Araucaria araucana in West Norway*.

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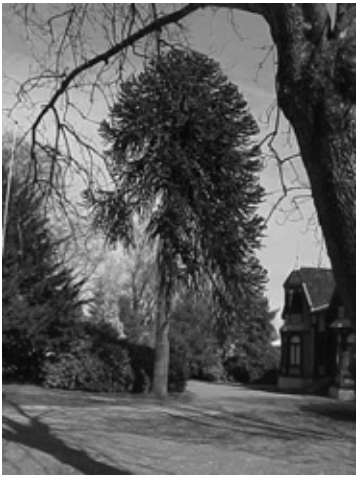
Araucaria araucana has its natural distribution in the Andes Mountains between 37ºand 40º S and between 600 and 1800 m.a.s.l. Around 1960 its distribution area was estimated at 250,000 - 300,000 ha, with 75% on the Chilean side of the border, and the remaining 25% in Argentina

(Hueck 1966). Human activity has strongly reduced the natural forests both in extent and content, and the species is now considered to be generally vulnerable in the whole of its natural range. Old trees are becoming so scarce that they must be regarded as threatened (see also p.104). Forest legislation in Chile and Argentina has changed between complete protection and controlled logging during the last 30 years; at present, logging of living trees is prohibited in both countries, and collection of seed is restricted, but this does not seem to have stopped the ongoing degradation of the forests. Unsolved disputes remain between the indigenous populations, the authorities and influential logging companies, especially in Chile (Aagesen 1998). Since 2000 *A. araucana* has been included in Appendix I (species threatened with extinction, all of which are, or may be, affected by trade) of CITES both for Chile and Argentina, the latter being added after illicit export of several hundred kg of seed to European nurseries was detected.

The seeds are an important source of food for the indigenous populations (Pehuenche, who later merged into the Araucanos), and this is reflected in the vernacular name of the tree, *pehuén*. In a case study in the Chilean Ralco National Reserve, families were found to collect an average of 1132 kg of seed per family per year (Aagesen 1998). The seeds are eaten raw, toasted, or boiled, and are ground into flour, used in soups and breadmaking and in the fermented beverage, *chavid*.

The first reported non-indigenous use of *A. araucana* dates back to 1780, during the Spanish colonial period in Chile, when local Araucano chiefs gave two Spanish captains permission to take 40 trunks from Chile's upper Bío Bío watershed; the long, straight and durable timber was used to replace masts on their ships. One year later seeds and seedlings collected for the Madrid Botanical Garden were lost during a shipwreck in the Atlantic (Aagesen 1998).

The first confirmed introduction to Europe was in 1795 by Archibald Menzies, who accompanied Captain Vancouver during explorations along the west coast of the Americas in 1791 – 1795. At a party given by the Governor of Chile in 1793 Menzies pocketed a few of the nuts served for dinner and later sowed them on board the *Discovery*. Five plants survived of what proved to be *A. araucana* and of these two were given to the Royal Botanic Gardens, Kew in 1795, the last surviving one dying in 1892 (Bean 1976). A "reputed" original was still extant at Holker in northwest England in 1972 (Mitchell 1972). Plenty of seed was imported around 1840 by William Lobb (Whittle 1970), and from this time young plants of *A. araucana* were on sale in English



Left: Male tree at Balestrand planted 1872. Female cones observed in 1962 & 1971. Photo taken 1972.
Right: Male tree at Breidablikk, Stavanger, planted around 1880. Photo taken 2001

nurseries as the "Monkey Puzzle" tree, a name said to have been invented during a dinner party in the mid 1830's given in honour of a newly planted *A.araucana* (Bøggild 1967).

History of introduction to the Nordic Countries

A. araucana was introduced to Denmark around 1855 (Søndergaard 1975) and to West Norway at the beginning of the 1860's. P. H. Poulsson, a well known plantsman in Stavanger in the last half of the 19th century (Molaug 1971), and designer of a number of large landscape gardens in Stavanger and Rogaland, was probably the first to introduce the species to Norway in 1863 (Wendelbo & Nedkvitne, 1960). Remnants of these landscapes still exist, and in the best preserved of these, the Breidablikk Garden in Stavanger, are two majestic trees planted c.1880 (see above). In 1873 a monkey puzzle, now the tallest and largest in Norway, was planted on the north side of Sognefjorden in the Lunde Vicarage Garden at Balestrand (see above). The tree was 30 cm and probably four years old when planted, and had attained a height of 66 cm by the autumn of 1875. In 1878 it measured 117 cm, and by 1885, at the age of 16, it had reached 4.28m

(Schübeler 1886). When last measured in June 1999 this tree was 22 m x 94 cm, while the tallest tree at Breidablikk measured 21 m x 78 cm in April 2001.
The Lobb introductions from the 1840's must have produced plenty of seed during the last two decades of the 19th century, and *A. araucana* became a frequently planted tree in Britain. It also became more abundant in West Norway, a first inventory in 1974 bringing to light 47 trees over 40 years old in the Bergen area (Søndergaard 1975). All of the trees had survived the very cold winters during World War II, but in other parts of the Nordic Countries southernmost Denmark seems to be the only place where monkey puzzles have survived these exceptionally cold winters (Ødum 1978).
Planting of *A. araucana* reached its zenith in Bergen between 1900 and 1920. Of the 47 trees recorded, 42 were planted during this period, while only two were planted before the turn of the century and three during the following ten years, as shown below:

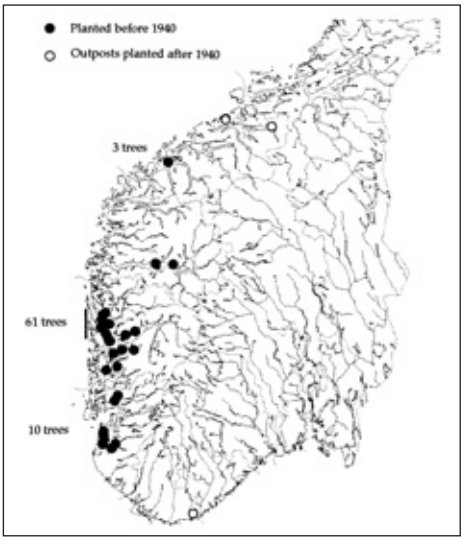
Age of 47 trees in the Bergen area extrapolated to 2002

Age in years:	70-74	75-79	80-84	85-89	90-94	95-99	100-104	105-109
Number of trees:	1	2	8	15	11	8	1	1

Figures extrapolated from table 4 in Søndergaard 1975. Number of year rings were counted on cores taken at 1.3 m height from 47 trees in the Bergen area, when measured in 1974. Approximate age before reaching 1.3 m from seed was found to be 12 years, calculated on the basis of 13 trees with known planting year and assuming an average age at planting of 4 years (Søndergaard 1975).

Recording Monkey Puzzle in West Norway

The first recordings of *A. araucana* took place during the years 1972 – 1974, mainly in the Bergen area. Seed of *A. araucana* was particularly abundant in 1972. With assistance from the Bergen Fire Department 229 cones were collected from six female trees (see p.98), which together contained 6,585 fully developed seeds. Additional seed was collected on the ground, and the final number of seeds collected was close to 9,000. During 1974, heights, and diameters at breast height (1.3 m), were measured on 47 trees. Plug samples were taken at 1.3m to determine the number of annual rings. Information regarding date of planting and life history of each tree was recorded as far as possible. The number of cones was counted and their distribution to the four quarters of the crown (SW, SE, NE, NW) was indicated for each tree.
After 12 years out of the country, the author returned in 2000, and carried on with new recordings of *A. araucana* in the southernmost part of



Distribution of Monkey Puzzle trees in West Norway.

West Norway, the Rogaland and South Hordaland Counties. Some of the trees recorded 26 years earlier in Bergen were revisited, and a tentative map of trees over 50 years old in Norway established. Work continues to assess the number of trees recorded in the 1970's still remaining.

Sex expression in *Araucaria araucana*

Of the 47 trees recorded in Bergen in 1974, 18 were female and 18 male, whilst sex could not be determined in the remainder. From the observations in Bergen (later confirmed by work in Rogaland) it became apparent that flowering was not initiated before the trees were 40–50 years old. Heights and diameters were measured and numbers and orientations of male and female cones recorded (Søndergaard 1975). Both male and female cones were most abundant on the south-facing parts of the crowns - approximately three times as many as on the north side. A curious difference was found between the occurrence of male and female cones, with the female cones being most abundant in the SW part of the crown, while the male cones were most abundant in the SE part (counted on 18 female- and 18 male trees). However, the figures varied so much from tree to tree that this difference could not be confirmed by statistical analysis. Favre–Duchartre (1960 & 1962) studied flowering of *A. araucana* in Paris and found that male flowers were initiated in June (differentiated in August) one year before

spreading pollen, while female flowers were initiated during February-March and ready for pollination two to three months later. Could the different times of initiation of male and female flowers play a role in the distribution of male and female cones in the crown of *A. araucana*? Favre-Duchartre further observed that 11 months passed between pollination and fecundation (which took place during April). The still green female cones finished their growth during the following summer until disintegration of the cones and seedfall in September-October.

A. araucana is normally dioecious, but exceptions are reported (Søndergaard 1975). During the registration of 18 female and 18 male trees in the Bergen area 1972-1974, no occurences of both sexes on the same tree were observed. The only known confirmed example from Norway at that time was the male tree at Balestrand, which had produced one female cone in 1962 and one in 1971 with fertile seed (Søndergaard 1975). However, during observations in Rogaland in 2001 no less than four out of 15 flowering trees were found to produce both male and female cones. All of the four trees were basically female but each of them carried from one to five male cones, and they all produced fertile seed in 2001 (see p.99). Three of the four trees were isolated with no possibilities for cross-pollination.

A tree at Rommetveit on the island of Stord was recorded as a female when visited in 1972. During a visit in September 2002 a couple of male cones were observed on this tree together with several females.

Two completely isolated female trees, one in Jåtta and one in Sandnes south of Stavanger produced a lot of cones in 2001, but not a single filled seed was found. They apparently did not produce male cones (at least not during a period appropriate for successful pollination).

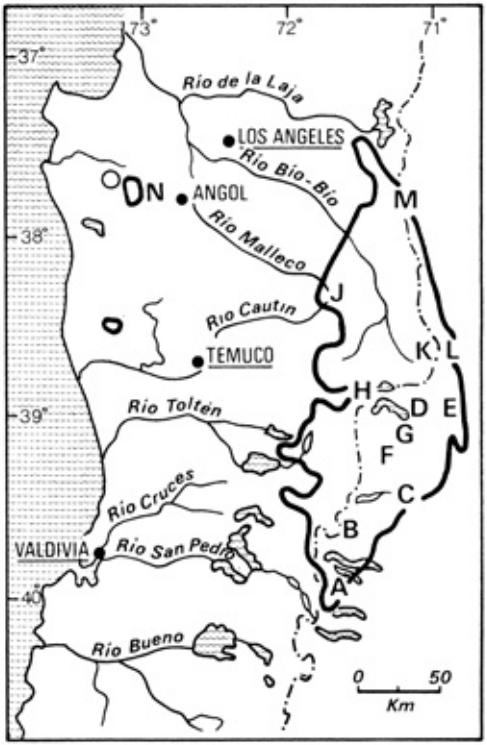
Release of pollen was seen on one of the male trees in the Breidablikk garden in mid-June, which corresponds fairly well with observations in Paris. Release of pollen was observed by Favre-Duchartre (1960 & 1962) during May. Paris is situated about 1000 km, or 9^{o} latitude, south of Stavanger, and the difference in springtime temperatures between Paris and Stavanger corresponds fairly well to the difference in time (about one month) for release of pollen and seedfall at the two sites.

Monitoring of *A. araucana* trees over a longer period of years could show if sporadical monoecious behaviour is more common than hitherto believed. It would be interesting to investigate if there could be a correlation between stress (by isolation or climatically exposed situations) and monoecious behaviour in *A. araucana*.

The Araucano Indians in South America have a more poetic view of the regeneration and social life of the *pehuén* (Aagesen 1998 a): "The species provides them with both symbolic and spiritual sustenance, and the Araucanos perceive the monkey-puzzle forest as an extended family, which they call *lobpewen*. The male tree (*domopewen*) and the female tree (*wentrupewen*) are thought to reproduce through intercourse of their extensive root systems rather than by anemophilous means. The Araucanos respect a pair of deities living in the forest, *pewenucha* and *pewenkuzé*. The will of this couple is believed to influence the reproduction of monkey-puzzle trees. To ensure a good harvest of *piñones*, supplicants make offerings during a ritual called *Ngillatun*. The sacred and central area around which this three- day, open air ceremony takes place contains a monkey-puzzle tree. *Piñones* are also used in tombs and burials, and monkey-puzzle trees are occasionally planted in indigenous cemeteries. A sacred monkey-puzzle tree called *El Pino del Cajón del Manzano*, located in the northern part of its Argentine range, is the subject of an annual pilgrimage for many Araucanos".

New introductions of Monkey Puzzle to Scandinavia

In 1975 the Nordic Arboretum Committee arranged a collecting expedition to southern South America (Ødum 1977). Seeds and plants of *A. araucana* were collected in several localities, but no plants from the 1975 collection seem to have survived in the Nordic countries. Seeds were again collected in Argentina and Chile by The Danish Scientific Expedition to Patagonia and Tierra del Fuego in 1979 by Søren Ødum and Trondur Leivsson (Breuning Madsen, Schmidt Nielsen & Ødum 1980). Nine populations were sampled on the Argentinian side of the border and three populations on the Chilean side adjacent to Argentina. Finally two Chilean populations were sampled in the Cordillera Nahuelbuta Range close to the Pacific Ocean, see opposite. Seeds were distributed to a number of institutions in the northern hemisphere. All of the 14 provenances were sown in the Norwegian Arboretum, Milde (Bergen), during spring 1979. The young plants were kept in containers during the following five years, and protected from frost. Of the 14 provenances 74 plants were planted in three plots in 1984. Two of the plots were located in the Norwegian Arboretum, Milde, and one in the garden of the Lunde Vicarage at Balestrand (Sognefjorden). The plots were monitored and heights were measured during the following years. The table on p.100 shows the results from



The approximate range of *Araucaria araucana* with the collecting localities A to O indicated. Figure redrawn after Montaldo (1974). (Reproduced from Madsen, Nielsen & Odum 1980).

one of the trial plots at Milde and the plot at Balestrand.

The coastal provenances from Cordillera Nahuelbuta were expected to be too sensitive for the climate of West Norway, but apart from rather slow growth at Milde these plants showed no signs of frost damage after cold winters. On the whole no difference in hardiness was observed between the different provenances when grown at Milde and Balestrand, and in fact the Nahuelbuta provenances were among the best performing at Balestrand. When establishing the trials in 1984 we were prepared to lose a high percentage of the plants due to climate damage, but to our great surprise 95 % of the plants not only survived but grew amazingly well.

The number of replicates is insufficient to establish statistically significant differences, but this is not too important since growth rates are not the main characteristics we are looking for in this trial.

So far (during 17 years) the trials have shown no clear differences between provenances in survival rate and cold resistance. Differences

Seed collection in 1972 with assistance from the Bergen Fire Department (see p.93)

in vigour seem to be present, but this must await future confirmtion. A study of 13 populations of *A. araucana* throughout its natural range (Bekkesy et al. 2002) showed extensive genetic variability, with the majority of variation existing within populations (87.2%). However, variation among populations was also significant, even if only 12.8 %. The high variation within populations might explain the lack of differentiation observed between the 14 provenances tested under field conditions in West Norway.

Further provenance trials along the west coast of Norway

In no other place is *A. araucana* found at such high latitudes as on the west coast of Norway. Compared to its natural distribution area it has been moved more than 20º of latitude (c. 2.500 km) closer to the pole, although it should be remembered that the cooling of climate with increased latitude in the southern hemisphere is much steeper than in the northern hemisphere, especially along the gulf stream-influenced coast of Europe. Day length does not seem to have a strong influence on the growth and development of the Monkey Puzzle. Day length dependant trees, for instance Scots Pine, would never survive a similar displacement. Growth would begin too early and cease too late causing extensive frost damage and eventually killing the plants. Introduction to Norway has been taking place for about 150 years,

photographs © Poul Sandergaard

Above: Isolated female tree with male cone at Kalberg south of Stavanger. Photo taken June 2002

Right: Mature seed from the isolated tree at Kalberg (photo taken November 2001

with many plants reported to have been brought home from South America by sailors. Norwegian trees might therefore contain parts of the gene-pool in *A. araucana* which has now been lost in its home land. Revisits to a number of the trees registered in the 1970's have shown that about 90% still exist. Of the trees now missing, most were cut down because of new housing development or because of supposed decay (which after felling often proved to be wrong) or because they were badly sited when planted. An effort should be made to preserve as many as possible of the extant trees in order to secure the gene pool of *A. araucana* in Norway. Over the next few years, it is hoped that further trials will be established, one at a site 63ºN near Kristiansund and another at 59ºS in the Rogaland Arboretum.

Seeds were collected in the Stavanger region and south of Bergen during November-December 2001 and about 250 young plants were raised (and are at present kept under glass) in the Stavanger Botanical

Provenenances of Araucaria araucana at Store Milde Bergen) and at Balestrand (Sogn), planted spring 1984 (5 years from seed and 40 – 50 cm tall) measured 1994 and 1999.

		Milde								Balestrand							
		Heights (m)					Internodes			Heights (m)					Internodes		
		1994		1999			1994		1999		1994		1999			1994	1999
Lago Currhué **A** (79.0090)	**ARGENT**	1, 8	1,6	**3,5**	2,8		6	8	10 12		0,9	1,5	2,5	2,9		7 6	9 9
Lago Tromen **B** (79.0097))	**ARGENT**	2,0	1,6	2,9	**3,4**		8	7	14 11		1,6	1,6	**3,2**	**3,0**		7 10	11 14
Bajada de Rahue **C** (79.0096)	**ARGENT**	2,3	2,3	**3,8**	**4,4**		8	10	16 12		1,2		2,5			9	14
Pampa Lonco Luan **D** (79.0094)	**ARGENT**	1,5	1,6	2,9	**3,3**		7	6	11 9		1,2	1,8	**3,5**	**4,2**		8 8	12 13
Primeros Pinos **E** (79.0087)	**ARGENT**	1,5	2,1	**4,3**	**3,0**		10		12 16		1,2		1,6			8	10
Lago Ruca Choroi **F** (79.0093)	**ARGENT**	1,9	1,3	2,3	**3,5**		10	6	16 8								
Rio Aluminé **G** (79.0095)	**ARGENT**	0,5	1,3	1,6			9		10		1,4	1,2	**3,2**	2,7		8 7	12 11
Lago Icalma **H** (79.0089)	**CHILE**	1,5	1,6	2,5	2,8		7		11 10		1,5	2,1	2,8	**4,1**		7 8	10 13
Lonquimay **J** (79.0092)	**CHILE**	1,2	1,3	2,5	2,3		9	5	12 9		1,4		**3,3**			7	12
W of Paso Pino Hachado **K** (79.0100)	**CHILE**	1,5		2,9					12		1,2		2,7			7	10
E of Paso Pino Hachado **L** (79.0091)	**ARGENT**	2,2		**3,4**			10		13		1,4	2,2	**3,2***	**4,5***		10 6	9 13
W of Lago Caviahue **M** (79.0099)	**ARGENT**	0,9	1,9	1,8	0,9				8		1,1	1,7	2,0	**3,7**		5 7	8 13
Cordillera Nahuelbuta, Rdge **N** (79.0098)	**CHILE**	1,0	0,5	1,0	2,5		8		9 13		2,9	1,9	**4,9**	**3,8**		10 10	15 13
Cordillera Nahuelbuta, W-slope **O** (79.0088)	**CHILE**	1,4		2,3			10		13		2,5	2,1	**4,8**	**4,5**		8 11	16 16
Plants from seed collected in Bergen 1972		1,2	1,3	1,8	1,9		6	5	9 8		1,9 1,9	2,6 2,4	4,6 3,7	4,9 3,7		8 8 7 8	12 13 12 12

Garden. Experiments with grafting of shoots from the wild - collected material in the provenance trials on young Norwegian - bred *A. araucana* should be initiated, when the last mentioned obtain a suitable size, hopefully in 3-5 years. The possibility of propagating the *A. araucana* by means of tissue culture should also be investigated if grafting proves not to be a satisfactory solution.

ACKNOWLEDGEMENTS

Thanks to everybody who kindly gave me information about Monkey Puzzle Trees. Special thanks to Magne Sandvik and Alfred Granmo who, back in 1972 and 1974, assisted with the collection of seed and recording trees. And finally, thanks to the Bergen Fire department for help in overcoming the Puzzle!

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*This article was first published in Norwegian under the title: Apeskrekk (*Araucaria araucana*) i Vest-Norge,in the 2003 Yearbook of the Norwegian Arboretum and the Bergen BotanicalGarden (Årsskkrift nr. 7 for Arboretet og Botanisk hage, Milde, Universitetet i Bergen. P 21-30.)

Chosenia arbutifolia, near Esso, Kamchatka (see p. 89)