Achieving large roots AND high sugar content

PhD Update – for The British Beet Review Spring/Summer 2017

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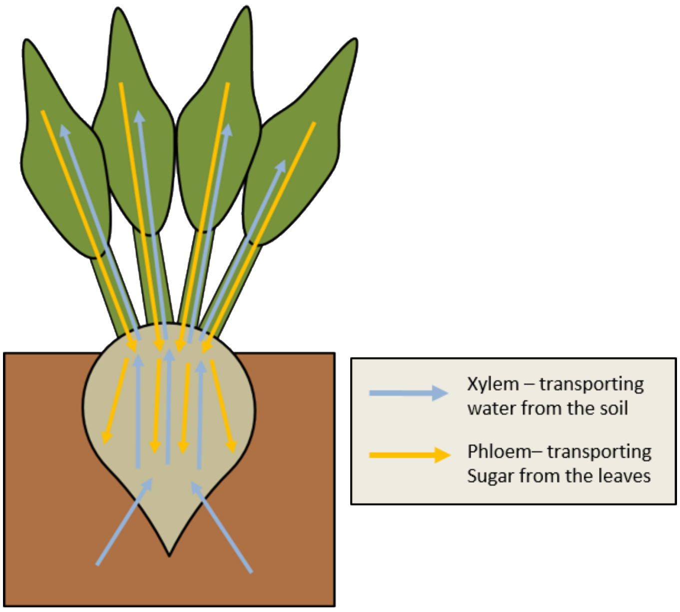
The goal of my PhD project is to advance the understanding of the internal structures of sugar beet roots to identify key aspects which may point to useful breeding targets to drive crop improvement. These improvements could range from increased sugar yield to enhanced root structure and strength, as well as a potentially more valuable pulp once the sugar is extracted.

To aid my research I have been utilising various methods to analyse the internal structures of sugar beet roots. These methods have included microscopy of sugar beet root cross sections with the areas of interest highlighted using fluorescent probes as well as the analysis of sugar beet root composition when converted into pulp. Using these methods, I have been able to gain insight into the structures dictating sugar content and characteristics which may affect root strength. In this PhD update I will share some of my results and how these could be beneficial to the industry.

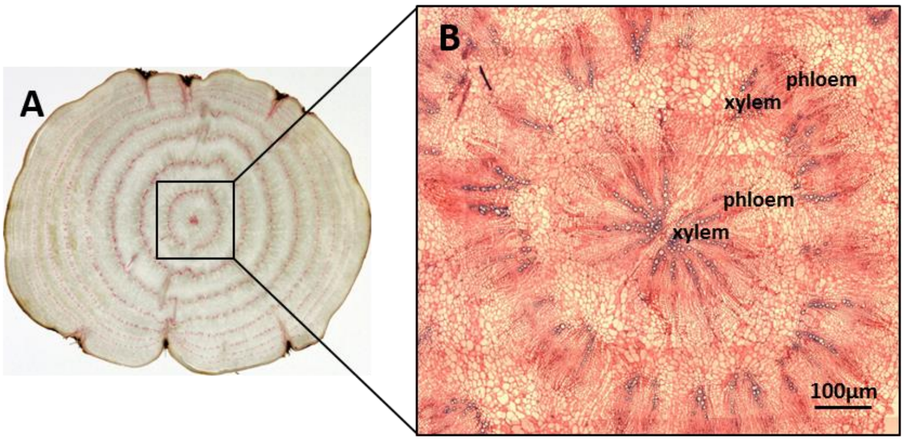
The search for the sugar highway

Sugar (sucrose) in plants is a product of photosynthesis, the process where plants use light energy from the sun and convert it into sugar. Sugar is a form of chemical energy which the plant can use to power everyday functions. Many plants transport this sugar to storage organs such as fruit or grain, and in the case of sugar beet, roots. Specialised transport tissues called xylem and phloem form the plants vascular system and are required to allow movement throughout a plant (Pic. 1). Xylem transports water from the roots to the leaves and phloem transports the products of photosynthesis (sugar) from the leaves to the rest of the plant, including the roots. The structure of these transport tissues is very specialised.



Pic. 1 – Diagrammatic representation of transport tissues within a plant

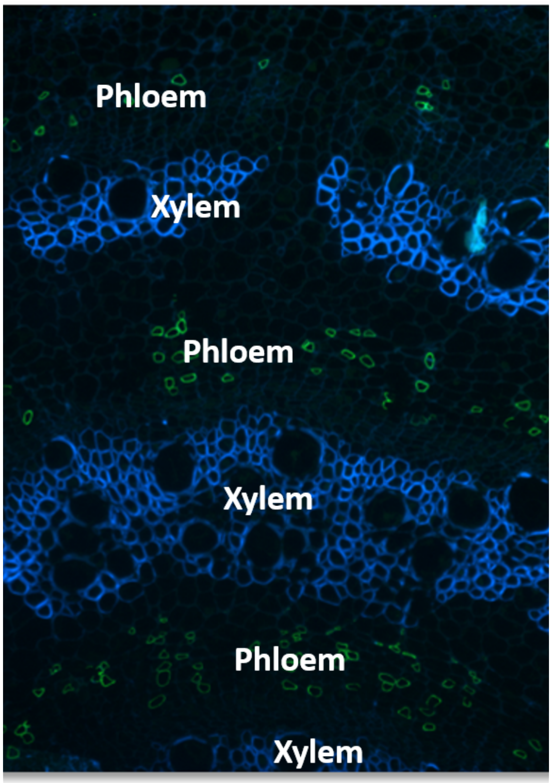
In sugar beet roots the vascular system is in a novel arrangement of repeating vascular rings starting from the centre of the root, and each ring contains an additional set of phloem and xylem tissues (Pic. 2). This arrangement of the transportation tissue is one explanation for the amazing ability of sugar beet to store sugar at such high concentrations. Having the phloem arranged in repeating rings ensures sugar is being delivered and can be stored throughout the root, which would not be the case if the phloem were located in one vascular ring as is the case with most other plant species.



Pic. 2 – **A**; Cross section of a mature sugar beet root with rings of transport tissue highlighted in pink, **B**; Section of sugar beet root under the microscope, xylem shown in purple.

A fascinating result from my work uses fluorescent probes to highlight the internal root layout and visualise structures which have a direct effect on sugar concentration in the roots. I have been using a new fluorescent probe (Ref. 1) that has been developed in my lab at the University of Leeds. This probe is able to highlight the location of the phloem cells within the sugar beet root (Pic. 3) and fluoresces green when phloem is present. Using this probe I am providing understanding about where and when phloem is being created by using the probe at different stages of root development.

Combining the ability to pin point the stage where all phloem rings have developed with genetic knowledge allows for breeding targets to be identified. These breeding targets would aim to increase the number of phloem cells and/or vascular rings containing them. It is known that larger roots do not correlate with higher sugar content as large roots have a higher water content (Ref. 2). This is because sugar has to travel out of the phloem and along a gradient between the storage cells (parenchyma), meaning that the sugar is not readily stored too far from the phloem and water is stored instead. Consequently the number of phloem present per cross-sectional area of the root is very important in the pursuit of increased sugar concentration in the roots. A high number of vascular rings increases phloem number and therefore is a key factor to increasing sugar concentration as more rings leads to more sugar being deposited in the roots. This theory has been shown by comparing beet root and sugar beet, both are the same plant species and have the ring structures in their roots but with differing sugar concentrations and yield. Beetroot have up to seven vascular rings on average where sugar beet can have up to eleven, supporting the hypothesis that fewer phloem relates to a lower sugar concentration.



Pic. 3 – A cross section of a sugar beet root under the microscope. New probe used to highlight the phloem in green. Xylem highlighted in blue. (Ref. 2)

Spending or saving sugar?

In addition to visualising tissues within the root structure, I can use similar probes (Ref. 3) to highlight other characteristics of the sugar beet root which relate to structural strength of the root, such as flexibility. This is important because the sugar beet root can go through high impact environments from field to factory during which root damage can cause sugar loss.

Plant cells are protected by a cell wall which surrounds the cell and maintains the cell shape. The composition of cell walls differs between different plant parts depending on their function.

The overall strength of the sugar beet root arises from each individual cell within the root. The cell walls are the skeleton of plants and dictate the overall structure and strength as well as protection and defence from environmental pressures like harvesting or pests and diseases. The mechanical strength of cossettes rendered during the processing of sugar beet is also dependent on the cell wall properties.

In the lab I can break down the roots to assess what makes up the cell wall. I have been looking at samples from a large number of different sugar beet lines to understand what effect different compositions have upon its physical attributes. This data on root composition can allow for improvements during processing. Roots that damage less easily will suffer less sugar loss post-harvest increasing overall yield.

Cell walls also make up the majority of sugar beet pulp, produced after sugar extraction. Assessing its content can lead to improved and additional uses of this resource. If improvements can be made to the composition of the pulp this can lead to enhanced animal feed with higher nutritional value.

Additionally the pulp is a source of energy which could be used for digestion into bioethanol increasing the value of the crop.

For further information and updates of my research contact me at bsreon@leeds.ac.uk.

Sugar beet storage root cell walls influence:
- Sugar yield
- Harvest damage
- Post-harvest losses
- Sugar extraction efficiency
- Pest and disease resistance
- By-product qualities (e.g. pulp)

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