# Broadleaf break crops improve the profitability of low rainfall crop sequences

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## Abstract
At the end of the millennium drought, broad-leaved crops made up a very small proportion of the sown crops in the low rainfall (LR) regions of south-eastern Australia. However, the productivity and profitability of these intensive cereal cropping sequences was declining due to increasing agronomic constraints. Furthermore, the impact of broad-leaved crops on subsequent cereal productivity had been rarely tested in these LR regions and farmers regarded them as risky to grow and were uncertain about their system benefits. To address this uncertainty, replicated trials were conducted in paddocks where locally important agronomic constraints such as grass weeds, soil borne diseases and declining soil fertility were reducing the yields of cereal crops. Each trial comprised 19 unique crop sequences which included both one and two-year break phases in 2011 and/or 2012 followed by wheat in 2013 and 2014. Each trial also maintained a continuous wheat treatment for the four years of the trial as a benchmark to assess the impact of the other crop sequences. Cumulative break crop benefits were generally in the order of 0.5 – 1.5 t/ha of extra grain yield in subsequent wheat crops and as high as 2 t/ha, findings that are comparable with break crop benefits reported in higher rainfall regions in southern Australia. The inclusion of break phases also improved the overall profitability of the crop sequence, providing that at least one of the break phases was profitable. The profitability of the four-year crop sequence was improved by up to $100/ha per year when a break crop was included, relative to maintaining continuous wheat.

## Keywords
Rotation, break effect, wheat, pulse, canola, pasture.

## Introduction
At the end of the millennium drought, broad-leaved crops made up a very small proportion of the total area of sown crops in the low rainfall (LR) regions of south-eastern Australia. A survey conducted by LR farming system groups showed that in 2009 wheat and barley grown for grain production occupied over 90 percent of the cropping area in this LR zone. As a consequence, the landscape was dominated by paddocks which had been in continuous cereal (often wheat) for many years. However, the productivity and profitability of these intensive cereal cropping sequences was declining due to agronomic constraints such as grass weeds, declining soil nitrogen fertility and crop diseases.

In higher production systems both within Australia and internationally, the ‘break crop’ effect (increased yield following a break crop) is well recognised. For example, Angus et al. (2015) reported that wheat yields following a range of break crop species to be 0.5 – 1.2 t/ha higher than where wheat followed wheat. In the LR zone of south-eastern Australian, long term wheat yields are commonly less than 2 t/ha and there was little data that provided estimates of the break crop effect in these low production environments.

To increase the adoption of more diversified crop sequences in the LR zone, farmers needed confidence that long term profitability would be enhanced by the inclusion of break phases in the rotation relative to maintaining continuous cereal. Therefore, multi-season field trials were undertaken from 2011-2014 to test if one or two years of well managed break phases in LR crop sequences could successfully address agronomic constraints, increase the productivity of subsequent cereal crops and, most importantly, improve the profitability of the crop sequence when compared to continuous cereal.

## Methods
Replicated field trials commenced in 2011 at Mildura (Mallee, Victoria, 34° 15.152'S 141° 50.350'E, 273 mm annual rainfall (AR)) and at Appila (Upper North, South Australia, 33° 0.052'S 138° 22.468'E, 384 mm AR). Trials were located in paddocks where locally important agronomic constraints were present, with brome grass, Rhizoctonia and poor soil nitrogen fertility affecting production at the Mildura site and grass weeds (annual ryegrass and wild oats) identified as the primary constraints at the Appila site. Each

trial consisted of up to 19 unique crop sequences which included both one and two-year break phases in 2011 and/or 2012 followed by wheat in 2013 and 2014 (Table 1). These treatments were selected in consultation with local farmers and advisors. Each trial also maintained a continuous wheat treatment for the four years of the trial. Agronomic management was tailored for each individual sequence to help maximise the profitability of that rotation and to correct the agronomic constraints present. For example, nitrogen inputs, varieties, sowing dates or herbicide applications were varied depending on the level and type of agronomic constraints in each rotation.

Pasture and crop productivity was measured as above ground dry matter and grain yield where appropriate. Dry matter was measured when break crops and pastures reached peak biomass and cereals had reached flowering. All grain yields were estimated using a mechanical plot harvester soon after each crop species had matured. Gross margins were calculated for each treatment in each season using the 'Rural Solutions Farm Gross Margin and Enterprise Planning Guide' (http://pir.sa.gov.au/consultancy/farm_gross_margins_and_enterprise_planning_guide. Costs were calculated using the actual inputs used in the trial and the values provided in the corresponding gross margin guide. Gross margins were calculated using the five-year average price stated in the 2015 guide. Treatment grain yields were used for calculating income and 85% of dry matter yield was used for calculating hay yield. For grazing livestock, income was calculated using the dry sheep equivalent (DSE) cereal zone gross margin for a prime lamb enterprise and a nominal stocking rate of two DSE per winter grazed hectare, irrespective of pasture production.

**Table 1. Details of the crop sequence treatments implemented at Appila and Mildura sites from 2011-2014.**

| Appila | Ident | Mildura | Ident |
|---|---|---|---|
| canola-field pea-w-w | C-FP | canola-chickpea-w-[cl]w | C-CP |
| field pea-canola-[cl]w-w | FP-C | canola-field pea-w-[cl]w | C-FP |
| [h]millet-[bm]vetch-w-w | MT-V | canola-[bm]vetch-w-[cl]w | C-V |
| medic-[h]pasture-w-w | M-P | chickpea-canola-w-[cl]w | CP-C |
| medic[(p)]- [h]pasture-w-w | M(P)-P | fallow-canola-w-[cl]w | F-C |
| pasture-[h]oats+vetch-w-w | P-O+V | fallow-fallow-w-[cl]w | F-F |
| [c,h]mix1- [c,h]mix1-w-w-w | MX1-MX1 | fallow-field pea-w-[cl]w | F-FP |
| [h]canola+vetch-fieldpea-w-w | C+V-FP | [a,g]medic-[g]pasture-w-[cl]w | M(H)-P |
| fallow-fallow-w-w | F-F | [b,g]medic-[g]pasture-w-[cl]w | M(L)-P |
| fallow-canola-[cl]w-w | F-C | field pea-canola-w-[cl]w | FP-C |
| fallow-lentil-w-w | F-L | field pea-[bm]vetch-w-[cl]w | FP-V |
| [h]vetch-fallow-w-w | V-F | [bm]vetch-canola-w-[cl]w | V-C |
| fallow-w-[cl]w-w | F-W | [bm]vetch-field pea-w-[cl]w | V-FP |
| lentil-w-[cl]w-w | L-W | barley-w-[cl]w-[cl]w | B-W |
| w-barley-[cl]w-w | W-B | canola-[cl]w-w-[cl]w | C-W |
| w-[h]pasture-[cl]w-w | W-P | canola+field pea-w-[cl]w-[cl]w | C+FP-W |
| w-[g]medic-[cl]w-w | W-M | [h]oat-w-[cl]w-[cl]w | O-W |
| [d]wheat[(p)] -[h]pasture-w-w | W(P)-P | field pea-w-[cl]w-[cl]w | FP-W |
| [h]oat-w-[cl]w-w | O-W | fallow-w-[cl]w-[cl]w | F-W |
| w-[cl]w-[cl]w-w | CONW | w-[cl]w-w-[cl]w | CONW |

| | |
|---|---|
| [a]Low Sowing Rate (5 kg/ha) | [h]Treatment cut for hay |
| [b]High Sowing Rate (15 kg/ha) | [bm]Treatment was brown manured |
| [c]Mix1:oats+vetch+medic | Fallow refers to chemical fallow |
| [d]Wheat undersown with medic pod (p)Medic sown as pod | w - wheat |
| [g]Treatment grazed | [cl] Clearfield variety |
| [h]Treatment cut for hay | Note: Medic refers to sown medic pasture: Pasture refers to |
| [bm]Treatment was brown manured | regenerating medic pasture |

## Results and Discussion

*Break effect*

Significant break crop benefits (yield of wheat crop following a break phase minus the yield of the continuous wheat treatment) were measured at both sites (Figure 1). A chemical fallow in 2011 at Appila improved wheat production by 1 t/ha in 2012 and a medic pasture in 2012 increased wheat yield in 2013 by up to 0.4 t/ha. All two-year breaks provided exceptional break crop effects at the Appila site with an average combined yield increase of 1.5 t/ha in 2013 and 2014. The 'vetch-fallow' treatment doubled the production of wheat over the 2013-2014 seasons, with a combined break effect of 2 t/ha.

A one year break of fallow or field pea at the Mildura site increased wheat yield by 0.3 t/ha in 2012, relative to the low yielding continuous wheat treatment (1.1 t/ha). However the benefit of a one-year break lasted only a single season, largely due to the rapid re-establishment of brome grass (data not shown). The implementation of a double break phase in 2011 and 2012 resulted in longer lasting benefits with combined break crop effects of between 0.5-1.5 t/ha in 2013 and 2014. Treatments that included a brown manure vetch as part of the double break phase had break effects larger than 1.25 t/ha in the first wheat crop following the break.

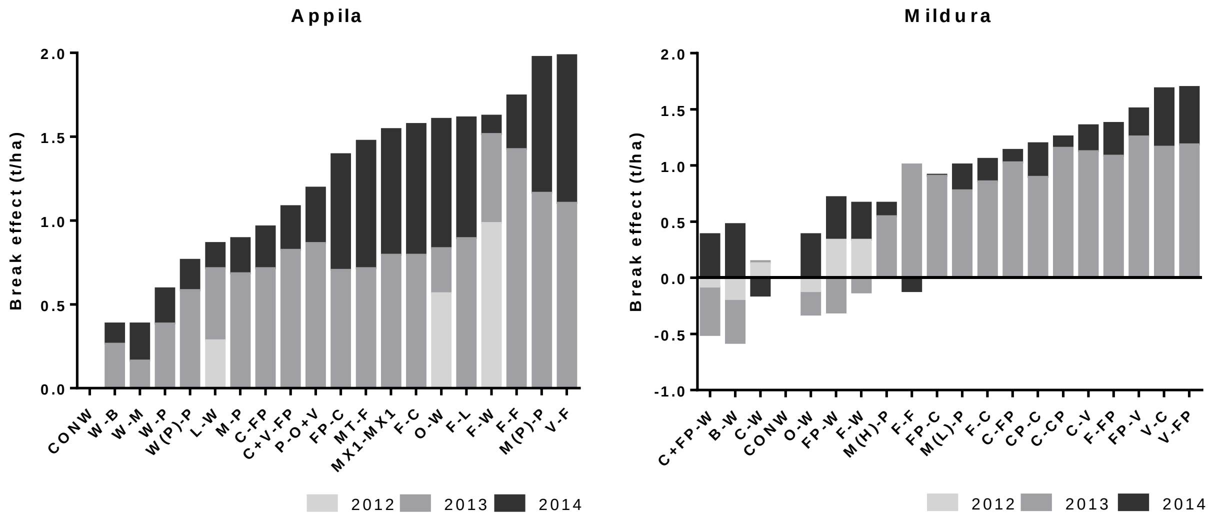


**Figure 1. Break crop effect (treatment wheat yield – continuous wheat yield) measured in 2012, 2013 and 2014 wheat crops following break phases at Appila and Mildura. Only treatments with a single year break had effects measured in 2012. Yields of the continuous wheat treatment (CONW) at the Appila site were 1.70, 1.66 and 3.28 t/ha and at the Mildura site were 0.93, 1.42 and 1.31 t/ha in 2012, 2013 and 2014 respectively.**

Angus et al. (2015) reported mean break effects of 0.8 for canola and 0.92 t/ha following a pulse crop. McBeath et al. (2015) also measured cumulative break crop effects of over of 1 t/ha in three subsequent wheat crops at Karoonda in the South Australian Mallee. Both Angus et al. (2015) and McBeath et al. (2015) proposed that the break crop effect is of a fixed amount rather than being proportional to the yield of the cereal crop. Our data support these findings given that similar break crop effects were observed across a number of sites even though the yield of the continuous cereal treatment ranged from 1.5-3.5 t/ha.

Angus et al. (2015) attributed the break crop effects to suppression of root diseases such as take-all, nitrogen benefits from legumes and residual water following some break phases. Similarly, McBeath et al. (2015) primarily attributed the break benefit to beneficial effects on the cycling and supply of nutrients and suggested that the inclusion of break crops is likely to improve subsequent cereal production where nitrogen is a factor limiting productivity in low-rainfall, semi-arid environments such as the Mallee. However, in this study we selected sites with significant weed burdens and have demonstrated large productivity benefits that break crops can provide through managing grassy weed populations.

*Profitability*

Over half of the crop sequences with break phases were more profitable than continuous wheat at both sites (Figure 2). At Mildura, the top five rotations increased gross margin by an average of $320/ha over the four years or approximately $80/ha/year. At Appila, the profit advantages were greater with the top five most profitable crop sequences delivering an average of $395/ha additional profit or approximately $100/ha/year.

Key attributes of the most profitable crop sequences at both Mildura and Appila were having at least one profitable break phase in the rotation and that the rotation delivered large yield benefits to subsequent wheat crops. At Mildura, field peas, canola and chickpeas produced good yields and gross margins in the 2011 season. The yield of field pea was 2 t/ha, canola was 0.9 t/ha and chickpeas was 1 t/ha with corresponding gross margins of $379/ha, $239/ha and $286/ha respectively. Seasonal conditions were poor at Mildura in 2012, but field peas still averaged 1.2 t/ha while canola and chickpea crops both yielded below 0.5 t/ha. Field peas also out-yielded wheat over both seasons with continuous wheat yielding 1.7 t/ha and 1.1 t/ha in 2011 and 2012.

At Appila, profitable gross margins were achieved from crop sequences where crops and pastures were cut for hay. The top producing hay treatments in 2011 and 2012 produced 4-7 t/ha of dry matter resulting in profitable gross margins of $350-$500/ha. Continuous wheat produced a profit of $315/ha and $250/ha in 2011 and 2012. At Appila, broadleaved break crops grown for grain generally performed poorly due to severe frost events impacting grain yield in both 2011 and 2012. The exceptions were canola and lentils, which produced excellent gross margins of $580/ha and $330/ha respectively in 2012. Both of these treatments followed a chemical fallow in 2011 and both crops are high value grain crops where revenue is boosted by higher prices than other enterprises.

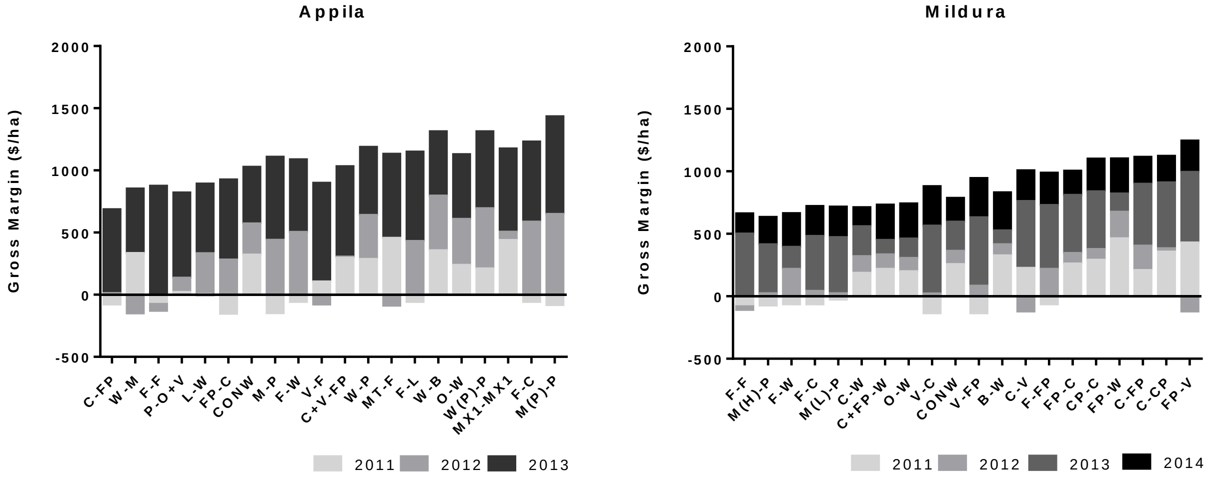


**Figure 2. Cumulative gross margin (2011 – 2014) of each crop sequence at Appila and Mildura sites.**

## Conclusion

The inclusion of one- or two-year break phases within crop sequences in the southern Australia LR zone is a reliable management option to improve the yield of wheat where agronomic constraints such as grassy weeds, declining soil fertility and root disease are impacting production. Cumulative break crop benefits were generally in the order of 0.5-1.5 t/ha and as high as 2 t/ha which is comparable to break crop benefits reported in higher rainfall regions in southern Australia. The inclusion of break phases can also improve the overall profitability of the crop sequence providing that at least one of the break phases was profitable in its own right and that the inclusion of the break phases conferred break crop benefits to the subsequent wheat crops. Where this was achieved, the profitability of the four-year crop sequence was improved by up to $100/ha per year relative to maintaining continuous wheat.

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