Feature

By Dr Georgina Barratt,
BBRO Applied Crop Scientist

Physiology focus #3

Root structure and function

As a continuation in our series looking at sugar beet physiology basics, this article explores the structure and function of storage roots and fibrous roots and the key roles they play in sugar storage and the uptake of water and nutrients.

Sugar beet yields are directly related to the amount of light intercepted by the canopy which contributes to the production of sucrose, but it is not the canopy where sucrose is kept but the large storage root. This storage root can grow to an almost unlimited size, but its development and growth can be affected by several different factors. Additionally, the fibrous root system of the plant is crucial for water and nutrient uptake, to ensure a healthy canopy and continued photosynthesis (Fig. 1.). In this article we will look at the development and structure of the storage root and the factors that affect this as well as the function of the wider root system.

The sugar beet storage root is comprised of cambium rings which contain the xylem and phloem which are the structures that transport water and nutrients through the plant coupled with storage cells which make up the parenchyma between the cambium rings (Fig. 2.). The formation of the first cambium rings is linked with leaf development as the pathways for water and nutrients from the roots is connected through the leaves, this pathway is also used to export sucrose from the leaves into the storage root cells. This means that the first 6 cambium rings are formed early in the plants development as the first leaves develop. The first cambium rings are important as they produce the bulk of the storage cells in the parenchyma which develop simultaneously between each cambium ring rather than sequentially. Overtime more cells are produced and existing cells expand which drives the growth of the root and increases the capacity for sucrose storage, but the central 6 rings will make up about 75% of the storage roots volume (Belllin et al., 2007).

Fig. 1. Fibrous roots can be seen at depth and provide a crucial part in water and nutrient uptake.

Fig. 2. Cambium rings and parenchyma clearly visible in root slice

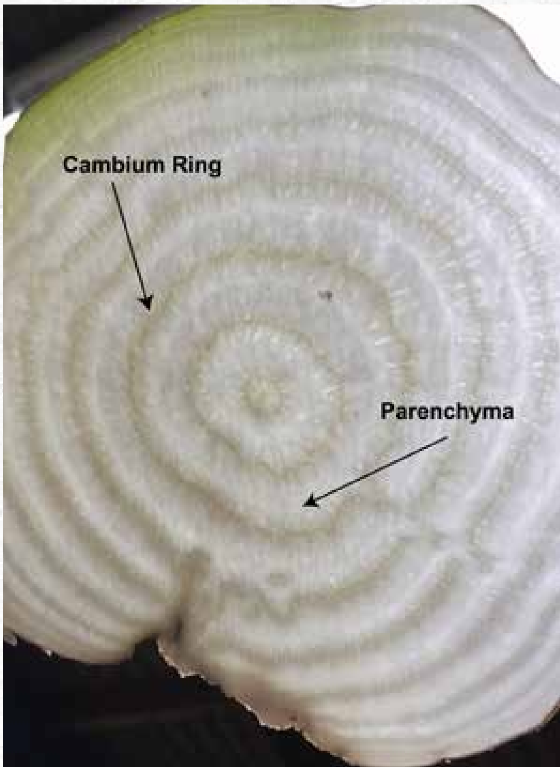

Fig. 3. Fibrous roots are important for the take up of water and nutrients

Milford (1973 & 1976) showed that sucrose concentration increases with cell volume but only up to a set size, beyond this less sugar is accumulated per unit volume. As the storage cells in the parenchyma enlarge, they move away from the cambium ring and have less access to sucrose which results in a lower concentration of sugar compared to the small newly formed storage cells closer to the cambium ring. This means that the larger the storage root the larger the storage cells with a lower concentration of sucrose resulting in an overall lower sucrose concentration in the storage root. Excessive N and low plant populations both lead to large root cells and lower sugar concentrations and varieties can also have different sized root cells. The gradient of sucrose across different sized storage cells also has an important influence on impurities. This is because high levels of sucrose must be balanced out with other molecules such as sodium and potassium to ensure some water remains in the cell for biological processes to continue. This means that smaller storage cells have higher levels of impurities which is why reduced water availability increases impurity levels as cells shrink through loss of water the impurities increase. Disease and drought stress can also lead to a loss of sugar in the storage root as these are remobilised to the shoots to provide the energy needed for leaf regrowth after premature leaf senescence.

It is important to remember that the storage root is only one part of the root system and that it is the job of the smaller fibrous roots to explore the soil and take up water and nutrients. Observations have shown that fibrous root mass in sugar beet can be around 1.15 t/ha which is not insignificant when considering this contributes to soil organic matter build up as it breaks down after harvest (van Noordwijka et al., 1994). Sugar beet root systems can reach depths of more than 1.5 meters but there is evidence to show that water is only taken up from such depths under extreme drought. In the absence of water stress 80% of the crops water uptake can be from the top 30cm of soil (Brown and Biscoe, 1985). This highlights that crop resilience to water stress can be increased if rooting is not impeded by compaction. This root system is also key to effective uptake of nutrients including nitrogen which is transported to the canopy to manufacture chlorophyll and drive photosynthesis.

Harvest is the time when the focus switches from the sugar beet canopy to the storage root, with the aim being to harvest as much of the storage root as possible whilst minimising root breakages and damage. There is evidence that varieties vary in their susceptibility to breakage at harvest which is likely linked to storage root structure and BBRO PhD student Paul Chunga is investigating this as outlined in a previous issue of Beet Review.

Overall, the storage root is the part of the plant that is harvested but the accumulation of sugar in the storage root is only possible because of photosynthesis and sucrose production in the canopy. This is why sugar beet agronomy is focused on optimising canopy cover and health. This also relies on the network of fibrous roots that ensure water and nutrients are supplied to the plant and highlights how all parts of the plant must perform well to ensure yields are maximised.

Fig.4. Cambium rings are visible throughout the storage root

References

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