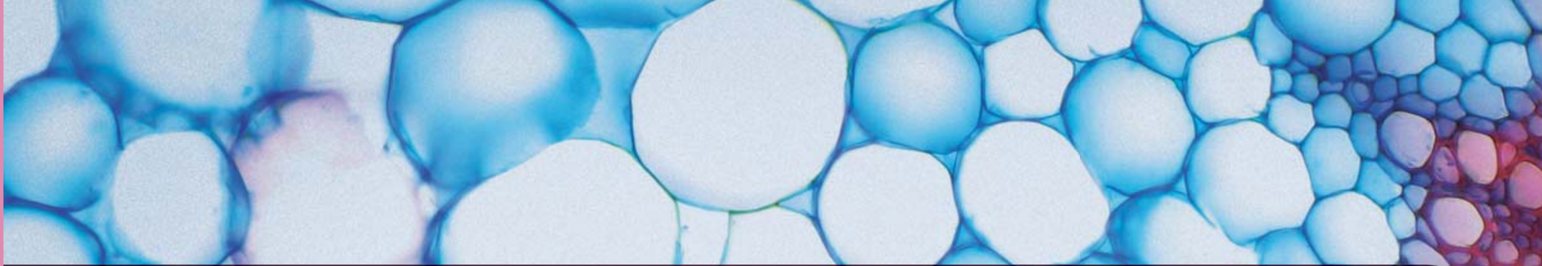


Aspen aspirations

The future success of biofuels relies upon improving their efficiency. **Dr Totte Niittylä** explains his team's efforts to achieve this by increasing the available biomass and producing elite tree genotypes

To begin, what are key objectives of your research?

Increased stem biomass and wood density are important target traits in tree breeding. Our objective is to understand the genetic factors contributing to these traits. We are especially interested in mapping out the pathways and mechanisms of carbon transport and incorporation to wood. Most of our work with trees is conducted on aspen, which is the most widely used model species in tree biology. We are also eagerly awaiting the soon-to-be-published genome sequence of spruce and the molecular biology possibilities it will create. Spruce is economically and ecologically very important in the northern latitudes.

In simple terms, can you explain the approach you are taking in order to achieve these goals?

The carbon in wood is mostly found in three main cell wall polymers: cellulose, hemicelluloses and lignin. In most tree species the majority of this carbon is derived from sucrose imported from leaves. Therefore, charting sucrose transport to developing wood and the subsequent production of cell wall polymer precursors is central for understanding factors controlling stem biomass. We are using transgene technology to alter the expression of genes we suspect play a part in sucrose derived carbon flux to wood. To analyse the effects of the gene modifications on metabolism we are using state-of-the art metabolomics platforms and more targeted metabolite analysis tools. The possible changes to cell walls are first analysed using different mass spectrometry and spectroscopy fingerprinting techniques before more detailed cell wall polymer quantification. We have also developed carbon-13 isotope labelling techniques to measure the rate of carbon flux from the leaves to wood. This technique is proving useful in characterising sucrose transport rates at the whole plant level.

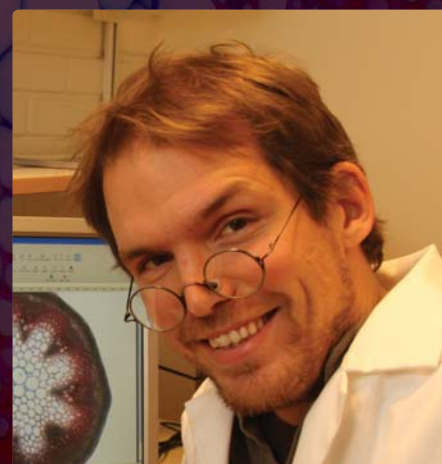
POPLAR FIBRES AND VESSELS

Will your research lead to the development of new elite tree genotypes?

Our work is contributing to the development of genetic markers related to wood density and stem biomass. These markers can potentially be used in molecular tree breeding programmes to develop new elite tree lines with enhanced stem biomass and wood density. We are also identifying enzymatic bottlenecks in the carbon flux to cell walls. In the future we may be able to modify these enzymes by transgenic means to increase the amount of carbon allocated to wood. Although it is difficult to predict what the ideal material for future biomass industries will be, increased wood density and biomass will likely be key factors when choosing the best raw material regardless of the end use.

To what extent does your project provide a solution to the increase in global demand for renewable materials and fuels?

Our research is part of the larger feedstock to biorefinery supply chain development. We are working together with other teams who, for example, assess the ability of enzymes to degrade different biomass feedstocks. The cost-effective release of sugars from these feedstocks is currently a major obstacle in liquid biofuel development. Some of the novel aspen genotypes we have generated release more sugars from wood upon enzymatic treatment compared to wild-type trees.



DR TOTTE NIITTYLÄ

What have been your key findings so far?

We started this project in 2009 and so far we have identified an important enzyme responsible for fructose metabolism and carbon partitioning to cellulose in aspen wood. Recently we also identified a sugar transporter that plays an important role in sucrose transport to developing wood. We have discovered some key sucrose metabolism enzymes which are critical contributors to wood density.

In what ways have you collaborated with other researchers and institutions on the projects?

We regularly collaborate within our own institute, the Umeå Plant Science Centre. Collaborations with technology platforms operating analytical techniques for metabolomics, proteomics and cell wall analysis have been particularly fruitful. We also benefit from important international cooperation with researchers at the Max Planck Institute in Germany. Many of our projects draw on diverse skill sets, and through collaborations we can combine proficiencies and move research forward. Individuals from different disciplines often look at the same research questions differently. This is always a source of fertile discussion.

Better biofuels

A Sweden-based group is investigating sugar fluxes in plants, delivering important contributions to improve production of renewables worldwide

A RESEARCH PROJECT is underway at the Swedish University of Agricultural Sciences to understand how plants are able to sense and then respond to changes in sugar flux. It also investigates how these responses contribute to the control of metabolism, ultimately affecting the way in which sugars are allocated in plants. Although *Arabidopsis* is taken as the model for the research, the goal is to work towards improving the species that are used for biofuel production. By improving biomass accumulation and yield potential in crops, it is hoped that significant gains can be made in the production of green energy. Focusing on the group's recent discovery of sugar flux responsive proteins, the project aims to log and characterise the operation of putative flux sensors and modifiers, and how these work to regulate sugar flux in *Arabidopsis*. The initial stage of the project focuses on the sugar flux through a combination of molecular and biochemical methods, and also utilises cutting-edge proteomics and protein crystallography to progress this understanding. *Arabidopsis* is a good model for investigation, and the first stage of work is progressing swiftly.

In addition to *Arabidopsis*, the researchers also work on the regulation of carbon allocation to wood in aspen trees. The role of industrial forest plantations to provide timber is expected to increase strongly, with its share reaching one-third of total supply by 2015 (FAO), and this demand is matched with the need for other renewable resources, the importance of the team's studies are obvious. To date, the engineering of metabolic fluxes in plants has been relatively unsuccessful, but a greater understanding of pathway controls should begin to change this. Dr Totte Niittylä, who leads the project, understands the importance of identifying and characterising the components in the regulation of sugar flux: "Our aim is to use the knowledge gained to improve biomass accumulation and yield potential for important crop species. By approaching this under explored area of plant science, we are seeking to improve plant design, leading to more efficient renewable energy sources, which will improve green energy in the future".

> The role of industrial forest plantations to provide timber is expected to increase strongly, with its share reaching one-third of total supply by 2015

TRAILBLAZING TECHNIQUES

The regulatory mechanisms guiding metabolic sugar flux are not well understood in any organism, and the team's work is contributing to the filling of this knowledge gap in plants. The theory behind the work states that a metabolite may be sensed either in a concentration-dependent manner, or by a mechanism measuring the flux around a dynamic set point. By focusing on the initial protein phosphorylation responses during flux change using the latest proteomics technology, they have been able to gain new insights into the ways in which plants sense sugar flux changes. Niittylä is one of the pioneering researchers in this field, having published a paper on the subject as it was just emerging.

GLOBAL IMPACT

There are wider impacts for the work being produced by the two projects. Wood continues to be used for a number of large-scale industrial applications, and as demand for renewable resources grows, this too is likely to increase. Research is being focused on the uses of wood for green materials and chemicals, and the team's efforts to make it a more economical and denser crop will aid the protection of natural resources which are constantly under threat from exploitation. This brings forth the necessity of domesticating forest trees, removing the incentive for deforestation. The combination of increasing biomass and gaining greater consistency in the physical and chemical properties of the wood fibres has placed the team's pursuit of elite genotypes and growth mechanisms at the forefront of arboreal possibilities.

INTELLIGENCE

PLANT PRIMARY METABOLISM AND CELL WALL BIOSYNTHESIS

OBJECTIVES

To understand the mechanisms that regulate primary metabolism and carbon allocation to cell walls in plants with special focus on wood formation in trees. This work gives a glimpse into the future of plant biology in which the effect of protein modification on metabolism is becoming increasingly important.

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Trees and Crops for Future

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