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Tree Species Experiments at the Northern Timberline Region in Finland

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Abstract

The arboreal flora of the northern timberline region is species-poor with only about 20 tree species growing in the forest-tundra region. The question of afforesting areas beyond the treeline has been of interest already for centuries and many more or less scientifically well-founded plantations have been established in the timberline region. This article presents 74 experiments with exotic tree species established for forest genetic purposes in Finnish Lapland north of the Arctic Circle. A total number of 22 exotic taxa, most of them conifers, have been tested in these experiments. There are only four exotic species: *Picea glauca, Picea mariana*, *Pinus contorta* var. *latifolia* and *Larix sibirica*, which have been tested rather well at the timberline conditions. There are more than ten potentially promising species which have not at all been tested in Finnish Lapland, among them e.g. *Larix lyallii* and *Chosenia arbutifolia*. The cultivation of exotic tree species is discussed in the light of climatic change and the improvement of forest productivity. Also the importance of considering selection of the proper provenance is stressed in connection with testing exotic tree species.

Key words: climatic change, exotic tree species, provenance, silviculture, timberline

Introduction

Northern Finland belongs to north boreal and arctic (tundra) vegetation zones, thus the timberline is running through it (Hämet-Ahti *et al*. 1992). It has a cold semi-maritime climate with mean temperature of the warmest month decreasing from 15 °C in the south to below 10 °C in the mountainous areas in the northwest (Hannelius & Kuusela 1995). The bedrock and soil of whole Finland are acidic and poor of nutrients. The soils and the landscapes have been modified by the Ice Age and the melting waters during the retreating phase of the glaciers (Hannelius & Kuusela 1995). There are only a few native tree species in northern Finland: two conifers and less than ten broad-leaved species. Most of the broadleaved species have no economic value, so there remain only a few tree species which have interest in silvicultural meaning. Therefore it is understandable, that the question of utilising exotic tree species to improve forest production and even afforest areas beyond the timberline has intrigued foresters and scientists already for centuries (Mikola 1952, Hustich 1966, Hagman 1995a, Veijola 1998) and there are many documented old plantations with exotic tree species in northern Finland (Ilvessalo 1920, Kalela 1937). In addition to the above mentioned economical reasons, the cultivation of exotic tree species has also theoretical dimensions, as for example the determination of the potential timberline (Kallio 1990).

The enthusiasm for growing exotic tree species in northern Finland is further supported by the fact, that many of those species, which are currently foreign to the area have been growing there before the Ice Age or even after that. The arboreal flora of the temperate and boreal forests was, before the Ice Age, much more similar throughout the whole circumpolar area than it is today (Huntley 1993, Svenning 2003). Pollen from the genera *Corylus*, *Abies*, *Larix* and *Tsuga* have been found in Lapland in soil layers deposited before the last Ice Age (presumably over 100 000 years old) (Hirvas 1991). All these genera are now foreign to Lapland, Finland or even the whole of Europe. In fact, *Larix sibirica* has demonstrably been growing in the Scandes Mountains also after the last Ice Age (Kullman 1998). Thus the question of native and exotic tree species can be discussed only for a given point of time; with a longer time scale and changing climate it is meaningless.

The tree species question in the timberline region can also be discussed in respect to the anthropogenic climatic change, which is estimated to increase the mean temperature in Finland from 2 to 5 °C by the 2050's as compared to the period 1961-90 (Carter & Kankaanpää 2003). Such a major change in the temperature climate will inevitably also lead to changes in the distribution areas of individual tree species (Davis & Shaw 2001, Carter & Kankaanpää 2003). It has been predicted that an increase of already 0,5 °C in the mean July temperature in Finnish Lapland will result in a considerable northward shift of the Scots pine treeline (Kultti 2004). However, the rate of change is undergoing some discussion. The models used to predict the response of vegetation to climatic change often either totally neglect the dispersion phase of species or assume that the species occupy the new suitable areas immediately after an improvement of the climate (Cain *et al*. 2000). There are also factors other than the large-scale climate, like difficulties in seedling establishment and browsing and mechanical damage

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caused by reindeer, which influence the colonisation success of species (Holtmeier *et al*. 2003). The necessary within-population adaptation will also take time, and can impede the dispersal of the species into new areas (Davis & Shaw 2001, Savolainen *et al*. 2004).

The aim of this paper is to describe the field experiments containing exotic tree species that have been established for the purposes of tree breeding or forest genetics in the timberline region in Finnish Lapland, and to discuss their value in studying the tree species question in the timberline region. The scientific nomenclature and taxonomic division follow those used by Hämet-Ahti *et al*. (1992).

Existing experimental material

The pioneering work in the field of growing exotic tree species in northern Finland was carried out by some private enthusiasts and foresters in the late 19th century (see Reuter 1918, Parvela 1930, Hagman 1995a). The first species to be cultivated were *Larix sibirica*, *Abies sibirica* and *Pinus cembra*, all of them species for which it was easy to obtain seed at the time when Finland belonged to the Russian empire. The Finnish Forest Research Institute (Metla) started a large-scale cultivation project of exotic species in the 1920's, but the northernmost cultivations were slightly to the south of the Arctic Circle, close to Rovaniemi.

The most extensive network of experiments with exotic tree species in the timberline region in Finland was established for the purposes of forest genetics and tree breeding (Fig. 1). The experiments relatively uniformly cover the area north of the Arctic Circle. However, the clear majority of the experiments are located in the southern part of the study area. There are only 11 experiments, which are located at or beyond the coniferous treeline. The total number of experiments with exotic tree species established north of the Arctic Circle is 74 (17 % of all the forest genetic experiments in the area) and they include a total of 22 exotic species or other taxa (Table 1). Most of the tested species are conifers, with only two genuine species of exotic broadleaved trees and three broadleaved cultivars or hybrids. The most intensively studied species are the three North American conifers *Picea glauca*, *P. mariana* and *Pinus contorta* var. *latifolia*, and the Eurasian *Larix sibirica*, all of which are represented in at least 25 experiments. In addition to these comprehensively tested species, only *Larix laricina* and *Pinus banksiana* are represented in more than ten experiments, the rest of the species being included in only one or a few of the experiments. It is indicative that all the experiments established with exotic broadleaved species have been destroyed to such an extent that they have been discontinued.

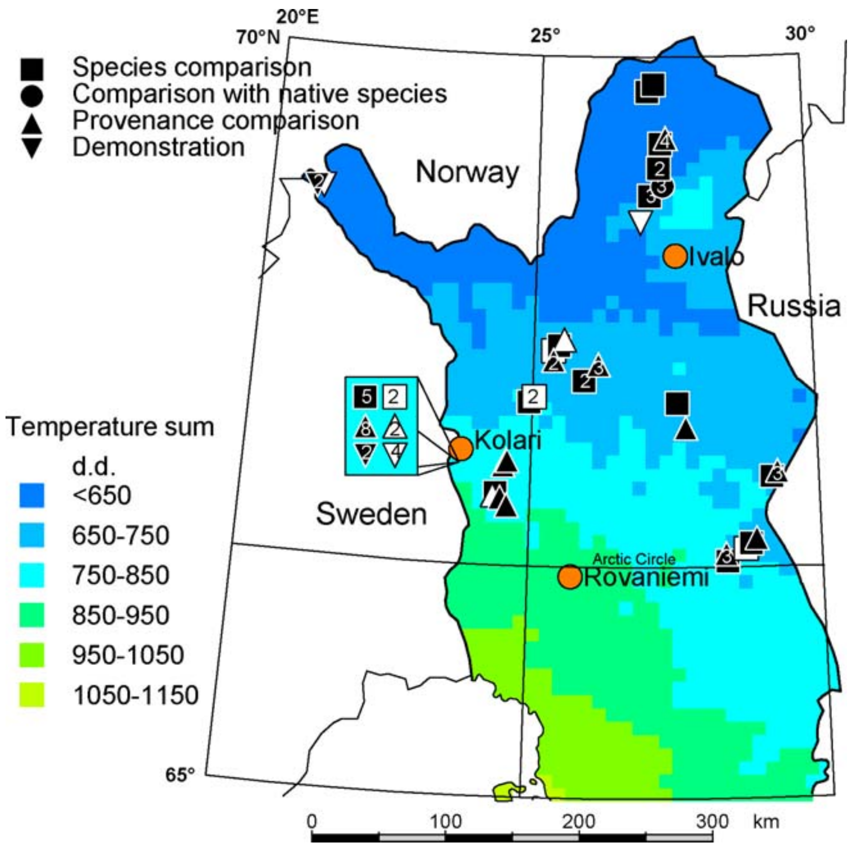

Fig. 1. The locations of different types of forest genetic experiment with exotic tree species in Finnish Lapland north of the Arctic Circle. The number of experiments is given inside the symbol if more than one is at the same location. Filled symbols refer to existing experiments, and open ones to those discontinued due to damage. The temperature sums are mean annual temperature sums with +5 °C threshold. Data from the Register of Forest Genetics, the Finnish Forest Research Institute , 2003.

Table 1. Exotic tree species in the forest genetic experiments in Finnish Lapland north of the Arctic Circle. Data from the Register of Forest Genetics, the Finnish Forest Research Institute , 2003.

Species	No. of experiments		
	Existing	Discontinued	All
Abies balsamea	2		2
Abies lasiocarpa	5	2	7
Abies sibirica		2	2
Larix decidua	2		2
Larix gmelinii	5		5
Larix laricina	17	1	18
Larix sibirica	27	2	29
Picea engelmannii	2	4	6
Picea glauca	26	4	30
Picea koraiensis		2 [a)]	2
Picea mariana	25	1	26
Picea omorika		1 [a)]	1
Picea sitchensis		1 [a)]	1
Pinus banksiana	10	3	13
Pinus cembra	1		1
Pinus contorta var. *latifolia*	21	4	25
Pinus peuce		2	2
Alnus crispa		2 [a)]	2
Betula papyrifera		1	1
Populus 'Rasumowskiana'		2	2
Populus sp.		1	1
Populus x wettsteinii		4	4

a) The experiment is still valid, but the species in question has been eliminated

Table 2. Basic information about experiments including exotic tree species in Finnish Lapland north of the Arctic Circle (includes 58 existing and 16 discontinued experiments). Data from the Register of Forest Genetics, the Finnish Forest Research Institute, 2003.

	All	Existing experiments		
	Mean	Mean	Minimum	Maximum
Latitude, °N	67°48’	67°52’	66°36’	69°49’
Temperature sum, d.d	722	715	492	835
Altitude, m a.s.l.	222	226	100	480 [a)]
Age, years	22.6	20.1	8	45 [b)]
No. of species	2.5	2.6	1	8
No. of entries	73.1	89.9	1	682
No. of blocks	6.5	6.6	1	13
No. of plants	3,359	3,624	112	30,708
Area, ha	1.4	1.53	0.03	12.48

a) When the highest plot is taken into account, the maximum value is 550 m
b) Age for one discontinued experiment was 49 years, otherwise the extreme values were the same for both groups

Basic information about the forest genetic experiments with exotic tree species is given in Table 2. The experiments range in altitude from 100 m to 550 m above sea level and in effective temperature sum (+ 5 ºC threshold) from 490 to 835 d.d. Most of the experiments are located on mineral soil, but several peatland sites are also represented especially close to the Kolari Research Unit. The purpose, species composition and technical layout of the experiments vary considerably. Some of the experiments aim at comparing different tree species, and thus include several exotic species and usually also some native species as a benchmark. Half of the experiments have only one exotic tree species, and 72 % of them have at the most three exotics. Those experiments with only one exotic species are intended for testing different provenances within one species, or are species comparison trials where the other entries are native species. The number of entries ranges from one (demonstrational experiments) to more than 600 (combined provenance-progeny tests of North American conifers).

In spite of the great number of experiments with exotic tree species, not so many extensive studies have been conducted on them. The reason for this is that, although the exotic tree species arouse much public interest, their low importance in present day practical forestry has not justified any comprehensive studies. The following studies illustrate some of the work carried out on these experiments: vole damage in tree species trials (Rousi 1983a), comparison of seed sources of *Larix* (Hagman 1995a), the provenance question (Ruotsalainen & Velling 1993) and the effect of climatic warming on the wood production of *Pinus contorta* var. *latifolia* (Fries *et al*. 2000), and comparison of the survival and growth of several tree species (Hagman 1993).

Besides these formal experiments established by forest tree breeders, information about exotic species can also be obtained from experiments in other fields of research, from practical plantations, cultivations established by local dendrologists, and also some arboreta located in Lapland. Of the last-mentioned category, the arboretum established in 1990's by the Finnish Forest Research Institute in Kolari, with its more than one hundred woody taxa, deserves special mention (Ruokojärvi & Ruotsalainen 1996).

Examples of results

Some representative results from a pair of experiments in northernmost Lapland are given in Figure 2. These experiments belong to a joint research venture, the so-called forest-line arboretum, carried out by the University of Turku, the Forest and Park Service and the Finnish Forest Research Institute (Kallio *et al*. 1986). The results show that it is possible to find species with better survival and growth than the local *Pinus sylvestris*. *Pinus contorta* var. *latifolia*, which has

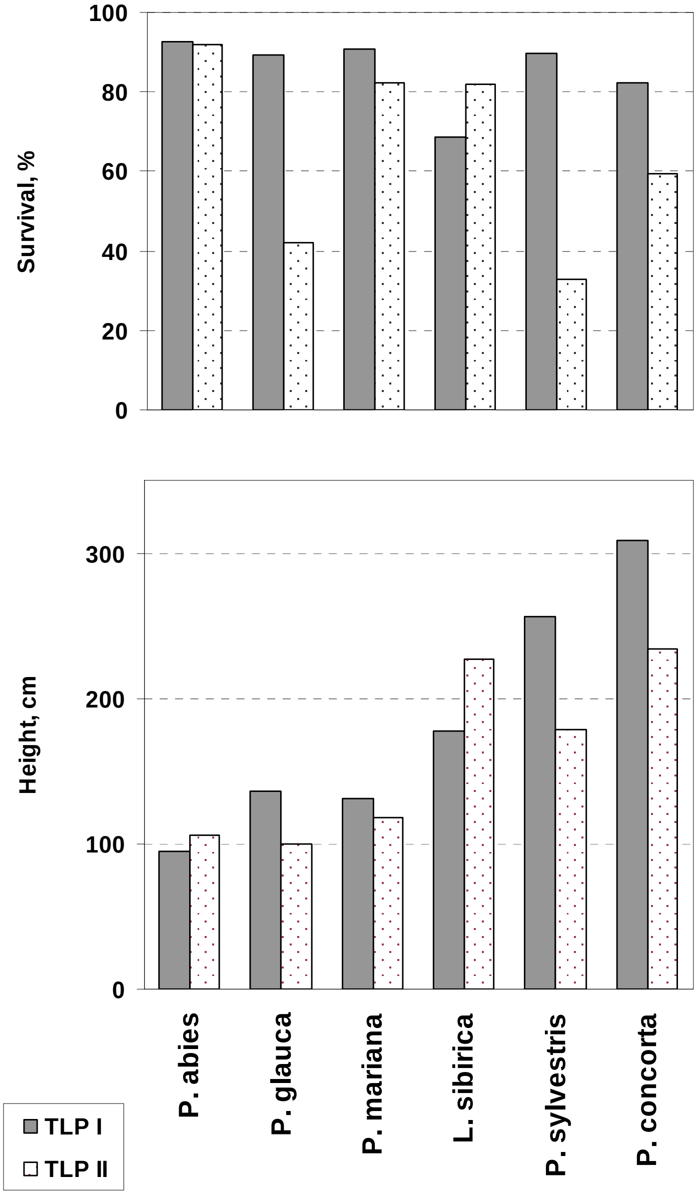

Fig. 2. Survival and mean height of six conifer species in two experiments of the forest-line arboretum in Utsjoki (latitude 69º45'N) at the age of 18 years. TLP I is located in a pine forest on dry sandy soil (100 m above sea level) and TLP II on a mesic slope at the birch treeline (280 m a.s.l.). (from Ruotsalainen 1998)

been widely used in forest plantations in northern Sweden due to its high productivity (von Segebaden 1993), is especially promising even in these harsh conditions. Another interesting feature in the results is that *Larix sibirica* has higher survival and growth in the climatically more severe treeline experiment (TLP II) than in the experiment located at a lower altitude. One explanation for this is that TLP II is located on a slope with fertile soil where the conditions are favourable for good growth of *Larix sibirica* (Hagman 1995a). For a more detailed discussion of these experiments see Ruotsalainen (1998).

Another descriptive example of this kind of experiment is given in Figure 3, which shows *Abies lasiocarpa* growing on a slope on Saana Mountain in northwestern Lapland. In this experiment, which is located above the coniferous treeline, the survival was 90 % and the mean height of the trees 1.7 m 39 years after planting. The experiment consists of several plots stretching over an altitudinal range of about 70 m. The uppermost plots have more fertile soil and thus the mean height of the trees there was 2.5 m. The tallest tree in the experiment was 5.0 m high.

The importance of the proper provenance cannot be too much emphasised, when cultivating foreign tree species. The interaction between provenance and environment is demonstrated by a pair of experiments in Kolari, western Lapland (latitude 67 °N) (Fig. 4). In both experiments survival is increasing with increasing latitude of origin, although in the experiment located on peatland the trend is more variable probably due to technical reasons (the experiment is a demonstrational field without proper blocking and replication). In height growth there is a similar trend, but in the peatland experiment it is drastically more pronounced, because the southernmost provenance is suffering from the cold local climate on that site.

Promising species

The research work conducted with the exotic species at the timberline region in Finnish Lapland has hitherto revealed some silviculturally valuable species. The

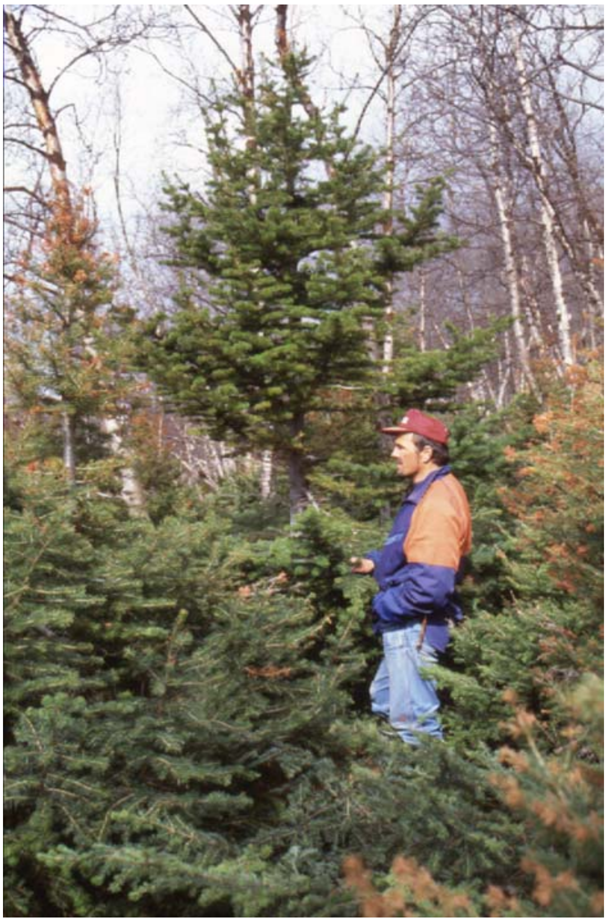

Fig. 3. One of the tallest *Abies lasiocarpa* (provenance British Columbia, Aleza Lake) trees in experiment No. 161 in Enontekiö, Kilpisjärvi (69º02'N, 20º51' E, 550 m a.s.l.) in 1994 (34 years after planting).
Photograph by Seppo Ruotsalainen.

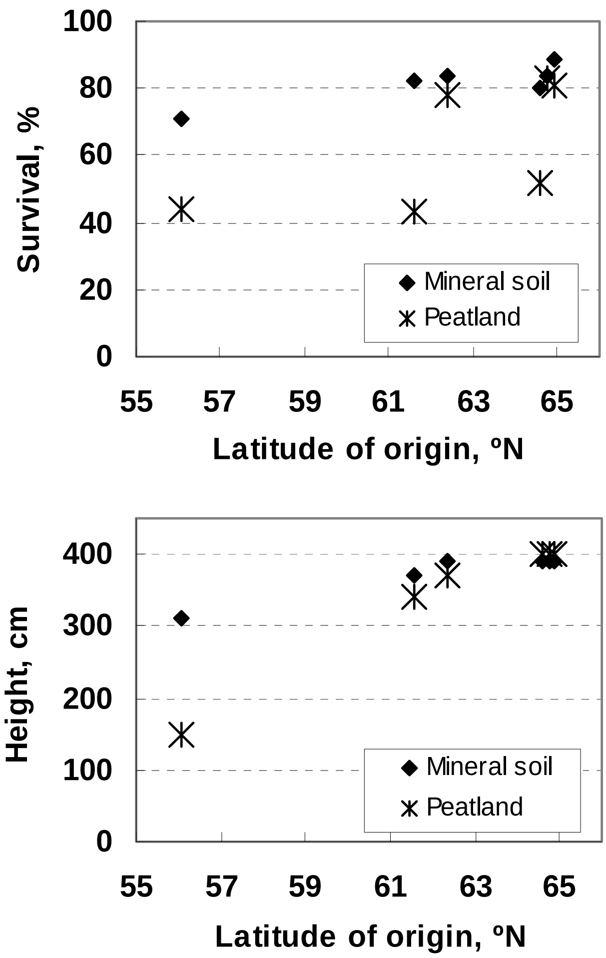

Fig. 4. Survival and mean height in two provenance experiments of *Picea mariana* (Nos. 444/1 and 444/3) in Kolari (latitude 67ºN) at the age of 20 years. The experiment No. 444/1 is located on mineral soil on a low hill and the experiment No. 444/3 on a frost-prone peatland site.

clearest example of successful introductions is *Pinus contorta* var. *latifolia*, which is clearly superior to local *Pinus sylvestris* in productivity (Varmola *et al*. 2000). *Larix sibirica* has also given good results on fertile sites, but seems not to be suitable on dry poor sites (Hagman 1995a, 1995b). These two species are also those which have been used to some extent in practical silviculture in Finnish Lapland. The two North American spruce species, *Picea mariana* and *Picea glauca* have been tested rather profoundly, and they have shown some promise in the experiments, especially as regards survival. However, they lack superiority in wood production capacity, and thus will probably not become some real alternatives in practical forestry. These two spruce species have not yet been subject to any extensive studies in northern Finnish conditions.

Larix laricina is a species, which has been studied less than the above mentioned four species, but some promising experiences concerning it have been obtained. Preliminary observations e.g. show that it is more resistant to vole attacks than other tree species (Rousi 1983b). In North American and Swedish studies it has also been shown to have great growth potential (Packee 1995, Simak & Jeansson 1995).

The whole genus of *Abies*, although tested in rather limited scale, seems to lack any real possibilities to become important forestry species. The species of this genus generally have high survival, but the growth is usually poor, because they require fertile soils, which are rare in Finnish Lapland. At Swedish timberline conditions, which have more fertile soils, e.g. *Abies lasiocarpa* has shown both good survival and height growth (Martinsson & Winsa 1986, Rosvall *et al*. 1996). Rest of the species presented in Table 1 either lack all possibilities in forestry at the Finnish timberline conditions or have been tested on so few sites, that nothing sure can be said from their growth potential.

Potential new species

Although the list of studied species is fairly long (22 species, Table 1), there are still several potential species, which deserve testing at timberline conditions (Table 3). A good candidate species for wood production in the timberline region, in addition to those species reaching the northern treeline, can also be sought from among the dominant species throughout the whole boreal region and in the alpine timberline regions. A total of 32 species with possible economic importance in Finnish Lapland are listed in Table 3. Among these species 27 are exotics, 12 of them have not been tested at all in Lapland, and 11 have been tested insufficiently. With some species the expectations are surely too optimistic; for instance, the two North American white pines (*Pinus albicaulis*, *P. flexilis*), will probably have difficulties with the blister rust (*Cronartium ribicola*), as is normally the case with American white pines in Europe (Sarvas 1964). The same species, as well as many broadleaved species, will probably have a limited use because they favour soils with low acidity and high nutrient content.

Perhaps the most interesting untested species in Table 3 are *Larix lyallii* and *Chosenia arbutifolia*. *Larix lyallii* is an alpine treeline species from western North America, with its northernmost occurrence at latitude 51º 36’ N in Alberta (Arno *et al*. 1992). It favours acidic granite soils and is thus suitable to Finnish conditions. Also Packee (1995) suggests that although this species is very poorly known, it is worth further studies. *Chosenia arbutifolia* is a broadleaved treeline species from eastern Siberia with a distribution area extending to the timberline. It is a fast growing, light and moisture demanding species, which can reach a height of 20 m in less than 30 years on the alluvial soils in the middle latitudes (60º N) of its distribution area (Moskalyuk 1990).

The list mentioned above (Table 3) also includes species other than those reaching the treeline. This is because the intended target area extends to the south of the treeline and, on the other hand, other species can also grow well at the treeline. A good example of this is *Pinus contorta* var. *latifolia*, which is not a treeline species, but seems to thrive in the treeline conditions in Finland (Fig. 2). The inclusion of alpine treeline species or species from adjacent areas is easier to justify, because both the alpine and the polar timberlines are thermal limits. An example of the good success of an alpine treeline species is provided by *Abies lasiocarpa* (Fig. 3).

The semi-maritime feature of the Finnish timberlines enables the use of a wider selection of exotic tree species than would be possible in purely maritime or purely continental climates. The lack of extremely low winter temperatures also provides opportunities for broadleaved species, whose water conducting vessels suffer damages during extremely cold winters (Woodward 1995). This kind of climate also seems to give competitive advantage to species from the genus *Pinus*, which otherwise do not usually reach the northern timberline region (Hustich 1966). On the other hand, the poor Finnish soils set limitations to the use of many demanding broadleaved species.

There is also a problem in including alpine timberline species in the survey; the alpine timberlines are of variable nature and they can differ from the Finnish timberline conditions in many respects, e.g. photoperiod and continentality. Thus, the most maritime timberline regions and areas south of about 45º N were excluded from this survey. The set of possibly promising introductions can, to some extent, be deduced by studying the climatic and biogeographical conditions of the donor and target areas (eg. Kujala 1945), but the final answer must always be sought through field experiments. In some cases species from a rather deviating climate can also grow well, as is evidenced by the two Balkan species *Picea omorika* and *Pinus peuce* in Finland (Hagman 1990).

Restricting the survey only to the dominant species makes it easier to perform the study, as it is difficult to obtain reliable information about many exotic minor species, with often also have disputable taxonomy. It is rather easy to accept the rationale of this restriction when considering e.g. the Finnish minority species *Salix caprea* and *Sorbus aucuparia*, which were excluded from the study although both are growing under timberline conditions. They can hardly be considered as real alternatives for wood production in the timberline region. However, although the probability of finding economically important species from among those species, which are of minor importance in their native range is small, there can always be exceptions. For instance, *Pinus radiata* is one of the most planted exotic tree species in the world, although its original distribution area is less than 100 km^2, and even there it has only limited commercial value (McDonald & Laacke 1990).

Research tasks

Another aspect, in addition to the selection of species to be tested, is the selection of the proper provenances of the tested species. Species with a large distribution area show great differences in the climatic adaptation of their provenances. Therefore it is essential that the hardiest possible provenances are used when testing different species in the timberline region. Unfortunately, due to difficulties in accessibility, many of the oldest experiments and plantations have been established with too southern provenances, and they are therefore underestimating the usefulness of many exotic species.

Table 3. List of potential tree species for the timberline region in Finnish Lapland north of the Arctic Circle, together with their testing status. The origin of the species is indicated as follows: northern Eurasia (NEA), European mountains (EM), northern America (NA), North American mountains (NAM). Species native to Finnish Lapland are marked with a bold X.

Species	Area of origin				Testing status		
	NEA	EM	NA	NAM	Well-tested	Some testing	Not tested
Betula pendula	**X**						
Betula pubescens	**X**						
Picea abies	**X**						
Pinus sylvestris	**X**						
Populus tremula	**X**						
Abies nephrolepis	X						X
Abies sibirica	X					X	
Betula ermanii	X						X
Chosenia arbutifolia	X						X
Larix gmelinii	X					X	
Larix sibirica	X				X		
Picea jezoensis	X						X
Pinus cembra	X					X	
Populus suaveolens	X						X
Larix decidua		X				X	
Pinus mugo subsp. *uncinata*		X					X
Pinus peuce		X				X	
Abies balsamea			X			X	
Betula papyrifera			X			X	
Larix laricina			X			X	
Picea glauca			X		X		
Picea mariana			X		X		
Pinus banksiana			X			X	
Populus balsamifera			X				X
Populus tremuloides			X				X
Abies lasiocarpa				X		X	
Larix lyallii				X			X
Picea engelmannii				X		X	
Pinus albicaulis				X			X
Pinus contorta var. *latifolia*				X	X		
Pinus flexilis				X			X
Populus trichocarpa				X			X
No of species by subgroup	14	3	7	8	4	11	12

Note: Species accepted in the list according to the following criteria: 1) attains tree size, 2) a dominant tree species in its original growing area, 3) climatically adapted to the intended area (excluded areas: south of latitude 45° N, maritime areas).

Sources: Arno and Hammerly (1984), Burns and Honkala (1990a, b), Hämet-Ahti *et al*. (1992), Nikolov and Helmisaari (1992), Reinikainen (1997), Sarvas (1964).

Many of the existing experiments have been established with a too southerly or a haphazard selection of provenances. Positive exceptions include the new joint Nordic experiments with material collected in North America (Skaret & Rosvall 1993, Rosvall 1995). It must be also noted that, although *Larix sibirica* is a relatively well-studied species, only a few tested entries originate from the natural distribution area of the species; the experiments have mainly been established with 2nd generation Finnish seed sources. Fortunately new genuine provenance material of *Larix sibirica* and *Larix gmelinii* has been obtained recently through the international SIBLARCH project (Abaimov *et al.* 2002).

The study of exotic tree species can be seen as cheap insurance in the face of an unknown future. The existing experiments offer an invaluable material for such studies, but there are also questions which necessitate the establishment of new experiments with new species and provenances. The described array of experiments offers good starting point also for international cooperation in studying tree species at the northern timberline conditions.

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