Natural Resources Canada | Ressources naturelles Canada

CWFC Facts 015

Canadian Wood Fibre Centre

Fibre Facts

Spruces in weightlessness

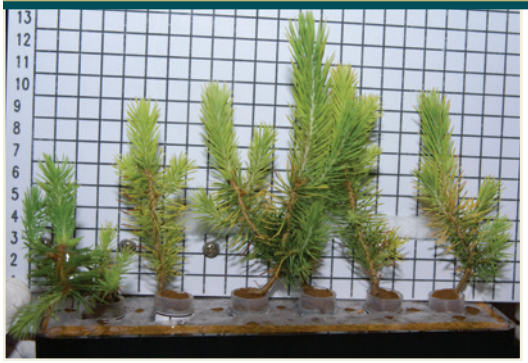
White spruce is an important species for the Canadian forest industry and its genetics is well known. However, there are still a few grey areas remaining. For example, what effect does gravity have on the expression of its genes? Eighteen white spruce plants spent 30 days aboard the International Space Station where their growth was compared with similar seedlings left on Earth. Here is the story and summary of a unique Canadian experiment in Forest Genomics.

In the fall of 2009, after a meeting with the Canadian Space Agency (CSA), which was in search of original research projects to be conducted in space, Jean Beaulieu, a scientist at Natural Resources Canada's Canadian Wood Fibre Centre (CWFC), proposed growing white spruce seedlings for 30 days in a growth chamber aboard the International Space Station (ISS) to evaluate the impact of weightlessness on the species. The project was accepted by the CSA, but with the stipulation that it had to be done very quickly since the space shuttle program was to end soon. A project requiring the collaboration of several organizations was quickly put together and all preparations were completed in just 4 months for a space shuttle launch in April 2010.

The objectives of this experiment were to help researchers understand the effects of weightlessness and the space environment on the growth of white spruce seedlings in addition to obtaining an idea of the role played by gravity in the formation of tree cells and therefore the quality of the wood produced by our Canadian species.

In April 2010, 24 white spruce seedlings were sent to the ISS aboard the space shuttle Discovery. On Day 3 of the mission, the seedlings were transported from the space shuttle to the Destiny space laboratory on the ISS. It was astronaut T.J. Creamer, a member of the Expedition 22 crew, who transplanted 18 of these seedlings into a small container and placed it in an incubator developed by NASA called the ABRS (Advanced Biological Research System). At the same time, other identical seedlings were placed in a similar growth chamber located at the Kennedy Space Center in Florida. Known as APEX-CSA2 (Advanced Plant Experiments on Orbit), the experiment was directed by the CWFC's Jean Beaulieu in close collaboration with the CSA and NASA.

Produced by somatic embryogenesis in New Brunswick by J.D. Irving Ltd., the plants used were from three different lines. Six seedlings from each of the three lines were allowed to grow in space and on Earth for 30 days, inside an incubator where the lighting, temperature and atmospheric parameters were controlled. Many challenges presented themselves before, during and after this unusual experiment. For example, the 24 seedlings had to be stored tightly in a small metal box a few days before liftoff and were not taken out until the transfer into the growth chamber a few days later. The seedlings needed to be in a physiological state that would allow them to keep their buds closed until the beginning of the experiment and budbreak had to occur quickly to allow for the growth of a young stem and roots needed to measure the effects of weightlessness during the short period allowed for the experiment. Lastly, the seedling roots were subjected



One of three white spruce somatic embryogenesis lines at the end of their growth period in International Space Station. Source: NASA

One of three white spruce somatic embryogenesis lines at the end of their growth period on earth, in the laboratory located at the Kennedy Space Center, Florida. Source: NASA

Tube developed at Kennedy Space Center for chemical fixation of biological samples in weightlessness conditions. Source: NRCan

to growth conditions without soil. The substrate used was the Smithers-Oasis foam used by florists.

On Earth, Jean Beaulieu and his collaborators monitored the growth of the plants using video cameras and telemetry and asked the ISS astronauts to water them when necessary. After 30 days of growth, the newly-formed seedling shoots and roots were cut and transferred into preservative solutions and stored under cold conditions. Samples from seedlings that grew on Earth were collected at the same time as in the ISS by NASA staff. Half the samples returned to Earth in May 2010 on the space shuttle Atlantis whereas the other half came back on the last flight of the space shuttle Discovery in March 2011, nearly a year later.

Jean Beaulieu and his team concluded that growth was "normal" in both cases (both on Earth and in space), but after analyzing the expression of 27 genes, they found that there were differences in the expression of the genes, i.e. in the number of molecules produced from these genes. Differences were observed in genes that affect how cells function and develop and this could have an impact on the formation of the wood.

The differential responses by the seedlings in space and on Earth also impacted the morphology of the seedlings, e.g. the length of the needles and their angle of insertion into the stems. These innovative observations were a first for trees and it was the exceptional experimental set-up put in place aboard the ISS that made it possible to obtain these results. Nearly two thirds of the genes produced a larger number of molecules in the weightless environment than on Earth. Although these differences were not for the most part statistically significant, the three genes showing significant differences were overexpressed in the weightless environment. These results clearly show that trees on Earth respond to gravity.

One of the challenges facing the forestry sector is finding a balance between the growing demand for wood fibre and the need to manage forest ecosystems in a sustainable manner for current and future generations in Canada. A better understanding of the genetics of white spruce, an economically important species, could one day make it possible to create genetically improved varieties capable of contending with climate change and producing fibre whose characteristics would make the Canadian forest industry more competitive.

The completion and success of this project came as the result of collaboration between researchers from the Canadian Forest Service, Université Laval, the Canadian Space Agency, the ministère des Ressources naturelles du Québec, J.D. Irving Ltd. in New Brunswick and Smithers-Oasis. Furthermore, without the collaboration of NASA, this project would never have seen the light of day.

This *Fibre Facts* was inspired by the following article:

Beaulieu, J., et al. 2013. Differential gene expression patterns in white spruce newly formed tissue on board the International Space Station. Advances in Space Research 52:760–772.

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Photos on front page, from left to right: Retrieving white spruce samples before performing histological and gene expression studies. Source: CSA-ASC; White spruce seedlings at the end of their period of growth in the incubator at Kennedy Space Center. Source: NASA; View of the International Space Station. Source: NASA

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