Break crops revisited

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Abstract
Break crops provide agronomic benefits and increased profitability to dryland cropping systems but only 50-55% of cereals in Australia are preceded by a break crop, legume-based pasture or long fallow. This paper points out benefits of break crops that may have been previously undervalued and, if recognised, may encourage greater adoption: (1) reducing the spread of cereal wildfires before and after harvest, utilising the fire-retardant properties of break crops by placing them in strips alternating with cereals, at right angles to the prevailing wind (2) injecting lime into acidic subsurface soil layers, for break-crop species that are identified as being sensitive to subsurface acidity (3) growing break crops to secure the exceptionally high yields of early-sown, long-duration crops (4) recognising the yield benefit of break crops in crop simulation models.

Keywords
Canola, pulses, cereals, cropping mosaic, subsurface acidity, early sowing

Introduction
Break crops are broadleaf species that, along with legume pastures and long fallows, break the life cycles of cereal root pathogens and also provide, in some circumstances, other benefits to following cereals – weed control, increased N mineralisation, residual soil water, possible suppression of parasitic mycorrhizae and, for legumes, N input from biological fixation and hydrogen fertilisation. The profit from a break crop-cereal sequence is usually greater than a cereal-cereal sequence (Kirkegaard et al. 2008; Angus et al. 2015). For this discussion, break crops are taken to include legume pastures and long fallows.

Despite the benefits, many Australian cereal crops are not preceded by a break crop. The GRDC practices surveys between 2011 and 2016 show that on average 32% of cereal crops followed canola, a pulse or legume pasture, and a further 12% followed long fallow (GRDC 2017). Two caveats need to be considered with these numbers. One legitimate consideration is that break-crop benefits extend to later crops. In Australia the average yield increase by a second cereal crop is about half that to the first cereal and to the third crop is negligible (Angus et al. 2015). There are no data on the proportion of second cereals following a break crop, but even if it is another 20% the discount on the yield effect for the second cereal would still only bring the a full break-crop benefit to 50-55% of cereal crops. Another, less legitimate, objection to the value of break crops is that there are some regions in Australia for which there is no adapted canola or pulse. In these regions there are still options for long fallow and winter-cleaned pastures so there are no grounds for altering the estimated 50-55% of cereals following break crops. Although low, this proportion compares well with the world estimate of 40% of temperate cereals following a break crop (Angus et al. 2015). There is still scope for break crops to improve productivity.

The incomplete adoption of break crops suggests that many graingrowers do not consider that the returns from a break crop and subsequent cereals compensate for their additional production cost and yield risk. This paper aims to point out previously undervalued benefits that may encourage more use of break crops.

Can strips of break crops limit the spread of cereal wildfires?
Cereal crops are highly inflammable both before and after harvest, and cereal wildfires are a threat to life, livestock and property. Their risk and severity is extreme in the hot and dry conditions during and after harvest in southern Australia (Cruz et al. 2020). For two reasons cereal fires are becoming more dangerous. One is that higher temperature and the longer fire season increases the risk and severity of

fires. The other is that the increased use of 'block farming' means that fires can travel further than before. Block farming is the strategy of concentrating each crop species on separate parts of a farm rather than spreading them in separated paddocks. Graingrowers' reasons for farming in blocks are the savings in cost and time in moving machinery and the reduced risk of herbicide drift onto susceptible crops. Where there are contiguous blocks of cereals on adjacent farms there can be tens of kilometres of fuel downwind of a fire.

Canola and pulses are break crops that are mostly less inflammable than cereals (and grassy pastures). Break crops (and perennial pastures) can have a roll in limiting the spread of cereal wildfires if they are strategically placed in the farm landscape. To maximise their value as fire breaks, areas of crops and pastures should be sown not in square blocks but in elongated strips with the long axis facing the prevailing wind. With this arrangement cereal fires are likely to spread only as far as the next strip of break crop. On many farms the mosaic of crops and pastures in the landscape is designed around soil type, access and the risk of frost. Here I suggest that growing crops in strips to limit the spread of wildfires should be another consideration. Insurance companies should reward strategies to limit pre-harvest wildfires with reduced premiums.

Can break crops help solve subsurface acidification?

The area of canola expanded rapidly, from a low base, starting in the mid-1990s. Much of the canola is grown in regions with acid-prone soils and relatively high rainfall. The tonnage of agricultural lime also increased suddenly in the mid-1990s and both canola and lime tracked together from then until the millennium drought (lime tonnage applies only to NSW, the only jurisdiction with long-term data). Since then canola area and lime usage have tended to fluctuate together, depending on droughts and good seasons. A partial reason for the linkage is that canola yield responds to surface lime (Slattery and Coventry 1993) but probably little more than acid-tolerant wheat. Most importantly the canola-wheat system was profitable enough to pay for surface lime. Before the adoption of canola, liming cereals was not justified because an alkaline surface soil promoted the root disease take-all of cereals, caused by *Gaeumannomyces graminis* (Sacc.) Arx and Oliv. var. *tritici* Walker (*Ggt*). Take-all greatly reduced cereal yields. Lime is normally applied before canola, which suppresses Ggt to such an extent its level in the soil is normally too low to damage one or more subsequent cereals. Agricultural lime has been broadcast on the soil surface, ameliorating the topsoil (0.1 m) over about half the area of the acid-prone crop-pasture land (Gazey et al. 2013; Harding and Hughes 2018). Surface liming has no effect on acidity in subsurface layers, located at depths of 0.05-0.15m (Conyers and Scott 1989).

Experiments by AD Swan and colleagues (in preparation) showed that canola growth was unaffected by an acid subsurface, provided the topsoil was limed. They also showed that injecting lime into an acid subsurface did not increase canola yield. These result presents us with a dilemma. In the short term they mean there is no economic reason for ameliorating subsurface acidification using canola, which had been the trigger for surface liming. In the long term, subsurface acidification is a nationally important form of resource degradation that, if left unchecked, will become more and more difficult to ameliorate as the acid layer becomes thicker. There is currently little or no amelioration of subsurface acidity and a strategy is needed that is both effective and profitable.

An approach suggested here to ameliorate subsurface acidity is by identifying break crops that need to grow on a non-acid subsurface to achieve potential yield. These crops and following cereals need to deliver enough profit to pay for lime injection into the acid layer. Possible candidates are the high-value food-grade pulses, chickpea, faba bean, lentil and field pea. Cereals that may be suitable are durum and barley. Canola is not a candidate because it can tolerate subsurface acidity. Breeding for acid tolerance is counterproductive because it postpones the inevitable need for liming.

Break crops express the value of early sown, long-duration crops

The strategy of early sowing with a late-maturing cultivar has produced outstanding crop yields (Hunt et al. 2019). These results are consistent with extensive experiments in which early sowing with a late-maturing cultivar outyielded late sowing with an early-maturing cultivar (Penrose 1993; Latta et al. 2012). Other experiments have shown the reverse ranking, with higher yields from late-sown, early-maturing cultivars (Table 1).

Table 1. Yield comparison (t ha^{-1}) of early wheat cultivars sown late, with late cultivars sown early.

Early cv, late sown	Late cv, early sown	Previous		Reference
3.5 Takari 16 June	1.5 Oxley 28 April	n.a.	1	Braunack-Mayer & Smith 1989
4.5 Banks 23 June	4.3 Quarrion 15 May	Fallow	2	Connor et al. 1992
6.0 Silverstar April	4.4 Lawson April	Grass pasture	2	Riffkin et al. 2003
5.1 3 cvv 30 May	3.9 Wylah 30 April	n.a.	1	Zhang et al. 2006

The different results may be at least partly due to variation in the incidence of wheat disease in early sown crops. It is likely that *Ggt* infection play an important role. *Ggt* is sensitive to soil temperature with an optimum around 18°C (Grose et al. 1984), This is close to the mean temperature in southern Australia in late March, a typical time for early sowing. Mean temperature in June is around 9°C, well below the *Ggt* optimum, so cereals sown at that time avoid *Ggt* infection, at least until spring. It is likely that before the era of break crops yields of early-sown cereals, such as those reported in Table 1 were limited by take-all because of its high activity in warm soil. Other risks of early-sown wheat are barley yellow dwarf virus and wheat streak mosaic virus both of which can oversummer in volunteer cereals. The lesson for the current cropping system is that break crops should be maintained for early-sown, long-duration crops to achieve their extraordinarily high yields.

The break-crop effect and simulation models

There are many models of dryland cereals that simulate yield, based mainly on the interacting effects of crop duration, solar radiation, temperature, water supply and nitrogen (CERES, SIRIUS, DSSAT, CROPSIM, SUCROS, APSIM, STICS, AFRC, Daisy, WOFOST, SIMTAG). Apparently, none of them simulate the effects of break crops. Many farmers and advisers consider the output of simulation models in making cropping decisions. Recognition of the break-crop effect in simulation models would improve their accuracy and would promote the use of break crops to the large population of farmers who have not adopted them.

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