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CANOLA

SECTION 14

ENVIRONMENTAL ISSUES

FROST | WATERLOGGING AND FLOODING

SECTION 14

Environmental issues

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 the most damaging frosts occur 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.

Moisture stress and heat stress are linked; 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 lower seed weight are the main effects, occurring either independently or in combination. [1]

Catastrophic events

Farming is a risky enterprise, with great uncertainty about production and profitability from season to season. Australia has a wide variety of climates, each with high variability, which means exposure to great variation in yields. Australian farmers are generally very good at managing this variation. However, a sudden shock may put systems for managing variation to the test.

Recent events of frost and disease in the grain-production regions of south-eastern Australia have tested growers' resolve for managing catastrophes. A catastrophe is a sudden and widespread disaster, and in farming, the potential causes of catastrophe are numerous. In a cropping context, returns can be severely affected by external factors over which growers have no control.

More information

Managing the catastrophes—for-example, frost, BWYV, pests

Growers cannot avert a catastrophic event but they can spread risk to minimise its effect. No single strategy will cope with a catastrophic event; multiple strategies are required.

When confronted with a catastrophic event, growers may be in a state of shock. Decision-support tools can be useful for focusing on what can be done to salvage the situation. [2]

GRDC's new approach to frost

Frost has been estimated to cost Australian growers ~$360 million in yield losses both direct and indirect every year. The Grains Research and Development Corporation (GRDC) has long acknowledged the severe impacts of frost on crop production, and since 1999 has invested ~$13.5 million in more than 60 frost-related projects.

By 2014, GRDC increased investment in frost research to establish the National Frost Initiative (NFI). This 5-year, national initiative is tackling frost from several angles and aims to deliver growers a combination of genetic and management solutions to be combined with tools and information to improve prediction of frost events.

[1] 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

[2] T McClelland, H van Rees (2014) Managing the catastrophes—for example; frost, BWYV, pests. GRDC Update Papers, 18 September 2014, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/09/Managing-the-catastrophes-for-example-frost-BWYV-pests

The three-pronged initiative addresses:

1. Genetics. The aim is to rank current wheat and barley varieties for frost susceptibility and identify more frost-tolerant wheat and barley germplasm
2. Management. Are there management practices or preventive products that growers could use to reduce the impact of frost?
3. Environmental prediction. Focus is on predicting the impact of frost events on crop yields and mapping frost events at the farm scale to enable better risk management. [3]

Listen to GRDC Driving Agronomy podcasts:

- New GRDC-funded research will seek to find out whether applying additional potassium to a crop will help it resist the stress of drought and frost.
- 2015 will see the introduction of frost-tolerance ratings in cereal crops. On this program, GRDC Managing Director, John Harvey, explains how it came about and talks about some other research and development highlights.

More information on GRDC Driving Agronomy:

http://grdc.com.au/Media-Centre/GRDC-Podcasts/Driving-Agronomy-Podcasts/2014/02/Potassium-Frost-and-Drought

http://grdc.com.au/Media-Centre/GRDC-Podcasts/Driving-Agronomy-Podcasts/2013/12/Frost-Tolerance-Ratings-on-the-Way

14.1 Frost

More information

Frost-damaged crops—where to from here?

Frost and cropping

What's going on with frost?

The GRDC National Frost Initiative

Canola is least tolerant to frost damage from flowering to the clear watery stage (~60% moisture).

Symptoms include:

- yellow-green discoloration of pods (Figure 1)
- scarring of external pod surfaces
- abortion of flowers (Figure 2)
- shrivelling of pods
- pods eventually dropping off (Figure 3)
- shrivelling and absence of seeds (Figure 4)

[3] T March, S Knights, B Biddulph, F Ogbonnaya, R Maccallum, R Belford (2015) The GRDC National Frost Initiative. GRDC Update Papers, 10 February 2015, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/The-GRDC-National-Frost-Initiative

Figure 1: Yellow-green discoloration of pods, compared with healthy green pods.

Figure 2: Canola plant showing various stages of pod loss and flower abortion.

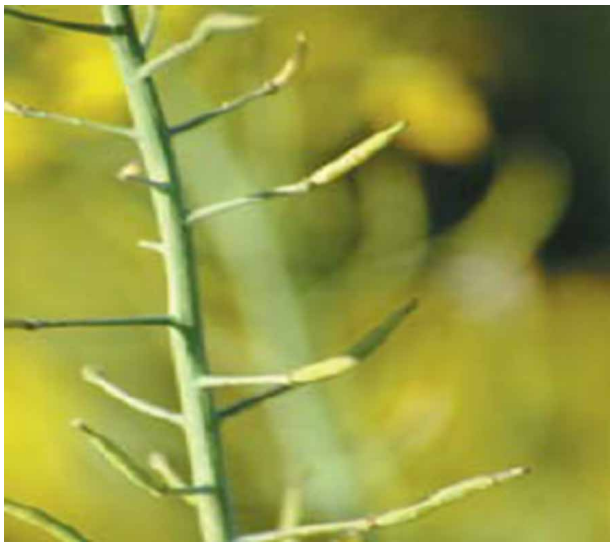


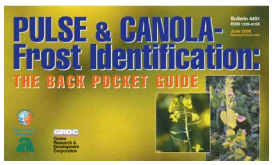
Figure 3: Stunted pods that have dropped off.

Figure 4: Missing and shrivelled seeds.

More information

Diagnosing frost damage in canola

Pulse and canola frost identification. The Back Pocket Guide



Cautious optimism for frost-tolerance advance

Canola flowers for a 30–40-day period, allowing podset to continue after a frost. Open flowers are most susceptible to frost damage, whereas pods and unopened buds usually escape. If seed moisture content is <40% when frost occurs, oil quality will not be affected. [4]

Once established, canola is relatively frost-tolerant, but damage can occur during the cotyledon stage and the seedlings can die if frosted. Plants become more frost-tolerant as they develop.

Seedling growth and vigour are reduced at temperatures <7°C, and occasionally seedlings will die.

Soluble carbohydrates accumulate when there is a rapid reduction in leaf temperature. This accumulation suppresses photosynthesis, and therefore seedling growth rates, during the cooler winter months. [5]

14.1.1 Frost damage in crops—where to from here?

- Frost is a relatively rare occurrence but some areas are more prone to it.
- Frost frequency has increased in many areas in the last 20 years.
- Minor agronomic tweaks might be necessary in some frost-prone areas but for most growers it should be 'steady as she goes'.
- In the event of severe frost, monitoring needs to occur up to 2 weeks afterwards to detect all of the damage.

More information

Sowing date, heat stress and frost risk in irrigated wheat crops

A small survey conducted by the Department of Environment and Primary Industries, Victoria (DEPI) in October–November 2013 showed that 68% of 111 respondents in south-eastern Australia were very or moderately concerned about frost damage in cereals. For frost damage in canola, the percentage was less, at 40%, and in pulses 57%. [6]

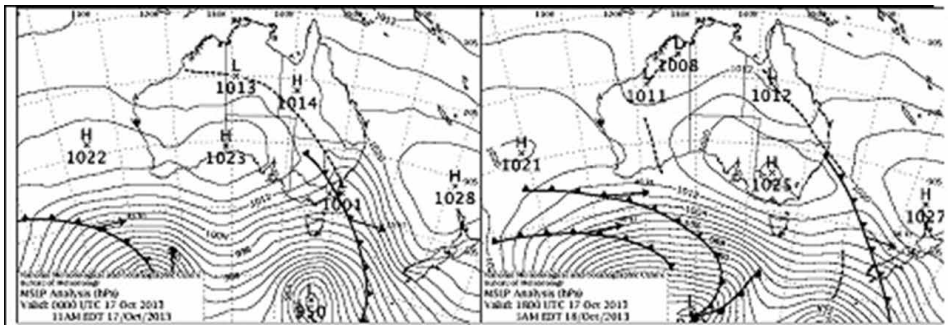
[4] C White (2000) Pulse and canola—frost identification. The Back Pocket Guide. Reprinted 2003. Department of Agriculture, Western Australia/GRDC, https://www.grdc.com.au/Resources/Bookshop/2012/01/Pulse-Canola-Frost-Identification-The-Back-Pocket-Guide-GRDC046

[5] J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf

[6] D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here

What causes frost?

Clear, calm and dry nights following cold days are the precursor conditions for a radiation frost (or hoar frost). These conditions are most often met during winter and spring where high pressures follow a cold front, bringing cold air from the southern ocean but settled, cloudless weather. When the loss of heat from the earth during the night decreases the temperature at ground level to 0°C, a frost occurs (Figure 5). Wind and cloud reduce the likelihood of frost by reducing the loss of heat to the atmosphere. The extent of frost damage is determined by how quickly the temperature reaches 0°C, the length of time its stays below 0°C, and the how far it drops below 0°C. [7]



A cold front passes through, injecting cold air in from the Southern Ocean the day before the frost.

Overnight the high stabilises over SE Australia meaning clear skies and no wind. Frost happens.

Figure 5: Common weather patterns experienced prior to frost occurrence.

Frost effect on the plant

Two types of frost are experienced in Victoria, 'white' and 'black'. White frost occurs when the air around the plant is moist and the temperature around the plant is ≤0°C. Ice crystals form on the surface of the plant (hence, 'white'). The water between plant cells freezes and draws water out of surrounding cells to form more ice. When frost melts slowly (e.g. in winter), damage is minor and the plants repair themselves. Often, the least damage is in the shadows of trees where the thaw is slower, or on the side of the grain head away from the sun. The visual effect is similar to drought stress because plants can temporarily appear wilted. In spring, the thawing can be rapid and damage can be severe.

Black frost occurs when the temperature drops below 0°C but the surrounding air is dry (e.g. in drought conditions). Ice cannot form on the plant surface and the water between cells freezes quickly and forms large crystals. These large crystals 'pop' holes in the cells, causing permanent damage. Once thawed, the plant parts affected immediately look floppy, spongy and discoloured. If that plant part is a flower or a developing ovary, the result can be detrimental to yield.

Frost damage occurs to canola pods, flowers and seeds. Podding canola is very sensitive to frost. [8]

Are frosts becoming more frequent?

- In southern regions of Australia, despite global warming, the number of spring frosts has increased and the period of frost occurrence has changed (i.e. broadened over the southern New South Wales (NSW), Victoria and part of South Australia and become later over Western Australia and western parts of South Australia).
- Frost occurrence is linked to a long-term, southerly shift in position and intensification of the band of high pressure typically located over Central Australia in spring.

[7] D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here

[8] D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here

- Over many parts of NSW, the length of the frost season has increased by as much as 40 days.
- Subsequent studies have shown that this current level of risk is expected to continue over the next 20 years despite continued increases in mean temperatures. [9]

In the DEPI survey, 66% of respondents thought that frost occurred 1–3 years in 10, but the spread of responses between 'never' and 'every year' was large. Geographic viewing of the data might help to elucidate this for the different regions.

It is ironic that as temperatures (particularly those in winter and spring) are increasing, frost remains a major issue. CSIRO researchers have discovered that in some areas of Australia, the frost number is rising (greatest in August) (Figure 6). Eyre Peninsula, Esperance, northern Victorian Mallee and Central West NSW were the only major crop-growing areas to be less affected by frost in the period 1961–2010 (Crimp *et al. 2014*). Contributing factors are thought to be that the latitude of the subtropical ridge of high pressure is drifting south (causing more stable pressure systems) and the existence of more El Niño conditions during this period. [10]

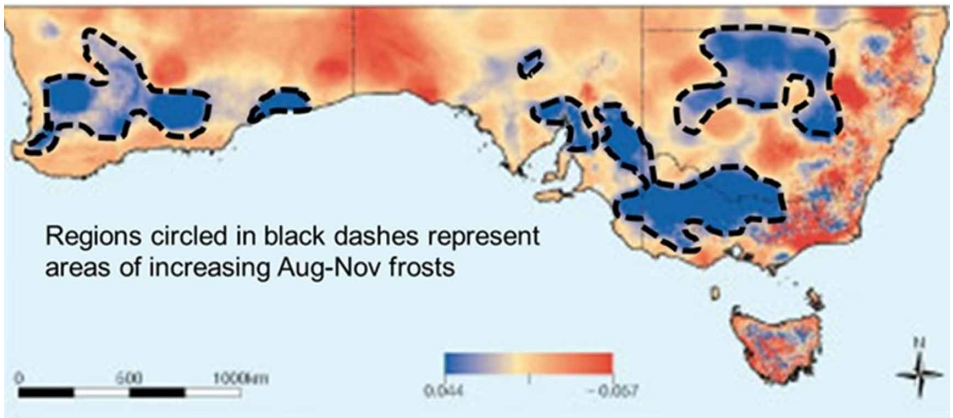


Figure 6: Regions of increasing frosts in August–November. (Source: Steven Crimp)

Key management strategies

Paddock selection is critical for canola. Avoid sowing canola on paddocks with high frost risk because frost damage is irreversible.

Risk may be reduced by:

- later sowing or choosing varieties to spread flowering time of crops
- avoiding potassium deficiency
- early grazing
- sowing more tolerant crops in frost-prone paddocks
- inspecting crops between grainfill and prior to swathing timing if night air temperature (recorded 1.2 m aboveground) falls below –1°C
- checking low-lying, light-coloured soil types and known frost-prone areas, followed by other areas

[9] S Crimp, D Gobbet, D Thomas, S Bakar, U Nidumolu, P Hayman, G Hopwood (2015) 'Jack' of frosts—recent trends and drivers of change. GRDC Update Papers, 17 February 2015, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Jack-of-frosts-recent-trends-and-drivers-of-change

[10] D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here

To identify frost damage, open up pods and check for mushy or shriveled grain. Often, these pods will have a scarred or blistered surface when inspected closely. [11]

The importance of sowing time and flowering dates

To maximise frost-risk resilience, you need a mix of sowing dates and maturity types to avoid damage from the late frosts. In years of severe frost, it may be impossible to prevent damage. [12]

A simulation study at locations in southern NSW in 2014 showed that slower developing spring varieties had their highest yield from early sowing (early–mid April), whereas faster developing spring varieties were at flowering/early podfill before and during the harsh frost period of early August if sown early, which reduced grain yield at frosty sites.

This is because pod development is the stage at which canola is most sensitive to frost damage. The youngest water-filled pods (>60% water) are the most sensitive to frost damage; however, they have also demanded less energy at this stage, so the loss of these pods may not significantly limit yield if time and favourable seasonal conditions are sufficient for compensation. The older and more developed the seed within the pod, the lower the water content and the more frost-tolerant it becomes, but also the greater energy it has used to develop. When temperatures are cold enough to damage these pods, there is generally a much greater yield loss to the plant due to less ability to compensate, especially in low rainfall environments. [13]

More information

Early sowing of canola in southern NSW

The DEPI survey asked growers and advisors what they currently do to mitigate frost damage (Table 1). Most respondents use crop types and maturity length regularly, but few will mix their sowing times to manipulate frost risk exposure. Even fewer choose to sow later. Some do treat frost-prone areas differently or grow smaller areas of the susceptible crops. [14]

More information

Driving Agronomy podcasts. New frost ratings

What to do with a frosted crop

Cold problem in the hot seat

Frost: no room for complacency

Driving Agronomy Podcasts. Frost to stay

Table 1: Results of DEPI survey regarding growers' methods of mitigation of frost damage (n = 111)

	All the time	Most of the time	Some of the time	Never	Other
Sowing a mix of crop types	26%	36%	28%	10%	
Sowing a mix of crop maturities	20%	33%	37%	10%	
Sowing at a mix of times	5%	16%	46%	32%	
Delaying sowing	3%	2%	37%	59%	
Treating frost-prone areas differently	9%	10%	32%	49%	
Growing less of the most susceptible crops	7%	13%	48%	32%	
Other					3%

14.1.2 Issues that can be confused with frost damage

Many other problems can be confused with frost damage. The main ones are those causing distortion of the plant, absence of the seeds or unusual colour (see examples in Figures 7–9). Management and recent environmental conditions should be taken into account when identifying any crop disorder.

[11] DAFWA (2015) Diagnosing frost damage in canola. MyCrop. Department of Agriculture and Food Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-frost-damage-canola

[12] D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here

[13] R Brill, J Kirkegaard, J Lilley, I Menz, D McCaffery, C McMaster (2015) Early sowing of canola in southern NSW. GRDC Update Papers, 17 February 2015, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Early-sowing-of-canola-in-southern-NSW

[14] D Grey (2014) Frost damage in crops—where to from here? GRDC Update Papers, 12 March 2014, https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Frost-damage-in-crops-where-to-from-here

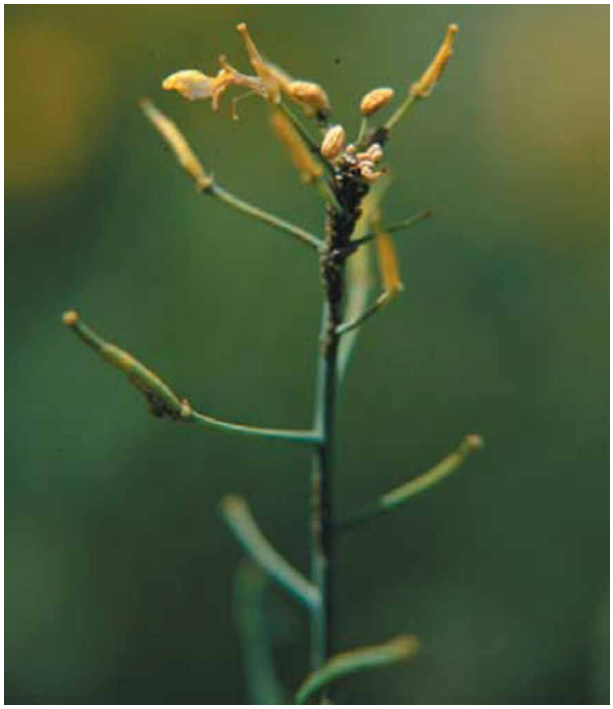


Figure 7: Aphids on canola flower stem.

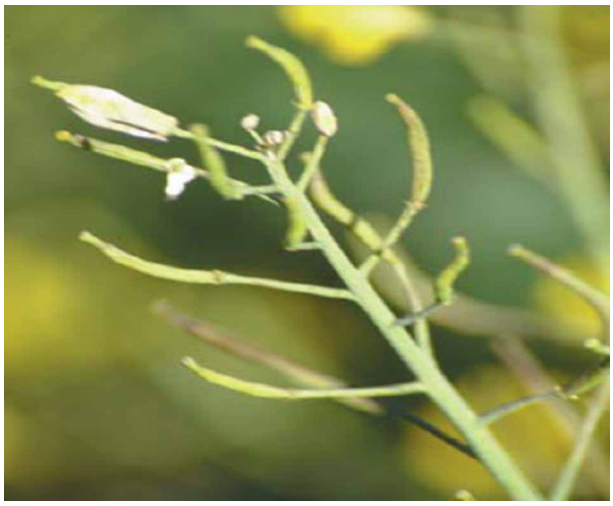


Figure 8: Sulfur deficiency and aphids. Flower petals retained; pods stunted with yellowing–reddening.

Figure 9: Herbicide damage in canola. Photo: Harm van Rees

It is important to remember that frost damage is random and sporadic, and not all plants (or parts of plants) will be affected, whereas most disease, nutrient and moisture-related symptoms will follow soil type. [15]

The optimum temperature range for leaf development of canola is 13°–22°C. At higher temperatures, growth is faster, and the period of leaf development is therefore shorter. Lower temperatures do not reduce yield in early growth, except when heavy frosts occur, but they do slow the rate of development. As temperatures increase to >20°C in July and August, yields are reduced.

For frost injury, ice must form between or inside the cells. Water surrounding the plant cells will freeze at 0°C, but water inside the cells needs to be a few degrees cooler to freeze. The length of exposure of the plant to cold is another important factor. Plants can be cold-hardened by repeated exposure over several days. They can survive –8°C to –12°C in Canada, but exposure to warm weather will reverse this hardening, making the plants susceptible to temperatures of –3°C to –4°C. [16]

14.2 Waterlogging and flooding

14.2.1 Symptoms of waterlogging

Paddock symptoms:

- Poor germination or purple-yellow plants can occur in areas that collect water, particularly on shallow duplex soils.
- Bare wet soil and/or water-loving weeds are present.
- Plant lodging and early death occur in waterlogging-prone areas.
- Saline areas are more affected.

Plant symptoms:

- Waterlogged seedlings can die before emergence or show symptoms similar to nitrogen deficiency.
- Lower leaves turn purple-red to yellow, then die.
- Prolonged waterlogging causes root death and eventually death of the whole plant; plants are more susceptible to root disease.
- Waterlogging of adult plants causes yellowing of lower leaves.
- Salinity magnifies waterlogging effects, with more marked stunting and oldest leaf marginal necrosis and death. [17]

More information

All not lost if dry spring thwarts N uptake

14.2.2 Effect on yield

Canola roots need a good mix of water and air in the soil. When the amount of water exceeds the soil's water-holding capacity, waterlogging may occur. Canola is susceptible to waterlogging and shows a yield reduction after only 3 days.

The severity of yield loss depends on the growth stage at the time of waterlogging, the duration of waterlogging, and the temperature (Figure 10).

[15] C White (2000) Pulse and canola—frost identification. The Back Pocket Guide. Reprinted 2003. Department of Agriculture, Western Australia/GRDC, https://www.grdc.com.au/Resources/Bookshop/2012/01/Pulse-Canola-Frost-Identification-The-Back-Pocket-Guide-GRDC046

[16] J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf

[17] DAFWA. Diagnosing waterlogging in canola. MyCrop. Department of Agriculture and Food Western Australia, https://www.agric.wa.gov.au/mycrop/diagnosing-waterlogging-canola

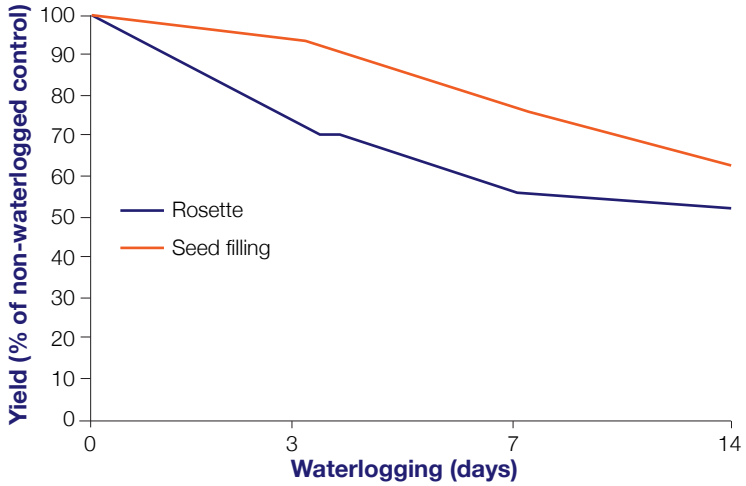


Figure 10: Effect of waterlogging on yield. (Source: Canola Council of Canada 2003)

Wet soils will slow or prevent gas exchange between the soil and atmosphere, causing oxygen deficiency. High temperatures cause high respiration rates in roots and soil microorganisms, so soil oxygen is consumed more quickly.

Soil texture also affects the time at which critical levels of soil oxygen are reached. This is due to the oxygen-carrying capacity of soils. Coarser textured soils can hold more oxygen, increasing the amount of time before oxygen levels are reduced to a critical point.

Other effects of waterlogging are reductions in root growth, plant growth, plant height, dry matter production and nutrient uptake. [18]

14.2.3 Germination

Canola is sensitive to waterlogging during germination. When soils become waterlogged, the oxygen supply in the soil solution rapidly decreases. Oxygen is essential for seed germination. Without oxygen, seeds cannot continue their metabolic processes, and germination ceases. Prolonged waterlogging can kill canola seeds and seedlings. [19]

14.2.4 Seedfill

During seed-filling, waterlogging for >7 days decreases individual seed weight and oil content. High temperatures exacerbate the effects of waterlogging on canola yield.

The impact of waterlogging is greater if it occurs at the rosette stage. The longer the period of waterlogging, the greater the impact. [20]

More information

Should waterlogged crops be topdressed with N fertiliser?

Over the bar with better canola agronomy

More information

Diagnosing waterlogging in canola

Alleviation of waterlogging damage by foliar application of nitrogen compounds and tricyclazole in canola

Growing canola on raised beds in south-west Victoria

Nitrogen and sulfur for wheat and canola—protein and oil

APSIM Canola

Waterlogging and canola

Waterlogging in Australian agricultural landscapes: a review of plant responses and crop models

Crop production potential and constraints in the high rainfall zone of southwestern Australia: Yield and yield components

Improving canola establishment to reduce wind erosion

[18] J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf

[19] J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf

[20] J Edwards, K Hertel (2011) Canola growth and development. New South Wales Department of Primary Industries, http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/516181/Procrop-canola-growth-and-development.pdf