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Present Distribution of Cryophilous Plants and Palaeoenvironment in the Korean Peninsula.

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韓半島 寒地選好植物의 分布와 古環境

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ABSTRACT

The distribution of cryophilous arctic-alpine and alpine plants in Korea is reviewed in connection with palaeoenvironment, along with a discussion to their origins, patterns of migration, and their refugia.

At present, the estimated number of Korean arctic-alpine and alpine species is 419, and this includes 75 arctic-alpine species, 239 alpine species and 105 Korean endemic alpine species.

The disjunctive distribution of cryophilous arctic-alpine and alpine plants is likely to be due to first, the downslope and southward expansion of those species towards the Korean peninsula as a primary refugia from the arctic region as the Pleistocene glacial phases approached, and then their subsequent isolation upslope in mountain areas toward a secondary refugia as the interglacial and post-glacial climatic ameliorations followed; secondly, the expansion of forest tree communities on lowland and montane areas subsequent to the end of the Pleistocene has had the effect of dividing formerly high mountains as a result of the increased competition; and thirdly, the general disapperance or restriction of available habitats for arctic-alpine and alpine species because of post-glacial climatic amelioration.

The existance of 139 alpine species exclusively in the north of Korea may be due to the following reasons; first, frequent exchanges of alpine floras with other neighbouring East Asian regions would have been facilitated; secondly, there are numerous high mountains available for the alpine plants to survive and prosper during the post-glacial period; thirdly, the existance of easy accesses between mountains within the north, which has enabled alpine floras to migrate when necessary; and finally, the availability of diverse environments and habitats for the alpine flora of the north.

However, the continued survival of those species in Korea at the world's or East

Asia's southernmost limits of their distribution for many species is in danger if global warming associated with the greenhouse effect takes place.

要 約

本 硏究는 韓半島 內에서 寒地를 選好하는 것으로 알려진 極地-高山植物과 高山植物의 分布를 古環境과 관련시켜 考察하여, 이러한 植物들의 起源, 移動 그리고 逃避過程을 밝히고, 아울러 韓半島의 植生變遷史를 把握함을 目標로 한다.

現在 韓半島에는 75種의 極地-高山植物과 239種의 高山植物 그리고 105種의 韓國 特産 高山植物등 약 419種의 寒地選好植物이 生育하고 있는 것으로 알려졌다. 이러한 植物들은 주로 高山을 중심으로 隔離 分布하고 있는데 그 理由는 첫째, 플라이스토世에 氷期가 다가오면서 極地와 그 周緯에서 살던 植物들이 혹독한 추위와 건조를 피해 보다 良好한 生育 適地를 찾아 下山하거나 南下하여 移動하던 중, 韓半島가 이들에게 一次 逃避處가 되었던 것으로 본다. 그 후 氷期가 끝나고 間氷期나 後氷期에 들어서면서 氣候가 温暖해져 이러한 植物들은 氣温 上昇에 따라 發生되는 生育環境變化와 暖地選好植物들에 밀려 高山이나 北方으로 移動하여 現在 隔離되어 分布하는 곳에 二次 逃避處를 마련한 것으로 간주된다; 둘째, 특히 後氷期에 들어서 氣候 温暖化에 의한 低地와 山麓地의 森林發達은 氷期중에는 넓은 地域에 걸쳐 廣分布하던 寒地選好植物들을 隔離시킨 것으로 사료된다; 세째, 後氷期에 氣候가 温暖해지면서 사라지거나 縮小된 寒地選好植物 棲息處도 이들이 隔離되어 분포하는데 作用한 것으로 본다.

아울러 韓半島 北部地方에 局限해서 139種의 高山植物이 出現하는 要因은 첫째, 이 地域과 東아시아 地域 사이에 高山植物의 交流가 容易했고; 둘째, 北部地方에 散在하는 高山이 後氷期에 寒地選好植物들이 逃避해 生存할 場所를 提供해 주었으며; 세째, 山地들이 서로 連結되어 있어 필요할때 植物들이 移動할 수 있는 通路가 될 수 있었으며; 네째, 北部 山地에 多樣한 環境과 棲息處가 마련되었기 때문으로 본다.

그러나 現在와 같은 氣温 温暖化 추세가 계속되면 韓半島를 全世界的으로 혹은 東아시아에서 分布上 南限界로 삼는 많은 植物들이 滅種할 危機를 맞게될 것으로 사료되어 保存을 위한 대책이 요구되고 있다.

I. INTRODUCTION

1. Issues

Despite the general recognition by botanists and biogeographers of the presence of a diverse and unique flora and vegetation in East Asia, not very much is known about species composition, structure and species distributional patterns within it. Even less is known about these features in the Korean peninsula, especially in connection with arctic-alpine and alpine plants which appear to prefer cryophilous (cold-loving) environment. In order to remedy this, and so as to meet the growing need for a detailed investigation of the biogeography of the Korean peninsula, its component cryophilous plant groups, and its environmental history the author

have made these the main themes of this paper.

2. Aims

The distribution of cryophilous arctic-alpine and alpine plants in Korea is reviewed, along with a discussion as to their origins, patterns of migration, especially during the Pleistocene period, their refugia, and also their patterns of endemism.

The project also aims to show the idea that floristic and faunal data either fossil or present ones can be used for the reconstruction and interpretation of past environmental changes.

3. Data

Existing range maps of arctic-alpine and alpine plants and fossil flora data in the northern hemisphere, and in respect of the vegetation history of East Asia, also are employed in the elucidation of their origins, migration routes and refugia. The major floristic sources for the distribution of arctic-alpine and alpine species in Korea come from the floristic literatures (see Kong 1989a for detail). The main source for vertical range data of these species in Korea is the work completed by Chung & Lee(1965). Data on the worldwide distribution of arctic-alpine plants has been derived mainly from the works of Hultén (1937, 1958, 1962, 1970).

II. DISTRIBUTION

The term 'alpine plant' in the Korean context is interpreted as referring to plants which grow mainly above the treeline, and 'arctic-alpine plant' refers to plants which grow both in the arctic and the alpine regions of Korea.

At present, the estimated number of Korean arctic-alpine and alpine species is 419, and this includes 75 arctic-alpine species (*i.e.* 17 arboreal and 58 herbaceous spp.), 239 alpine species (*i.e.* 108 arboreal and 131 herbaceous spp) and 105 Korean endemic alpine species (*i.e.* 58 arboreal and 47 herbaceous app). (see Kong, 1989a for detail).

The number of arctic-alpine, alpine and endemic alpine species in Korea and their distributional patterns of these species in East Asia and Korea are presented in Table 1. In this, on the basis of scale, a 'continuous' or 'disjunctive' ditribution refers to the spatial patterns of arctic-alpine and alpine plants in East Asia, and 'widespread' or 'restricted' distribution refers to the spatial patterns of alpine and endemic alpine plants in Korea.

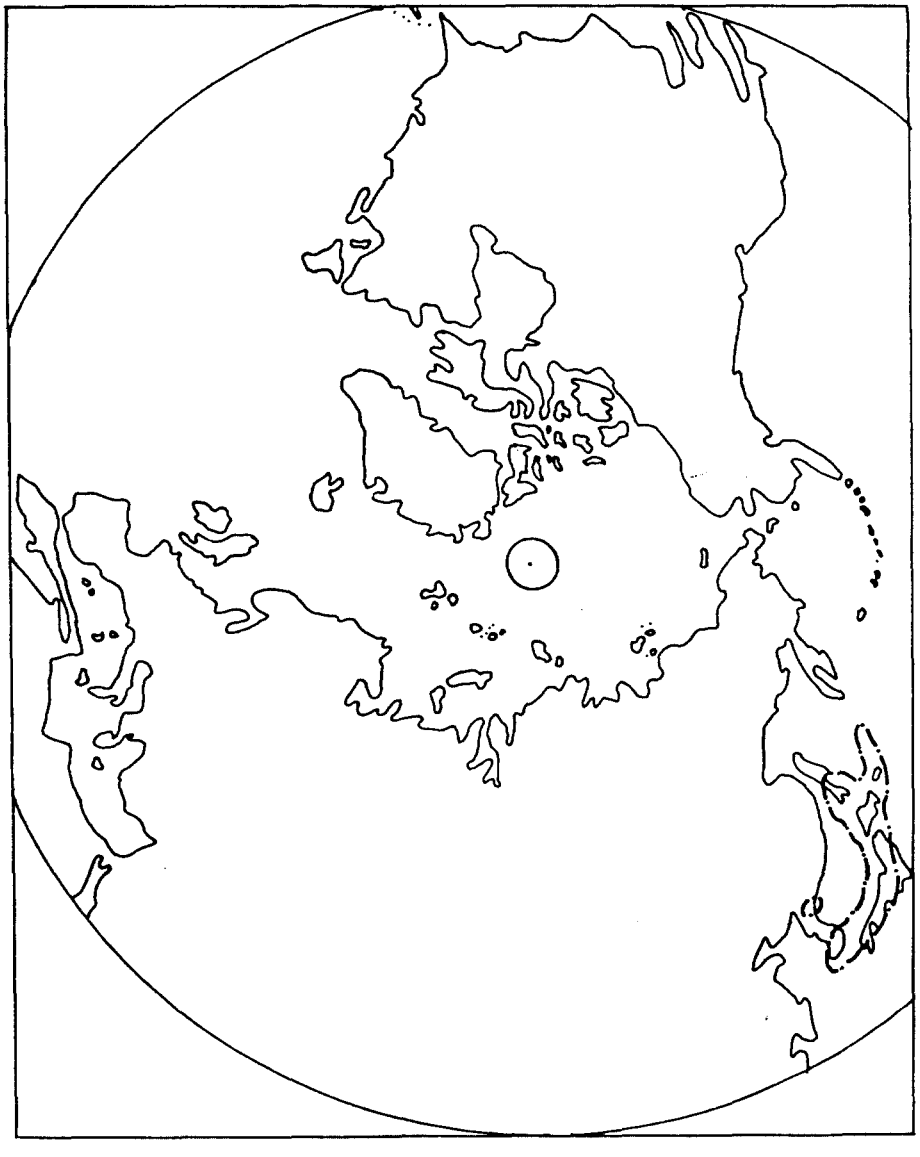
Table 1. shows that four distributional types are to be found from the arctic-alpine species taken into consideration, along with two distributional types from both the 239 alpine and 105 endemic alpine species. The ranges of species are as follow; 1) species with continous distribution in East Asia and widespread in Korea (5 spp; *Empetrum nigrum* var. *japonicum*, *Equisetum hiemale*, *Stellaria longiflora*, *Calamagrostis canadensis* subsp. *langsdorffii* and *Luzula refescens*); 2) those with a continuous distribution in East Asia, but restricted in Korea

Table 1. Distributional Types of Arctic-Alpine, Alpine and Endemic Alpine Plants in East Asia and Korea

	Continuous-widespread	Continuous restricted	Disjunctive-widespread	Disjunctive-restricted	Endemic-widespread	Endemic-restricted	Total
Arctic-Alpine	5 (1,4)	12 (3,9)	30 (3,27)	28 (10,18)	--	—	75 (17,85)
Alpine	—	—	87 (44,43)	152 (64,88)	—	--	239 (108,131)
Endemic Alpine	--	--	--	—	24 (18,6)	81 (40,41)	105 (58,47)
Total	5	12	117	180	24	81	419

(Sources; Hultén, 1958, 1962, 1970; & Kong, 1989a)

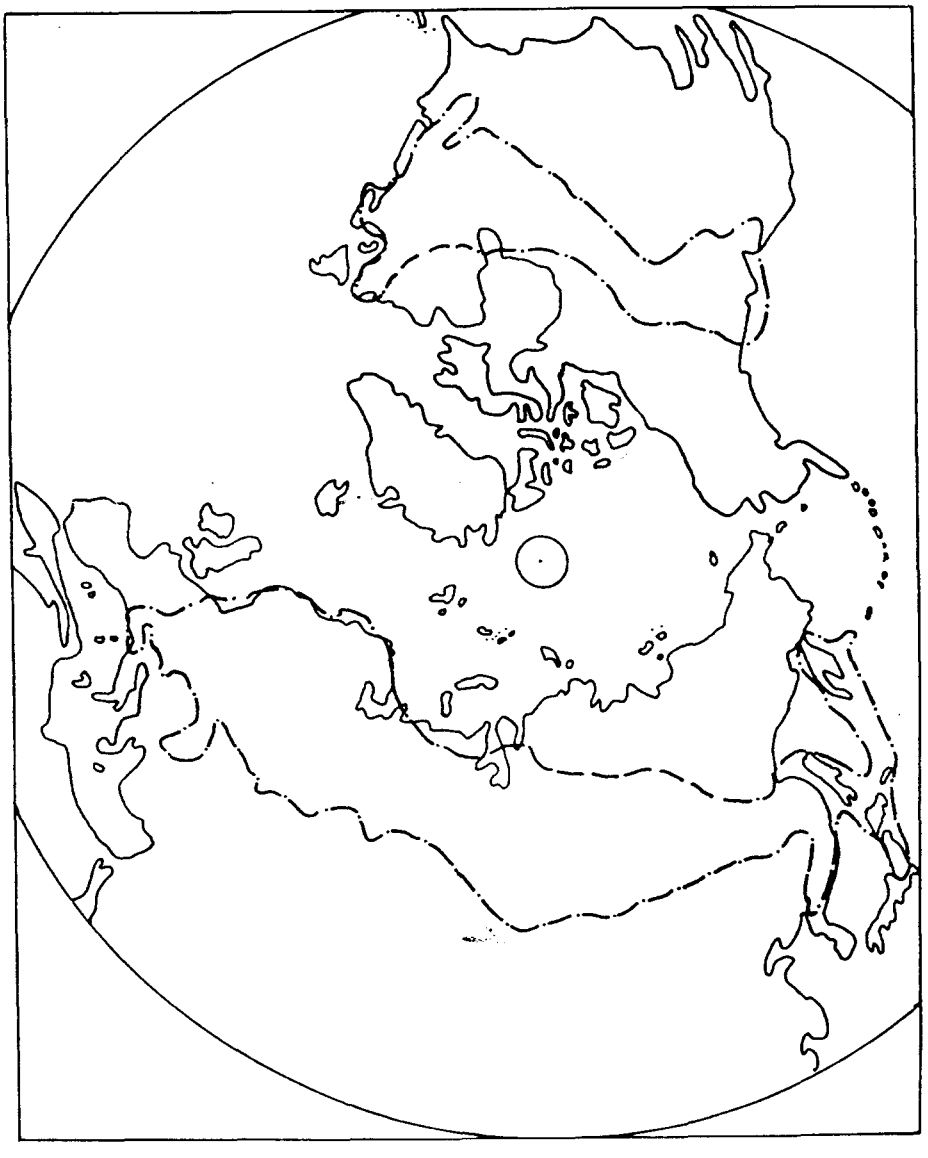
(12 spp.; *Oxycoccus quadripetalus, Vaccinium vitis-idaea* var. *alpinum, Phyllodoce caerulea, Anemone dichotoma, Carex rotunda, Caltha palustris* var. *sibirica, Eriophorum alpina, Agrostis canina* subsp. *trinii, Allium schoenoprasum, Carex loliacea, Calypso bulbsa,* and *C. pseudo-curaica);* 3) those with a disjunctive distribution in East Asia, but widespread in Korea (30 spp; *Juniperus communis* var. *montana* (=? *Sabina sargentii*), *Sorbus amurensis, S. commixta, Turritis glabra, Triglochin maritimum* var. *asiaticum, Lathyrus maritimus, Bromus japonicus, Viola selkirkii, Digitaria ischaemum, Pyrola minor, Lycopodium complanatum, Lamium amplexicaule, Osmunda cinnamomea* var. *asiatica, Gallium aparine, G. spurium, Dryopteris filix-mas, Polystichum braunii, Zostera marina, Rumex maritimus, Typha latifolia, Glaux*



(Modified from Hultén, 1970)

Fig. 1. Continuous Distribution in East Asia, and Widespread in Korea (*Empetrum nigrum* var. *japonicum*)

maritima, Cinna latifolia, Galeopsis bifida, Polypodium vulgare subsp. *virginianum, Utricularia intermedia, Suaeda maritima, Ruppia maritima, Brasenia schreberi, Cynodon dactylon* and *Monotrapa hypopitys* subsp. *japonica);* and 4) those with a disjunctive distribution in East Asia, and restricted in Korea (28 spp; *Dryas octopetala* var. *asiatica, Oxycoccus microcarpus, Rubus articus, Rhododendron lapponicum* (=? *R. parvifolium), Chamaedaphne calyculata, Vaccinium vitis-idaea* var. *minus, Ledum palustre* var. *diversipilosum, Linnaea borealis, Ledum palustre* subsp. *decumbens, Diapensia lapponica* subsp, *obovata, Oxyria digyna, Hackelia deflexa, Rubus chamaemorus, Scheuchzeria palustris, Ranunculus hyperboreus, Poa glauca, P.palustris, P. trivalis, Moneses uniflora, Pyrola secunda, Carex rostrata, Pinguicula villosa, Luzula*



(Modified from Hultén, 1970)

Fig. 2. Continuous Distribution in East Asia, but Restricted in Korea (*Oxycoccus quadripetalus*)

wahlenbergii, Botrychium virginianum, Elatine triandra, Ophioglossum vulgatum and *Hymenophyllum wrightii.* The distributional ranges of typical species are presented in Fig 1,2,3,4.

Overall, up to 76.5% (13 spp.) of the arboreal and 77.6% (45 spp.) of the herbaceous arctic-alpine plants shows a disjunctive distributional pattern in Korea. Many hypotheses are available to explain the worldwide disjunctive distribution of cold-loving arctic-alpine plants (Hultén, 1955; Löve, 1967; Bremer, 1983). It is likely that the disjunctive distribution of arctic-alpine plants in Korea may be due to primarily to the southward expansion of species towards the Korean peninsula from the arctic regions into refugia, as the Pleistocene glacial phases approached, and then their subsequent isolation upslope in mountain

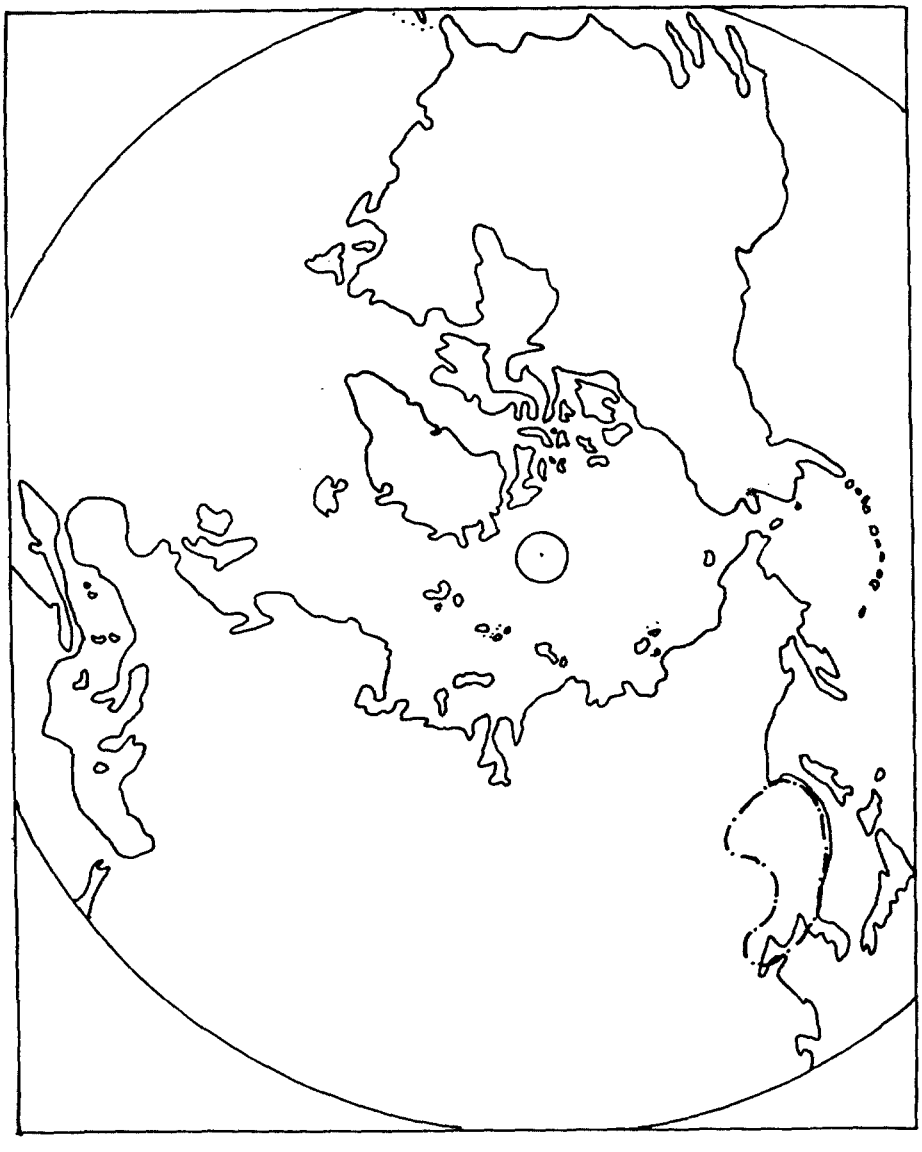


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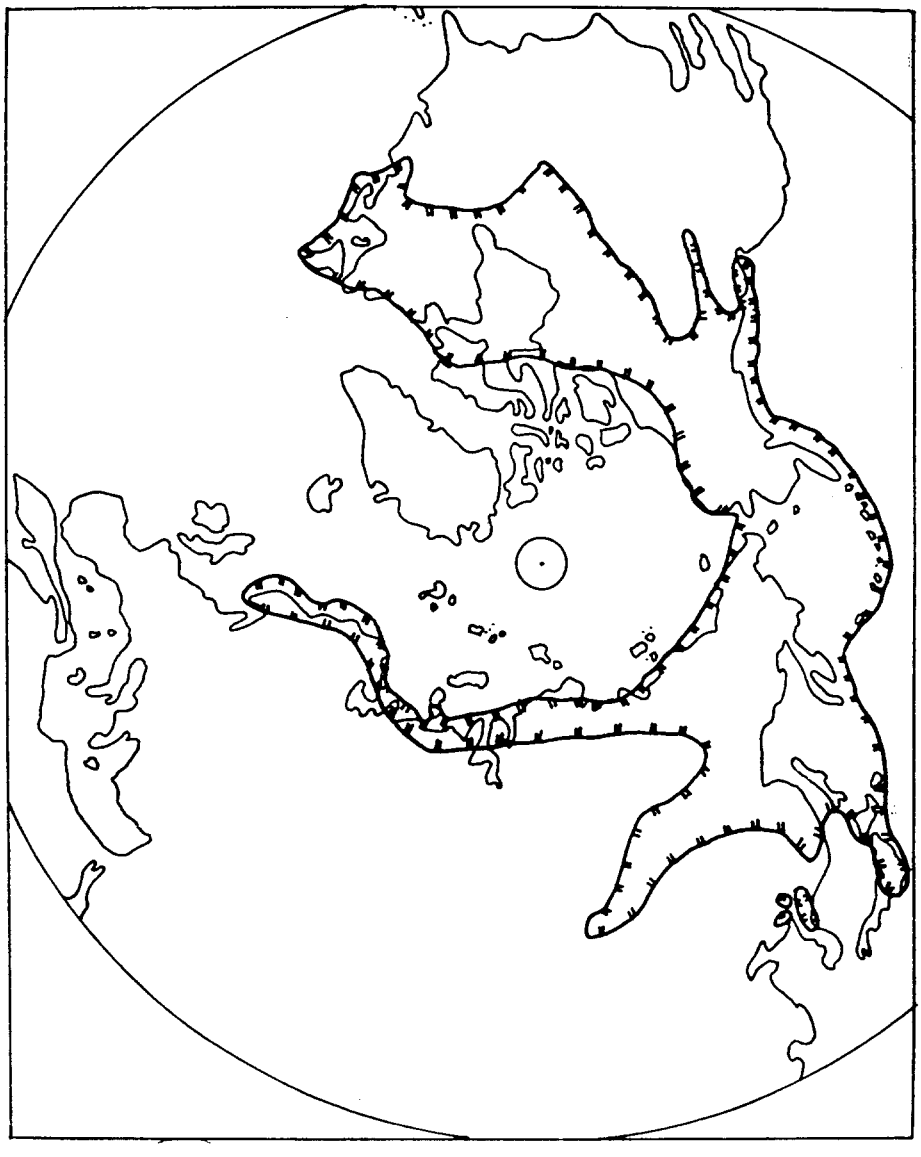
Fig 3. Disjunctive Distribution in East Asia, but Widespred in Korea (*Sorbus amurensis*)



(Modified from Hultén, 1970)

Fig 4. Disjunctive Distribution in East Asia, and Restricted in Korea (*Vaccinium vitis-idaea* var. *minus*)

areas as the post-glacial climatic amelioration followed.

However, the existence of several solely East Asian arctic-alpine species, subspecies and varieties in Korea also may suggest the possibility of some species evolution in East Asia itself. This may be the case for *Empetrum nigrum* var. *japonicum*, *Sorbus amurensis*, *S. commixta*, *Triglochin maritimum* var. *asiaticum*, *Osmunda cinnamomea* var. *asiatica*, *Monotrapa hypopithy* subsp. *japonica*, *Dryas octopetala* var. *asiatica* and *Hymenophyllum wrightii*.

Two broad distributional types are noticed for 239 alpine plants of Korea, (see Table 1), *i.e.* i) a disjunctive distribution in East Asia, but widespread in Korea (87 spp.) and ii) a disjunctive distribution in East Asia, but restricted in Korea (152 spp). The existence of 139 alpine

species (58.2% of the total alpine species of Korea) exclusively in the north may be due to the following reasons; first, frequent exchanges of alpine floras with other neighbouring East Asian regions would have been facilitated; secondly, there are numerous high mountains available for the alpine plants to survive and prosper during the post-glacial period; thirdly, the existence of easy accesses between mountains within the north, which has enabled alpine floras to migrate when necessary; and finally, the availability of diverse environments and habitats for the alpine floras of the north.

Two general distributional types are found from the 105 endemic alpine plants of Korea (see Table 1). They are; i) endemic species, but wide spread distribution in Korea (24 spp) and ii) endemic species, and restricted distribution in Korea (81 spp.).

III. ORIGIN, MIGRATION AND REFUGIA

1. Origin

It is very difficult to determine the origins of present-day alpine floras, due to a lack of relevant macrofossils (Billings, 1974, 1978). Most of the available information comes from microfossils and pollen data, and this varies in quality.

From the available evidence, many research workers have considered what might be the possible times of origin of arctic-alpine and alpine plants, and it is only fair to say that their conclusions have varied widely (Hadac, 1966; Yurtsev, 1972; Tralau, 1973; Billings, 1974; Löve & Löve, 1974; Murray, 1981; Haber, 1986) For Eurasia, one may say that arctic-alpine and alpine plants most likely evolved in the central Asian high mountains and surround localities, since the late Miocene, but mainly during the Pleistocene.

In Korea, cryophilous evergreen coniferous genera can be traced back mainly to particular phases of the Pleistocene. Thus, *Taxus, Abies* and *Thuja* date back to the Middle Pleistocene, and *Juniperus, Pinus pumila, P. sibirica* and *P. koraiensis* to the Upper Pleistocene (Kong, 1989a).

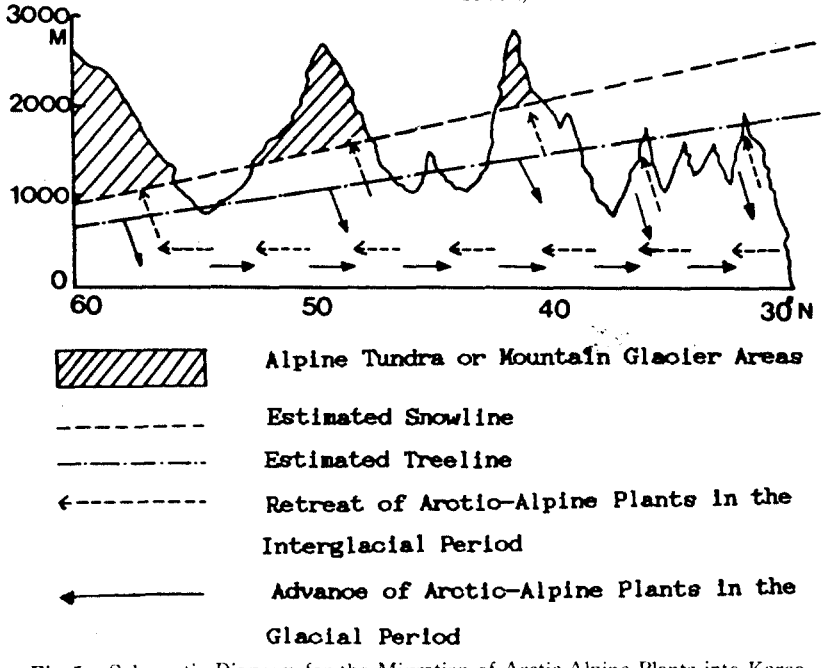


Fig 5. Schematic Diagram for the Migration of Arctic-Alpine Plants into Korea

2. Migration

On the basis of the present-day latitudinal distribution of arctic-alpine and alpine plants in Korea, their altitudinal ranges, the fossil evidence, (Kong, 1989a,b, 1990) the distributional patterns of circumpolar plants (Hultén, 1958, 1962, 1970) and using all the available evidence, including East Asian vegetation history, the pattern of migration of arctic-alpine plants may be reconstructed in general terms for the Korean peninsula, and its immediate vicinity for the first time. Fig 5 shows a schematic diagram for the migration of arctic-alpine plants into the Korean peninsula. In this, the estimated treeline and snowline are approximated though, according to Lautensach (1945), the upper timberline during the Pleistocene glacial phases probably lay at *c.*1,300m a.s.l. in northern Korea, *i.e.* 700m lower than today.

As the climate deteriorated during the cold phases, most of the coniferous and broadleaved forests would have shifted downward from the mountains and southward from the north. During the penultimate glaciation the annual temperature of the peninsula is thought to have been lowered by *c.*8° to 12° c, as compared to present-day temperatures. This figure had been derived from temperature data for China and Japan, and from the general thermal indicators of the last glaciation (Minato, 1972; CLIMAP, 1976, 1981: Zhang, 1984). At the same time, cold-tolerant arctic-alpine and alpine plants moved downward and southward as well.

The absence of major topographic barriers, and of extensive glaciation, coupled with the presence of a north-south orientation in the mountain ranges of both East Asia and Korea, facilitated the dispersal of arctic-alpine and alpine plants southward from the circumpolar area possibly through the Maritime Territory of the USSR, and especially along the Sikhote-Alin mountain range, consequently giving rise to the rich arctic-alpine and alpine flora in Korea. This migration was also aided by the lowering of sea-level during the glacial phases of the Pleistocene, especially in respect of the areas now covered by the West Sea (Yellow Sea), and the Korean Straits between Korea and Japan.

However, the climatic amelioration during the post-glacial period caused glaciers and the areas of permafrost, to retreat towards the north and upslope. This appears to have resulted in the removal of both the permafrost and alpine glaciers from mountain lands in most of Korea. The thermophilous (warmth-loving) temperate species of both lowland and mountain lands then became more common than the cryophilous arctic-alpine and alpine plants.

As a result of the increased competition associated with this process, arctic-alpine plants retreated upward towards mountain tops in the peninsula, and a fragmentation of the arctic-alpine plant distributional range took place as elsewhere in East Asia. At present, therefore, arctic-alpine plants are mainly confined to the alpine and subalpine zones of mountains in Korea, along with specific-habitat-adapted species which grow below the alpine zone.

3. Refugia

After reviewing all the available information, Holland (1981) presented evidence for the existence of six different types of Pleistocene refugia, *viz.* nunataks, ice-free areas, refugia near the ice margin, refugia on the continental shelf, mainland refugia which are far from the ice margin, and dispersed mainland refugia.

Despite the presence of so many arctic-alpine, alpine and endemic alpine plants in Korea, there has been no report to date to suggest that the Korean peninsula contained glacial refugia on a large scale. However, such refugia may will have existed there, on both a primary and secondary level. Although the cold-phase

Pleistocene climates in the present alpine zones of Korea seems to have been too cold and harsh for arctic-alpine plants to survive, and these plants then had to confine themselves to lower montane and or lowland areas, possibly including coastal areas, it is likely that these places effectively became primary refugia. The north-south orientation of mountain chains facilitated the southward migration of arctic-alpine plants from Siberia to Korea, especially via the Sikhote-Alin mountain ranges, which connect arctic Siberia and the alpine regions of northern Korea. Then, as the climate subsequently ameliorated, arctic-alpine plants moved upslope on to the mountain tops and northwards, and the range of thermophilous temperate and warm temperate plants was then expanded in the wake of this movement to cover large areas of lowland, and the lower mountains. As a result, arctic-alpine plants retreated farther upwards on to mountain tops, as well as on to mountain tops, as well as on to montane and coastal areas in the Korean peninsula, and a fragmentation of arctic-alpine plants ranges took place.

Today, therefore, arctic-alpine plants are confined mainly to the alpine and subalpine zones of the Korean mountains. The relatively long period of post-glacial isolation of arctic-alpine and alpine plants on these scattered sites, (mainly mountain tops), the earlier environmental stresses to which they had to adapt within primary refugia (*e.g.* in montane and coastal lowlands), and the extreme degree of environmental diversity, together has resulted in relatively large number of endemic alpine plants being produced. The mountain tops accordingly have proved to be important secondary refugia within the peninsula. The importance of these primary and secondary refugia within the general environmental framework of Korea (especilly within the predominant north-south mountain chains) to the biogeography of East Asia is generally emphasised by; first, the presence of 75 arctic-alpine plants within these refugia; and secondly, by the fact that six of these (*e.g. Phyllodoce caerulea, Ledum palustre* var, *diversipilosum, L. palustre* subsp. *decumbens, Rhododendron parvifolium, Diapensia lapponica* subsp. *obovata* and *Empetrum nigrum* var. *japonicum*) lie at the southernmost global limit of their range (Fig 6.7.8.). Another six species at the southernmost limits of their range in the East Asian continent (*e.g. Chamaedaphne calyculata, Dryas octopetala* var. *asiatica, Oxycoccus microcarpus, O. quadripetalus, Vaccinium vitis-idaea* var. *minus* and *Linnaea borealis*) further promotes the idea of the existence of

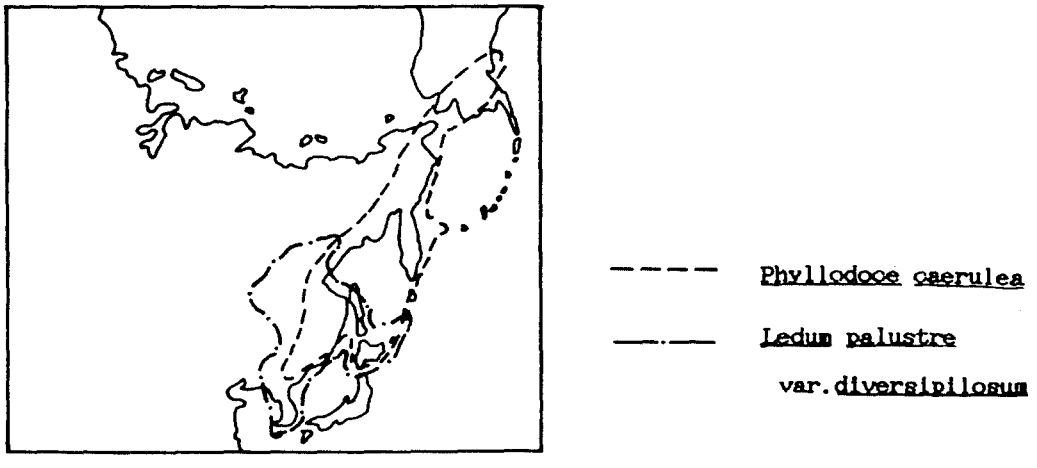


Fig 6. Continuous Distribution of Arctic-Alpine Plants from the Circumpolar Area to Korea

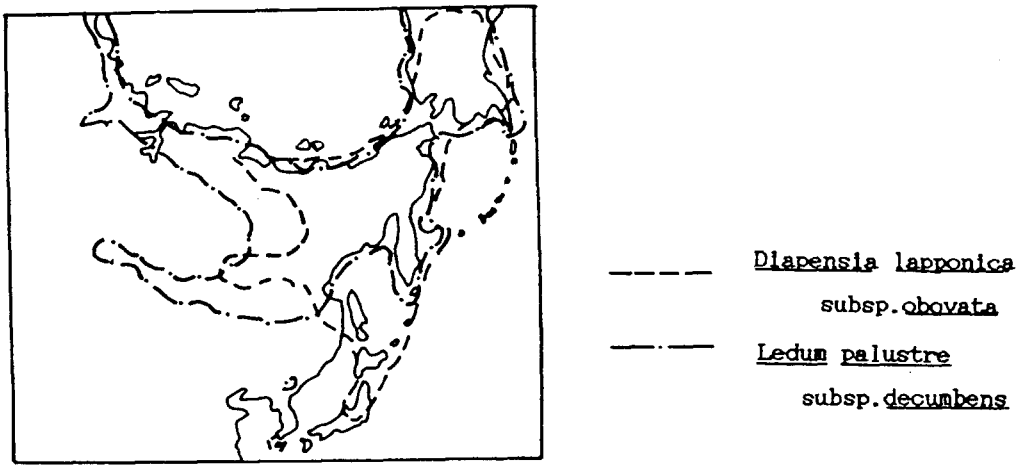
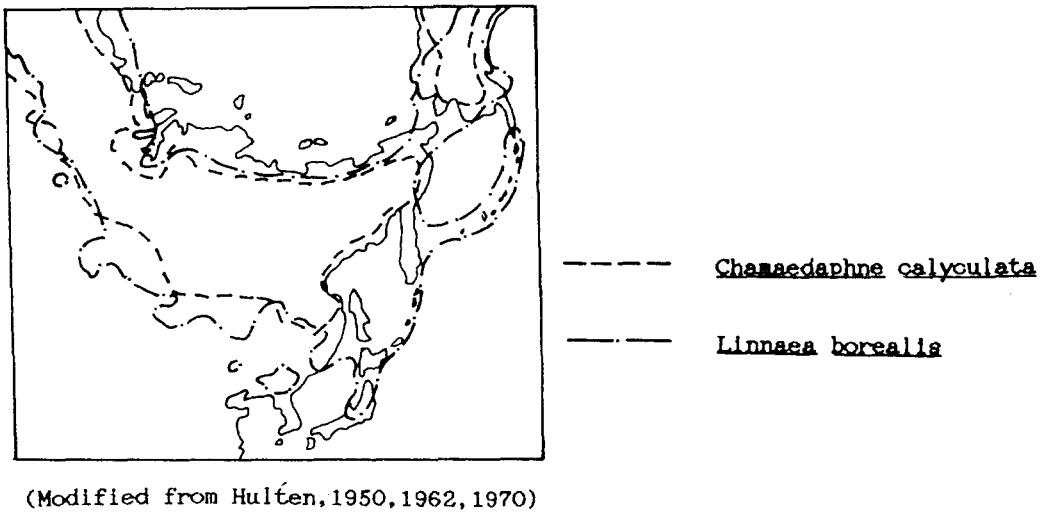


Fig 7. Disjunctive Distribution of Arctic-Alpine Plants from the Circumpolar Area to Korea



(Modified from Hultén, 1950, 1962, 1970)

Fig 8. Continuous-Disjunctive Distribution of Arctic-Alpine Plants from the Circumpolar Area to Korea

refugia for these species in particular in the Korean peninsula, both in the Pleistocene glacial phases and during the post-glacial period.

The particular large-scale disjunctive distribution of their arctic-alpine plants, *i.e Diapensia lapponica* subsp. *obovata* between East Asia and Cheju Island, and *Empetrum nigrum* var. *japonicum* and *Luzula refescens* between northern Korea and Cheju Island, further implies the possibility of a previous land connection between the mainland of Korea and Cheju Island during at least some of the cold phases of the Pleistocene glaciation.

Take as a whole, the disjunctive distribution of cryophilous arctic-alpine and alpine plants in Korea is likely to be due to; first, the downslope and southward expansion of these species towards the Korean peninsula from the arctic region as the Pleistocene glacial phases apprached, and then their subsequent isolation upslope in mountain areas as the post-glacial climatic amelioration followed; secondly, the expansion of forest tree communites on lowland and montane area subsequent to the end of the Pleistocene has had the effect of diving formerly continuous arctic-alpine and alpine plants into

disjunctive areas on high mountains; and thirdly, the general disapperance or restriction of available habitats for arctic-alpine and alpine plants because of the post-glacial climatic amelioration. In fact, the continued survival of these species in Korea is in danger if global warming associated with the greenhouse effect takes place. Arising from this, a plea for more urgent research on these cryophilous arctic-alpine and alpine plants species in particular is made, not only for the further better understanding of biogeography in the Korea peninsula, but also an exempler for what may happen to arctic-alpine, alpine plants and environments generally should the threated increase if globel temperatures begine to materialise.

REFERENCES

Billings, W.D., 1974, Adaptations and origins of alpine plants, *Arctic & Alpine Res.*, **6**, 128-142.

Billings, W.D., 1978, High mountain ecosystems, evolution, structure, operation and maintenance, In; Webber, P.J.(ed.), *High Altitude Geoecology*, 97-125, Westview Press, Boulder, Colorado.

Bliss, C.C., 1981, Evolution of tundra ecosystems, In; Bliss, L.C. Heal, O.W. & More, J.J. (eds), *Tundra ecosystems; a comparative analysis*, 5-7, IBP, No.25, CUP, Cambridge.

Bremer, K., 1983, Vicariance biogeography, *Svensk. Bot. Tidskr.*, **77**, 33-40.

Chung, T.H. & Lee, W.C. 1965, Horizontal and vertical distribution of Korean woody plants, *Theses Coll. Sungkyunkwan Univ.*, **10**, 367-435(in Korean).

CLIMAP Project Members, 1976, The surface of the Ice-age earth, *Science* **191**, 1131-1137.

CLIMAP Project Members, 1981, *Seasonal Reconstructions of the Earth's Surface at the Last Glacial Maximum*, Geol. Soc. Amer. Map & Chart Series, MC-36.

Haber, E., 1986, Flora of the circumpolar Arctic, In; Sage, B.(ed.), *The Arctic and its Wildlife*, 59-71, Croom Helm, London.

Hadac, E., 1963, On the history and age of some arctic plant species, In; Löve, A. and Löve, D. (eds.), *North Atlantic Biota and Their History*, 207-219, Pergamon Press, Oxford.

Holland, P.G., 1981, Pleistocene refuge areas and the revegetation of Nove Scotia, Canada, *Progr, Physic, Geogr.*, **5**, 535-562.

Hultén, E., 1937, *Outline of History of Arctic and Boreal Biota During the Quaternary Period*, Bokf. Akt. Thule, Stockholm.

Hultén, E., 1955, The isolation of the Scandinavian mountain flora, *Acta Soc. Pro. Fauna et Flora Fenn.*, **72** (8), 1-22.

Hultén, E., 1958, The amphi-altantic plants and their phytogeographical connections, *Sv. Vetensk. Akad. Handl.*, **7**, 1-340.

Hultén, E., 1962, The circumpolar plant I, *Kungl. Svenska Venten. handl.*, Fjarde Serien Band 8(5), 1-275.

Hultén, E., 1970, The circumpolar plant II, Dicotyledons, *Kungl. Svenska Vetenskap Handl.*, Fjarde Serien Band **13**(1), 1-463.

Kong, W.S., 1989a, *The Biogeographic Divisions of Korea and Their Past and Present Environments, with Special Reference to Arctic-Alpine and Alpine Floras*, The Univ. of Hull, Ph. D. Theses, U.K. 440pp.

Kong, W.S., 1989b, The biogeographic divisions of Korea and their species composition, *Geography (Korean Geographical Society)*, **40**, 43-54. (in Korean)

Kong, W.S., 1990, The biogeographic divisions of Korea, their physiognomy and distributional range, *The Kyunghee Geographical Review*, **18**, 1-15. (in Korean)

Lautensach, H., 1945, *Korea*, Koehler Verlag, Leipzig.

Löve, A., 1967, The evolutionary significance of disjunctions, *Taxon*, **16**, 324-334.

Löve, A. & Löve, D., 1974, Origin and evolution of the arctic and alpine floras, In; Ives, J.D. & Barry, R.G.(eds.), *Arctic and Alpine Environments*, 571-603, Methuen, London.

Minato, M., 1972, Late Quaternary geology in northern Japan, *Intl. Geol. Congr. Canada*, Sect. **12**, 63-71.

Murray, D.F., 1981, The role of arctic refugia in the evolution of the arctic vascular flora. In; Scoudder, G.G.E. & Reveal, J.L.(eds.), *Evolution Today*, 11-20, Proc. Second. Intl. Congr. Syst. Evol. Biol.

Hunt. Bot. Documentation, Carnegie Mellon Univ., Pittsburg.

Tralau, H., 1973, Some Quaternary plants, In; Hallam, A.(ed.) *Atlas of Palaeogeography,* 499-503, Elsevier Sci. Publ. Amsterdam.

Yurtsev, B.A., 1972, Phytogeography of northeastern Asia and the problems of Transberingian floristic interrelations, In; Graham, A(ed.), *Floristics and Palaeofloristics of Asia and Eastern North America,* 19-54, Elsevier Publ. Amsterdam.

Zhang, L.S., 1984, Reconstructions of the climate of the Late Pleistocene Ice Age in East Asia. In; Whyte, R.O.,(ed.) *The Evolution of the East Asian Environment,* Vol. **1,** 252-270, Univ. Hong Kong.

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