GRDC GROWNOTES™

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

CANOLA

SECTION 4

PLANT GROWTH AND PHYSIOLOGY

CANOLA TYPES | PLANT GROWTH STAGES | THE DRIVERS OF PLANT PHENOLOGY

SECTION 4

Plant growth and physiology

4.1 Canola types

Almost all canola grown commercially in Australia is the Swede rape type of *Brassica napus*. *Brassica juncea* (brown or Indian mustard), which has the same quality as canola, is also grown but in much smaller quantities.

The 10 oilseed rape types grown throughout the world are mainly annual and biennial forms of *B. napus* and *B. campestris*. In Canada, both species are important; in Europe and the Indian subcontinent, *B. napus* is the dominant species. Each species has an optimum set of environmental and growing conditions.

4.1.1 Conventional

The first rapeseed varieties were introduced into Australia from Europe and Canada in 1969. Under Australian conditions, these varieties were late flowering (and so restricted to the higher rainfall zones) and very susceptible to blackleg.

From 1970 to 1988, conventional breeding techniques were used to improve yield, adaptation, blackleg resistance and seed quality (low erucic acid, low glucosinolates). These varieties were based on *B. rapa* (formerly known as *B. campestris*). They had earlier maturity and tolerance to pod shattering.

In 1988 the first varieties were released that combined blackleg resistance with higher yield. These varieties were based on *B. napus* material from Asia and Europe. From this time, there was a complete change of trend to breeding *B. napus* varieties.

Brassica napus is thought to have originated from natural crosses (hybridisation) of *B. rapa* and *B. oleracea*. It is distinguished from other species by the shape of the upper leaves; the lower part of the leaf blade half-grasps the stalk. [1]

More information

DAFWA: Current canola variety guide for Western Australia

Canola National Variety Trial results 2014

4.1.2 Triazine-tolerant canola

Triazine-tolerant (TT) varieties were first commercialised in 1993, with the release of the variety Siren. Genes for tolerance to the triazine group of herbicides were bred into conventional canola varieties. This enabled the control of *Brassica* weeds, which were previously unable to be controlled in standard canola varieties.

[1] J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

The TT trait is associated with reduced conversion of sunlight into biomass (i.e. reduced radiation-use efficiency). TT varieties are therefore generally less vigorous as seedlings and produce less biomass than conventional varieties. This results in 10–15% lower yields and 1–3% lower oil contents than in conventional varieties; however, the effective weed control available in these varieties means that actual yield is often higher than in conventional varieties competing with weeds. Another effect of the TT trait is a delay in plant development. [2]

4.1.3 Hybrids

Hybrids were first released in 1988. Hybrid varieties are produced by using controlled pollination of a female parent by a male parent (the source of pollen). The progeny (the F1 hybrid) may contain the best characteristics of both parents, and typically exhibit 'hybrid vigour'. Hybrid varieties are usually associated with larger seeds, strong seedling vigour and greater biomass production. [3]

4.1.4 Specialty canola: high oleic–low linolenic

Specialty canola varieties were bred by traditional means to increase the content of the monounsaturated fat oleic acid and decrease the level of the polyunsaturated fat linolenic acid in the oil (hence, high oleic–low linolenic (HOLL) canola). This oil from HOLL canola is more stable at higher temperatures and more suited for deep-frying than other canola oils. [4]

4.1.5 Imidazolinone-tolerant canola

Canola varieties have been bred that are tolerant to imidazolinones (IMIs), the active ingredients of herbicides such as OnDuty® and Intervix®. They are grown as part of the Clearfield® production system. IMI-tolerant canola varieties were developed by selection of naturally occurring mutations from conventional canola varieties. Unlike the TT gene, the gene for IMI tolerance is not associated with a yield penalty. [5]

4.1.6 Condiment (Indian) mustard

Condiment mustards are varieties of *B. juncea* grown for their hot, peppery taste. Although related to juncea canola (see below), condiment mustards have different meal and oil qualities. The level of glucosinolates in the meal after crushing is much higher in condiment mustard and is responsible for the hot and spicy taste of table mustard; however, the erucic acid level is sufficiently low to make it suitable for human

2 J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

3 J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

4 J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

5 J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

consumption. The oil has a distinctive 'nutty' flavour. Indian mustard is the preferred oilseed in many parts of South Asia, northern and western China, and eastern Russia. It has a reputation for having greater drought and shattering tolerance than canola. [6]

4.1.7 Juncea canola (*Brassica juncea*)

Juncea canola is the name given to plants bred from *Brassica juncea* to have all of the oil and meal quality specifications of canola. The oil has high levels of oleic acid and low levels of erucic acid, and the meal has low levels of glucosinolates (Table 1). The meal can be substituted for canola meal in animal diets. Juncea canola has the same market end-use as canola.

Juncea canola is being developed as a drought- and heat-tolerant alternative to canola for the low rainfall zone. It also has excellent seedling vigour (similar to that of hybrid canola) and is more tolerant of shattering than canola. Because it is a relatively new crop, breeding, selection and agronomic research have not progressed as far as with canola. The first commercial varieties were grown in 2007.

Table 1: Typical seed quality characteristics for canola, juncea canola and condiment mustard when grown in the low-rainfall zone (source: NSW DPI)

Characteristic	Canola	Juncea canola	Condiment mustard
Oil %	36–42	34–40	34–40
Oleic acid %	57–63	57–63	variable
Linoleic acid %	18–25	18–25	variable
Linolenic acid %	8–13	8–13	variable
Erucic acid %	<1	< 1	1–20
Glucosinolate in meal (μmol/g – 10% MC)	< 30	< 30	110–160
Allyl glucosinolate in meal (μmol/g – 10% MC)	0	< 1	NA

4.1.8 Roundup Ready® canola

Roundup Ready® varieties have been bred by genetic modification technology to be tolerant of the herbicide glyphosate. This allows glyphosate to be sprayed over canola in the early stages of growth without affecting the development of the crop. The first varieties were grown commercially in 2008.

4.1.9 Industrial mustard

Industrial mustard is a *B. juncea* type that is not suitable for either of the edible markets because of its high levels of erucic acid and/or glucosinolates. Industrial mustard is grown for use in several industrial products, including biodiesel.

4.1.10 Winter types for grazing

Unlike the other canola varieties, which are spring types, winter types require a period of cold (vernalisation) before they can flower. This makes them suitable as a dual-

[6] J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

More information

[GRDC Ground Cover: Revisiting canola management can lift returns]

[GRDC Update Papers: Canola growth and development—impact of time of sowing (TOS) and seasonal conditions]

[Research paper: Canola: phenology, physiology and agronomy]

[CropPro: Canola crop phenology for advisors]

[OGTR: The biology of Brassica napus L. (canola)]

[GRDC Presentation: Canola physiology, tactical agronomy and simulation]

purpose crop. They can be grazed during winter, then locked up for harvest in late spring. Currently, only one winter type is commercially available. [7]

The life cycle of the canola plant is divided into seven principal stages. By recognising the beginning of each stage, growers can make more accurate management decisions on timing of weed-control operations, introduction and removal of grazing livestock in crops managed as dual-purpose, timing of fertiliser applications, timing of irrigation, and timing of pest-control measures.

Each growth stage covers a developmental phase of the plant. However, the beginning of each stage is not dependent on the preceding stage being finished, which means growth stages can overlap.

The beginning of each growth stage from budding is determined by looking at the main (terminal) stem. In the literature, it is referred to as a decimal code, similar to the Zadoks code for wheat growth stages (Figure 1). [8]

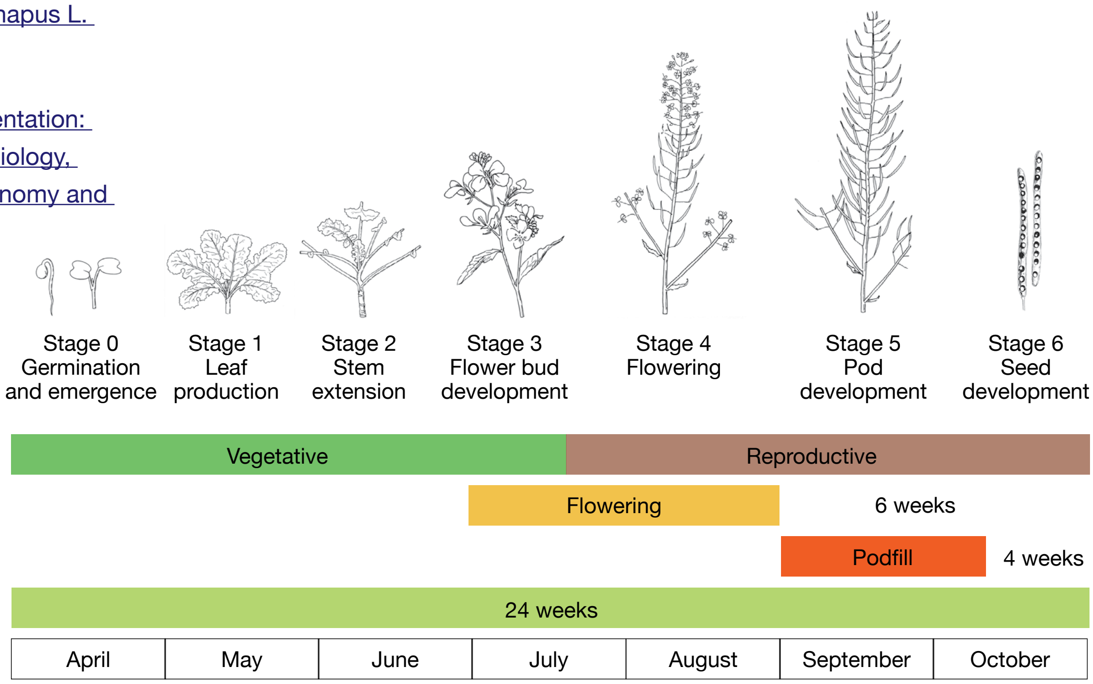

Figure 1: Canola growth stages (Source: NSW DPI)

[7] J Edwards (2009) Introduction. Ch. 1. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

[8] T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

in focus

4.1.11 Why know about canola development?

- Understanding the drivers behind canola development will help to improve canola management and variety selection.
- Varietal maturity ratings do not always correlate with varietal phenology.
- Early sowing opportunities may provide a means to maximise canola yield, but selection of the correct variety is important.

Despite the success of canola in Australian cropping systems, significant gaps remain in the underlying knowledge of canola physiology and agronomy, a situation exacerbated by its expansion into new areas and the release of new technologies, including vigorous hybrid varieties with herbicide tolerance.

Although growers recognise the high profit potential and the farming-system benefits of canola, a perceived risk of growing canola remains, largely due to the high level of input required (e.g. seed, nitrogen (N) fertiliser, sulfur fertiliser, windrowing). There is a need to determine the level of investment appropriate for these inputs on a regional scale and the agronomic management practices (for example sowing date decisions) that reduce the overall risk and increase the profitability of canola.

Sound, tactical agronomic decisions require improved understanding of the physiology of yield and oil formation in canola, and of how they are affected by variety, environment and management, and the interaction (G x E x M).

Maximising canola yield and profit will be achieved through an increased understanding of canola physiology. This will occur by taking the following steps:

1. Identify the optimum flowering window to minimise heat and frost risk at specific sites.
2. Identify the variety–sowing date combinations that achieve the optimum flowering window.
3. Manage the trajectory of biomass accumulation (of specific varieties) to maximise water-use efficiency, optimise N-use efficiency and minimise the risk of high-input costs (e.g. seed costs, N fertiliser, herbicide types, harvest strategies).

Having optimised these steps, further investigation may reveal specific varietal adaptations that provide yield advantage under specific stress (heat, drought, frost) or provide further G x E x M synergies.

As a first step to improve the understanding of G x E x M interactions in current varieties, CSIRO conducted pre-field-experiment modeling by using the best available information on variety development prior to 2014 trials, and the APSIM model. This modeling explored the potential for planting canola early at locations across Australia and the potential yields to be achieved by planting cultivars with differing maturity

More information

[GRDC Update Papers: Canola growth and development—impact of time of sowing (TOS) and seasonal conditions]

[GRDC Update Papers: Improved understanding of thresholds of armyworm in barley and aphids in canola]

[Oilseeds WA: Growing western canola]

at a range of sowing times. The results show that potential exists for longer season varieties to be planted in locations such as Cummins, South Australia, and to have improved yield potential. However, the opportunity for successful sowing of these varieties occurs in only 15% of years (when sufficient summer rainfall occurs).

The manner in which each canola variety develops can have a large influence on yield, when planted at different times and in different environments. The challenge for researchers is to develop and deliver information on new varieties in a way that is timely and relevant to growers and advisers. Growers and advisers will be able to use this information when selecting a set of varieties suited to the sowing opportunities that most often occur in their district and to capitalise on early or delayed sowing opportunities as the seasons dictate. [9]

4.2 Plant growth stages

4.2.1 Germination and emergence (stage 0 [0.0–0.8])

Emergence occurs after the seed absorbs moisture and the root (radicle) splits the seed coat and the shoot (hypocotyl) pushes through the soil, pulling the cotyledon leaves upward and in the process shedding the seed coat (Figure 2). When exposed to light, the cotyledons part and become green. [10]

After sowing, the seed adsorbs moisture and the various biochemical processes begin, resulting in the production of the first root and shoot. The root grows downward and develops root hairs, which anchor the developing seedling. The hypocotyl begins growing up through the soil, pushing the cotyledons or seed leaves. Emergence takes 6–15 days depending on soil temperature, moisture and sowing depth.

As well as an energy source to fuel the biochemical processes, the developing plant needs oxygen for respiration. Waterlogging results in oxygen being driven from the soil, as well as cooling the soil, resulting in slower growth rates.

At this stage, all of the energy required for the cotyledons to emerge is provided by the seed reserves. Deep sowing, small seed or any other factor that requires the plant to expend more energy in getting the first leaf through to the surface (e.g. crusting) will, apart from delaying emergence, result in weaker and smaller seedlings that may be more prone to weed and pest competition. [11]

[9] A Ware *et al.* (2015) Canola growth and development—impact of time of sowing (TOS) and seasonal conditions. GRDC Update Papers, 10 February 2015, http://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Canola-growth-and-development-impact-of-time-of-sowing-TOS-and-seasonal-conditions

[10] T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

[11] Canola crop phenology for advisors. CropPro. http://www.croppro.com.au/cb_pages/canola_crop_phenology.php

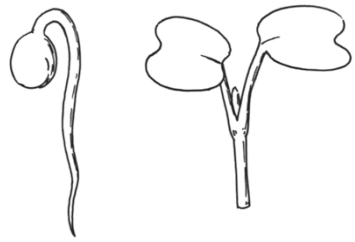

Figure 2: Canola germination and emergence, stage 0–0.8.

4.2.2 Leaf production (stage 1 [1.00–1.20])

A well-grown canola plant normally produces 10–15 leaves. Each leaf is counted when most of its surface is exposed to light (Figure 3). Early leaves may drop from the base of the stem before leaf production is complete. [12]

The growing point of canola is above the soil, between the two cotyledons. The exposed growing tip makes canola seedlings more susceptible than cereals to insect damage. At 4–8 days after emergence, the seedling develops its first true leaf. Subsequent leaves are produced at a rate determined by temperature. No definite number of leaves is produced by a canola plant. A canola plant under good growing conditions normally produces 9–30 leaves on the main stem depending on variety and growing conditions.

As the shoots continue to develop, a similar process is happening with the root system. Canola plants have a taproot system. The root system continues to develop, with secondary roots growing outward and downward from the taproot. Root growth is due to cell division and enlargement at the tip of the root. Root development is relatively constant, averaging nearly 2 cm/day as long as good soil moisture exists.

Roots do not grow in search of water or nutrients; they intercept water and nutrients present in the soil pore space that they happen to contact. Factors limiting root penetration through the soil include dry soil, soil compaction, weed competition for moisture and nutrients, salinity and cold soil temperatures. [13]

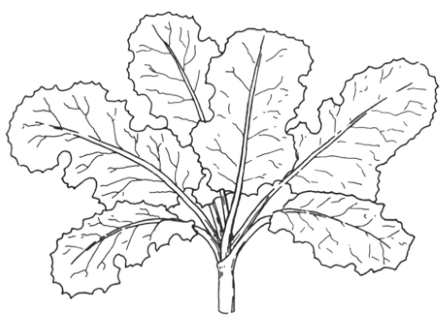

Figure 3: Canola leaf production, stage 1.

12 T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

13 Canola crop phenology for advisors. CropPro. http://www.croppro.com.au/cb_pages/canola_crop_phenology.php

4.2.3 Stem elongation (stage 2 [2.00–2.20])

Stages of stem elongation are defined according to how many detectable internodes (minimum length 5–10 mm) are found on the stem (Figure 4). A leaf is attached to the stem at each node. Each internode is counted. A well-grown canola plant normally produces 15–20 internodes. [14]

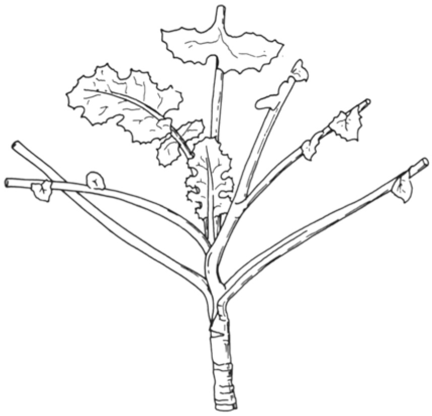

Figure 4: Stem elongation, stage 2.

4.2.4 Flower bud development (stage 3 [3.0–3.9])

Initially, flower buds remain enclosed during early stem elongation and they can only be seen by peeling back young leaves. As the stem emerges, they can be easily seen from above but are still not free of the leaves; this is described as the green bud stage (Figure 5). As the stem grows, the buds become free of leaves and the lowest flower stalks extend so that the buds assume a flattened shape. The lower flower buds are the first to become yellow, signaling the yellowing bud stage. [15]

Figure 5: Canola flower bud development, stage 3.

[14] T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

[15] T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

4.2.5 Flowering (stage 4 [4.1–4.9])

Flowering starts when one flower has opened on the main stem and finishes when no viable buds are left to flower (Figure 6). [16]

Figure 6: Flowering, stage 4.

4.2.6 Pod development (stage 5 [5.1–5.9])

Podding development starts on the lowest one-third of the branches on the main stem and is defined by the proportion of potential pods that have extended to >2 cm long (Figure 7). [17]

[16] T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

[17] T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

Figure 7: Pod development, stage 5.

4.2.7 Seed development (stage 6 [6.1–6.9])

Seed development is also seen on the lowest one-third of branches on the main stem (Figures 8, 9). The stages are assessed by seed colour as follows:

- 6.1, seeds present
- 6.2, most seeds translucent but full size
- 6.3, most seeds green
- 6.4, most seeds green–brown mottled
- 6.5, most seeds brown
- 6.6, most seeds dark brown
- 6.7, most seeds black but soft
- 6.8, most seeds black but hard
- 6.9, all seeds black and hard

Seed oil concentration in Australian crops increases through seed development following an 'S'-curve pattern, which starts 20 days after flowering and reaches a plateau ~60 days after flowering, the time when seed dry weight is ~70% of its final value (Figure 10). Final seed oil concentrations usually vary between 30% and 50% (as received). In general, high temperatures during grain filling, terminal water stress, and high N supply depress final seed oil concentration. Variety has a significant impact, with TT varieties typically having lower oil concentrations than conventional varieties because of their less efficient photosynthetic system. The growth stage when the crop is physiologically mature is important and one that growers should learn to recognise. It occurs when the seeds have reached their maximum dry weight and the crop can be windrowed. At this time, 40–60% of seeds have started to change from green to their mature colour (growth stage 6.4–6.5). Seed moisture content is 35–40% and most seeds are firm enough to roll between the thumb and forefinger without being squashed. It is a period of rapid change, when all seeds can develop from translucent to black over a 12-day period. It is important not to windrow too early; windrowing before physiological maturity will reduce yields by 3–4% for each day too early, because of incomplete seed development. Oil content will also be reduced. Canola can be harvested when the moisture content of mature seed is 8%. [18]

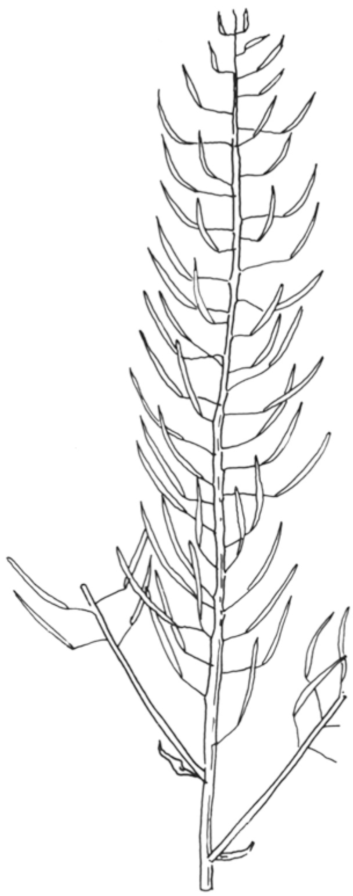

Figure 8: Seed development, stage 6.

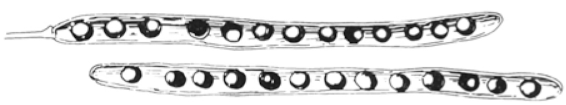

Figure 9: Seed pods.

[18] T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

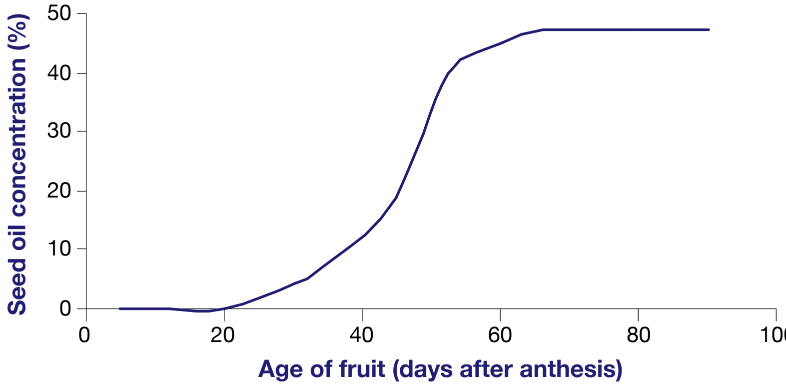

Figure 10: Seed oil concentration in Australian crops increases throughout seed development and reaches a plateau at ~60 days after flowering. (Source: P. Hocking and L. Mason)

4.2.8 Environmental stresses impacting yield and oil content

Frost, moisture stress and heat stress can all have an impact on grain yield, oil content and oil quality. Frost can occur at any time during the growth of the canola plant, but frosts are most damaging when pods are small. Pods affected at this time have a green to yellowish discoloration, then shrivel and eventually drop off. Pods affected later may appear blistered on the outside of the pod and usually have missing seeds (Figure 11).

Figure 11: Frost damage before the watery seed stage results in either missing seeds or very shrivelled seeds. Frost damage at this time may or may not affect oil content. (Photo: T. Potter, SARDI)

Moisture and heat stress are linked, in that the plant will suffer heat stress at a lower temperature if it is also under moisture stress. Flower abortion, shorter flowering period, fewer pods, fewer seeds per pod and lighter seed weight are the main effects, occurring either independently or in combination (Figure 12). [19] Hail damage to pods can also affect seed development (Figure 13).

[19] T Potter (2009) The canola plant and how it grows. Ch. 3. In Canola best practice management guide for south-eastern Australia. (Eds D McCaffrey, T Potter, S Marcroft, F Pritchard) GRDC, http://www.grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf

Figure 12: Severe moisture stress during pod filling results in seeds being underdeveloped and small. (Photo: D. McCaffery, NSW DPI)

Figure 13: Hail damage may penetrate through the pod wall and affect seed development. (Photo: D. McCaffery, NSW DPI)

4.3 The drivers of plant phenology

4.3.1 Temperature

Temperature influences plant development principally via effects on rate of growth and developmental phases.

Temperature and vegetative growth

Generally, plant vegetative growth increases as temperature increases. There are upper and lower temperature limits at which growth ceases. The lower limit, or base temperature, for growth in Australia is generally accepted as 3°C, although studies have shown a broader range of lower limits from 0°C to 5°C.

Optimal temperature for growth is in the range 20–25°C.

The upper limit is generally regarded as 35°C, but crops have been shown to acclimatise if they have previously been exposed to high temperatures.

The concept of degree-days was developed to quantify the influence of temperature on crop growth and it is used to predict crop growth stage. Degree-days are calculated by taking the daily average temperature (maximum plus minimum divided by 2) and subtracting the base temperature.

For example, if the daily maximum was 20°C and the minimum 10°C, then the average daily temperature was 15°C; after subtracting the base temperature of 3°C, the crop therefore experienced 12 degree-days for growth. [20]

Development of the plant in response to temperature

Germination and emergence

Germination is the process whereby the seed imbibes moisture and produces the first root and shoot, which emerge from the seed coat. The coleoptile (e.g. wheat) or cotyledons (e.g. canola) push through the soil surface and the first leaves appear. Temperature, moisture and oxygen are needed to instigate this process.

An estimate of the time needed for the crop to germinate can be calculated using degree-days, with the range being 80–100 degree-days, or if the soil temperature is 16°C, then ~7 days. [21]

Vegetative growth

Following emergence, the plant then produces leaves at a rate determined by temperature. The appearance of one leaf to the next is a constant in thermal time, accepted as 80 degree-days. This period is also known as the phyllochron. There are variations to this value, influenced by sowing date, but for most crops sown from late April to mid-June, the phyllochron is 80 degree-days.

If the daily mean temperature is 15°C as per the previous calculation, then a leaf will appear every 6.7 days, or if it is cooler and the daily mean is 10°C, then it will take 11.5 days for the next leaf to emerge. This information can be used to predict leaf timing for herbicide operations.

The transformation from vegetative to reproductive growth occurs ~500–800 degree-days after emergence. [22]

Flowering and podfill

High temperatures (>32°C) at flowering will hasten the plant's development, reducing the time from flowering to maturity. High temperatures during flowering shorten the time for which the flower is receptive to pollen, as well as the duration of pollen release and its viability.

High temperature can decrease total plant dry matter, the number of pods that develop, number of seeds per pod and seed weight, resulting in lower yields. Very hot

[20] Canola crop phenology for advisors. CropPro, http://www.croppro.com.au/cb_pages/canola_crop_phenology.php

[21] Canola crop phenology for advisors. CropPro, http://www.croppro.com.au/cb_pages/canola_crop_phenology.php

[22] Canola crop phenology for advisors. CropPro, http://www.croppro.com.au/cb_pages/canola_crop_phenology.php

weather combined with drought and high winds may cause bud blasting, where the flower clusters turn brown and die, resulting in serious yield losses.

Although temperature is the key driver of plant development, the plant's response is modified by vernalisation and daylength. [23]

Vernalisation

Vernalisation is the requirement to be exposed to cold temperatures in order for the reproductive phase to begin. Temperatures of ~0°C are needed to meet this requirement depending on varietal characteristics. Canola varieties that have little or no vernalisation requirement are often referred to as spring types, and temperatures in the range of 7–18°C for brief periods will be sufficient for vernalisation. Canola varieties with strong vernalisation requirements are called winter types, and lower temperatures of 0–7°C for several weeks are needed for vernalisation.

Vernalisation is an adaptation that gives the plant an environmental cue for when is the most suitable time to transform to the reproductive phase, so offering a greater sowing window.

Spring types will simply go through the vegetative phase and transform to reproductive phase based on the temperatures and/or daylength experienced by the plant. [24]

Daylength

Canola develops and flowers more rapidly when grown under long day conditions. Canola is not an obligate-daylength plant (i.e. a plant that will not commence the reproductive phase until a certain daylength requirement is met), but the change to reproductive phase can be delayed if the daylength is too short. Although varieties have differing responses, a daylength longer than ~11 h is required by the canola plant to trigger reproductive development.

This results in an autumn-sown canola crop remaining in the vegetative phase during the winter, accumulating biomass, and, hence, yield potential, as well as delaying flowering until the risk of frosts is reduced. However, early-sown canola may experience the 11-h photoperiod shortly after emergence, which may result in the plant flowering prematurely.

Daylength requirement is a desirable characteristic because it allows flexibility in sowing dates. [25]

What does all this mean?

When growing a canola crop, the aim is to have the crop grow sufficient biomass to flower late enough to reduce the risk of a major frost event, but early enough

[23] Canola crop phenology for advisors. CropPro, http://www.croppro.com.au/cb_pages/canola_crop_phenology.php

[24] Canola crop phenology for advisors. CropPro, http://www.croppro.com.au/cb_pages/canola_crop_phenology.php

[25] Canola crop phenology for advisors. CropPro, http://www.croppro.com.au/cb_pages/canola_crop_phenology.php

to ensure that grainfill is not adversely affected by either moisture or temperature stress. Therefore, the optimum flowering window is generally known for each district. However, getting a crop to flower in this period is not easy, because many variables such as sowing date, seasonal temperatures and available moisture influence crop phenology.

Canola varieties already possess the characteristics that give a reasonable sowing window to allow flowering at the optimal time for maximising grain yields. A key advantage of canola over many crops is the much longer flowering period, so whereas a frost may kill the flowers for that day, there will be new flowers the next day to compensate.

A characteristic such as vernalisation allows canola to be sown at the first opportunity early in the season, and the grower can be confident that it will remain vegetative until its temperature requirements are met for flowering in late spring. In a high-rainfall zone where summer rain is assured, theoretically, spring sowings will remain vegetative until late winter. In lower rainfall areas, the delay to the reproductive phase can mean that flowering occurs too late for the optimum conditions for grainfill.

Similarly, a variety that is sensitive to daylength has a wider sowing window because the vegetative period is extended, developing biomass and yield potential, and the flowering period is delayed until the optimum time. [26]

[26] Canola crop phenology for advisors. CropPro, http://www.croppro.com.au/cb_pages/canola_crop_phenology.php