Feature

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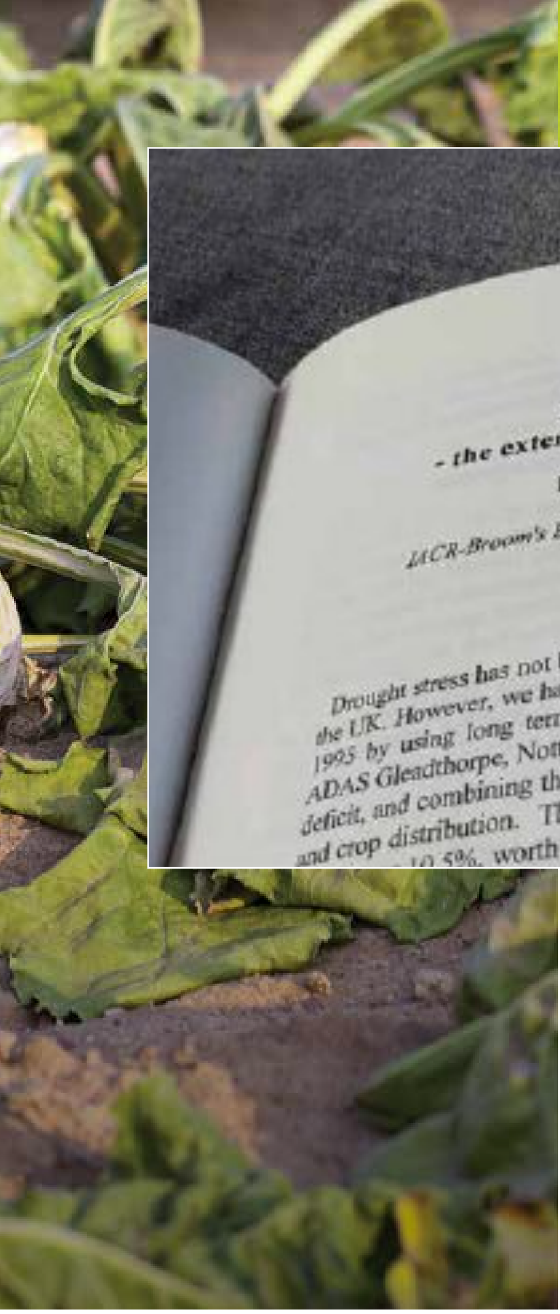
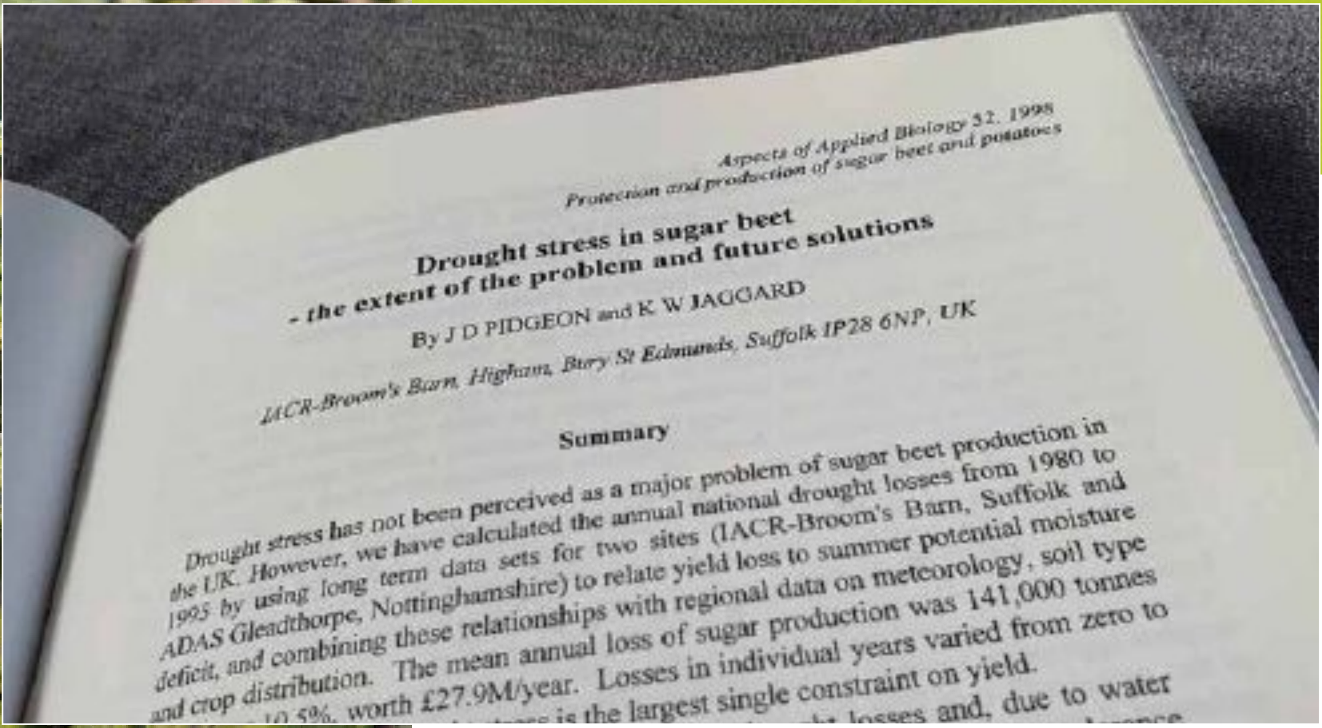
Drought tolerance – what's in the genetic tool-box?

With climate change scientists warning of the increased likelihood of droughts affecting the UK in the future and memories of the impact of the dry spring and summer drought in 2020 still etched in our memories, can variety drought tolerance form part of the solution? BBRO's Dr Georgina Barratt reminds us that this is not a new challenge and reviews how the industry has been responding.

Fig. 1. Georgina monitoring water use efficiency in 2019

When I started my PhD examining water use efficiency in sugar beet one of the first papers I read was entitled 'Drought stress in Sugar Beet – the extent of the problem and future solutions' (Pidgeon & Jaggard, 1998). Written in 1998 it highlights how yield losses due to drought from 1980-1995 ranged from 0-25% in the driest years in the UK, and that drought was the largest single constraint on yield.





Aspects of Applied Biology 32, 1998
Protection and production of sugar beet and potatoes

**Drought stress in sugar beet
- the extent of the problem and future solutions**

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Summary

Drought stress has not been perceived as a major problem of sugar beet production in the UK. However, we have calculated the annual national drought losses from 1980 to 1995 by using long term data sets for two sites (IACR-Broom's Barn, Suffolk and ADAS Gleadthorpe, Nottinghamshire) to relate yield loss to summer potential moisture deficit, and combining these relationships with regional data on meteorology, soil type and crop distribution. The mean annual loss of sugar production was 141,000 tonnes ... 10.5%, worth £27.9M/year. Losses in individual years varied from zero to ... is the largest single constraint on yield. ... losses and, due to water

Fig. 2. Scientific paper on drought stress that helped to pique George's interest.

So, what has happened in the intervening years with regards to drought research and why despite these observations 23 years ago has so little advancement been made in this area?

Well advancement was, in fact, made by researchers during the early 2000s when extensive work was undertaken at Brooms Barn to identify traits associated with drought tolerance in collaboration with breeders. This research involved multiple approaches to identifying drought tolerance in varieties suited to the UK growing area with the biggest study involving large scale field trials and rain out shelters to examine over 40 different sugar beet genotypes (Ober et al, 2005) (varieties which differ in their genetic makeup, and therefore observable traits). Much of this work was led by Eric Ober who worked closely with breeders to identify what, if any, differences in drought tolerance were evident and what traits were associated with these differences.

Fig. 3. Georgina's earlier work measured drought tolerance in a controlled environment.

The authors noted that 'The obvious, though technically difficult, way forward is to breed for improved drought stress tolerance. This is not an explicit target of any of the major sugar beet breeding companies at present, partly for perceptual reasons and partly because of the cost and technical problems. Nevertheless, it represents the largest single opportunity for yield and profitability improvement in the UK at present.'

The years examined also partly cover a period before neonicotinoid seed treatments when virus yellows was prevalent in the crop. In a further study it was observed that the effect of virus and drought stress was additive (Clover, 1999) and when both occur together, their independent effect on yields can be devastating. Unfortunately, this is something experienced by some crops in 2020 which highlights that solutions to reduce the impact of drought are as important as virus yellows research.

To test drought tolerance the approach used, which is common in drought work in other crops, is to grow each variety under conditions where water is freely available and under drought. This is achieved by growing the plants in rain out shelters, which are open sided polytunnels, with irrigation in place to control water availability. The need for such an approach is what can make drought research costly, as mentioned by Pidgeon and Jaggard. Although rain out shelters can create a somewhat artificial environment the conditions the plants experience is not unrealistic to those that can be encountered in the open field. Varieties can then be assessed using a drought tolerance index (DTI) which gives a value of how much yield is maintained under drought compared to when water is freely available. The conclusion from Ober's research after multi-year trials and the measurements of multiple traits was that sugar beet varieties that maintained a greener canopy for longer under drought had a greater DTI. This is of course no surprise as the relationship between light interception and yield is a key part of sugar beet agronomy. However, what was of interest was how these varieties managed to keep a healthy green canopy as soil moisture depleted, and the key to this was optimal rooting and water uptake. Ober and his team showed that varieties which maximised water uptake at all soil depths avoided moisture stress longer than those that did not extract as much water. This observation suggests we already know what to look for in drought tolerant varieties and even better, is the fact that this is a trait that can be relatively cheaply and easily measured using soil moisture probes assessing water availability at different depths.

Fig. 4. Different responses to drought clearly visible in polytunnel experiments.

Fig. 5. Rhizotron shows the depth of root and water uptake at differing levels.

Additionally, a challenge in the UK climate is to develop sugar beet varieties which perform well in a range of conditions, for example a plant that survives well under drought but does not yield highly under optimum moisture is no good for the UK climate where drought is intermittent and often unpredictable. The benefit of increased water uptake is that it is unlikely to be detrimental to overall yield potential, facilitating improved performance under drought without limiting the yield potential in ideal conditions. In another study linked to this work it was found that varieties differed in their growth under drought as early as seedling stage and therefore early seedling assessments can be used as an initial assessment of drought tolerance before plants are put into field trials (Ober & Luterbacher, 2002).

Drought research in sugar beet in the UK ceased around 2010 and in the past 10 years there has been little research on it in sugar beet, although my PhD on sugar beet water use efficiency touched on the subject. This is concerning as the observation that drought can reduce yields by up to 25% still seems accurate. The Beet Growth model showed that in 2020 the early spring and summer drought reduced yields by 15%, and therefore yields were down before virus yellows even appeared in the crop. This highlights that little has changed since the observations by Pidgeon and Jaggard in 1998. The persistent threat of drought means it is imperative to continue with the work already started in the early 2000s and reduce the effect of drought on yields. BBRO has already produced guidance on some aspects of supporting the crop in dry weather such as drilling seed deeper to find moisture, in dry seed beds, rolling of crops, building organic matter levels up to increase the soils ability to retain moisture and reducing compaction to ensure deep rooting. As is key for so many areas of crop performance early canopy closure is also important as it minimises moisture lost from evaporation from the soil surface. However, there is also a need for research specifically targeted at increasing crop resilience under drought and a new three-year BBRO project consisting of three work packages will be the start of this work. The new drought project has two main objectives:

- To develop a method to give the RL varieties a drought tolerance score for the new descriptive list.
- To collaborate with breeders to introduce drought tolerant UK varieties.

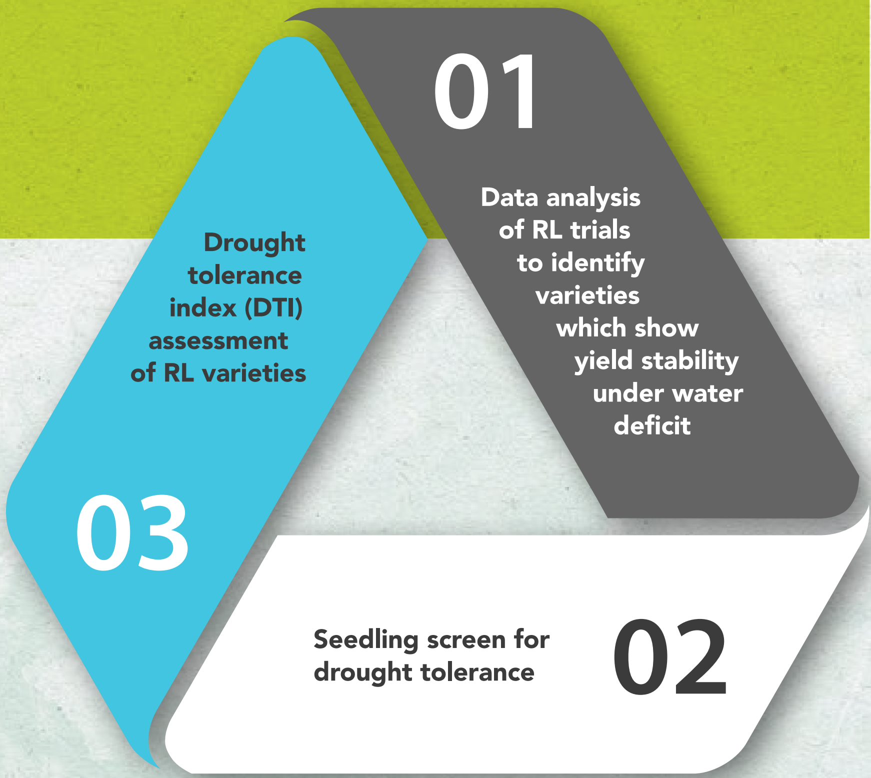

Fig. 6. The three work packages for assessing drought tolerance.

The three work packages of the new BBRO drought project

The three work packages are based on the previous drought research undertaken and allow an assessment of drought tolerance in current RL varieties. The RL data analysis will involve giving each site a drought stress index (DSI) based mainly on weather and soil type, with varieties that have a stable sugar yield regardless of the DSI likely to be drought tolerant. There will also be experiments to assess performance under drought at both the seedling and mature plant stage through to harvest. Rather than costly and time-consuming large-scale field trials BBRO are testing an alternative method by using large frames, like those used in the BCN and virus work at Bridgham, placed under a rain out shelter and supplied with drip irrigation. This will also be the foundation for future collaborations with breeding companies who will be able to include any breeding lines that show potential drought tolerance. All aspects of this project are already underway, with data requests made to the breeders, the seedling screen ready for set up and the frames in place at Bridgham and the rainout shelter ordered. We also have at our disposal an array of sophisticated measuring techniques to help us measure and assess performance, many of which were not available twenty years ago.

Fig. 7. Boxes ready for new drought tolerance trial at Bridgham, Thetford.

We have challenged ourselves to make a significant 'step-change' compared to the last twenty years in helping to make our crops more resilient to drought. New research will facilitate improvements in genetic drought tolerance which can be coupled with existing agronomy advice and soil management practices to deliver practical advice and resources to the industry.

As this work progresses, I look forward to discussing it in more detail at our trial sites and demo farm events.

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