and ornamental trees. Macmillan, London, pp 166-172. ISSN 0-333-32357-2.

Rapp, D. 2001. Breddat utbud med lärk. NTT Såg, No 8, p 38. (In Swedish.)

Remröd, J. & Strömberg, S. 1977. Den sibiriska lärkens produktion i norra Sverige. Föreningen Skogsträdsförädling & Institutet för Skogsförbättring Årsbok, pp 45-71. ISSN 0281-143X. (In Swedish.)

Rosell, A. 1988. Lärkvirke - virkeskvalitet, egenskaper och användningsområden. SLU. Institutionen för virkeslära. Examensarbete, No. 11, 74 pp. (In Swedish.)

Rönnberg, J. & Vollbrecht, G. 1999. Early infection by Heterobasidion annosum in *Larix × eurolepis* seedlings planted on infested sites. European Journal of Forest Pathology, No 29, pp 81-86. ISBN 91-576-5630-4.

SLU 2001. Skogsdata 2001. Aktuella uppgifter om de svenska skogarna från Riksskogstaxeringen. SLU, Institutionen för skoglig resurshushållning och geomatik. ISSN 0280-0543. (In Swedish.)

Scheepers, D., Eloy, M.-C. & Briquet, M. 2000. Identification of larch species (*Larix decidua, Larix kaempferi* and *Larix × eurolepis*) and estimation of hybrid fraction in seed lots by RAPD fingerprints. Theoretical and Applied Genetics, No 100, pp 71-74.

Schmidt, W.C. 1995. Around the world with *Larix*: an Introduction. Ecology and management of *Larix* forests: A look ahead. Proceedings from an international symposium. United States Department of Agriculture, Forest Service, pp 6-10.

Schneck, V., Schneck, D., Grotehusmann, H. & Pâques, L.E. 2002. Testing of hybrid larch over a broad range of site conditions. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality. Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, pp 119-126.

Schober, R. 1981. Vom 1. Internationalen Lärcheprovenienzversuch 1944. Bericht über drei deutsche Teilversuche. Allgemeine Forst und Jagdzeitung, No. 152, pp 181-233. (In German with English summary.)

Schotte, G. 1917. Lärken och dess betydelse för svensk skogshushållning. Meddelande från Statens Skogsförsöksanstalt, No.13-14. Årsbok. ISSN 0283-3093. (In Swedish with English summary.)

Schulenburg, von der, A. Fr. 1958. Om lärken och dess odling i Norden. Svenska Skogsvårdsföreningens Tidskrift, No. 4, pp 359-370. ISSN 0562-7605. (In Swedish.)

Simak, M. 1979. *Larix sukaczewii*, naturlig utbredning, biologi, ekologi och fröanskaffningsproblem. SLU. Institutionen för skogsskötsel. Rapport No. 1, p 16. ISSN 0348-8969. (In Swedish.)

Sindelar, J. 1987. Health and growth of larch (*Larix spp.*) progeny from open pollination and controlled cross breeding in the Krusne hory Mountains. Prace Vyzkumneho Ustavu Lesniho Hospodarstvi a Myslivosti, No. 70, pp 68-69. (In Czech with English summary.)

Sjöström, E. 1981. Wood chemistry. Fundamentals and applications. Laboratory of wood chemistry. Forest Products Department. Helsinki University of Technology Espoo, Finland.

Skogsstyrelsen. 1994. Skogsvårdslagen. Handbok. Skogsstyrelsen - Förlaget. Jönköping. ISBN 91-88462-11-0. (In Swedish.)

Skogsstyrelsen. 2000. Official policy on the use of larch in Swedish forestry. Presented by Maria Norrfalk on an international seminar on ”The properties and use of larch wood”, Jönköping 22 May 2000.

Stener, L-G. & Ahlberg, G. 2002. Study of root and butt rot frequency in hybrid larch stands in southern Sweden. SkogForsk. Arbetsrapport, No 521, 19 pp.

Stener, L-G., Stenlid, J. & Karlsson, B. 2002. Genetic evaluation of growth, external stem quality, wood density and sensitivity to root and butt rot in a *L. eurolepis* trial in south Sweden. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality.

Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, pp 141-153.

Stern, M. 1988. Hybridlärk - en sammanställning av praktiska erfarenheter och litteratur. SLU. Institutionen för skogsskötsel. Arbetsrapport, No. 24, 52 pp. ISSN 0281-7292. (In Swedish.)

Sylvestre-Guinot, G., Pâques, L.E. & Delatour, C. 1999. Annals of Forest Science, No 56:6, pp 485-492. (In French with English summary.)

Sylvestre-Guinot, G. & Delatour, C. 2002. Twenty years of research on larch canker in France. Improvement of larch (*Larix sp.*) for better growth, stem form and wood quality, Proceedings from an international symposium in Gap and Auvergne in September 16-21, 2002, pp 194-203.

Taylor, 1964. The place of larch in Scottish silviculture. Scottish Forestry, No. 18, pp 189-198.

Thormann, A. & Madsen, S.F. 1998. Proveniensforsøg med japansk lærk. Naturlig udbredelse. En international forsøsserie. Forskningscentret for Skov & Landskab, Videnblade Skovbrug, No 3.3-11. (In Danish.)

Thunell, B. & Perem, E. 1952. Svenskt trä. Strömbergs Förlag, Stockholm. (In Swedish.)

Ullström, K-E. 1966. SPF's växtatlas. Sveriges Pomologiska Förening. Stockholm. (In Swedish.)

Vicena, I. 1998. Larch increases stand resistance to windstorms. Lesnictvi Forestry. Vol. 44:5, pp 230-234. (In Czech with English summary.)

Vidakovic, M. 1991. Conifers – morphology and variation. Graficki zavod Hrvatske, pp 255-279. ISBN 0-85198-807-5.

Vollbrecht, G., Johansson, U., Eriksson, H. & Stenlid, J. 1995. Butt rot incidence, yield and growth pattern in a tree species experiment in southwestern Sweden. Forest Ecology and Management, No 76, pp 87-93.

Vollbrecht, G. & Stenlid, J. 1999. Transfer of the P-type of Heterobasidion annosum from old-growth stumps of *Picea abies* and *Larix* × *eurolepis*. European Journal of Forest Pathology, No. 29, pp 153-159.

Wagn, O. 1987. Smitteforsøg med rodfordærveren, *Fomes annosus* (Fr.) Cooke i lætræer, II. Afsluttende opgørelse. Tidskrift for planteavl, No. 91, pp 173-181. (In Danish with English summary.)

Wielgolaski, F.E. Opdahl, H. & Nes, K. 1993. Growth studies in plantations of European larch (*Larix decidua* Mill.) and Japanese larch (*L. kaempferi* (Lamb.) Carr.) in western Norway. 2. Forecasting growth and yield by various site-indices and thinnings. Meddelelser fra Skogforsk 46 (12). Norsk institutt for skogforskning. Institutt for skogfag, NLH, 42 pp.

Zavitkovski, J. & Strong, T.F. 1984. Biomass production of 12-year-old intensively cultured *Larix eurolepis.* USDA Forest Service research note NC - United States, North Central Forest Experiment Station, No. 321, pp 1-3.