Assessing drought tolerance in UK sugar beet varieties

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Introduction

On average, water deficits reduce the yield potential of UK sugar beet crops by around 10%, with losses rising to as much as 25% in the driest years. Climate projections indicate that warmer, drier summers are likely to become more common, increasing the frequency and severity of drought-related yield losses.

Consequently, it is essential that varieties maintain strong performance across a range of moisture deficits. Given the variability of the UK climate, and despite forecasts of warmer and drier conditions, there will still be years with sufficient rainfall to allow crops to achieve their maximum yield potential. For this reason, BBRO is conducting drought tolerance trials on current recommended list varieties and collaborating with breeders to test varieties yet to enter the UK market.

Materials and Methods

The assessment of drought tolerance can be calculated using the drought tolerance index (DTI) approach of Ober *et al.* (2004)[1].

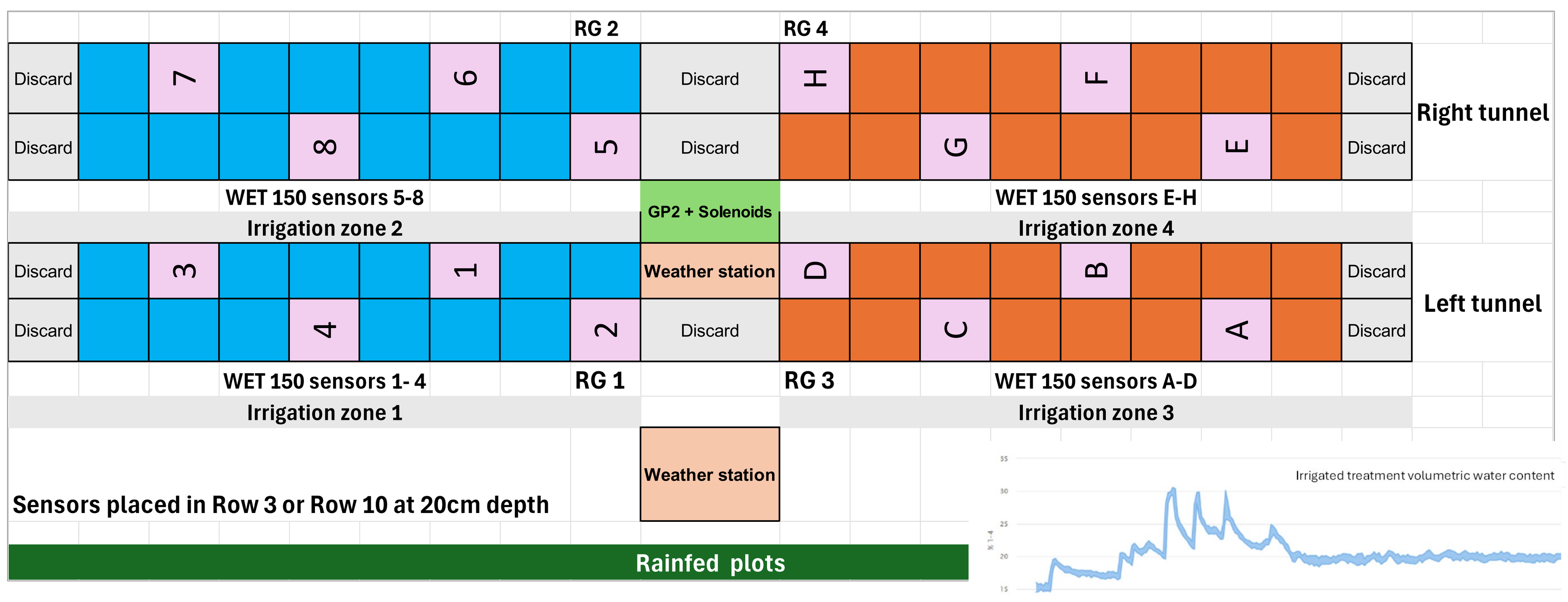
$$\text{DTI} = \frac{\text{yield under drought/yield under irrigation}}{\text{mean droughted yield of all genotypes/mean irrigated yield of all genotypes}}$$

This approach requires droughted and irrigated plots which are arranged in a split plot randomised block design. Prior to 2026 plots were 2 m long and 6 rows wide. In the first year (2021) the trial utilised wooden frames filled with topsoil and hand sown. This progressed to using a 12-row commercial drill in 2023, 2024 and 2025 and manually switching out seed between plots. For 2026 the commercial drill was used to plant the discard rows and coulters left in to produce channel for hand planting. This resulted in larger 2.5m long 6 row plots and consistent establishment in 2026.

Plots are located under a Spanish style polytunnel (Fig. 1) which is covered once drilling and herbicide applications are complete to protect the beet from damage, this is typically in June/July. It has been observed this may be too late to drive physiological differences in drought response between varieties. Next to the polytunnel fully randomised and replicated plots are also drilled to give a comparison to how the varieties perform under that season's conditions.

Figure 1. The drought trial set up with two polytunnels and the rainfed plots outside to the left.

- Water deficit is controlled using a Delta T GP2 logger and WET150 sensors. Four WET150 sensors are placed in each irrigation zone (1-4) and the average volumetric water content (VWC) used to turn the irrigation solenoids on and off (Fig.2). Irrigation is provided via drip irrigation lines to each row of beet, and each irrigation zone has a rain gauge placed under an irrigation dripper to ensure that the system is running as expected.
- The system logs data from two weather stations and PAR sensors located inside and outside the polytunnel respectively as a useful comparison.



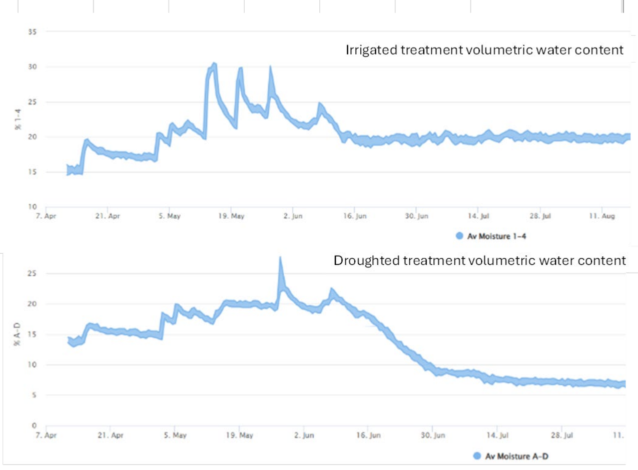


Figure 3. The trial layout from 2025 onwards showing the location of the 16 WET150 sensors in 4 irrigation zones, rain gauges (RG) and the weather station inside and outside the polytunnel all controlled by a central Delta T GP2 logger. Volumetric water content (VWC) of the droughted and irrigated zones in 2025 is also shown (Right).

Summary

- The approach achieves the conditions required to test DTI
- No varietal differences in DTI have been observed but the late drought timing may be driving this, early drought is needed in future years

Results

There were no significant differences in DTI in any trial year, results focus on the difference between the droughted, irrigated and rainfed treatments to show that the trial protocol is delivering the conditions needed to test DTI. Statistical analysis is undertaken between the droughted and irrigated treatments only due to the polytunnel limiting the trial design.

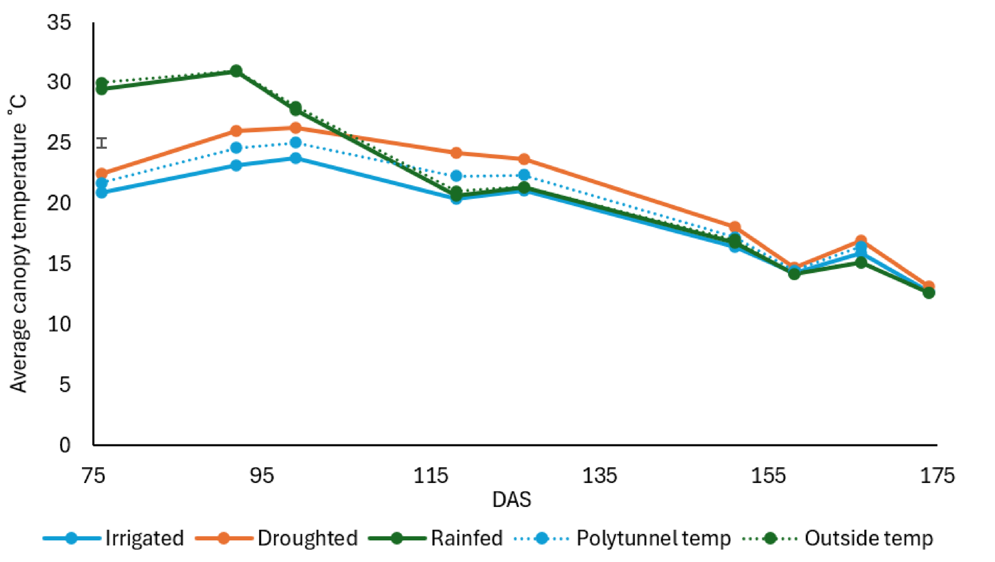


Figure 4. The average canopy temperature of the irrigated, droughted (in polytunnel) and rainfed sugar beet (outside) with corresponding air temperature measured at 76, 92, 99, 118, 126, 151, 158, 166, and 174 DAS with corresponding average air temperature. Error bar shows Time.Treatment LSD = 0.80 P<0.001 DF = 275 of irrigated and droughted canopy temperature only.

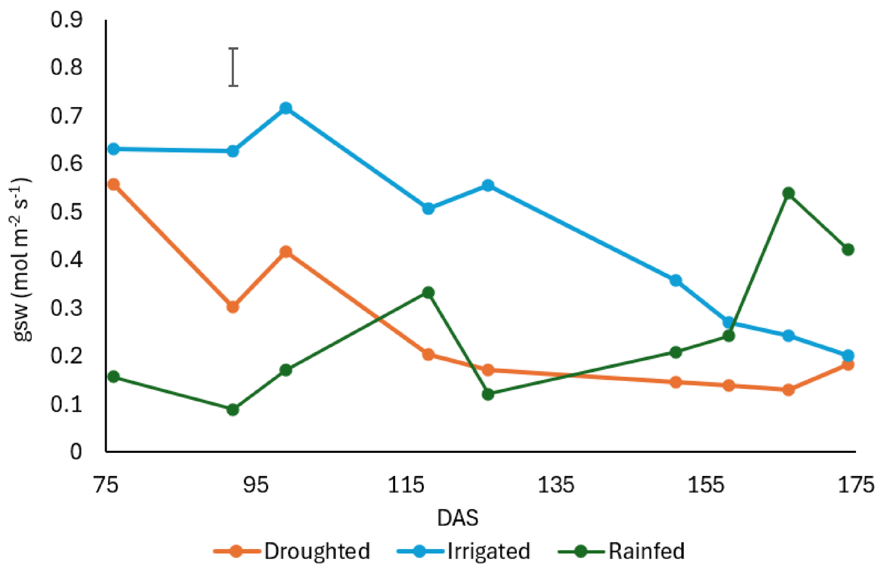


Figure 5. The average stomatal conductance (gsw) of the irrigated, droughted and rainfed sugar beet measured at 76, 92, 99, 118, 126, 151, 158, 166, and 174 DAS. Error bar shows Time.Treatment LSD = 0.078 P<0.001DF = 575 of irrigated and droughted treatments only.

- Irrigated plants showed a significantly lower (Fig. 4, *P<0.001*) canopy temperature and corresponding higher stomatal conductance (Fig. 5, *P<0.001*).
- Rainfed beet showed more variation in canopy temperature (Fig. 4) and stomatal conductance (Fig. 5) due to greater fluctuations in air temperature and photosynthetically active radiation (PAR) (not shown).

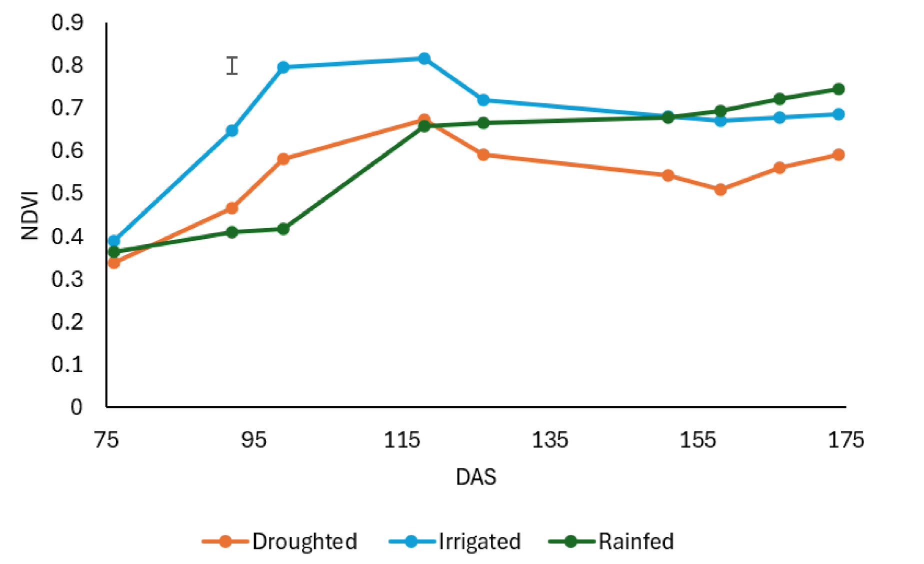


Figure 6. The average NDVI of the irrigated, droughted and rainfed sugar beet measured at 97, 126 and 139 DAS. Error bar shows Time.Treatment LSD = 0.038 P<0.001 DF = 575 of irrigated and droughted treatments only.

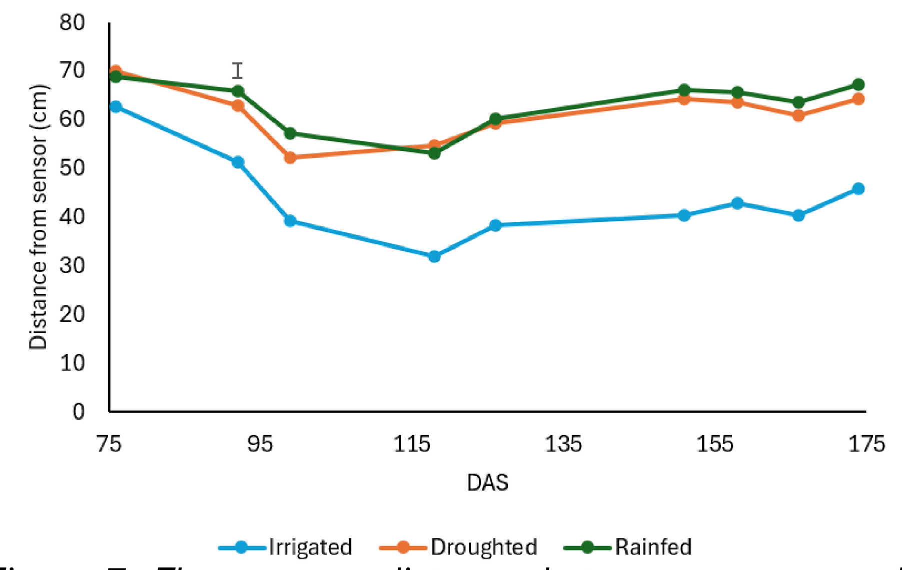


Figure 7. The average distance between canopy and sensor of the irrigated, droughted and rainfed sugar beet measured at 76, 92, 99, 118, 126, 151, 158, 166, and 174 DAS. Error bar shows Time.Treatment LSD = 3.0 P<0.001 DF = 511 of irrigated and droughted treatments only.

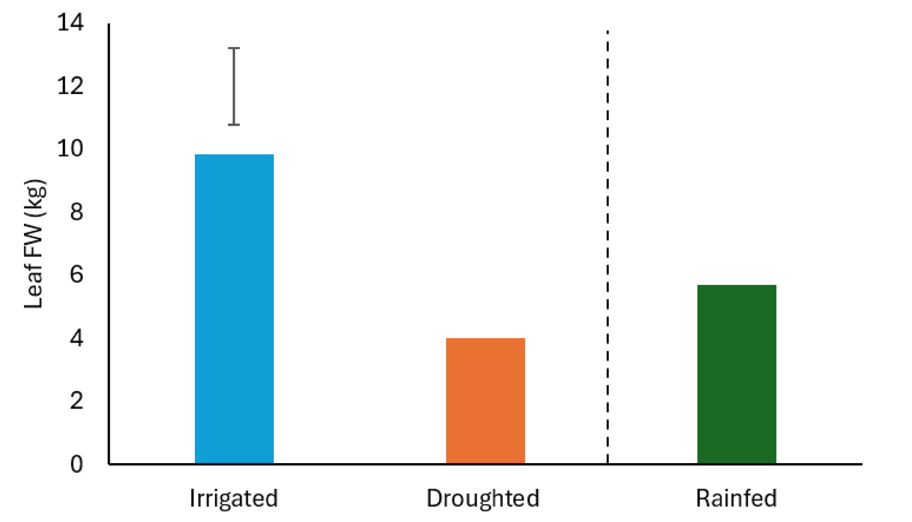


Figure 8. The average leaf fresh weight (FW) per plot to the sensor of the irrigated, droughted and rainfed sugar beet measured at 76, 92, 99, 118, 126, 151, 158, 166, and 174 DAS. Error bar shows Treatment LSD = 2.4 P=0.005 DF = 63 of irrigated and droughted treatments only.

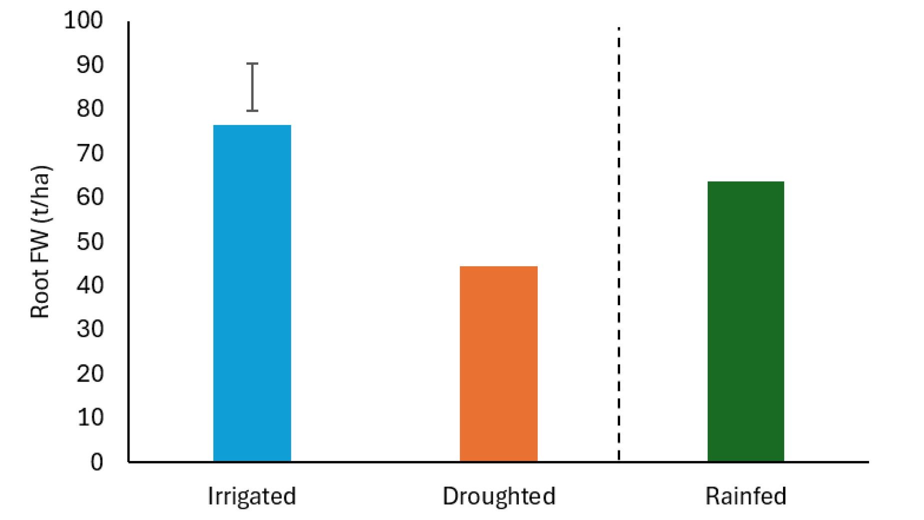


Figure 9. The average root fresh weight (FW) per plot of the irrigated, droughted and rainfed sugar beet harvested 223 DAS. Error bar shows Treatment LSD = 10.76 P=0.002 DF = 63 of irrigated and droughted treatments only.

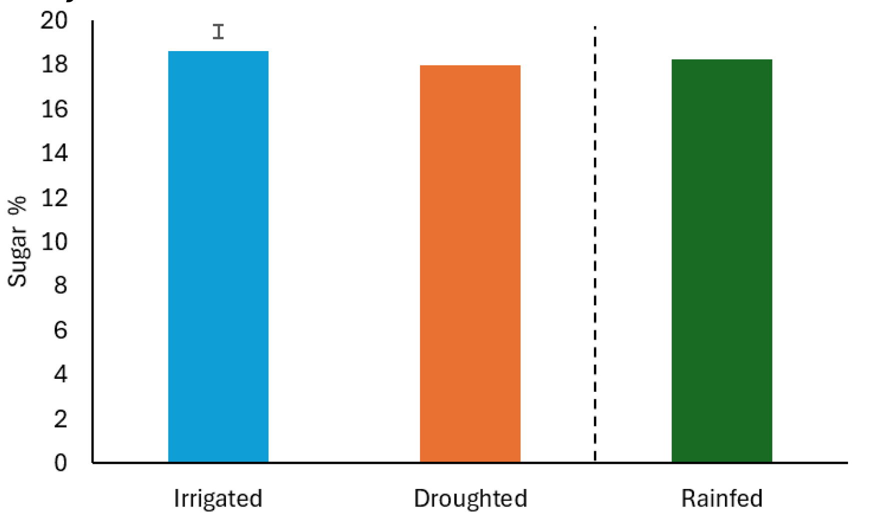


Figure 10. The average root sugar % of the irrigated, droughted and rainfed sugar beet harvested 221 DAS. Error bar shows Treatment LSD = 0.57 P=0.041 DF = 63 of irrigated and droughted treatments only.

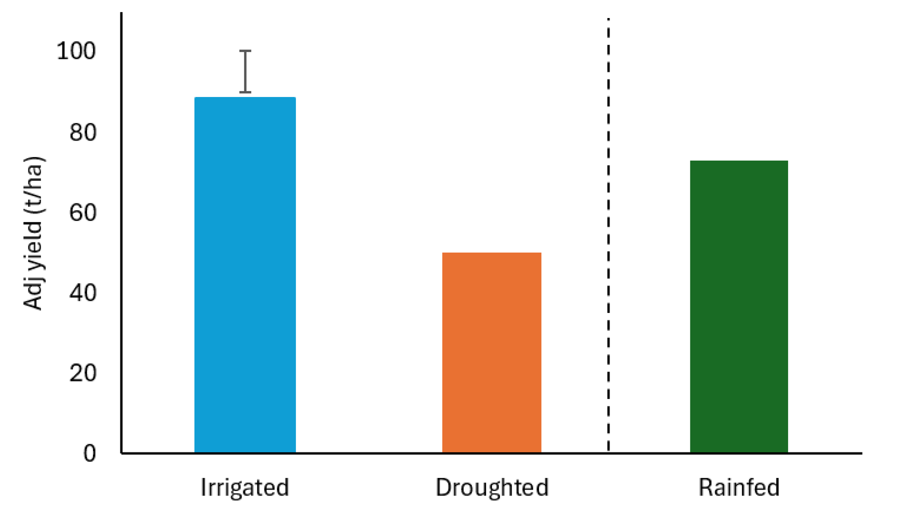


Figure 11. The average adjusted yield of sugar beet grown in droughted, irrigated and rainfed conditions and harvested at 221 DAS. Error bar shows Variety LSD = 10.3 P=0.001 DF = 63 of irrigated and droughted treatments only.

- NDVI was significantly higher (Fig. 6, *P<0.001*) in the irrigated beet than the droughted, with reduced canopy size evidenced by the lower canopy height (Fig. 7, *P<0.001*) and leaf fresh weight at harvest in the droughted plants (Fig. 8, *P<0.001*).
- The droughted plants had a significantly lower root fresh weight (Fig. 9, *P<0.001*) and sugar content (Fig. 10. *P<0.001*) resulting in a significantly lower adjusted yield (Fig. 11, *P<0.001*) of 50 t/ha compared to 89 t/ha in the irrigated.
- The rainfed beet were more comparable to the droughted beet early in the season, when it was dry and hot, but from around 135 DAS observations were similar to those in the irrigated plants. Final yield of the rainfed beet was 73t/ha reflecting these observations .

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References: [1]Ober, E.S., Clark, C.J., Le Bloa, M., Royal, A., Jaggard, K.W. and Pidgeon, J.D., 2004. Assessing the genetic resources to improve drought tolerance in sugar beet: agronomic traits of diverse genotypes under droughted and irrigated conditions. *Field Crops Research*, *90*(2-3), pp.213-234.

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