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Identifying genetic and environmental characteristics affecting sugar beet tissue strength

In the UK, substantial amounts of sugar (0.1 % per day, per volume) can be lost from sugar beet roots after harvesting mainly from damage at harvest. This damage appears to be linked to weaker root tissues. Despite varieties being reported to statistically differ in terms of resilience to tissue damage, there is no information that scientifically correlates sugar beet's physiological and cellular properties to tissue strength across recommended genotypes and environments.

The project started in 2019 to identify varieties and agronomic practices which are associated with greater levels of damage. The plan was to spend the first two years assessing varieties' tissue strength, then later expose the vulnerable varieties to various environmental and agronomic practices that would help to improve the tissues and hence reduce damage.

The study hypothesised that both genotype and agronomic management influence physiological and morphological properties that contribute towards root tissue strength of sugar beet varieties. The research has four aims;

1) to identify extreme sugar beet varieties for tissue damage susceptibility and resilience,

2) to identify morphological factors that affect variety's tissue resilience to root tip breakage,

3) to identify textural properties that affect tissue resilience to root breakage,

4) to study the effect of delayed harvesting on textural properties and resilience to tissue damage.

Field experiments were planted at Bracebridge and Fotheringhay during the 2019 and 2020 campaigns in a randomized complete block design with eight varieties and three replications per trial. Data set for two years have been completed and the trials have been planted again during this campaign (2021) for a third season to check data consistency across three years of experimentation.

A root damage assay was optimised by exposing hand harvested sugar beet roots from the trial sites to controlled damage at Harper Adams University using a sugar beet basher for root tip breakage and surface damage. Roots of equal size and from the same variety were rotated in the basher for a uniform time.

Samples from one replication were damaged on the same day to avoid effects of storage time on textural properties. Samples used for bashing were also measured for morphological properties like length, weight, root tip diameter and width.

The trial at Bracebridge was replicated across two plots, with harvest spaced at a 30-day interval to check the effects of sequential harvesting on root tissue properties. Textural properties for root tissues like puncture, shear and compression forces were analysed using a texture analyser (TA.HDplus - Stable Micro systems Texture analyser, Godalming UK).

Texture and shear forces were analysed axially on the top, middle and tip of the roots while compression forces were analysed using root tissues extracted radially from the peripheral, middle, and central part. To establish a link between root damage and physiological properties/tissue strength, textural and morphological data were correlated with root tip and surface damage.

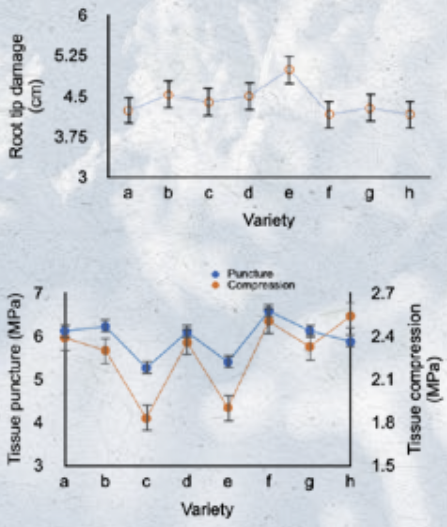

Fig. 1. Effect on varieties of root tip damage, root tissues puncture force

Fig. 2. A textural analyser TA.HDplus - Stable Micro systems Texture analyser, (Godalming UK) used to analyse root tissues.

Fig. 3. Sugar beet basher used to damage sugar beet roots.

Figs 4 and 5: One of the varieties (Sabatina) before (left) and after (right) damage

Results show significant differences among varieties in terms of root tip damage, width, length, puncture, and compression. Root tip damage was positively correlated with width ($r = 0.61$) and weight ($r = 0.66$) and negatively correlated with length ($r = 0.75$), puncture ($r = 0.27$) and root compression ($r = 0.45$).

Varieties with a wider root tip and greater weight have shown to be more vulnerable to damage compared to lighter varieties with smaller root tip. Detailed statistical analysis shows that root tip damage is purely a varietal factor with some varieties more prone to damage regardless of the crop location. The root tissue's ability changes across the root, with resistance to puncture being higher at the top and middle of the root. This answers the question why the root tip easily breaks and suggests that the root tips form an easy entry point for pathogens that contribute to post harvest losses.

Harvest time also had an important effect on damage with later harvested crops at the same location being more easily damaged. This may be due to physiological ageing of tissues or climatic factors. During the two years of testing, varieties e and c (as shown in fig 1) showed to have weaker root tissues and have been incorporated in the next set of trials which are exploring the role of environmental factors (water, temperature, and nutrients) on the susceptibility to damage and aims to provide information for growers to help them to reduce post-harvest losses through damage. These trials are in the field for the third year and will be repeated again in 2022.

Fig.6. PhD student, Paul Chunga