

Shaped by snow and ice

As part of the GenESIS project, Teagasc is using genomic and phenotypic data to understand the nature of adaptation and evolution in the North American Sitka spruce tree. This knowledge can then be implemented through the GenESIS research when breeding new and improved trees in Ireland.

It's no easy task for researchers based in Ireland to fully understand the genetics of a tree species that spans 3,000 kilometres of the Pacific North American coast. While *Picea sitchensis* (Sitka spruce) has many uses in Irish and European forestry, this coastal tree's native range spans from Alaska to California.

Luckily, in the 1960s, seed was collected from native North American forests and donated to Ireland as part of an International Union of Forest Research Organizations (IUFRO) project. Today, understanding the evolutionary history of this tree can uncover adaptations that directly lead to better forestry crops in Ireland.

Picea sitchensis occupies a diverse range of ecological niches. Eighty different provenances consisting of populations with about 40 individuals, each forming a mature stand, have grown in JFK Arboretum in



New Ross, Co. Wexford, acting as a genetic resource. We extracted DNA from the cambial layer of the tree using a new high throughput DNA extraction system. Genomic libraries of the DNA of these samples were prepared and then sequenced, creating a huge amount of data for the research of conifers.

Tracing the evolutionary history of conifers

Susanne Barth, Teagasc Principal Research Officer for Plant Genetics, explains the findings from the team's data mining: "We discovered Sitka spruce was pushed onto islands and to the fringes of the range during the Pleistocene ice age 18,000 years ago, when glaciers spread throughout North America. These fringe refuges for Sitka allowed the mainland to recolonise once the ice sheets began to retreat.

"We see the earliest stages of recolonisation from the islands in Alaska and from Haida Gwaii in British Columbia, Canada. The latest recolonisation occurred around 15,000 years ago, when the ice sheet retreated from the southern ranges and allowed for the recolonisation of Washington and Oregon. The patterns of recolonisation has given Sitka a diverse mixture of ancestry, with modern Sitka being a combination of Alaskan Sitka, Southern Sitka, Haida Gwaii Sitka and some admixture with white spruce."

Recolonising leading to adaptation

The initial collection of seed came from a large range of habitats. Some seed came from areas with an annual precipitation of up to 4,000mm, whereas some only had 620mm. Temperatures of the habitats ranged from -7.3°C to 17.4°C . These habitats had between four-and-a-half and 11 hours of sunlight per day.

Left: Rows of trees native to North America growing as a genetic resource in JFK Arboretum, Co. Wexford; each row represents one provenance





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This diversity in habitats directly leads to adaption in conifers, explains Susanne.

"Conifers are likely to adapt to their local environment slowly. In Sitka, we see a key divide in northern and southern ranges at the 50th latitude, along the US-Canadian border. The northern ranges have more adaptations that negatively affect height, whereas the southern populations have adaptations that positively affect height.

"However these decreases in height allow for increased tolerance to snowfall, with trees reducing their height to cope with the weight of the snow. Southern populations are more adapted to high solar radiation, reduced rainfall and more temperate climates."

Implications for Irish forestry

We have elucidated the colonisation history of Sitka spruce and discovered ranges where adaptations have occurred. Trees originating from Haida Gwaii have negative adaptations towards height. Trees from Haida Gwaii are commonly used in Ireland and the UK.

To maximise the growth of Sitka, trees from below the 50th latitude should be considered for use in Irish breeding programmes. We have identified adaptations to low water stress in the southern populations, which may unlock resilience to climate change if we incorporate the southern ranges into the breeding program. **T**

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