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Short Report

Freezing Resistance of Temperate and Sub-arctic Conifers Native to the Southern Hemisphere[1]

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Abstract The subalpine and alpine shrubby species such as *Podocarpus nivalis, P. lawrencii, Dacrydium bidwillii* and *Phyllocladus alpinus* weer the most hardy conifer species in New Zwaland and Australia, resisting freezing to −20 to −23°C. This hardiness was comparable to that of the conifers native to the warm temperate or temperate parts of Japan such as *Cryptomeria japonica* and *Abies firma*. In the Southern Hemisphere, very hardy conifer species which withstand below −30°C seem not to have evolved probably due to the mild oceanic climate and the origin of flora.

Introduction

Troll (13) reported that there is a fundamental contrast in climate, vegetation types and floras between the temperate and sub-cold zones of the Northern Hemisphere and the cool-temperate and sub antarctic zones of the Southern Hemisphere. He suggested that this asymmetry of the two hemispheres is demonstrated by a profile-diagram of the climatic vegetation belts from the northern to the southern polar regions, or by the proportions of land and sea in the different latitudes of the globe (13). The typical boreal vegetation types —tundra, sub-cold coniferous forests and temperate deciduous broad-leaved forests— are restricted to the continental, winter-cold climates of North America and Eurasia.

Characteristics of climates in southern temperate and antarctic zones are far more equable than is usual at similar latitudes in the Northern Hemisphere, that is, cool wet summer and mild winter (3). Climatic stresses, above all winter low temperatures, may be important among the natural selection pressures which have led to the evolution of adapted ecotypes and species to cold regions. And winter temperature is evidently among the important factors setting the northern boundaries of natural ranges of many tree species in the Northern Hemisphere (6, 10, 11).

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In this study, to understand effects of climatic stresses and the origin of floras on the development of cold hardiness, freezing resistance of southern temperate conifers was assessed.

Material and Methods

The twigs were collected during July (mid-winter) of two or three years, mostly from natural habitats in both New Zealand (10) and Australia. Planted materials were collected from Christchurch Botanical Garden in New Zealand and Canberra Botanical Garden in Australia. Twigs were sent by air to Sapporo taking 1 to 3 days. All twigs were subjected to an artificial hardening regime which consisted of holding samples at 0°C to −1°C for 10 days, at −3°C for 14 days and −5°C for 1 day to increase resistance and to overcome differences in sites of collection and handling procedures (5, 10, 11). To evaluate viability after freezing, thawed twigs were placed in water in polyethylene bags at room temperature for 20 days. Freezing injury was evaluated visually using browing as the criterion. Freezing resistance is expressed as the lowest survival temperature in each organ.

Results and Discussion

Freezing resistance of southern conifers is shown in Table 1. In the South Island of New Zealand, mild maritime climates (3) extend to Foveaux Strait (mean air temperature in the coldest month : 5.3°C extreme-minimum :

Table 1. Freezing resistance of temperate and subalpine conifers growing in New Zealand and Australia

Family and Species	Freezing resistance (°C)				Collecting locality	Native habitat
	Leaf	Bud	Cortex	Xylem		
Taxodiaceae						
Athrotaxis selaginoides	−17	—	−15	−15	Canberra (BG, pl)	Tasmania, Australia
A. cupressoides	−20	−20	−20	−20	〃	〃
Cupressaceae						
Callitris oblonga	−13	−15	−15	−15	Christchurch (pl)	〃
Diselma archeri	−17	−17	−20	−20	Canberra (pl)	〃
Libocedrus bidwillii	−13	−13	−13	−13	Otira (900, NZ)	New Zealand
Podocarpaceae						
Dacridium bidwillii	−23∼−25	−23	−23	−23	Waim (670 m, NZ)	〃
Podocarpus nivalis	−23	−22	−23	−23	Arthur Pass (910 m, NZ)	〃
P. lawrencii (No. 1)	−22	—	−22	−22	Mt. Ginini (1962 m, AS)	Australia
〃 (No. 2)	−22	—	−22	−22	〃	〃
Phyllocladus alpinus	−23	−20	−23	−23	Arthur Pass (910 m, NZ)	New Zealand

pl: Planted trees, BG: Botanical garden; NZ: New Zealand; AS: Australia

−8.0°C), the far sourthern tip and even Stewart Island (47°20′S). The most extreme climate is that of inter-montane basins east of the main alpine divide, where there are also sharp temperature inversions. The mean air temperature in July and the extreme minimum in Cralgieburn (1,555 m alt. in New Zealand) are −1.5 and −11°C, respectively. *Dacrydium bidwillii, Phyllocladus alpinus* are all shrubby subalpine or alpine *Podocarpaceae* in New Zealand and extend to the intermontane basins. Subalpine *Podocarpus* also extends to Stewart Island which has podocarp-dicotylos forest. Among these, *Dacrydium bidwillii,* most successfully occupies the forest valley floors. *Podocarpus lawrencii* is also the alpine shrubby *Podocarpus* of the Snowy Mountains of southeastern Australia (about 36°S), the highest mountain range (timber line : about 1,900 m) in Australia. These subalpine or alpine shrubby species, which survived freezing to −20 to −23°C, seem to be the most hardy conifers of the Southern Hemisphere (Table 1). The timber lines correspond quite well with the elevation at which the mean air temperature during the warmest month is 10°C (3). Subalpine conifers of the Snowy Mountains usually winter under a snow cover. The mean air temperature in July and the extreme minimum of Perisher Mountain (2,046 m alt.) are −4.5°C and −12.6°C, respectively (12).

Athrotaxis is the only genus belonging to Taxodiaceae in the Southern Hemisphere. *Athrotaxis cupressoides* and *A. selaginoides* occur on the higher plateau in central and western Tasmania. *Diselma, Cupressaceae,* is typical of older and more exposed habitats in Tasmania. *Diselma* and *Athrotaxis* survived freezing to −15 to −20°C. Most other conifer species belonging to *Podocarpaceae, Cupressaceae* and *Araucariaceae,* which grow in lower altitudes in Australia and New Zealand were marginally hardy to −5 to −10°C (10). The four hardiest southern conifers in Table 1 show the same order of resistance as species native to warm temperate or temperate parts of Japan such as *Cryptomeria japonica* and *Abies firma* (8, 9).

Freezing resistance of trees native to nearly the same latitudes differed greatly between the Northern and Southern Hemispheres. This may reflect both differences in climate and origin of the floras. By the end of the Cretaceous substantial generic elements of the livng flora including *Agathis, Podocarpus, Dacridium* and *Nothofagus* had appeared, judged by their pollen records (3). The wide Southern Hemisphere distribution of these plants in the upper Mesozoic and Tertiary was discussed by Couper and McQueen (1). Another characteristic Paleoaustral angiosperma family has also a similar history. The similarity of tree vegetation between the Patagonian rain forest in Chile and the South Island of New Zealand was discussed by Godley (2). Most of the Paleoaustral genera are characterized by their poor dispersal abilities. Salix is the most widely ranging genus in the world. *Salix safsaf,* one of the primitive willows (7), expands from the Near East southward to South Africa crossing the Africa continent (4, 7). *Salix mucronata,* Cape willow, which is very close to *Salix safsaf* ranges widely in South Africa, expanding to as far south as Cape Town. Twigs of *S. safsaf* which were collected in Pretoria (25°45′S, 1,400 m) and planted in Sapporo survived freezing to −30°C. However, *Erica* and *Protea* which are native to South Africa (4) and were planted near Tokyo were marginally hardy to −10°C or above. In the Northern Hemisphere some coniferous genera belonging to *Pinaceae* have evolved very hardy species (8, 9) which are hardy to −70°C or blow, but any genera of *Taxodiaceae* has not evolved any sub-cold species (9). Most of them are now confined as relics to warm temperate climate.

These facts suggest that the floral potential to evolve very hardy species has also to be taken into consideration. In the South Island of New Zealand the snow line is round 2,000 m in summer while in the Northern Hemisphere, the snow line at the same latitude (40°) is as high as 4,000 to 5,000 m. For the east glaciation in the South Island of New Zealand, Willett (1950) estimated an average lowering of snow-line by about 1,000 m which is comparable to that estimated in Japan (3). The southern temperate climate is characterized by a small annual temperature range, summer wet cool and winter mild which reflects high-oceanic climates. The annual temperature difference is 8 to 10°C at most in New Zealand, Tasmania and Patagonia. However, Japan is an archipelago, which though similar in size, topography and latitude to New Zealand, differs in lying close to a continental land mass. The annual temperature difference in Sapporo (43°03′N) near the Japan Sea amounts to as great as 25°C.

There is considerable interest in intraspecific difference in freezing resistance among ecotypes and climatic races of widely ranging species (11). Available data regarding ecotypic differences so far indicate that a marked variation in cold hardiness among climatic races generally appears to be closely related to the winter minimum of their native habitats. From these considerations, it may be postulated that very hardy species have failed to evolve in the Southern Hemisphere, probably due to the highly oceanic, winter-mild climate and floral origin.

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