

## Improving winter crop productivity through increased capture and storage of summer fallow rain

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### Abstract

The capture, storage and use of summer fallow rain is one of the most effective ways of improving winter crop productivity in the Victorian Mallee. Soil surface conditions, including crop residues, weeds and tillage, may influence how well summer rain is captured and stored. To determine what is the potential of management practices on summer fallow efficiency, an experiment was established on two different soil types (sand over sandy loam, clay loam over medium clay) near Hopetoun in north-western Victoria. Six treatments were applied over two seasons, 2008/2009 and 2009/2010: 1. standing stubble from a previous wheat crop; 2. standing stubble plus summer weeds; 3. slashed stubble; 4. bare earth; 5. bare earth plus summer weeds; and 6. cultivation with stubble retained. From November 2008 until sowing on 22 April 2009, 90 mm of rain fell with the largest single event being 27 mm. When treatments were averaged across soil types, there was 10 mm more water available in treatments with stubble and no weeds compared to treatments with weeds. There was no significant difference ( $P > 0.05$ ) either in dry-matter at anthesis or the grain yield of barley cv. Hindmarsh that was sown across all treatments. During the 2009/2010 summer, there was 224 mm and 254 mm of November to March rainfall at the sand and clay sites respectively, the majority of which fell in a single event over 3 days in November (128 mm at the sand site, 163 mm at the clay site). Control of summer weeds more than doubled summer fallow rain storage at both sites. This difference in soil water has affected the early growth of the subsequent canola crop. We conclude that rainfall amount and distribution is a major factor determining how efficiently rainfall is captured and stored in the soil. Small rainfall events with no follow-up rain usually do not infiltrate deeply enough into the soil and are evaporated rapidly. Weed control has the biggest management influence on fallow efficiency, and tools need to be developed which allow managers to assess whether control of summer weeds following rain events of varying magnitude is likely to be profitable.

### Key Words

Summer rain, fallow efficiency, weeds, residue

### Introduction

In the grain-growing regions of Australia dominated by winter rainfall, a fallow period of 4-6 months follows the harvest in early summer and precedes planting of the subsequent crop in late autumn (Fischer 1987). This summer or 'short' fallow occurs when mean monthly rainfall is low (20-50 mm) and evaporation rates high (250-300 mm), with a significant portion falling in large, infrequent events. Rainfall in excess of 20-30 mm can infiltrate more deeply into soil and be stored for subsequent crop growth. Summer fallow or out-of-season rainfall has not traditionally been valued as a resource for cool-season crops in regions of winter dominant rainfall (Freebairn et al. 2006). This is because in-crop rainfall in this environment has historically been adequate to achieve the attainable yield of cereal crops, particularly wheat, as determined by non-water limiting factors such as nutrient availability and root diseases etc (Angus and Good 2004). However, recent increases in water productivity (e.g. increased use of fertiliser nitrogen, control of pathogens with break crops) and a decade of below-average growing season rainfall, particularly during spring, have increased awareness of the contribution that summer fallow rain may make to subsequent wheat crop yield.

In their modeling analysis of farming systems in the Mallee region of north-west Victoria, Kirkegaard and Hunt (2010) identified that enhancing the capture, storage and use of summer fallow rainfall is one of the most effective ways of improving wheat yields. The proportion of fallow rain that is stored and made available to a subsequent crop is influenced by the management of weeds, crop residues and soil tillage during the fallow. Weeds transpire water that could otherwise be used by subsequent crops (Fromm and Grieger 2002). Retaining crop or pasture residues minimises the physical impact of raindrops on the surface soil, maintains structural integrity and infiltration rates, and reduces run-off (Felton et al. 1987). Residues also slow the flow of water on the soil surface, allowing more time for infiltration (Freebairn and Boughton 1981) as well as slowing soil evaporation following rainfall events. If conditions remain dry for an extended period, total evaporation will be unaffected by residues (Felton et al. 1987). Tillage can increase or decrease fallow efficiency according to numerous mechanisms that depend on site and season, but most authors agree that the greatest and most reliable influence of tillage on fallow efficiency is through weed control (Fischer 1987).

The aim of this study was to determine how the control of summer weeds, residue cover and tillage, influence the accumulation and storage of summer rain, on two Mallee soils types in Victoria and how this in turn affects subsequent crop yield.

## Methods

This experiment was established 13 km south of Hopetoun, Victoria and was repeated on two different soil types, located 2 km apart. Soil is sand over sandy loam (Calcarosol) and a clay loam over a medium clay with subsoil constraints (Sodosol) typical of the region. The site with the Calcarosol was on top of an east-west dune while the Sodosol was located on a low-lying flat (swale). Both sites were in paddocks that had a wheat stubble load of 2.4 t/ha and 2.7 t/ha at the clay and sand sites respectively. Rainfall pattern at Hopetoun is similar to a Mediterranean-type environment, with an average of 230 mm falling during the growing season (April to October) and 112 mm during the summer fallow period (November to March).

The experiment was established in December 2008 with six summer fallow management treatments in a randomised split block design with four replicates. The treatments were;

- Standing stubble
- Standing stubble and summer weeds
- Slashed stubble
- Bare earth
- Bare earth and summer weeds
- Stubble retained and cultivated

The stubble treatments were applied on 10 December 2008 with the stubble on treatments 3, 4 and 5 being slashed and raked from plots in treatments 4 and 5. Two intact soil cores per plot were taken on 11 December 2008, 22 April 2009 and again on 12 November 2009. Samples were segmented into depths of 0-10, 10-20, 20-40, 40-70, 70-100, 100-130 cm and bulked according to plot and analysed for gravimetric water content and mineral nitrogen. Following rain in December 2008, summer fallow weeds (volunteer wheat, *Cucumis myriocarpus*, *Citrullus lanatus*, *Heliotropium europeum*) emerged and weed densities were measured. In January 2009 treatments 1, 3 and 4 were sprayed and kept weed free until sowing. Treatment 6 was cultivated following rainfall events and subsequent weed emergence. Weeds in treatment 2 and 5 were allowed to continue growing over the summer.

All treatments were sown to barley cv. Hindmarsh on 23 April 2009 and were managed so that nutrients, weeds or disease did not limit yield. Dry matter production was measured at crop anthesis and maturity. Grain yield was measured with a plot harvester. Gravimetric soil samples taken following harvest on 12 November 2009 are assumed to be at the crop lower limit and are used to calculate plant available water (PAW). The six weed and stubble treatments were imposed again on 18 November 2009 and the experiment repeated as above over the summer of 2009/2010. All treatments were sown to canola cv. Scorpion on 28 April 2010 and at time of writing have been managed so that nutrients, weeds or disease

will not limit yield. Normalised Difference Vegetation Index (NDVI) was measured at the 4 leaf stage with a hand held GreenSeeker<sup>?</sup> (NTech Industries Inc., Ukiah, California).

## Results and Discussion

From November 2008 until April 2009, 90 mm of rain fell at the site. At sowing there were no differences found in plant available water (PAW) between the treatments at the two sites. When treatments were averaged for both sites there was approximately 10 mm more water available from 0-40 cm depth at sowing in the treatments with stubble and no summer weeds compared to the treatments with weeds (Table 1).

April to October rainfall in 2009 was 213 mm at the sand site and 202 mm at the clay site. Both sites had good crop establishment, 123 plants/m<sup>2</sup> at the sand site and 110 plants/m<sup>2</sup> at the clay site. There was no significant ( $P>0.05$ ) treatment effect on plant dry-matter at flowering (5 t/ha clay site and 5.2 t/ha sand site) or maturity (6.6 t/ha clay site and 6.7 t/ha sand site). There was no treatment effect on grain yield or screenings; mean grain yield at 12.5 % moisture was 3.4 t/ha at the sand site and 2.8 t/ha the clay site.

**Table 1. Mean plant available water (PAW) at sowing 2009 (0-40cm) for all treatments at both sites and averaged for both sites.**

Treatment	PAW Sand (mm)	PAW Clay (mm)	PAW Mean for both sites (mm)
Standing Stubble	2	1	1 <sup>b</sup>
Standing Stubble + Summer Weeds	- 11	- 3	- 7 <sup>a</sup>
Slashed Stubble	4	0	2 <sup>b</sup>
Bare Earth	- 1	- 1	- 4 <sup>ab</sup>
Bare Earth + Summer Weeds	- 12	-8	- 10 <sup>a</sup>
Stubble retained and cultivated	- 4	- 4	- 4 <sup>ab</sup>
P Value	NS	NS	0.04
LSD (P=0.05)	-	-	8

Despite a total of 90 mm of rain falling during the summer of 2008/2009, no individual event was larger than 27 mm. Rainfall events smaller than 20 mm do not infiltrate deeply enough into the soil to be protected from evaporation (see Verburg et al. in these proceedings). This meant that controlling summer weeds and retaining stubble only increased the amount of plant-available water at sowing at both sites by a marginal amount (~10 mm, Table 1). Based on known values of transpiration efficiency for dry matter and grain (French and Schultz 1984), a difference of 10 mm of soil water will, at best, result in only an extra 0.6 t/ha of dry matter or 0.2 t/ha of grain. In field-based experiments on spatially variable soil types such as those in this study, it is difficult to detect such a level of difference in either dry-matter or grain yield.

In summary for 2008/ 2009, this experiment described a worst-case scenario for farmers who wish to manage summer fallow weeds. Sufficient rain fell to cause summer weeds to emerge, but not to store a large amount of soil water. This meant that an investment in summer weed control was not met with a measurable return in crop yield, although there may be implications for weed seed banks if weeds are left to grow.

During the 2009/2010 summer fallow there was a total of 224 mm rain at the sand and 254 mm at the clay site, including individual events of 128 mm and 163 mm at the sand and clay sites respectively. These rain events were large enough for water to infiltrate and be stored deep in the profile where it is less prone to evaporative losses. This was evident at soil sampling on 30 March 2010 where there were large amounts of plant-available water at both sites (Table 2) where weeds were controlled. In treatments where weeds continued to grow over summer there was significantly ( $P<0.05$ ) less plant available water.

**Table 2. Mean plant available water (PAW) at 30 March 2010 (0-130cm) for all treatments at both sites.**

Treatment	PAW Sand (mm)	PAW Clay (mm)
Standing Stubble	75 <sup>a</sup>	110 <sup>a</sup>
Standing Stubble + Summer Weeds	32 <sup>b</sup>	41 <sup>b</sup>
Slashed Stubble	85 <sup>a</sup>	116 <sup>a</sup>
Bare Earth	75 <sup>a</sup>	104 <sup>a</sup>
Bare Earth + Summer Weeds	40 <sup>b</sup>	28 <sup>b</sup>
Stubble retained and cultivated	70 <sup>a</sup>	100 <sup>a</sup>
P Value	0.01	0.05
LSD (P=0.05)	29	53

In contrast to 2008/2009, control of summer weeds in 2009/2010 resulted in much more water being stored in those treatments. Provided the 2010 crop is managed to its water-limited potential, this could translate to differences in yield. At the four-leaf stage NDVI was higher in treatments where weeds were controlled indicating that differences in soil water and perhaps nitrogen (results not available at time of publication) have resulted in more early dry matter production (Table 3). Analysis of historic summer rainfall patterns in the Mallee shows that the 2009/2010 outcome occurs in the majority of seasons. Hunt (2006) found that events large enough in magnitude to store water available for a subsequent crop occurred in 74% of years from 1976-2002, and whilst water storage was highly variable over that period, the mean was 24 mm. Analysis with APSIM at the Hopetoun site indicates the 2008/2009 outcome, where enough rain fell to establish weeds but there was no yield benefit from control, occurs in the minority of cases, but would happen more frequently on the Sodosol (26% of years in the last 120) than the Calcarosol (2%).

**Table 3. NDVI of the 2010 canola crop under the different treatments at the sand and clay sites.**

Treatment	Sand	Clay
Weeds (treatments 2 and 5)	0.10	0.13
No weeds (treatments 1, 3, 4 and 6)	0.16	0.24
P Value	0.05	0.01
LSD (P=0.05)	0.05	0.09

The canola crop will continue to be monitored during the 2010 season and the experiment repeated for another two years.

## Conclusion

The two seasons of this study illustrate that in the Victorian Mallee, summer fallow rain is a highly variable resource, contributing up to 100mm of additional available water as stored soil water at sowing. Control of summer weeds had the greatest impact on the amount of summer fallow rain stored. Crop residue and tillage made no significant difference in either season and did not affect subsequent crop yield in 2009. This finding is consistent with previously reported studies of summer fallow efficiency in southern Australia.

Management of summer fallows in the Mallee will be improved by the ability to predict whether rainfall events that cause summer weeds to emerge are of sufficient magnitude to be stored until the next growing season. In 2008/2009, weeds emerged but their control resulted in only small differences in the amount of water stored and no measurable increase in yield meaning that the cost of control would not have been recouped. Control of weeds in 2009/2010 is likely to significantly increase yield and provide a very good return on the cost of control. Rules of thumb must be developed that can help guide managers in deciding whether control of summer weeds will be economical or not.

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