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Primary Industries Climate Challenges Centre

WINTER CHILL AND FRUIT TREES

What is dormancy and winter chill?

Temperate perennial fruit trees, such as apples and cherries, annually cycle through different physiological phases to produce fruit (Figure 1). In spring, trees are in flower, leaves are photosynthesising to generate energy for the tree, pollination occurs and fruit development begins. Fruit matures through summer and autumn. After harvest, and with the onset of autumn and winter, trees drop their leaves and enter a dormant phase. The emergence from dormancy in late winter or early spring is signalled by the development of flowers and leaves, with the cycle then repeating.

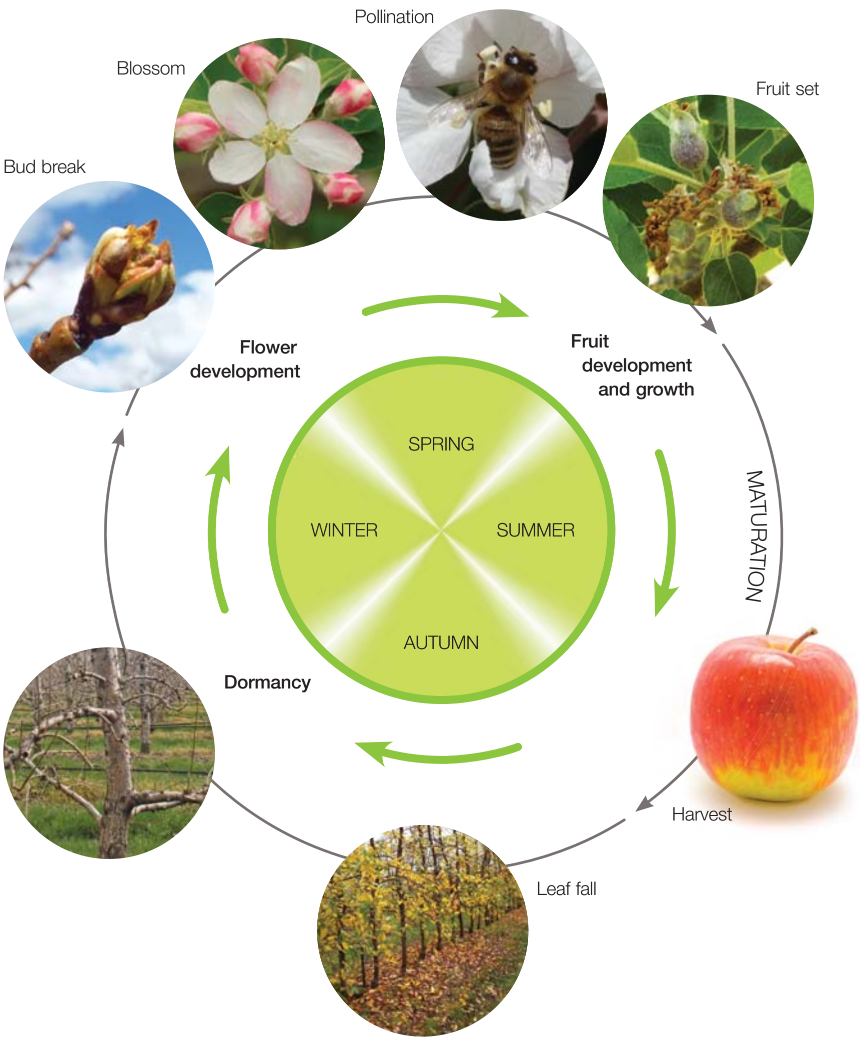


Figure 1 Generalised perennial fruit tree annual cycle.

The dormant winter phase is an evolutionary advantage that protects fruit trees from cold weather damage by preventing the growth of cold-sensitive shoots and flowers in response to a winter warm spell. For trees to resume growth in spring this dormant phase must be 'broken'. Perennial fruit trees break dormancy after a prescribed 'sum' of winter conditions has passed — the tree has then determined that winter has finished and will begin to flower in response to warm temperatures.

This sum of cold weather is known as winter chill. The winter chill required to break dormancy, the chill requirement, differs by fruit type and variety.

How does temperature influence winter chill?

Accumulation of winter chill to break dormancy is largely a temperature dependent process. The relationship of different temperatures and temperature regimes to dormancy breaking are varietal-specific but there are some general aspects:

- freezing temperatures do not contribute to dormancy breaking
- there are optimum temperatures for the accumulation of winter chill
- temperatures either side of the optimum decrease in ability to contribute to winter chill
- high temperatures can undo previously accumulated chill
- cycling moderate temperatures with effective chilling temperatures enhances the accumulation of winter chill.

Why does winter chill matter?

Winter dormancy, although an effective protective measure, can pose production challenges during mild winters when fruit trees do not accumulate sufficient winter chill to meet chill requirements. Light and variable flowering and a protracted flowering period may result from insufficient accumulation of winter chill. These conditions can markedly affect fruit yield through poor pollination, increased risk of frost damage or by directly reducing the amount of fruit produced.

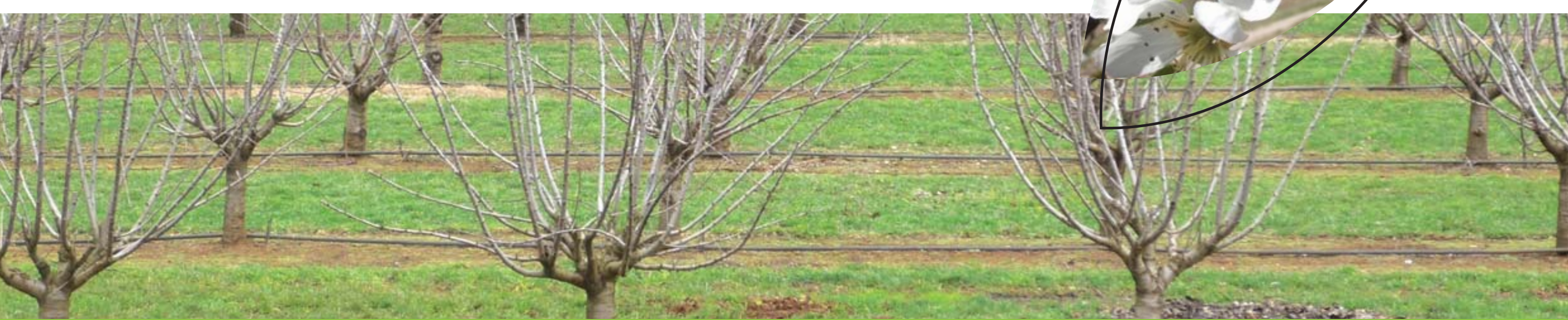
Future anthropogenic climate change will continue to increase global temperatures, leading to warmer winters in Australian fruit growing regions. This may reduce the ability of fruit trees to accumulate their winter chill requirements, resulting in irregular flowering and potentially the separation of the flowering periods of cross-pollinating species, therefore reducing pollination success.

From a production viewpoint, matching varietal winter chill requirements to site conditions is an important consideration for orchard development. This is increasingly important under changing climate conditions. Assessment of winter chill conditions in relation to the viability of existing orchards and the potential of new growing regions is needed to assist with judicious forward planning.

How is winter chill estimated?

Many models of winter chill have been developed using the observed effects of temperature on dormancy breaking. The Chill Hours model (Weinberger, 1950) was the first to be developed and estimates winter chill based on hourly temperatures. This is a 'yes–no' model with temperatures between 0–7.2 °C allocated 1 chill hour (yes) and temperatures outside of that interval allocated a 0 chill hour (no). These chill hours are summed over autumn and winter to give an estimate of total winter chill.

Knowledge of temperature effects on winter chill has since expanded and the Dynamic chill model (Fishman et al., 1987) is the current best practice model. It calculates chill in units known as 'chill portions', based on hourly temperatures. The Dynamic model has many features which capture known temperature-winter chill relationships which are lacking in other models including the Chill Hours model. According to the Dynamic model, effective winter chill temperatures follow a bell shape with an optimum chilling temperature at 6 °C, tapering to zero at –2 °C and 14 °C. High temperatures act to negate previously accumulated chill and moderate temperatures can enhance chill accumulation.



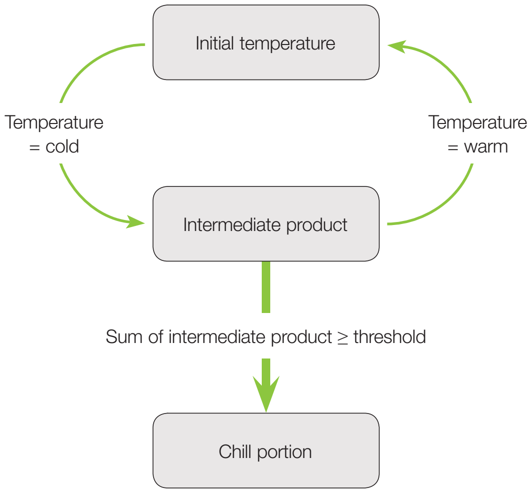


Figure 2 Schematic of the Dynamic model (Darbyshire et al., 2011).

Unlike previously constructed chill models, the structure of the Dynamic model is time-dependent and follows a two-step process. Firstly, an intermediate product is produced through exposure to effective winter chill temperatures. This intermediate product can be destroyed by subsequent exposure to high temperatures. Once a threshold amount of this intermediate product is amassed it is irreversibly banked as a chill portion (Figure 2). Summing chill portions over autumn and winter provides an estimate of accumulated winter chill.

What are the chill requirements of fruit trees?

Few estimates of varietal chill requirements have been reported in chill portions, as it is not possible to convert the outputs of earlier chill models and there have been few studies conducted using the Dynamic model. However, the University of California has started to compile estimates for some fruit tree varieties (Table 1).

Table 1 Selected variety chill requirements in chill portions. (Source: UC–Davis Fruit & Nut Research and Information Center, 2011.)

Fruit	Variety	Chill requirement (chill portions)
Apple	Golden Delicious	50.0
Apricot	Selene	57.4
Cherry	Lapins	35.0
Nectarine	Flavortop	41.4

How much winter chill do Australia's growing regions receive?

Figure 3 and Table 2 describe winter chill received across Australia and in specific fruit growing regions, as calculated from historical temperature records between 1911 and 2012. The 10th percentile of total accumulated chill from 1 March–31 August is presented and represents the minimum amount of chill that is likely to be reliably received.

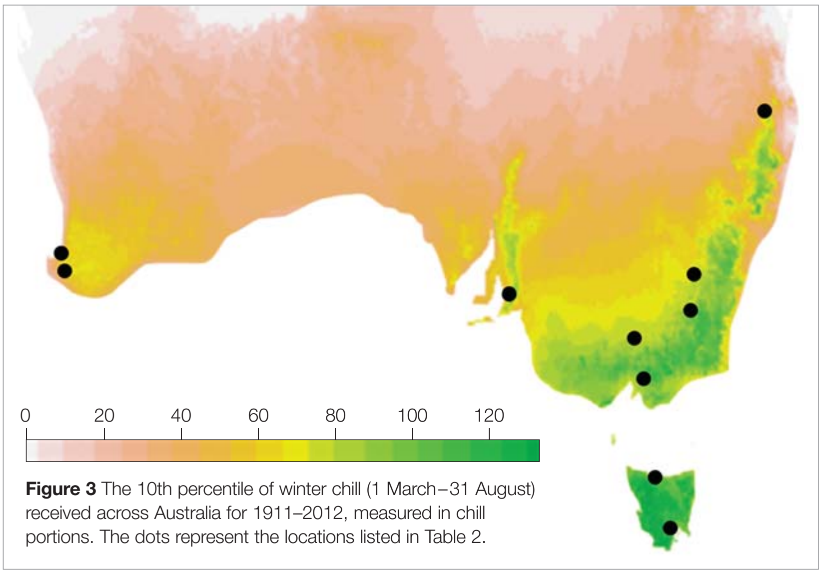


Figure 3 The 10th percentile of winter chill (1 March–31 August) received across Australia for 1911–2012, measured in chill portions. The dots represent the locations listed in Table 2.

Table 2 The 10th percentile of winter chill (1 March–31 August) received for temperate fruit regions for 1911–2012.

Location	State	Chill portions	Location	State	Chill portions
Donnybrook	WA	52	Lenswood	SA	91
Manjimup	WA	64	Spreyton	TAS	94
Applethorpe	QLD	69	Yarra Valley	VIC	94
Tatura	VIC	81	Batlow	NSW	100
Young	NSW	81	Huonville	TAS	105

What don't we know?

There is still much to learn about the dormancy process and these knowledge gaps need to be addressed to help inform future management decisions:

- What are the winter chill portions requirements for economically important fruit species?
- What are the physiological changes that dictate the progression into and out of dormancy, and how can these be better modelled?
- Is there an influence of rootstock on varietal chilling requirements?
- Does the length of daylight hours affect dormancy induction and breaking?
- Is there an effect of leaf fall on dormancy induction?
- How does climate change affect each of these unknowns?

A better understanding of dormancy and the factors that affect varietal chill requirements will improve perennial fruit production outcomes under both current and future climates.

References

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