Feature

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# The impact of canopy angle on radiation use efficiency and yield in sugar beet

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Current sugar beet varieties vary widely in their canopy angle; some have a prostrate canopy angle whilst others are much more upright. Radiation use efficiency (RUE) is the amount of biomass accumulated per unit of light intercepted by the crop. In crops such as rice and wheat, upright canopies are associated with higher RUE. Field trials have been carried out in 2019 and 2021 measuring the RUE of different sugar beet canopy types alongside controlled environment experiments to measure canopy photosynthesis. This project aims to understand the relationship between light interception and photosynthesis across different canopy types and its implication on RUE and yield.

The initial task of my project was to select varieties with a range of canopy angles/architectures. This involved a series of glasshouse experiments where I put varieties from the RL to the test and developed a method to measure the petiole angle accurately. The method I developed involved tagging leaves of similar age and imaging plants from the side (Fig. 1). These images were then processed using software with an angle tool. I then took this method out to the field trial, after each biomass harvest there was a gap in the canopy, this enabled me to measure the canopy angle in-situ. I was able to classify varieties according to their petiole angle; a smaller petiole angle in upright varieties, prostrate varieties had a larger petiole angle and I selected two intermediate varieties which had a petiole angle in between these two canopy angle extremes (Fig. 2). When the plants were at the 8-10 leaf stage there were no significant differences between varieties in the petiole angle. From the 12 leaf stage, the upright canopy types had a smaller and steeper petiole angle than the prostrate canopy types (P<0.05). This was consistent up until December when the canopy began to decline.

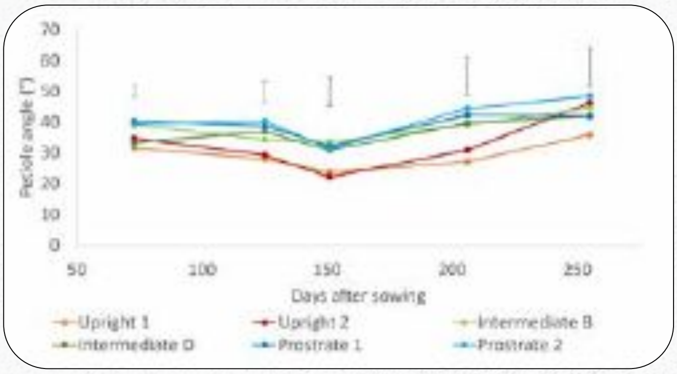


**Fig. 2.** Petiole angle measured across the season in 2021. Error bar is $LSD_{5\%}$

**Fig. 1.** Quantifying canopy angle measurements in the field

## Canopy angle and photosynthesis

Canopy light interception and photosynthesis is fundamental to yield formation in sugar beet (Jaggard and Qi, 2006). The canopy angle determines the amount and quality of light intercepted by the crop (Duncan, 1971). The efficiency in which the leaves can utilise the light for photosynthesis is an essential component of RUE. The photosynthetic performance of an upright, prostrate and intermediate canopy type were measured at increasing levels of light in a controlled environment experiment. The intermediate canopy type had the greatest photosynthetic activity and, in general, younger leaves had a significantly higher photosynthesis rate than older leaves (P<0.001) (Fig. 3A).

The light compensation point is described as the amount of light required for respiration and photosynthesis to cancel one another out. The prostrate canopy type reached light compensation point at lower light levels than the upright and intermediate varieties (P<0.05). Leaf age differences were also seen where the older leaf required a lower light intensity than the newer leaf to reach compensation point (P=0.001) (Fig. 3B). The findings show that the intermediate canopy type has a high photosynthetic capacity and a great yield building potential. It also shows that the prostrate canopy type is well adapted to less light and can potentially perform better than the intermediate and upright canopy types when incident light is reduced across the canopy.

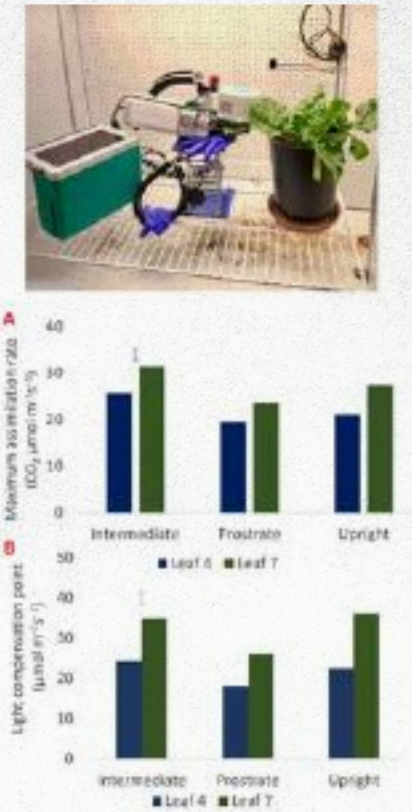


**Fig. 3.** Measuring canopy photosynthesis in response to light using a LI-COR 6800. **A)** Maximum assimilation rate and **B)** Light compensation point across different canopy types and leaf age (P<0.05). Leaves are numbered in order of appearance. Error bar shows LSD5%.

### Calculated RUE

RUE is the amount of biomass accumulated per unit of light intercepted by the crop. To calculate this requires a series of sequential biomass harvests and the collection of incident radiation data and canopy cover across the season to calculate accumulated intercepted radiation (incident radiation x canopy cover fraction). The RUE was measured in 2019 and 2021 field trials; in 2019 four varieties were selected and in 2021 six varieties and an alternate sowing treatment (prostrate and upright varieties in alternate rows) were grown (Fig. 4.). In Figure 4, two columns of RUE data for 2021 are shown: an October harvest which is closer to the 2019 final harvest and the final harvest in December.

The intermediate canopy types had the highest RUE in 2019 (measured to October), this was also seen in 2021 up to October harvest, with the intermediate B canopy type having a high RUE alongside the Prostrate/Upright alternate sowing treatment (Table 1). Interestingly, the upright varieties continued to put on biomass (yield) between October and December harvests in 2021 (this was not measured in 2019), this led to the upright canopy type having an overall higher RUE up to final harvest and the prostrate canopy types had the lowest RUE.

In both years, the Intermediate canopy types had the highest sugar yield (P<0.005) closely followed by the alternate sowing treatment in 2021 (Fig. 5).

**Table. 1** Calculated radiation use efficiency in 2019 (October harvest) and 2021 (October and December harvest)

| Calculated radiation use efficiency (g.MJ.m²) | | | |
|---|---|---|---|
| **Canopy type** | **2019** (up to final harvest in October) | **2021** (up to October harvest) | **2021** (up to Final harvest in December) |
| **Upright 1** | 1.67 | 1.46 | 1.49 |
| **Upright 2** | | 1.46 | 1.51 |
| **Prostrate/Upright** | | 1.55 | 1.45 |
| **Intermediate B** | 1.82 | 1.50 | 1.42 |
| **Intermediate D** | 1.77 | 1.45 | 1.46 |
| **Prostrate 1** | 1.66 | 1.44 | 1.37 |
| **Prostrate 2** | | 1.39 | 1.38 |
| **P** | <0.001 | <0.001 | <0.001 |

**Fig. 4.** Calculated radiation use efficiency in 2019 (October harvest) and 2021 (October and December harvest)

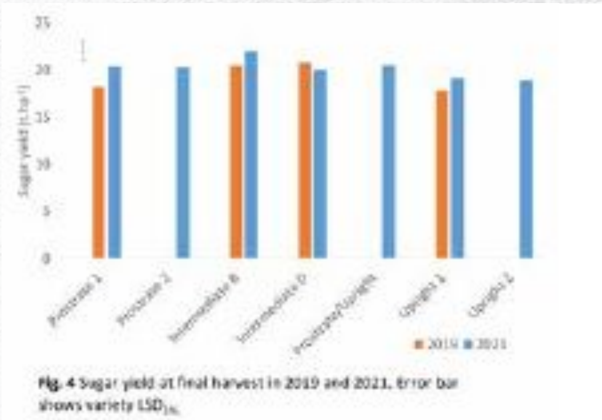


**Fig. 5.** Sugar yield at final harvest in 2019 and 2021. Error bar shows variety $LSD_{5\%}$.


**Summary**

Sugar beet varieties across the Recommended List differ significantly in their canopy angles. They can be classified as upright, intermediate or prostrate according to their petiole angles. In this project, the Intermediate B canopy type had the highest photosynthetic rate. The prostrate canopy type performed better under low light conditions. It was also seen that younger leaves at the top of the canopy were more photosynthetically active than older leaves and the older leaves were more active under lower light conditions.

In terms of RUE, the prostrate canopy has a leaf arrangement which is beneficial for early canopy closure and light interception however, after this steeper leaf angles enables light to distribute more evenly throughout the canopy. In conjunction with this a high photosynthetic rate facilitates maximal yield formation as seen in the Intermediate B variety which has 'upright' young leaves which become more prostrate with age.

For a later harvest in the winter months, an upright canopy may be more important to intercept lower sun angles. This hasn't been addressed in my PhD, but provides scope for future research into the importance of understanding the impact of canopy angle on radiation use efficiency and yield in sugar beet.



References

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Jaggard, K.W. and Qi, A. (2006). Agronomy. In Sugar Beet, A.P. Draycott (Ed.). https://doi.org/10.1002/9780470751114.ch7