Hybridization, introgression and taxonomy of the Mountain birch in SW Greenland compared with related results from Iceland and Finnish Lapland

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Samples from birch populations were collected in Qingua-dalen and Narssarssuaq during the excursion of SBP (the Subarctic Birch Project) to SW Greenland 1984. In Qingua-dalen, where the environmental conditions are more favourable, the stems of the Mountain birch (*Betula pubescens* ssp. *tortuosa*) are taller and thicker and the leaf size is larger than in populations at Narssarssuaq. Intermediate forms – probably introgressions – between *B. pubescens* and *B. glandulosa* were found in both populations. According to cytological investigations of Qingua-dalen populations, the putative hybrids between *B. glandulosa* (2n = 28) and *B. pubescens* (2n = 56) were found to be triploids (2n = 42). Seeds collected from hybrids did not germinate but the germination of the Mountain birch was also extremely low in 1984. In the same year, *B. glandulosa* produced abundantly seeds with high germination percentage. Germination experiments with seeds collected in 1982 and 1985 indicated that under climatically favourable conditions Mountain birch produces viable seeds. Reproduction through vegetative means was found to be strong in all birch taxa.

Considerable differences have been found between the provenances of birches from SW Greenland and Finland in cultivation experiments carried out since 1976 in South and North Finland. The clones of *B. pubescens* and *B. glandulosa*, originating from Kangerdluarssuk, mature very late in autumn and the shoots above snow level were badly frostdamaged during the winter. This was particularly noticeable for *B. pubescens* in test fields in Lapland. The plants have survived, however, by means of re-suckering and started flowering at an early stage producing viable seeds. Probably no reproductive barriers between birches of the two geographically isolated areas, SW Greenland and Finland, have developed.

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The term "Mountain birch zone" has been used in phytogeography to describe the more or less uniform birch woodland extending from the northern part of the Kola Peninsula through the mountain region of Northwest Fennoscandia to Iceland and South Greenland. In this zone the birch often forms the horizontal and altitudinal tree line (e.g. Böcher 1979, Kallio et al. 1983, Hämet-Ahti 1987).

The taxonomic status of the Mountain birch has been disputed since Ledebour in 1849 described *B. tortuosa* from the Altai Mountains. The taxonomic history of this taxon and the use of the name *tortuosa* in this connection have been reviewed by Vaarama & Valanne (1973). The systematic rank given for the Mountain birch has varied. Some earlier authors have regarded it as a separate species (*B. tortuosa* Ledeb.), but many taxonomists now have included it in the very variable *B. pubescens* Ehrh. Böcher et al. (1968) have used the name *B. pubescens* Ehrh. coll. for the S Greenland birch, which "may be related eastwards to Scandinavian-Icelandic ssp. *tortuosa* (Ledeb.) C. K. Schneid., westwards to the North American ssp. *borealis* (Spach.) Löve & Löve". In many recent studies dealing with the arboreal birch in the subarctic zone of NW Europe and Greenland, authors have used the name *B. pubescens* Ehrh. ssp. *tortuosa* (Ledeb.) Nyman (e.g. Walters 1964, Feilberg 1984).

It should be mentioned, however that according to Orlova (1978, in Hämet-Ahti 1987) the Mountain birch, occurring in Northwest Europe and *B. tortuosa* in the Altai Mountains, are not of the same origin – an opinion shared by many authors. Orlova (1978) has given the name *B. czerepanovii* to the European taxon and Hämet-Ahti (1987) suggests that this name should be used at the subspecific level.

Besides the historical background of the nomenclature, further complications in the taxonomy of the Mountain birch are due to an adaptive evolution (clinal and ecotypic variation) caused by the varying environmental factors prevailing within its range and an occurrence of interspecific hybridization. This has been con-

sidered to be one of the evolutionary trends in many birch groups even at a species level (e.g. Walters 1968, concerning the origin of *B. pubescens*).

Concerning the Mountain birch zone, introgressive hybridization between the diploid (2n = 28) species, *B. nana* L., and the tetraploid (2n = 56) *B. pubescens* has been described from northern Fennoscandia (Vaarama & Valanne 1973, Sulkinoja 1981, Kallio et al. 1983) and from Iceland (Gröntved 1942, Elkington 1968). In South Greenland where the diploid species is *B. glandulosa* Michx., hybrids between this species and *B. pubescens* are frequently found (e.g. Jörgensen et al. 1957). On the basis of morphological characters, Elkington & Jones (1973) suggest that introgressive hybridization has taken place between the two species.

The present paper reports preliminary results from birch material originating from south-western Greenland. The aim of the study is to provide information on the role of introgressive hybridization in the evolution of Mountain birch in South Greenland compared with studies carried out in northern Fennoscandia. The study is a part of a joint Nordic research program "Subarctic Birch Project", SBP, subproject A: The morphological, genetic and physiological variability and evolution of the Mountain birch.

Study sites, materials and methods

Study areas in South Greenland, cultivation sites in Finland, and birch species and hybrids sampled are given in Table 1.

During the SBP excursion to South Greenland, 23.7.–7.8.1984, samples were collected in Qingua-dalen and at Narssarssuaq. Thirty trees of *B. pubescens* on each site were marked at random for investigation. The height and the stem diameter were measured. Measurements of six leaf characters commonly used in the taxonomic studies of *Betula* species (e.g. Gardiner & Jeffers 1962) were made of ten leaves per plant (Table 3). In Qingua a few individuals of *B. glandulosa* and putative hybrids between *B. glandulosa* and *B. pubescens* were included.

Collecting of seeds from labelled trees was carried out by P. Bjerge and I. Burkal in Quingua-dalen in Sept. 1984 and in Narssarssuaq in 1984 and 1985. Earlier collections by S. Ødum in 1982 from the two populations were also included. The germinability was tested at the University of Turku, Finland. Hundred seeds per plant on the surface of destilled water in Petri dishes were kept under 16-hours photoperiod in a greenhouse at 23 ± 2°C for two weeks.

For the vegetative propagation of birches basal parts of stems from a few individuals growing in Kangerdluarssuk (coll. 1976) and in Qingua-dalen (1984) were transplanted in the greenhouse of the University of Turku. Cuttings of the shoots, developed from the basal buds, were rooted in the nutrient medium using the method described by Valanne (1978). After rooting, the plants arisen from cuttings were planted for cultivation experiments and root tips were used for cytological studies. A Feulgen and Giemsa douple staining method developed by Puro and Nokkala (1977), with some modifications for hardwood trees (Hömmö & Särkilahti 1986), was used for determining chromosome numbers in root tips.

Table 1. Study sites in South Greenland (A) experimental fields in Finland (B) and birch species and hybrids sampled for investigation.

A. Populations in South Greenland.

Locality	Altitude m a.s.l.	Species	Individual No.	Year of coll.
1. Kangerdluarssuk 60°54′N, 45°40′W	50	*B. glandulosa*	G1	1976
		B. pubescens	G2	1976
2. Qingua-dalen 60°17′N, 44°32′W	30	*B. glandulosa*	Q71, Q91	1984
		B. pubescens	Q1–Q30	1984
		B. glandulosa × *pubescens*	Q90, Q100 Q900, Q9000	1984
60°17′N, 44°32′W	170	*B. pubescens*	Q200	1984
3. Narssarssuaq 61°10′N, 45°24′W	70	*B. pubescens*	N1–N30	1984

B. Experimental fields in Finland.

Locality	Latitude and longitude	Altitude m a.s.l.
1. Ruissalo, Turku, South Finland	60°37′N, 24°26′E	10
2. Pakatti, Kittilä, Finnish Lapland	67°40′N, 24°56′E	170
3. Kevo, Utsjoki, Finnish Lapland	69°46′N, 27°01′E	100

Fig. 1. A stand of *B. pubescens* in Qingua-dalen. In the middle tree no. Q4, height ca. 3.5 m.

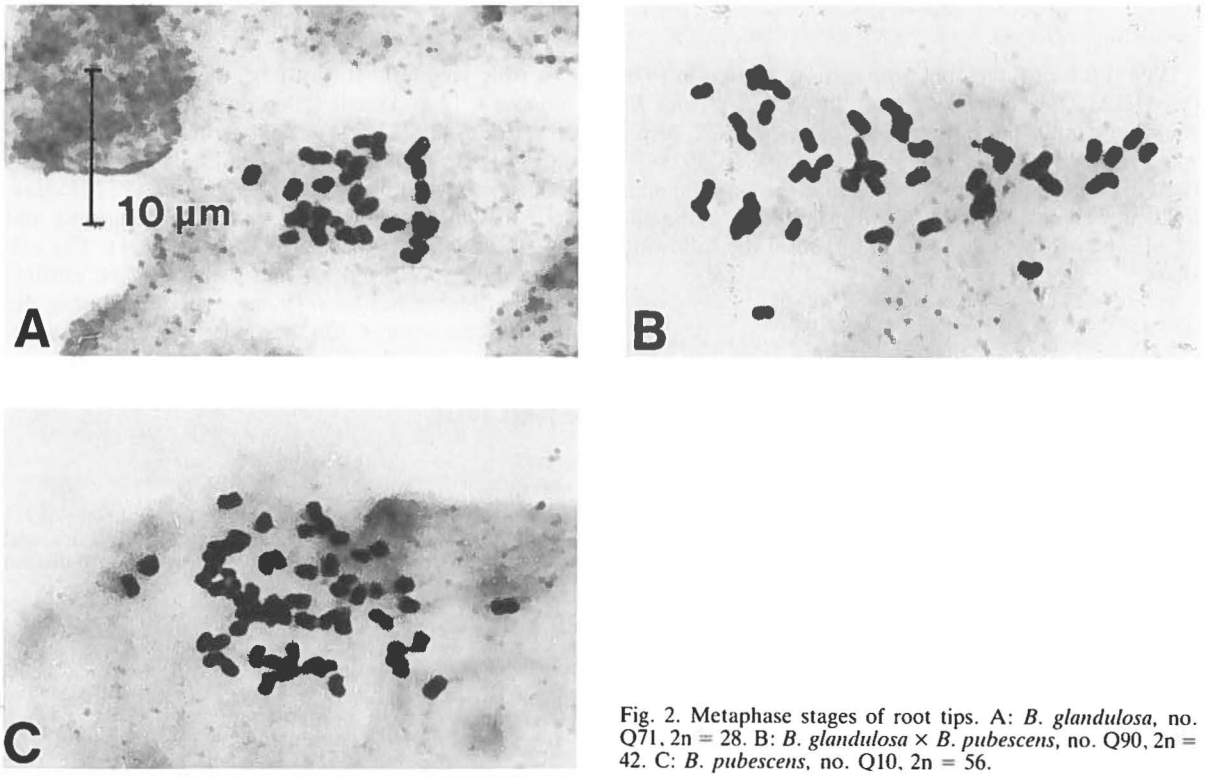

Fig. 2. Metaphase stages of root tips. A: *B. glandulosa*, no. Q71, 2n = 28. B: *B. glandulosa* × *B. pubescens*, no. Q90, 2n = 42. C: *B. pubescens*, no. Q10, 2n = 56.

Fig. 3. A view from a stand of different birch taxa in Qingua-dalen. In the background tree no. Q9 of *B. pubescens*, height ca. 6.5 m (2n = 56); the hybrid clone no. Q900, height ca. 1.3 m (2n = 42) in the middle, both surrounded by a prostrate belt of *B. glandulosa*, height ca. 0.3 m (2n = 28).

As a result of the clonal propagation, started in 1976 (see Table 1), a clone of 6 and 20 seedlings from *B. glandulosa* no. G1 and from *B. pubescens* no. G2, resp., were grown in Turku, Finland. In the years 1978–80 these seedlings were transplanted in three experimental fields in Finland. Survival, growth, flowering and quality of seed of the clones was observed in the following years.

Results and discussion

External characters and chromosome numbers

The means of height and stem diameter of the trees of *B. pubescens* in Qingua-dalen and Narssarssuaq are shown in Table 2. The trees in Qingua-dalen were higher and thicker than those in Narssarssuaq. The highest trees measured in Narssarssuaq and Qingua-dalen were 4.0 m and 6.5 m, respectively. Trees are mostly polycormic, particularly in Narssarssuaq, forming a bush-like habit. The stems are sometimes lying almost horizontal and the maximum lengths of stems recorded in Qingua-dalen were 8 m. According to Feilberg (this volume), and others, the maximum height recorded is 12 m. Detailed description given by Elkington & Jones (1973, 1974) about scrub-woodland at the south-western corner of the bay at Eqaluit, Nordre Sermilik Fjord, resembles the birch population of Narssarssuaq. In Qingua-dalen birches are more vigorous and some tree-like individuals are present (Fig. 1). The valley has been protected for half a century but, earlier, human influence has been strong, especially during the time of Norse settlers. On the sheltered east- and west-facing slopes of the valley there are favourable habitats, protected by deep snow cover during winter (Elkington & Jones 1974).

Table 2. Mean height and stem diameter (at the height of 1.3 m) of *B. pubescens* in the populations of Qingua-dalen and Narssarssuaq. Differences tested by Student's test. Statistical significance indicated as in Table 3.

Populations	Height (m)			Stem diameter (cm)		
	mean	S.E.	n	mean	S.E.	n
Qingua-dalen	3.5	0.3	30	10.2	1.0	27
Narssarssuaq	2.5	0.1	30	4.9	0.5	27
	t = 3.3**			t = 4.5***		

Table 3. Analyses of leaf characters in different *Betula*-groups in Narssarssuaq and Qingua-dalen. Mean and standard error in each group are given. Number of plants in parenthesis. Difference tested by Student's test. * = p <0.05, ** = p <0.01 and *** = p <0.001.

Locality	Narssarssuaq		Qingua-dalen	
	B. pubescens	*B. pubescens*	*B. glandulosa*	*B. pubescens* × *glandulosa*
Leaf characters				
1 Blade length, mm	19.3±1.0 (17)	24.5±0.8 (19)	10.7±0.3 (2)	17.4± 2.3 (4)
B. pubescens	4.0***			
B. glandulosa	2.9**	5.3***		
B. pubescens × *glandulosa*	0.8	3.4**	2.0	
2 Blade width, mm	17.1±0.9	22.0±0.8	9.5±0.3	14.7± 0.8
B. pubescens	4.1***			
B. glandulosa	2.9**	4.9***		
B. pubescens × *glandulosa*	1.3	4.0***	4.5*	
3 Petiole length, mm	4.6±0.3	6.7±0.3	2.1±0.7	4.6± 0.8
B. pubescens	4.6***			
B. glandulosa	2.6*	4.6***		
B. pubescens × *glandulosa*	0.0	2.7*	2.0	
4 Basal angle, °	47.0±2.9	50.3±2.9	33.5±0.8	49.4±12.2
B. pubescens	0.8			
B. glandulosa	1.6	1.8		
B. pubescens × *glandulosa*	0.2	0.1	1.3	
5 Apical angle, °	61.5±1.6	56.7±1.2	68.1±1.6	58.6± 3.5
B. pubescens	2.4*			
B. glandulosa	1.4	2.9**		
B. pubescens × *glandulosa*	0.8	0.6	1.8	
6 Angle of axis and 2nd nerve, °	46.6±3.6	45.7±3.2	60.3±1.2	44.2± 6.0
B. pubescens	0.2			
B. glandulosa	1.3	1.4		
B. pubescens × *glandulosa*	0.3	0.2	1.8	

Results of the analysis of leaf characters are given in Table 3. A few individuals of pure *B. glandulosa* and its hybrids with *B. pubescens,* from which the chromosome number have been counted (Table 5; Fig 3), are included with *B. pubescens* for comparison. The number of these specimens is, however, not sufficient for statistical analysis.

The most distinctive differences between the groups were found in leaf size and in petiole length (characters 1–3). Differences in the means of angles (characters 4–6) were found only in *B. glandulosa* reflecting an obovate form of leaves. The pronounced differences found in leaf size and in petiole length between the populations from Qingua-dalen and Narssarssuaq may be partly due to the more favourable environmenral factors prevailing in Qingua-dalen. Leaf measurements of putative hybrids were made only on specimens collected in Qingua-dalen. The leaf size of hybrids was intermediate between *B. glandulosa* and *B. pubecens* in the same stand, but, compared with *B. pubescens* in the stand at Narssarssuaq, the leaves of hybrids were almost of the same size.

On the basis of the present study it is not possible to give any detailed description of the introgressive hybridisation between *B. glandulosa* and *B. pubescens* reported by Elkington & Jones (1973) from South Greenland, nor to what extent it has contributed to the evolution of Mountain birch in a particular population. The fact is, however, that intermediate types between *B. glandulosa* and *B. pubescens* are frequent in Qingua-dalen and Narssarssuaq. Although these individuals were avoided when marking the trees of *B. pubescens,* it

Table 4. Leaf analysis on Mountain birch in two SBP-sites in Finnish Lapland, Utsjoki, Kevo:
1. Foot of Jesnalvärri, 69°46'N, 27°00'E, 95 m a.s.l.
2. Top of Jesnalvärri, 69°46'N, 26°55'E, 280 m a.s.l.
Statistical significance indicated as in Table 3.

Leaf characters	Jesnalvärri				
	foot (n=30)		top (n=30)		
	mean	S.E.	mean	S.E.	t-value
Blade length, mm	32.2	0.6	31.6	0.6	0.7
Blade width, mm	28.3	0.5	26.9	0.7	1.7
Petiole length, mm	10.2	0.3	9.1	0.3	2.7**
Basal angle, °	51.2	2.1	46.8	2.2	1.4
Apical angle, °	51.3	0.8	50.8	1.0	0.4
Angle of axis and 2nd nerve, °	49.2	1.6	47.0	2.2	0.8

Table 5. Chromosome numbers in a few specimens sampled in Kangerdluarssuk (in 1976) and in Qingua-dalen (1984) (for localities and individual no., see Table 1).

Species	Individuals studied, No.	Chromosome number
B. glandulosa	G1, Q71, Q91	28
B. pubescens	G2, Q5, Q9, Q10, Q200	56
B. glandulosa × *pubescens*	Q90, Q100, Q900, Q9000	42

is possible that back-crosses to parent species, resembling *B. pubescens*, migh have been included.

According to earlier studies (Vaarama & Valanne 1973) and the studies carried out with leaf samples collected from two SBP-populations in Finnish Lapland (Table 4), the leaves of the Mountain birch from North Lapland are longer and broader compared to the values of the two *B. pubescens* provenances from South Greenland presented in Table 3. The significance of external characters including the morphology of leaves, the growth and habit of trees etc., can, however, be evaluated in more detail, after the plans of the Subarctic Birch Project designed to study the different populations and cultivated progenies of the Mountain birch have been accomplished.

The chromosome number of *B. glandulosa* (2n = 28) and *B. pubescens* (2n = 56; Table 5; Figs 2 and 3) correspond to the results reported from Greenland by Jörgensen et al. (1957). Earlier cytological studies of hybrid types are unknown to me. Specimens, in which the chromosome number were studied, were typical representatives of each group. Most likely all the intermediate individuals investigated are triploid F_1-hybrids (2n = 42) or near-by aneuploids, even if it is a well-known fact that an exact count of the chromosomes in *Betula* species is difficult. An exeption was individual no. Q200 sampled outside the study area in Qingua-dalen at an altitude of 170 m (see Table 1). This specimen, which had very small leaves and a semi-prostrate habit, resembling hybrid types, turned out to be tetraploid, 2n = 56 (Table 5). Apparently this small shrub may be an example of an adaptive evolution of birch taking place in the extreme conditions prevailing on the tree line of the species. Similar forms described as a variety of the Mountain birch (var. *apressa*, Kallio & Mäkinen 1978) are found on the tree line of some mountains in Finnish Lapland.

Jörgensen et al. (1957), dealing with polymorphism in the Greenland birches, include *B. alpestris* Fr. in the hybrid complex. In their report from South Greenland Elkington & Jones (1973) have compared the *B. pubescens* population from England with the populations of birches from South Greenland. Based on morphological characters the authors suggest that introgressive hybridization between *B. glandulosa* and *B. pubescens* has affected the *B. pubescens* populations in South Greenland.

Many related descriptions of hybridization between the subsections *Nanae* and *Albae* of the genus *Betula* have been reviewed by Vaarama & Valanne (1973) and Kallio et al. (1983). Investigations on introgressive hybridization between the diploid species of *B. nana* and the tetraploid *B. pubescens* have been reported from Fennoscandia (Vaarama & Valanne 1973, Sulkinoja 1981, Kallio et al. 1983, Sulkinoja & Valanne 1987) and from Iceland (Elkington 1968).

In South Greenland the diploid representative of the *Nanae* subsection is *B. glandulosa*. The finding of triploid hybrids in the present study supports the interpretation presented by Elkington & Jones (1973), that introgression has taken place between *B. pubescens* and *B. glandulosa*, a species closely related to *B. nana*. Chromosome studies may, too, give cytological evidence for the mechanism by which introgression between species takes place in a birch population. In Finnish Lapland natural hybrids between *B. nana* and *B. pubescens* are triploids, but a few aneuploid and tetraploid individuals, probably backcrosses, have been found (Sulkinoja 1981).

Reproduction in nature

Many authors have stated that a vegetative reproduction is typical of birch in the mountain birch zone (cf. Elkington & Jones 1973 and 1974, Kallio et al. 1983). In the populations of Qingua-dalen and Narssarssuaq, shoots arising from basal buds of stems and from rooted branches of birches were frequent (Figs 4 and 5). Actually, the polycormic trees and shrubs are clones, in which the age of stems and branches varies. The age determined in one of the thickest stems (diam. 18 cm at base), from the polycormic tree no. Q9 in Qingua-dalen, was ca. 160 years old (Fig. 3). The decayed stems showed that, as a genotype, the tree was much older.

However, sexual reproduction takes place as well. The establishment of seedlings, however, under present conditions seems to be difficult, but some seedlings growing on open gravelly and sandy soil were found. Fertility of seed samples studied is shown in Table 6.

In the germinability of seeds collected in natural populations, both local and annual variation could be

Table 6. Germination tests on seeds collected in two natural populations (Qingua-dalen and Narssarssuaq). ^{m} = mixed seed sample. – = no germinative seeds, 0.0 = germination <0.05%, . . = not studied.

Species	Year	Germination %: mean ± S.E. Qingua-dalen	n	Narssarssuaq	n
B. pubescens	1982	–	12^m	44.5±5.0	16^m
B. pubescens	1984	0.1±0.1	16	0.0±0.0	27
B. pubescens	1985	. .		19.2±2.4	16
B. glandulosa	1984	72.0	1	. .	
B. glandulosa × *pubescens*	1984	–	3	. .	

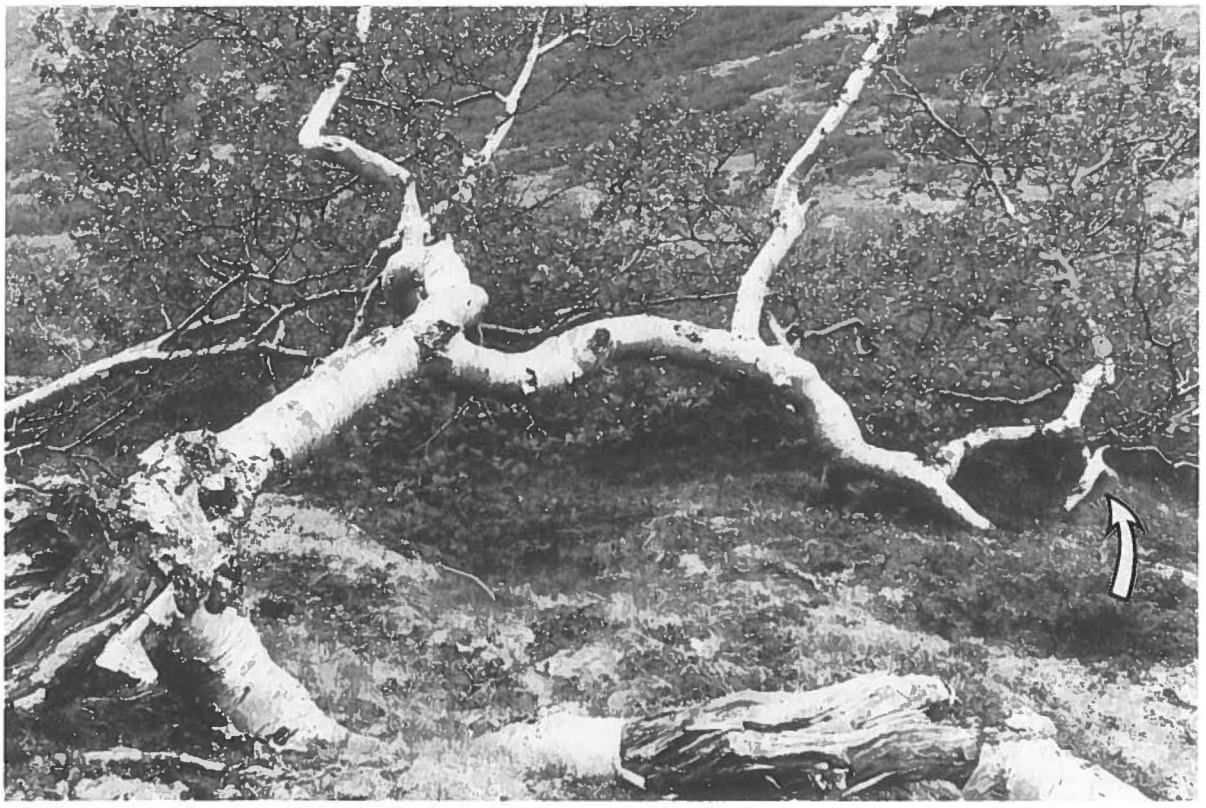

Fig. 4. A fallen tree in Qingua-dalen with rooted branch seen on the right side of the picture (arrow).

found (Table 6). In 1984, only few germinating seeds were found in *B. pubescens*, whereas in *B. glandulosa* the germination percentage was high. In the same year an abundant production of fruiting catkins was found in many bushes of *B. glandulosa*, while seed yield in *B. pubescens* was very poor. No evidence, however, of the fertility of hybrid specimens was provided by germination tests. This may be partly due to a low number of individuals studied and partly due to a poor seed year at Qingua-dalen in 1984.

In North Lapland (Sulkinoja & Valanne 1980, Sulkinoja 1981), a lower germination rate compared with the parent species is characteristic for natural hybrids between *B. nana* and *B. pubecens*, but in favourable seed years some of them produce viable seed. In the cultivated progenies of natural hybrids the chromosome number of different individuals varies from the triploid to the pentaploid level (2n = 70), including introgressants with aneuploid and tetraploid numbers. In the "families" grown from open pollinated seed of *B. nana* from northern Lapland, spontaneous hybrids are common. In experimental crosses, carried out between *B. nana* and *B. pubescens*, the crossability has been more successful when *B. nana* has been used as the female parent. Clausen (1970), in his studies of interspecific crossability in the genus *Betula*, found that *B. nana* as well as *B. glandulosa* as a female parent can be crossed with *B. pubescens* with good success while the reciprocal cross is highly incompatible.

F_1 progenies, grown from seed of experimental crosses, have been confirmed to be triploid and when

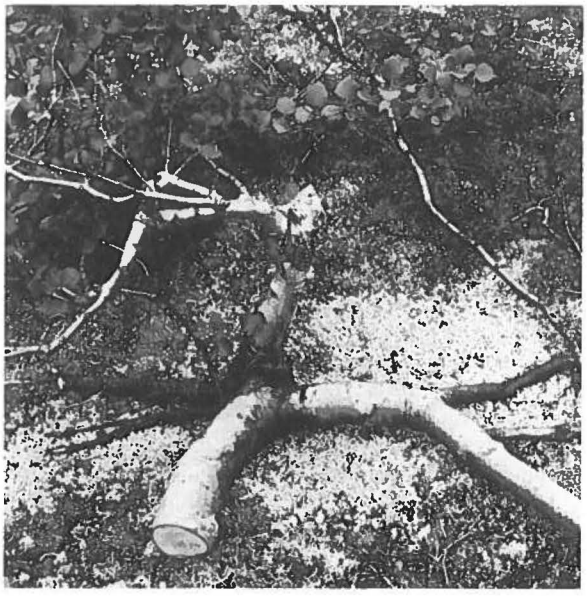

Fig. 5. Rooted branch (cf. Fig 4).

cultivated they grow well. In F_2 offsprings, as well as in those of natural hybrids, hybrid weakness and variation of morphological characters caused by an unbalanced chromosome set, have been found. However, a small number of F_3 seedlings have been able to grow from seeds of a tetraploid F_2 individual (Sulkinoja unpubl.).

Some authors (e.g. Löve & Löve 1956, considering the origin of *B. pubescens* in Iceland) have doubted the significance of introgressive hybridization owing to the sterility found in a triploid plant resulting from a cross between diploid and tetraploid species. Reports of a successful hybridization and introgression between two diploidbirch species, *B. glandulosa* × *nana* (Clausen 1970), *B. glandulosa* × *pendula* (Inki & Valanne 1979), and *B. pendula* × *nana* (Sulkinoja 1981), have been desribed. The main part of studies concerning the crossability between the three diploid species and *B. pubescens* have been carried out outside the range of Mountain birch. Hagman (1971) in his studies on the crossability between *B. pendula* and *B. pubescens,* has shown that a strong incompatibility exists between the two species, but an increased compatibility is found in some birch individuals in northern Lapland confirming the well-known fact that hybrids between birch species *(B. nana, B. pendula, B. pubescens)* are much more frequently occuring in Lapland than, e.g. in South Finland. Evidently, the environment in the subarctic region of Northwest Europe has favoured hybridization and gene flow between *B. nana* and *B. pubescens* giving rise to the evolution of the Mountain birch.

Cultivation experiments

The clones planted in field tests in Finland 1978–79 have shown distinct difficulties in adaptation to local environment, particularly in Lapland. *B. glandulosa* (G1), which has a prostrate habit, has survived better even in Lapland, where it, however, seems to be too late in the fall. The importance of a provenance could clearly be seen in the clone of *B. pubescens* (G2). The upper parts of stems and branches have died and it has survived by the means of a pronounced capacity to produce new shoots. Ten years after planting, the height of the living branches of the clone varied in Lapland and in South Finland 20–30 cm and 60–100 cm, respectively. Even in Ruissalo, South Finland, which is situated almost at the same latitude as Kangerdluarssuk (see Table 1), the trees were badly damaged during winter. A thin layer of snow, commonly recorded at the Southwest coast of Finland, may be insufficient to protect these birches, but probably also other environmental factors are involved, e.g. the more continental climate of southern Finland compared to S Greenland.

In spite of difficulties in adaptation to local environment the clones have produced seeds in many years. Seed production began in 1978 when the clones were two years old from the starting of propagation. The yield and quality of seed varied annually as in local birch species. As in nature, the seed production of *B. glandulosa* was more abundant than that of *B. pubescens.*

The highest and lowest germination percentages found in sample tests in different years are given in Table 7. In order to test the crossability between the clones and the local birches and to prevent self pollination, the clones were emasculated in some of the years (indicated by an + in Table 7). The results indicate that the two South Greenland species easily cross with birches in Finland, where the genus *Betula* is represented by two diploid (2n = 28) species, *B. nana* and *B. pendula,* and by the tetraploid *B. pubescens* (2n = 56). *B. pendula* does not occur in Utsjoki, and thus – at least in North Lapland – the clones must have been pollinated by *B. nana* or *B. pubescens.* Self-pollination within the clones has not been studied, but birch species are generally strongly self-incompatible, as has been shown by e.g. Hagman (1971). For further investigations, seedlings of the clones have been planted in experimental fields in Lapland during the years 1984–87.

An earlier experiment, started in South Finland, has proved marked differences between a parent clone and its F_1 progeny from the same field site. In 1979 a F_1 "family" was grown from open pollinated seeds of the clone G2 growing in Ruissalo, South Finland. In 1981 seedlings were planted in field test in Ruissalo. At the age of nine years (1987) the height of trees was 4.5 m ± 0.2 (n = 27). Compared with the parent clone (height 0.6–1 m) in the same field the growth of trees was much better. Crooked stems and branches, which are characteristic for the clone, were still found in this F_1 family, but damage caused by frost was not observed.

Evidently a clone, representative of one genotype only, can not show the whole range of variation likely to be found in a population. Therefore, cultivation of a seed population has been started in Lapland in 1983 from seeds collected from 16 trees at Narssarssuaq in 1982. It is too early to draw any far-reaching conclusions as to the thriving of this birch provenance but the external and phenological characters of seedlings resemble those found in the clone of *B. pubecens* G2. It may be stated that early flowering, which is also characteristic for the clone G2 and its F_1 "families", has been

Table 7. Germinability of clones in sample tests in the years 1978–87 in experimental fields of Finland. + = emasculated clones. – = no germinative seeds, 0.0 = germination <0.05%, . . = not studied.

Species/ Clone No.	Highest/lowest germination %: mean ± S.E. South Finland	Finnish Lapland	
	Turku Ruissalo	Kittilä Pakatti	Utsjoki Kevo
B. glandulosa	12.0±1.6+	66.8±1.6+	53.8±1.9+
G1	9.8±1.5	4.3±0.5	. .
B. pubescens	55.0±1.0	64.3±3.4+	20.0
G2	18.5±2.1	. .	. .
	35.8±3.8+	. .	. .

found in many three year seedlings when cultivated in the field site in Kittilä. Lappish Mountain birches begin flowering generally at an older age but early flowering, and abundant seed production, was found in the Icelandic "families" of *B. pubescens,* which have been cultivated in all field sites in Finland since the year 1979. Icelandic birches are quite well adapted to the environment at Ruissalo, South Finland, but in Lapland they seem to be too late and many trees are badly damaged by frost.

Further investigations on Greenlandic birch material, planted in test fields, will be included in the birch research program carried out in Kevo Research Institute since 1970, and in the Subarctic Birch Project (SBP). Besides studies in natural population, these programs include comparative studies of different birch provenances originating from the range of Mountain birch when cultivated in different test fields.

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References

Böcher T. W. 1979. Birch woodlands and tree growth in Southern Greenland. – Holarctic Ecol. 2: 218–221.

– , Holmen, K. & Jakobsen, K. 1968. The flora of Greenland. – Haase, Copenhagen.

Clausen, K. E. 1970. Interspecific crossability test in *Betula*. – Section 22, IUFRO Working Group Meeting of the sexual reproduction of forest trees, 1–10.

Elkington, T. T. 1968. Introgressive hybridization between *Betula nana* L. and *B. pubescens* Ehrh. in North-West Iceland. – New Phytol. 67: 109–118.

– & Jones, B. M. G. 1973. Botanical Reports; 1972 Expedition to Greenland. – Rep. Br. Sch. Explor. Soc. 1972–1973: 16–32.

– & Jones, B. M. G. 1974. Biomass and primary productivity of birch (*Betula pubescens* s. lat.) in South-West Greenland. – J. Ecol. 62: 821–830.

Feilberg, J. 1984. A phytogeographical study of South Greenland. Vascular plants. – Meddr Grønland, Biosci. 15: 1–70.

Gardiner, A. S. & Jeffers, J. N. R. 1962. Analysis of the collective species *Betula alba* L. on the basis of leaf measurements. – Silvae Genetica 11: 156–161.

Gröntved, J. 1942. The Pteridophyta and Spermatophyta of Iceland. The Botany of Iceland 4. – Copenhagen.

Hagman, M. 1971. On self- and cross-incompatibility shown by *Betula verrucosa* Ehrh. and *Betula pubescens* Ehrh. – Comm. Inst. Forest. Fenn. 73, 6: 1–125.

Hämet-Ahti, L. 1987. Mountain birch and mountain birch woodland in NW Europe. – Phytocoenologia 15, 4: 449–453.

Hömmö, L. M. & Särkilahti, E. M. 1986. A method of counting chromosomes of hardwood trees using root tips and young leaves. – Can. J. For. Res. 16: 401–403.

Inki, M. & Valanne, T. 1979. The F_1 hybrid between *Betula glandulosa,* subsection *Nanae* and *Betula pendula,* subsection *Albae*. – Rep. Kevo Subarctic Res. Stat. 15: 11–18.

Jörgensen, C. A., Sörensen T. & Westergaard, M. 1958. The flowering plants of Greenland. A taxonomical and cytological survey. – Biol. Skr. Dan. Vid. Selsk. 9: 1–172.

Kallio, P. & Mäkinen, Y. 1978. Vascular flora of Inari Lapland. 4. *Betulaceae*. – Rep. Kevo Subarctic Res. Stat. 14: 38–63.

Kallio, P., Niemi, S., Sulkinoja, M. & Valanne, T. 1983. The Fennoscandian birch and its evolution in the marginal forest zone. – Nordicana 47: 101–110.

Löve, A. & Löve, D. 1956. Cytotaxonomical conspectus of Icelandic flora. – Acta Horti Gothob. 20: 65–290.

Orlova, N. I. 1978. O statute dvukh vidov berez. – Vestnik Leningr. Univ., Ser 3 (Biol.) 1978, 1: 56–62.

Puro, J. & Nokkala, S. 1977. Meiotic segregation of chromosomes in *Drosophila melanogaster* oocytes. A cytological approach. – Chromosoma 63: 273–286.

Sulkinoja, M. 1981. Lapin koivulajien muuntelusta ja risteytymisestä (English summary). – Lapin tutkimusseura, Vuosikirja 22: 22–30.

– & Valanne, T. 1980. Polyembryony and abnormal germination in *Betula pubescens* subsp. *tortuosa*. – Rep. Kevo Subarctic Res. Stat. 16: 31–37.

– & Valanne, T. 1987. Leafing and budsize in *Betula* provenances of different latitudes and altitudes. – Rep. Kevo Subarctic Res. Stat. 20: 27–33.

Vaarama, A. & Valanne, T. 1973. On the taxonomy, biology and origin of *Betula tortuosa* Ledeb. – Rep. Kevo Subarctic Res. Stat. 10: 70–84.

Valanne, T. 1978. Soft-wood rooting experiments with *Betula*. – Rep. Kevo Subarctic Res. Stat. 14: 72–75.

Walters, S. M. 1964. *Betula*. – In: Tutin & al. (eds), Flora Europaea I: 57–58.

Walters, S. M. 1968. *Betula* L. in Britain. – Proc. Bot. Soc. Brit. Isles 7: 179–180.