The role of agronomy and genotype in tissue integrity and associated sugar losses during storage of sugar beet (*Beta vulgaris*).

Background

Sugar beet is a major crop grown in temperate countries as a source of dietary sugar. However, sugar can be lost from harvested roots during storage with losses of approximately 0.1% of total sugar volume per day (BBRO, 2016). These losses are a consequence of many factors including harvesting conditions, clamp design and management but a key aspect of these losses is the association with tissue damage. Damage can be caused through the harvesting process leading to cut roots or root breakage, particularly root tips (Hoffman & Schnepel, 2016) and bruising (Wiltshire & Cobb 2000). Damaged root tissue leads to sugar losses through a) leached cell solutes from affected cells, b) increased respiration in the tissue around the damage site linked to wound healing, and c) entry points for post-harvest infection, leading to further tissue damage. Sugar beet genotypes vary in sugar loss during storage (Schnepel & Hoffman, 2014) and sugar loss has been shown to be associated directly with root breakage (Hoffman & Schnepel 2016), bruising (Fugate et al., 2010) and the level of infestation by pathogens (Schnepel & Hoffman 2014 & 2016). This suggests that factors that reduce the propensity to root breakage and/or bruising may be associated with a reduction in sugar losses during storage.

Sugar beet genotypes vary in susceptibility to bruising and root tip breakage (van Swaaij & Huijbregts, 2010) and there is an association between tissue strength, tissue damage and sugar losses. This is an area of particular interest at the moment, with groups in Belgium and Germany studying the breeding potential for more robust varieties. However, the underlying physiological basis of 'robustness' is not known (Hoffman & Schnepel, 2016). Work at Harper Adams 20 years ago studied the biochemical processes of bruising in sugar beet (e.g. Ibrahim et al., 2001; Spackman & Cobb, 2001) but there is little or no understanding of factors affecting susceptibility to damage and/or bruising of sugar beet roots, although many such factors have been identified for other crops including potatoes (reviewed by Cobb, 1998), carrots (Herppich et al., 1999) and radish (Lockley et al., 2014). Tissue strength and hence propensity to damage can be influenced by physiological factors such as cell size, cell wall volume fraction, adhesion between cells, root water potential, osmotic potential and turgor pressure, tissue texture and the nutrient status of the tissue (Wiltshire & Cobb, 2000).

Aims & Objectives

This project aims to identify traits under genetic or agronomic control to enable plant breeders and growers to optimise tissue strength making roots more resilient to damage and hence reduce sugar losses during crop storage. This project addresses a specific commercial need and also develops a commercially relevant scientist who would be well suited to working in the UK/EU industry across a range of crop types.

- Objective 1 – To identify extreme sugar beet varieties for tissue damage susceptibility and resilience.
- Objective 2 – Identify the morphological and cellular basis of tissue resilience to root breakage and bruising
- Objective 3 – Study the effect of environmental factors on tissue resilience
- Objective 4 – Study the effect of nutrient status during growth on tissue resilience
- Objective 5 – To engage with the British Sugar Beet industry and transfer findings to a wide audience

Work plan proposed:

The overall aim of the project is to provide underpinning research on sugar loss linked to root damage, by identifying the physiological and cellular factors that contribute towards root tissue strength and how these factors are influenced by the growing environment.

The project would be delivered through four work packages:

WP 1 – Identify extreme sugar beet varieties for tissue damage susceptibility and resilience.

The work would study ~20 lines of sugar beet varieties (agreed with seed houses and BBRO and planted in multiple BBRO trial sites) to identify lines with a range of responses from easily damaged to robust types.

Mechanically harvested roots would be assessed for damage following standard BBRO protocols and performance during storage would also be assessed. Hand harvested roots would be exposed to controlled damage in a laboratory. Assays for root tip breakage, bruising and periderm solute leakage would be adapted and optimised from those used with other crops. In addition, tissue texture assays would be optimised for puncture, compression and shear forces. These assays would be used to identify lines with a range of tissue damage susceptibility.

WP 2 - Identify the morphological and cellular basis of tissue resilience to root breakage and bruising

The underlying physiological basis for difference in tissue resilience would be studied by comparing the properties of contrasting extreme lines. Morphological traits would include, size, shape and relative dimensions; cell properties such as periderm thickness and cell size/volume in sections of root tissue would be measured using microscopy. Cell changes around wound sites would be quantified using established techniques developed for sugar beet (Ibrahim et al., 2001). Cellular adhesion of cells around breakage and fracture sites would be studied using techniques developed for Carrot roots (McGarry, 1995). It is not known at this stage whether the cellular basis for breakage differs for that associated with bruising.

Having identified cellular traits that correlate with tissue damage sensitivity the effect of conditions pre and post-harvest on these traits would be studied in WP3 and 4.

WP 3 – Study the effect of environmental factors on tissue resilience and sugar loss

The physical environment, especially temperature, may affect damage and bruising susceptibility in beet, through changes in the properties of cell membranes (Wiltshire & Cobb, 2000). Tissue turgor and cell water status have been shown to influence damage potential in other root crops (e.g. McGarry, 1995; Lockley et al., 2014) and it would be expected that similar responses would be observed in sugar beet. Extreme lines identified in WP1 would be grown under varying conditions in glasshouse studies. The treatments studied would be informed by the literature review, BBRO input and the outcomes of WP1. It is anticipated that experiments would be designed to manipulate tissue water status and root temperature. Harvested roots would be assessed using assays developed in WP1.

WP 4 – Study the effect of nutrient status during growth on tissue resilience and sugar loss

Cell size and number are influenced during root growth by water availability and nutrition, particularly levels of N, K, Ca and Bo. Extreme lines identified in WP1 would be grown under varying conditions in glasshouse studies. The treatments studied would be informed by the literature review, BBRO input and the outcomes of WP1. It is anticipated that experiments would be designed to grow plants at a range of nutrient regimes. The effect of nutrition on the

cellular traits identified in WP2 would be quantified and the effect on the tissue resilience of harvested roots would be assessed using assays developed in WP1.

Starting dates and placement period at BBRO

The studentship would commence in April 2019 at HAU. During the PhD, 6 months will be spent at BBRO working with the technical team during the winter over the sugar beet harvest campaign. During this time the student would gain invaluable experience of sugar beet production as well as of the challenges faced by the grower and processor, develop strong working relationships with the BBRO team and undertake research relevant to their PhD.

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