Feature

By Dr Georgina Barratt
Applied Crop Scientist, BBRO

Physiology focus #2 – leaf and canopy growth

The primary goal in sugar beet crops after drilling is to reach canopy closure as soon as possible to maximum light interception and subsequent yield. Unlike cereals there is no flag leaf driving yield, instead the whole canopy is important, but how exactly does the sugar beet canopy develop and what effect does this have on the management of the crop?

Leaf growth

To understand canopy growth, it is important focus on how sugar beet leaves grow. Leaf growth consists of two parts, firstly the appearance of the leaf, and secondly the expansion of the leaf. Management practices and the environment can affect these two processes differently and it is therefore worth looking at them separately.

Leaf appearance

Leaf appearance in sugar beet is often judged to be when leaves have reached 2-3cm in length. The first two sugar beet leaves appear at the same time as a pair but after these, leaves appear one at a time and follow in what is known as a 5:13 phyllotaxis. This means that 13 leaves appear in five complete rotations of the crown.

The thermal time between leaves appearing is called the Phyllochron. The Phyllochron is largely consistent for the first 20 leaves with it taking around 30°Cdays for each leaf to appear in sequence. After this the speed of appearance slows but the rate by which it slows can vary significantly based on environmental conditions. The reason the rate of appearance slows is likely due to it being later in the season so there is less radiation, more shading between plants, and a greater rate of storage root development competing for resources.

Leaf expansion

The first 20 leaves are key to canopy cover and crop performance and, as already highlighted, the appearance of these leaves doesn't change much due to the weather or husbandry. This means that canopy cover is driven by leaf expansion. Leaf expansion and the final leaf size is determined by how quickly the leaves expand and how long this expansion lasts. The speed of leaf expansion is increased under warmer temperatures and by some aspects of crop husbandry which will be covered later. The duration of leaf expansion differs with leaf age, with expansion in younger leaves lasting around 450°Cdays, whilst for older leaves this can increase to 650°Cdays.

Fig. 1. A sugar beet with two cotyledons and two emerged leaves with the third and fourth leaf starting to emerge.

Fig. 2. represents the growth of two early leaves both with the same duration of expansion, but the leaf represented by the green line has a faster rate of expansion so reaches a greater final leaf area. This is important as it shows that to optimise canopy growth and maximise light interception a high rate of leaf expansion is required which is driven by optimal nutrition and warm weather.

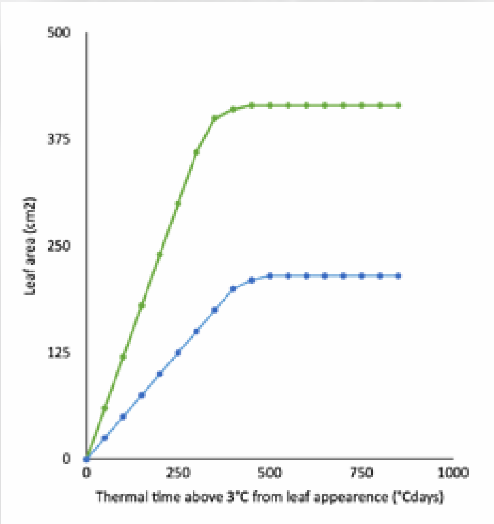

Fig. 2. Simulated leaf expansion of two leaves with the same thermal duration of expansion but the green line represents a leaf with a faster rate of expansion than the leaf depicted by the blue line so it reaches a larger final size. Modified from Milford, Pocock, Riley, et al. 1985.

Leaf death

Leaf death starts at around 800°C days with the first pair of leaves that appeared the first to die. The thermal interval between the death of the subsequent leaves, which die in the order they appeared, can vary significantly by around 100°Cdays. One consistent aspect of leaf death is that older leaves have a greater thermal longevity, that is the thermal time between appearance and death is longer. It has been observed that the 10th leaf, one of the biggest on the plant, survives for almost twice as long as leaf 5.

Impact of nitrogen and plant population

The first 20 leaves of the plant are crucial to achieving the optimal leaf area to cover the soil surface early in the season and maximise light interception and yield. As already mentioned, leaf appearance for the first 20 leaves is consistent regardless of nitrogen fertiliser rates but nitrogen availability can significantly influence the rate of expansion of these leaves. Plants with access to less nitrogen than optimal have leaves with slower rates of expansion and despite a similar thermal time of duration of leaf expansion (much like the two leaves represented in Fig. 2). This results in smaller leaves and a smaller canopy with reduced radiation interception and ultimately lower yields.

A high plant population can also reduce the rate of expansion of later leaves as plants compete for resources, including N, but mutual shading also reduces photosynthesis. This is why the BBRO recommendation of 100,000 plants/ha is a balance between getting full soil cover as quickly as possible to maximise light interception by the canopy whilst not excessively reducing individual plant performance.

Impact of drought

Leaf expansion is more greatly affected by water availability than leaf appearance as the meristem, which leaves develop from, maintains optimal water potential even under water deficit. A 25mm deficit has been shown to reduce leaf expansion rates by 50%, which in turn means that canopy cover can be greatly reduced. However, the crop has the ability to recover to some extent as the number of cells in the leaf are often the same and the return of pressure in the cells due to water uptake leads to cell expansion and growth. Drought also reduces the thermal time interval for leaf death, so they senesce faster. This means if canopy expansion is slow and leaf death faster canopy cover can decline more rapidly than in a crop with access to adequate moisture. It is rarely economical to irrigate beet to address low soil moisture but optimising the timing and method of tillage to conserve soil moisture in the seed bed can help get plants established and produce roots which can access water deeper in the soil profile.

Figure 4. Droughted sugar beet showing shrivelled leaves and a low leaf area index.

Definitions:

Thermal time: The sum of the average daily temperature, for example if the average temperatures for 3 days were 10°Cdays, 15°Cdays, and 12°Cdays the thermal time would be the sum of these temperatures – 37°Cdays.

Plant development is usually driven by thermal time which is why it is used instead of calendar days

Phyllotaxis: the arrangement of leaves on a plant stem

Phyllochron: the time between leaf appearance, usually measured in thermal time

References

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What does this all mean?

Thermal time is the predominant driver of leaf and canopy development in sugar beet, but we all know we can't control the weather. However, we can manage nitrogen availability, sowing density and to some extent water availability which can all have a significant impact on leaf growth, particularly leaf expansion rate which directly affects canopy cover. Additionally getting the crop sown as early as possible (when conditions are right) ensures 12th leaf stage is reached quickly, increasing the resistance of the plant to virus yellows. Overall, the first 20 leaves are key to crop performance and maximising light interception, so ensuring adequate nitrogen availability, the correct sowing rate to establish 100,000 plants/ha and optimising tillage to conserve soil moisture are key to maximising the leaf and canopy growth and subsequent yield of the crop.

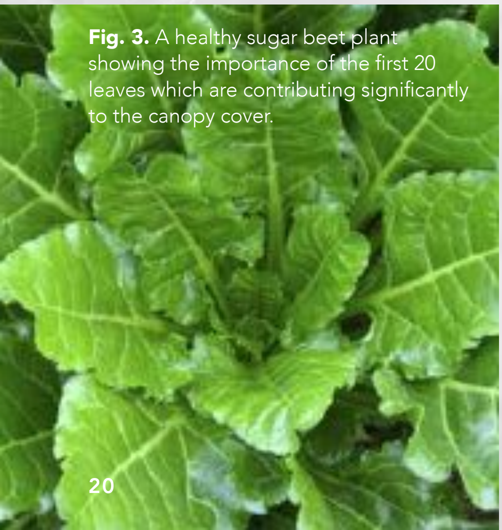

Fig. 3. A healthy sugar beet plant showing the importance of the first 20 leaves which are contributing significantly to the canopy cover.