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Successful growth of micropropagated ornamental tree forms in northern Finland

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Abstract: Micropropagated trees, *Alnus incana* f. *laciniata*, *Betula pendula* f. *crispa*, *Betula pubescens* f. *rubra*, *Populus tremula* 'Erecta' and *Prunus maackii*, were studied in a selection experiment at four different study sites in northern Finland. The aim of the field experiment was to identify hardy and valuable special tree forms for northern landscaping based on tree phenology and success. All the trees studied revealed some good characteristics and have potential in northern horticulture. *B. pubescens* f. *rubra* (red-leaved downy birch) is especially noted for its excellent winter hardiness and showy appearance at every study site. It is a valuable addition to the tree selection for use in northern landscaping.

Additional key words: hardiness, cultivation success, landscaping in northern areas

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Introduction

The Finnish arboreal flora includes a total of 60 tree taxa when all tree species, subspecies, tree like shrubs, varieties and hybrids are counted (Alanko 2001; Alanko 2005). Special forms of deciduous trees have not been used in Finnish gardens us much as the special forms of evergreen conifers, like the ones of the Norway spruce (Oskarsson and Nikkanen 2001). The commercially available hardy broadleaved tree material for northern landscaping and gardening environments is limited. Further, there are few studies in Finland on breeding and selecting ornamental trees (Linden et al. 2004; Alanko 2005).

In the 1980's hardy woody plant material was sought and registered from the areas of northern Finland (Laine et al. 1993; Tarvainen et al. 1993; Väinölä et al. 1995). On the basis of preliminary evaluation the promising woody plants were selected for field experiment to find the most valuable trees and shrubs from the collected substantial plant material. Using this material earlier studies have already revealed some promising ornamental shrub and shrub rose taxa for landscaping and gardening in northern areas (Pihlajaniemi et al. 2005a, b). The purpose of this study is to further identify the success of the woody plants by monitoring plant phenology, winter hardiness and disease and pest resistance. This study provides new information on the success, cultivation possibilities and qualities of some ornamental special tree forms in northern Finland. Results of the study can also be applied in areas with a corresponding bioclimate.

Fig. 1. Study sites of the plant selection experiment in Finland

Material and methods

Buds from five pre-selected individual trees were collected from parks and private gardens in northern Finland for *in vitro* propagation. Cultures were grown on the MS media described by Murashige and Skoog (1962) or on the Woody Plant Media (VPM) described by Lloyd and McCown (1980) (Haapala and Niskanen 1992). When derived from *in vitro* to the field trees were approximately 40 cm high pot plants. Trees were identified according to Hämet-Ahti et al. (1992) and Räty and Alanko (2004).

Tree taxa

Betula pubescens Ehrh. f. *rubra* Ulvinen (red-leaved downy birch) was propagated by the explants taken from the only wild specimen grown in nature in Yli-Kiiminki, 64°55'N, 26°20'E. Young leaves of the tree are green but soon after leaf burst all the leaves turn permanently red. Also the outer and old bud scales in axillary buds are red. The tree trunk is white (Kauppi and Ulvinen 1989).

Betula pendula Roth f. *crispa* (Reichenb.) Hämet-Ahti (cut-leaved silver birch) was propagated by the explants taken from a tree growing in Pietarsaari, 63°40'N, 22°42'E. It is a special ornamental growth form of common silver birch with deeply cut leaves. The sides of leaf strips are tightly serrated. The tree trunk is white. The genotype has good winter hardiness.

Alnus incana (L.) Moench f. *laciniata* Loudon (cut-leaved gray alder) was propagated by the explants taken from a tree growing in Ainola park in Oulu, 65°01'N, 25°28'E. It is a tree with dense, decorative light green leaves that are deeply incised with

Table 1. Climatic data minimum (min) and maximum (max) values at the experiment sites from north to south during the study period year 1993 to 1999. *Data are from Salla (66°50'N, 28°40'E, 215 m a.s.l.) the nearest meteorological station to the Naruska study site (Salla is 50 km to south from Naruska)

		Salla*	Rovaniemi	Ruukki	Sotkamo
Beginning of growth period (date)	min	May 15	May 5	April 21	April 28
	max	June 5	May 23	May 18	May 23
End of growth period (date)	min	September 2	September 6	September 12	September 12
	max	September 24	October 14	October 12	November 2
Duration of growing season (days)	min	98	124	133	137
	max	131	151	153	169
Effective temperature sum (C°)	min	606	720	924	814
	max	854	1007	1146	1136
Temperature in February (C°)	min	–40,6	–42,6	–32,2	–40,8
	max	4,2	6,6	6,2	6,0
Temperature in July (C°)	min	–0,1	0,7	1,6	–1,5
	max	27,5	29,5	31,3	30,6

*Growing season begins when the daily mean temperature exceeds +5°C on five days in succession and the ground is at least half snow free. Growing season ends when the daily mean temperature drops below +5°C on five days in succession. Effective temperature sum is calculated by summing the daily mean temperatures of the days on which temperature exceeds +5°C from the beginning of the growing season.

pairs of lobes. The tree trunk is gray. The genotype has a regular growth habit.

Populus tremula L. 'Erecta' (columnar European aspen) was propagated by the explants taken from a tree growing in Oulu, 65°01'N, 25°28'E. It is a narrow, upright growth form of aspen. The tree trunk is greenish with gray bark. The leaves are round, flat and repand. The columnar tree grows 5–17 meters high and is densely branched also form the lowest parts of the trunk. The genotype is hardy in Oulu.

Prunus maackii Rupr. (Amur chokecherry, Manchurian cherry) was propagated by the explants taken from a tree growing in a private garden in Kiiminki, 64°55'N, 26°20'E. It is a decorative tree due to its shiny, slightly peeling, red-brown bark and beautiful leaves. Its flower clusters are white with 6 to 10 flowers and its fruits are black berries. The genotype is fast growing and has a graceful growth habit (tree was not planted in Ruukki).

Field experiment

Twelve *in vitro* propagated plant individuals per genotype were planted in random order with a 2×3 m distance between individuals. Weeds were controlled with a covering sheet. The plants were fertilised with Kemira NPK 10:7:14, 10 g per plant. Damaged branches and shoot tips were cut off in spring. A survey of the phenological events and tree success was done between the years 1993 and 1999 at four different study sites in northern Finland; **Naruska** (67°09'N, 29°10'E, 213 m a.s.l.) an experiment field of University of Oulu, **Rovaniemi** (66°35'N, 26°01'E, 103 m a.s.l.), **Ruukki** (64°40'N, 25°05'E, 45 m a.s.l.) and **Sotkamo** (64°06'N, 28°20'E, 150 m a.s.l.) research stations of the Agricultural Research Centre of Finland (Fig. 1). The Naruska and Rovaniemi sites are located above the Arctic Circle with a subarctic climate. The climatic conditions at the study sites during the survey period are presented in Table 1. The soil in Naruska is peat land that, on the basis of soil analysis (Tarvainen et al. 1993), had to be improved by adding a sand and lime base. The Rovaniemi, Ruukki and Sotkamo sites have a mineral soil.

Data analysis

Taxa specific means for the phenological parameters measured in a continuous scale were computed for: beginning day of leaf burst, ending day of foliation, beginning and ending day of flowering, beginning and ending day of autumn coloration, beginning day of leaf senescence and ending day of defoliation. For the parameters measured in an ordinal scale, taxa-specific medians of the values (winter hardiness, ornamental value etc.) measured in different years were computed (Table 2). Above data (medians) are presented as Boxplot figures. In these figures (Fig. 2A–B and Fig. 3A–C) the median is presented by a thick line, while the central box contains 50% of the variation and whiskers show the minimum (below the box) and the maximum (above the box) values excluding outliers. If median is equal to the maximum or minimum value the box and the whisker is present only on the other half. In case all the individuals have the same value within the genotype within the study site there is no variation around the median and hence no box or whiskers are presented. Statistical analyses were performed, separately for each study site, by means of the nonparametric Kruskal-Wallis test with genotype as the grouping factor. Kruskal-Wallis results (χ^2_{df} – values with significance symbols, *** = $p < 0.001$ and NS = $p > 0.05$) are given in Figures 2A–B and 3A–C. Note that the flow-

Table 2. Monitoring parameters used in a selection experiment during the growing season

Variable	Scale	Scale explanation
Onset of foliation	date	when 10% of budscales are open and buds are green
Full foliation	date	when over 90% of buds are open
Onset of flowering	date	first 10% of flower buds flushed
End of flowering	date	last 10% of flower buds flushed, 90% of flowers wilted
Onset of autumn coloration	date	first 10% of leaves autumn coloured
End of autumn coloration	date	last 10% of leaves autumn coloured
Onset of leaf defoliation	date	first 10% of leaves shed
End of defoliation	date	last 10% of leaves shed
Winter hardiness	1–5	1:dead, 2:dead to ground level, 3:dead to snow level, 4:shoot tips dead, 5:tip buds dead or no damage
Ornamental appearance	1–5	1:ugly, 2:rather ugly, 3:moderate, 4:rather beautiful, 5:beautiful
Occurrence of leaf diseases	1–5	1:over 90% injury, 2:70% injury, 3:50% injury, 4:30% injury, 5:no significant injury
Occurrence of leaf pests	1–5	1:over 90% injury, 2:70% injury, 3:50% injury, 4:30% injury, 5:no significant injury
Occurrence of shoot diseases	1–5	1:over 90% injury, 2:70% injury, 3:50% injury, 4:30% injury, 5:no significant injury
Occurrence of shoot pests	1–5	1:over 90% injury, 2:70% injury, 3:50% injury, 4:30% injury, 5:no significant injury
Occurrence of flowers during full flowering	1–5	1:none, 2:few, single (1–10), 3:moderate (11–30), 4: rather abundant (31–50), 5:abundant (over 50)

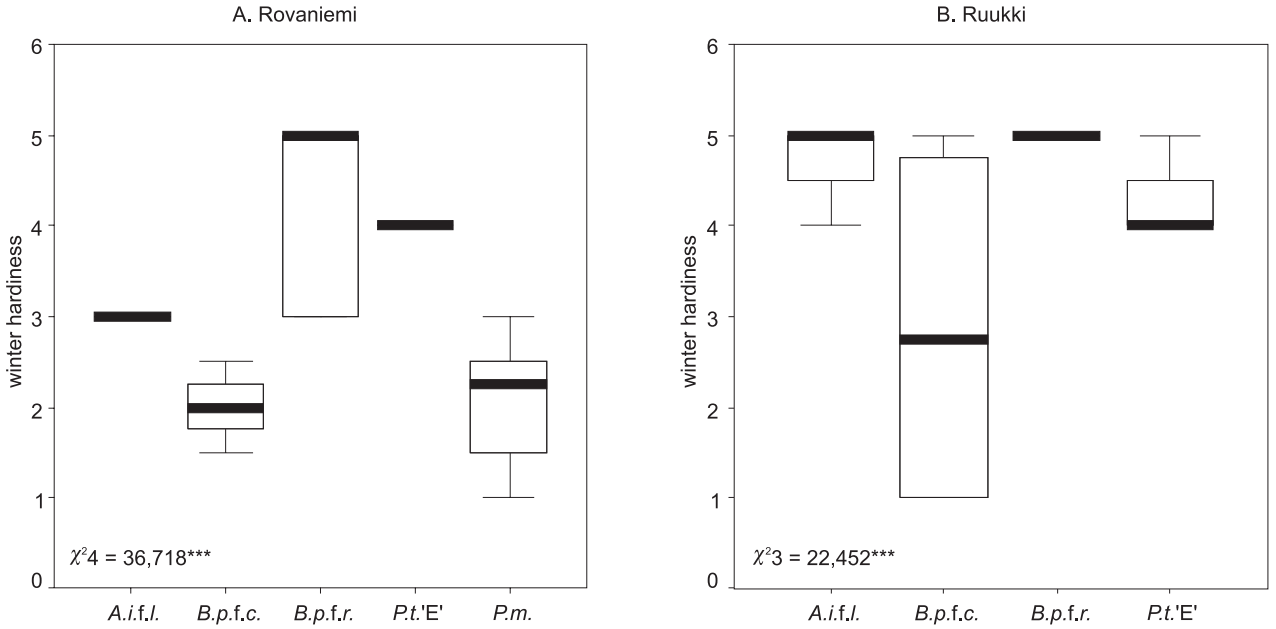

Fig. 2A–B. The winter hardiness of the trees (*A.i.f.l.*=*Alnus incana* f. *laciniata*, *B.p.f.c.*=*Betula pendula* f. *crispa*, *B.p.f.r.*=*Betula pubescens* f. *rubra*, *P.t.*E.= *Populus tremula* 'Erecta' and *P.m.*=*Prunus maackii*). Scale (y-axis) 1–5; 1 = dead to 5 = no damage, excellent winter hardiness see Table 2. Thick lines present the medians of winter hardiness classes at the study sites, while the central box contains 50% of the variation and whiskers show the minimum and the maximum values. For other details see Data analysis. (Naruska is not presented as only *B. pubescens* f. *rubra* survived, Sotkamo is not presented as all genotypes had median value of 5)

ering data was not recorded in Rovaniemi and there are deficiencies in the flowering data from Sotkamo and Ruukki.

Results and discussion

Betula

B. pubescens f. *rubra* was the only ornamental tree that survived and succeeded under the harsh conditions of the northernmost Naruska study site and had excellent winter hardiness at the other sites too (Fig. 2A–B). In Naruska the tree had an exceptionally handsome, dense growth habit, which may be explained by winter damage of tip buds and later development of lateral buds. Onset of foliation was at the beginning of June at the Naruska site and in May at the other sites (Table 3). Flowering was recorded in Naruska and Ruukki in June (Table 3). The start of autumn coloration was at the end of August or at the beginning of September (Table 3). During autumn coloration the leaves of the tree turned bright red as the chlorophyll in the leaves degraded and anthocyanins become clearly visible. Defoliation of the tree began in September (Table 3). In Naruska the ornamental value of the *B. pubescens* f. *rubra* was rated as good, while at the other sites the tree gained moderate or rather beautiful grades (Fig. 3A–C). The slender appearance of the young trees diminishes the ornamental value at the juvenile phase, but as the tree matures it gains a handsome appearance. *B. pubescens* f. *rubra* did not suffer any pest or disease problems in Naruska and Ruukki. In Rovaniemi the leaves suffered a small amount of damage due to rust fungi (class median 4.5, see table 2) and leaf pests (class median 4, see table 2) and in Sotkamo due to leaf pests (class median 4.5, see table 2).

Decorative forms of trees with anthocyanins in the leaves, e.g. *Acer platanoides* 'Schwedleri', *Prunus padus* 'Colorata' and *Malus* spp. are used in landscaping in Finland (Alanko et al. 1999), but these trees are not as hardy in the northern areas of Finland as *B. pubescens* f. *rubra*. Consequently it is a valuable ornamental tree for northern landscaping where the selection of hardy ornamental trees is narrow. In addition to being winter hardy, the tree has very unique, showy appearance due to the dark red coloration of the leaves throughout the growing season. It will be interesting to see how far up north f. *rubra* has value in cultivation, since use of the tree is spreading upwards. Based on this study f. *rubra* can be successfully cultivated at least up in the 67° latitude (Fig. 4). Most likely the tree form has the same tolerance as the common *B. pubescens* that exists throughout the northern boreal forest zone. The cultivation of the *B. pubescens* f. *rubra* has to some extent spread also abroad from Finland. For example in Sweden the tree is seen in many gardens today (URL: http://www.alltomtradgard.se/gaRDENINGLISTS/rose.php?list=1&id=24&order=alfa&section=B). Furthermore it has been introduced in Germany (Gartenpraxis 1989), but no information about its cultivation was found for this paper.

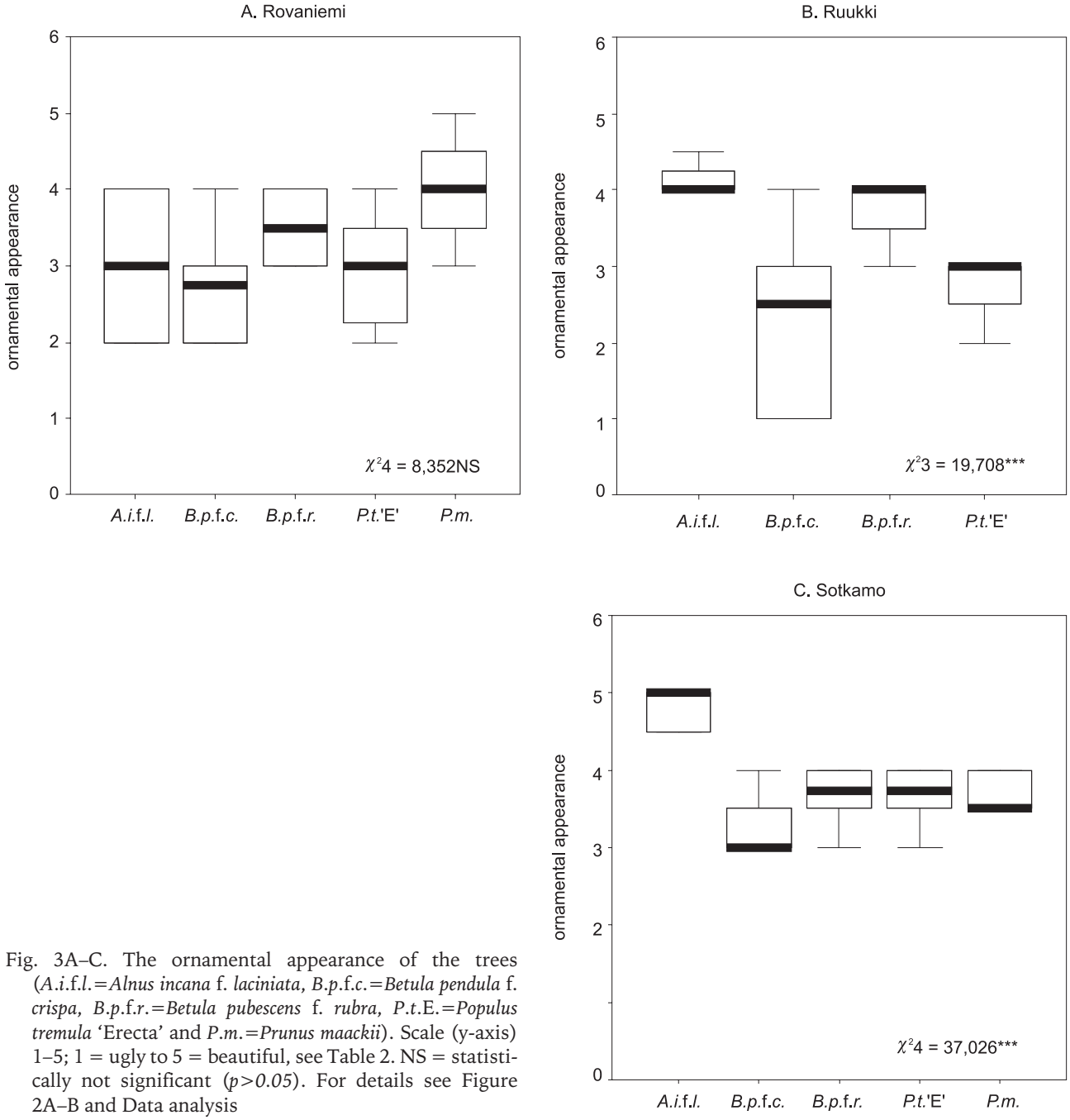

Fig. 3A–C. The ornamental appearance of the trees (*A.i.f.l.*=*Alnus incana* f. *laciniata*, *B.p.f.c.*=*Betula pendula* f. *crispa*, *B.p.f.r.*=*Betula pubescens* f. *rubra*, *P.t.*E.=*Populus tremula* 'Erecta' and *P.m.*=*Prunus maackii*). Scale (y-axis) 1–5; 1 = ugly to 5 = beautiful, see Table 2. NS = statistically not significant ($p>0.05$). For details see Figure 2A–B and Data analysis

The current genotype of *B. pendula* f. *crispa* was not hardy enough to be grown in the northern parts of Finland. All of the 12 replicates died at the Naruska site and the trees suffered serious winter damage in Rovaniemi as well. Only two replicates were alive in Rovaniemi at the end of the experiment. In Ruukki success was modest (Fig. 2A–B), but at the Sotkamo site the tree had excellent winter hardiness. *B. pendula* f. *crispa* had no significant pest or disease problems at any of the sites. The ornamental appearance of the birch was classified as moderate (Fig. 3A–C). Onset of foliation was in the end of May in Rovaniemi, Ruukki and Sotkamo (Table 3). Flowering was not observed at the sites. Trees with aberrations in leaves usually also have aberrations in other structures. Because the flowers are tended to atrophy, the cutleaf forms of trees are mostly sterile (Saarnijoki 1946, Piirainen 1992). Onset of autumn coloration was in September (Table 3), the latest in Rovaniemi, which could explain the poor winter survival at the site. Defoliation began in September in Sotkamo and at the beginning of October at the more northern sites (Table 3). The cut-leaved silver birch is a beautiful tree in general, but not hardy enough to be successfully grown in the northern areas of Finland. The genotype here was shown not to be exceptionally hardy (Fig. 4). *B. pendula* f. *crispa* (incl. 'Crispa' and 'Laciniata') succeeds best in southern and central parts of Finland

Table 3. Phenology of studied ornamental trees in a selection experiment at the study sites. Dates are averages of the study period of 1993–1999

Study site	Tree	Onset of foliation	End of foliation	Onset of flowering	End of flowering	Onset of autumn coloration	End of autumn coloration	Onset of defoliation	End of defoliation
Naruska	*Betula pubescens* f. *rubra*	6.6.	9.6.	11.6.	21.6.	1.9.	17.9.	15.9.	8.10.
	Alnus incana f. *laciniata*	13.5.	8.6.	–	–	–	–	29.9.	14.10.
Rovaniemi	*B. pendula* f. *crispa*	28.5.	25.6.	–	–	27.9.	–	5.10.	–
	B. pubescens f. *rubra*	17.5.	26.5.	–	–	16.9.	22.9.	26.9.	9.10.
	Populus tremula 'Erecta'	5.6.	16.6.	–	–	8.9.	12.10.	8.10.	12.10.
	Prunus maackii	8.6.	21.6.	–	–	18.9.	26.9.	4.10.	–
	A. incana f. *laciniata*	17.5.	24.5.	–	–	–	–	11.9.	17.10.
Ruukki	*B. pendula* f. *crispa*	20.5.	21.5.	–	–	4.9.	–	3.10.	15.10.
	B. pubescens f. *rubra*	19.5.	24.5.	31.5.	18.6.	28.8.	18.9.	3.9.	28.9.
	P. tremula 'Erecta'	23.5.	26.5.	–	–	28.8.	10.10.	11.9.	15.10.
	A. incana f. *laciniata*	20.5.	29.5.	–	–	–	–	17.9.	13.10.
Sotkamo	*B. pendula* f. *crispa*	21.5.	31.5.	–	–	9.9.	16.10.	13.9.	25.10.
	B. pubescens f. *rubra*	19.5.	27.5.	–	–	26.8.	27.9.	2.9.	30.9.
	P. tremula 'Erecta'	27.5.	1.6.	–	–	10.9.	1.10.	28.9.	11.10.
	P. maackii	21.5.	31.5.	21.6.	27.6.	13.9.	30.9.	18.9.	7.10.

– no data available

(see also Hämet-Ahti et al. 1992; Mitchell and Wilkinson 1997). The commonly sold and cultivated cut-leaved form of silver birch in Finland is a foreign cultivar. The cut-leaved form of *B. pendula* is rare in nature in southern parts of Finland (Oskarsson and Nikkanen 2001).

The two north European species, *B. pendula* and *B. pubescens* appear to be genetically very variable (Kauppi et al. 1999). According to Hylander (1957) within *B. pendula* numerous forms of trees with incised leaves were found growing in Scandinavian countries. The Finnish Forest Research Institute has listed 400 special birch trees found in Finland (Oskarsson and Nikkanen 2001).

Alnus

A. incana f. *laciniata* succeeded poorly at the northernmost Naruska site, where the soil is nutrient poor peatland. *A. incana* is known to prefer nutrient rich, fresh mull humus soils (Kullman 1992). Winter hardiness was moderate in Rovaniemi but the tree suffered no winter damages in Ruukki or in Sotkamo (Fig. 2A–B). Onset of foliation was in May and, as was the case with *B. pendula* f. *crispa,* flowering was not observed. *Alnus* pollen is among the worst causers of pollinosis in Finland and while cut-leaved forms are sometimes sterile, the lack of flowers may add value to the tree (Piirainen 1992). Defoliation begun in September at the sites, autumn coloration did not occur since *A. incana* drops its leaves green (Table 3). Ornamental value was moderate in Rovaniemi, rather beautiful in Ruukki and very decorative in Sotkamo (Fig. 3A–C). The intensity of the lobes in the

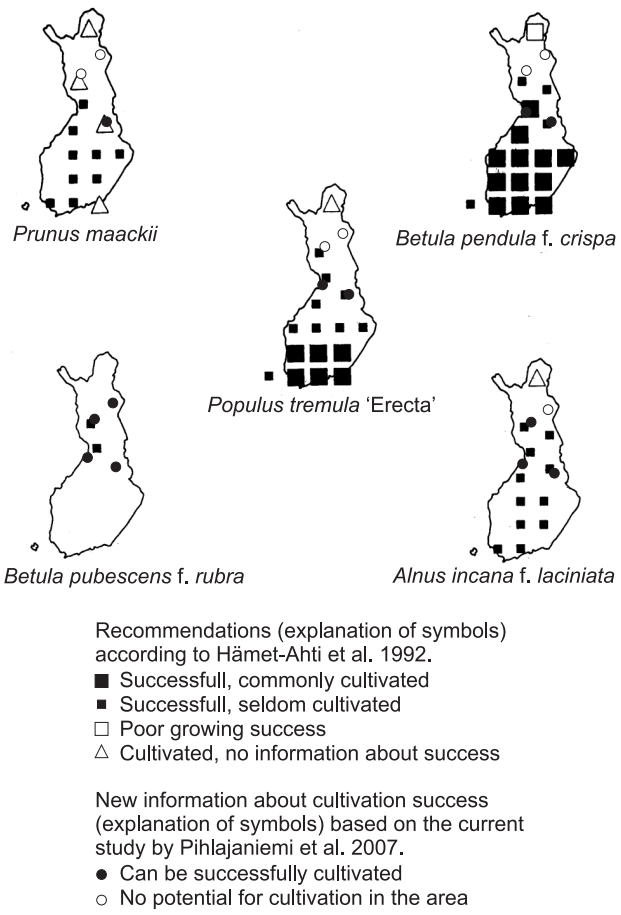

Fig. 4. Distribution and cultivation success of the special tree forms in Finland. New information about the cultivation success (symbols ●○) based on the studied tree genotypes is added in to the original maps by Hämet-Ahti et al. 1992

cut-leaved form is known to vary between individuals and within the same tree, suggesting that there is instability in the genotype of the gray alder (Saarnijoki 1946, Oskarsson and Nikkanen 2001). Such a variation was not observed within the *in vitro* propagated genotype here. *A. incana* f. *laciniata* did not suffer from damages due to plant diseases or pests at any of the study sites.

Alnus species are especially fast growing in their juvenile phase but usually live only for few decades (Piirainen 1992). *A. incana* f. *laciniata* is rarely found in nature in southern and central Finland, and grows mostly as a cultivated tree 'Laciniata' (Hämet-Ahti et al. 1992; Mitchell and Wilkinson 1997). The cut-leaved form of gray alder has some value in northern gardens (Fig. 4). It is showy and hardy and could be used more often in landscaping as a nurturing tree, especially when new green areas are built. The genotype studied here is valued for its dense and regular appearance. Cut-leaved alders are not new trees in northern gardens; they were successfully grown in parks as early as the 1930's (Parvela 1930). The Finnish Forest Research Institute's register of special plant forms includes 70 alders, of them 55 are from *Alnus incana* that is, besides *Alnus glutinosa,* the other native alder species growing in Finland (Oskarsson and Nikkanen 2001).

Populus

None of the 12 studied examples of *P. tremula* 'Erecta' genotype survived the harsh winters at the Naruska study site. Winter hardiness was moderate in Rovaniemi since the trees suffered from winter damage to shoot tips and frost cracks of the trunk (Fig. 2A–B). Only two replicates out of twelve reached over 4 metres in height at the end of the experiment in Rovaniemi. In Ruukki and Sotkamo no winter damage was observed (Fig. 2A–B). Foliation started at the beginning of June in Rovaniemi, Ruukki and Sotkamo in May (Table 3). There are no flowering data from any of the sites. Autumn coloration begun in September in Rovaniemi and Sotkamo, and in the end of August in Ruukki. Defoliation started in September at Ruukki and Sotkamo, but not until October in Rovaniemi (Table 3). Ornamental values varied from moderate to rather beautiful at the sites where trees survived (Fig. 3A–C). In Rovaniemi the tree suffered slight damage to the leaves due to leaf diseases (class median 4, see Table 2) and leaf pests (class median 4, see Table 2). In Ruukki *P. tremula* 'Erecta' suffered some damage to the leaves (leaf blackening) (class median 4, see Table 2). In Sotkamo no damage was recorded. *P. tremula* 'Erecta' suffered some damage due to rabbit herbivory, especially in the Rovaniemi site, which probably added to the frost damage on the trunk.

P. tremula (aspen) is the only native poplar in Finland. It is considered a tolerant tree in a wide range of climatic conditions (Worrell 1995) and it is found naturally throughout Finland. *P. tremula* 'Erecta' is commonly cultivated in Finland as an ornamental tree (Mitchell & Wilkinson 1997). The tree is used e.g. in roadside plantings and as a lane tree (Piirainen 1996). The columnar form 'Erecta' is not as hardy as the native *P. tremula,* which clearly limits the ornamental value of this tree in northern parts of Finland (Fig. 4). In nature *P. tremula* forms an abundance of suckers, forming large monoclonal stands or forests (Worrell 1995; Mitchell and Wilkinson 1997), but the cultivar 'Erecta' was not observed to form suckers. One natural stand of aspen that has columnar growth habit has been found in Finland from Elimäki, but the branches of the trees do not grow so tightly close to the trunk as with the cultivar 'Erecta' (Ahonen 1998; Oskarsson and Nikkanen 2001). The columnar aspen is also used as a horticultural tree elsewhere in Europe and in the United States (Sellmer et al. 1989), in addition to the columnar forms, *Populus nigra* var. *italica* and *P. nigra* 'Plantierensis', of poplar (Press 1993). The Finnish Forest Research Institute's list of special tree forms includes 17 aspens (Oskarsson and Nikkanen 2001).

Prunus

Besides the native *Prunus padus* (European bird cherry), *Prunus maackii* (Amur chokecherry, Manchurian cherry) is one of the hardiest *Prunus* species in Finland (Lagerström 1999). However, all the studied individuals died in Naruska. Winter hardiness was also poor in Rovaniemi (Fig. 2A–B). Winter hardiness was good in Sotkamo where no winter damage was recorded. In Rovaniemi onset of foliation was in the beginning of June and in Sotkamo after the middle of May (Table 3). Flowering data is available only for Sotkamo, where flowering begun at the end of June (Table 3). Compared to *P. padus*, *P. maackii* foliates later and with smaller flower clusters. Bright yellow autumn coloration and leaf defoliation started in September and at the beginning of October (Table 3). Ornamental value was evaluated as moderate in Rovaniemi and in Sotkamo (Fig. 3A–C). The tree's shiny red-brown bark was regarded in Sotkamo as very beautiful, as was the growth habit of the studied genotype. The *P. maackii* genotype was healthy and no damage was noticed in Rovaniemi or Sotkamo.

Overall *P. maackii* is a beautiful tree and it can be recommended for gardens and landscaping purposes but not in the northernmost areas. At the moment, the use of *P. maackii* is minor in relation to its value as a garden tree even though a hardier propagation source than the genotype studied here is available in Finland. The trunk and growth habit of the *P. maackii* make it a beautiful tree even without leaves and it is a

valuable feature of ornamental trees in the north since winter (temperature <0°C) is the longest thermal season for example in Finland (Atlas of Finland 1993). The species originates from Manchuria and Korea, and due to the origin succeeds and grows well in south and central Finland (Hämet-Ahti et al. 1992; Mitchell and Wilkinson 1997), and according to our study, the tree can be successfully cultivated in the more northern parts of Finland as well (Fig. 4). The origin of the studied genotype is from Lithuania and the propagation source has adapted and grows well in Kiiminki (65 km north of Ruukki study site).

Conclusion

The trees in the study were *in vitro* propagated. *In vitro* propagation offers an important alternative for the effective multiplication of trees (Welander 1993; Giri et al. 2004) and is the only method of propagation for poorly propagating or sterile plant material, like with the *B. pubescens* f. *rubra*. Due to the micropropagation method, own rooted material from the studied *P. tremula* 'Erecta' genotype was obtained.

The phenological observations proved to be a useful tool in identifying the responses of woody plants to regional and local climatic conditions. The spring and autumn phenology of the tree genotypes here followed the long-term climatic data presented in Table 3. The timing of foliation and defoliation is controlled by the latitudinal and altitudinal origin of the tree, as well as local conditions (climate, light and temperature). These factors set the limit for the use of woody ornamental plant material in northern areas. The origin and propagation source of the ornamental trees should be well adapted to the climatic and growing conditions. The trees that succeed best in northern Finland are of a northern origin or are from a bioclimatically corresponding area. In order to enrich the selection of hardy ornamental trees in the north new field experiments with promising foreign and domestic tree cultivars and forms should be established.

In the northern areas of Finland, like the Rovaniemi and Naruska sites, *B. pubescens* f. *rubra* is the only tree from the studied ones that has practical value. In more favorable climatic conditions, i.e. areas close to Ruukki and Sotkamo sites, all the studied special tree forms are of value in cultivation, especially *P. maackii*. More hardy propagation sources from the special tree forms are needed for the harsh northern growing conditions.

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