

# Biogeography of the Alpine Plants at Hallasan, Jeju Island, Korea

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The island alpine biogeography of Mt. Halla (Hallasan), Jeju Island (Jejudo), Korea is discussed. The presence of numerous species of alpine flora on Mt. Halla, the southernmost distributional limit for certain species, may primarily be attributed to palaeo-environmental factors, since it can not be wholly explained by reference to current environmental conditions. The alpine flora on the peak of Mt. Halla, mainly above 1,500m a.s.l, is evidently descended from immigrants from NE Asia via the Korean Peninsula during the epochs of the Ice Age. These plants, which are very intolerant of competition with temperate vegetation, have been able to persist in alpine belts thanks to their harsh climatic conditions, sterile soil, rugged topography and cryoturbation. The alpine plants on Hallasan are in a stage or process of retreat toward the mountaintop, most likely due to recent climatic amelioration. The lower limit of some species seems to coincide with maximum summer isotherms. The continued survival of arctic-alpine and alpine plants on the summit of Hallasan, Jejudo, the Korean Peninsula, however, is in danger, if global warming associated with the greenhouse effect continues.

## 1. Introduction

Many people are concerned about the possible ecological effects of global climate change. However, very little is known about the impact of global warming on the alpine vegetation of East Asia, especially in connection with biogeographically important alpine plants on remote islands, such as Jeju Island.

In order to remedy this, present work aims first, to elaborate the current distributional pattern of alpine plants on Mt. Halla (Hallasan in Korean), Jeju Island (Jejudo in Korean), the Korean Peninsula; secondly to reconstruct the migration and survival of alpine plants on Hallasan; and finally to delimit the thermal amplitude of alpine plants, to better understand the possible impact of global warming might have on the alpine plants of Hallasan. Related data has been collated from my own fieldwork at Hallasan, since 1995. Here the Korean Peninsula includes both the Republic of Korea (South

Korea) and the Democratic People's Republic of Korea (North Korea).

## 2. Biogeography of alpine plants of Hallasan

### 2.1 Horizontal Distribution of Alpine Plants

Of the about 4,500 species of vascular plants found in the Korean Peninsula (South and North Korea) at present, 340 species are alpine species (100%). Of those, the number of alpine plants in South Korea reaches 130 species (38%), 81 species (24%) are found on Hallasan, 54 species at Mt. Jiri (Jirisan in Korean) in southern Korea, 67 species at Mt. Sorak (Soraksan in Korean) in central Korea.

The alpine plants of Hallasan can be divided into eight groups based on their horizontal and vertical distributions, including species which solely grow on Hallasan (15 spp.); species common to northern Korea

and Hallasan (11 spp.); species common to Soraksan and Hallasan (5 spp.); species common to Jirisan and Hallasan (7 spp.); species common to Soraksan, Jirisan and Hallasan (40 spp.); species which are endemic to Hallasan or the Korean Peninsula (27 spp.); species common to numerous Korean mountains and Hallasan (22 spp.); and species common to Japan and Hallasan (6 spp.).

Floristic diversity and high endemism of Hallasan may be due to first, the long term isolation of the island and its summit from the Korean Peninsula since the Pleistocene; second, the wide range of local environmental conditions (topography, climate, soil, vegetation, etc) present; and finally the absence of catastrophic environmental change in the past, which has ensured the survival of diverse floristic and vegetational elements.

## 2.2 Vertical Distribution of Vegetation

Hallasan is characterized by an impressive altitudinal zonation of its vegetation. Five main altitudinal belts are; coastal, subtropical, temperate, subalpine or alpine. Depending on micro habitat condition, they are separated from each other by approximately the 50, 600, 1,300 and 1,800 meters contours.

Endangered alpine species on the summit of Hallasan number 19 species and include *Diapensia lapponica* subsp. *obovata*, *Leontopodium coreanum*, *Vaccinium uliginosum*, *Empetrum nigrum* var. *japonicum*, *Lonicera caerulea* var. *emphylocalyx*, *Tofieldia fauriei*, *Aquilegia japonica*, *Euphorbia fauriei*, *Pedicularis verticillata*, *Astragalus nakaiana*, *Trifolium lupinaster* var. *alpinum*, *Anaphalis sinica* var. *morii*, *Chrysanthemum zawadskii* spp. *coreanum*, *Adenophora coronopifolia*, *Scabiosa mansensis* for. *alpina*, *Hosta minor*, *Geranium modesta*, *G. jesana* and *Gymnadenia conopsea*.

*Empetrum nigrum* var. *asiaticum* that grows in the northernmost part of the Korean Peninsula is also found on the southern end of Hallasan; *Diapensia lapponica* subsp. *obovata* is found on Hallasan and in Japan. Those occurrences along with disjunctive distribution of en-

demic *Abies koreana* among Hallasan, Jirisan, Gayasan and Deokyusan may indicate a previous floristic connection, possibly through a former land bridge.

## 3. Alpine plants and paleo-environments

The presence of large numbers of alpine flora on Hallasan should primarily be attributed to geological and palaeo-climatic factors, since it cannot be wholly explained by reference to present environmental conditions. The alpine flora of Hallasan is evidently descended from immigrants from Northeast Asia via the Korean Peninsula, eventually moving down to the Japanese Isles during the epochs of the Ice Age. Seventy per cent of the alpine plants of Hallasan, which occur both in the Korean Peninsula and the Japanese Isles may indicate the previous floristic connections between the two areas in the past, probably through a former land-bridge.

These plants, which are very intolerant of competition, have been able to persist in alpine zone of Hallasan due to their adaptation to harsh climatic conditions, sterile soil, rugged topography and cryoturbation. Current distributional ranges of arctic-alpine and alpine plants on Hallasan are confined near its summit.

There is also abundant faunal evidence indicating of the presence of a land connection in the past between the Korean Peninsula and Jeju. These include fauna, occurring on Jeju as their southernmost distributional limit, such as amphibians (*Bombina orientalis*, *Kaloula borealis*, *Rana dybowskii*, *R. plancyi*), reptiles (*Elaphne dione*, *E. rufodorsata*, *Agkistrodon calinosus*, *Takydromus wolteri*), and fossil mammals (*Ursus arctos* var. *laciatus*, *Sus scrofa* var. *coreanus*, *Cervus nippon* var. *manchuricus*, *Capreolus pygargus*).

## 4. Alpine plants and global warming

The vertical range of eight alpine species on Hallasan on the east-, west-, south- and north-facing slopes re-

spectively, shows close relationship with climate. The excess heating of the plant dome is considered a major factor limiting the distribution of cold-resistant species, and the limits of cryophilous species seem to coincide with the maximum summer isotherms. Alpine plants, which are very intolerant of competition in milder environments, are able to persist in alpine belts because of their adaptation to harsh environmental conditions.

The distributional lower limits of eight alpine species studied on the peak of Hallasan seem to coincide with the daily maximum isotherms of 23.5 to 18.7°C, and in areas of relatively low summer temperature. Species with narrower range and thermal amplitude, for example *Diapensia lapponica* subsp. *obovata*, *Leontopodium corceanum* and *Juinperus chinensis* var. *sargentii* might be more vulnerable to the global warming than others. The presence of numerous alpine plants on Jeju is mainly due to their relative degree of sensitivity to high summer temperatures.

Due to high wind and extremely cold winter temperatures in the subalpine and alpine belts of Hallasan, the wind-shaped trees and deformed dwarf krummholz mats of Korean fir, juniper and birch can be seen.

The present-day alpine and subalpine belts, as well as relevant arctic-alpine and alpine plants on Hallasan, are likely to have been formed during the post-glacial warming phase. The existence of a north-south orientation of mountain ranges, and of scattered numerous mountains within the Korean Peninsula, along with the presence of different climatic regimes, enabled many arctic-alpine and alpine plant species to survive in the alpine and subalpine belts in both primary and secondary refugia during both the glacial and interglacial phases, respectively.

The present occurrence of arctic-alpine species on Hallasan, for example *Empetrum nigrum* var. *asiaticum*, and *Diapensia lapponica* subsp. *obovata*, at the world's southernmost limit of their distribution, as well as the southernmost distributional limit of many amphibians, and reptiles in the Korean Peninsula, further promotes the idea of the existence of refugia for these species.

The disjunctive distribution of many alpine and sub-alpine plants, including *Diapensia lapponica* subsp. *obovata* and *Empetrum nigrum* var. *japonicum*, at the top of Hallasan, suggests a former continuous distribution of these species. Their range once extended continuously down slope and southwards during the Pleistocene glacial phases, and then became fragmented as the climate ameliorated during the post-glacial warming phase.

## 5. Conclusions

The presence of numerous arctic-alpine flora on Hallasan, Jeju, in the middle of the Korea Strait between the Korean Peninsula and the Japanese Isles, especially as the southernmost distributional limit for certain species, may primarily be attributed to palaeo-environmental factors, since it can not be wholly explained by reference to present-day environmental conditions.

The floristic diversity and high endemism on Hallasan may be due to first, the long term isolation of the island and its summit from the Korean Peninsula, since the Pleistocene; secondly, the wide range of local environmental conditions that exist; and finally the absence of catastrophic environmental change in the past, which has ensured the survival of diverse floristic and vegetational elements.

Arctic-alpine floras on the peak of Hallasan, mainly above 1,500m a.s.l are evidently descended from immigrants from Northeast Asia via the Korean Peninsula during the epochs of the Ice Age. These plants, which are very intolerant of competition, have been able to persist in alpine belts thanks to their harsh climatic conditions, sterile soil, rugged topography and cryoturbation. The alpine plants on Hallasan are in a stage or process of retreat toward the mountaintop, most likely due to recent climatic amelioration.

The lower limits of alpine species studied, seem to coincide with the daily maximum isotherms of August between 23.5 and 18.7°C, and they grow well in areas of relatively low summer temperature. Species with narrower range and thermal amplitude might be more vulner-

able to the global warming than others. The presence of numerous alpine plant species on Mt. Halla is mainly due to their relative degree of sensitivity to high summer temperatures.