Fallow management, water storage and wheat yield in southern NSW

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Take-home messages

● Yield benefits associated with better fallow water storage have been significant but variable in the dry seasons since 2001 in southern NSW. Factors influencing this variability are of interest.

● Weed control has more impact on fallow storage efficiency than stubble treatment.

● Left uncontrolled, weed flushes occurring in January and February have the most impact on soil water storage.

● Controlling these flushed in February prior to water extraction beyond the evaporation front minimises their impact.

● In summers with prolonged dry periods, the effects of stubble management will be small, even if there is a single large rainfall event.

● The value of additional water stored at sowing varies significantly depending on seasonal conditions. The French and Schultz estimate (20 kg/ha/mm) provides a reasonable average but this has little predictive value in specific seasons.

● Water stored in the subsoil (below 1 m) is converted to grain more efficiently (average of 30 kg/ha/mm) than the French and Schultz estimate of 20 kg/ha.mm.

● Counter-intuitively, subsoil water is more valuable in wetter environments due to its more frequent occurrence and more efficient conversion to grain.

The value of stored water in southern NSW

Grain farmers in the northern wheat-belt have always paid particular attention to maximizing water storage during the summer fallow because it constitutes a significant proportion of the water available for crop growth. Traditionally, less importance has been placed on stored soil water in southern NSW. However the series of dry seasons since 2001 has re-focussed attention on water conservation due to some dramatic impacts on crop response attributed to management-related differences in stored water – in some cases harvesting a crop or not. Should we pay more attention to fallow water storage in the longer term or are we too influenced by a rare series of dry years? Increases in average crop yields, long-season dual-purpose crops and increased areas of perennial pastures all increase water use, and combined with possible future climate shifts may mean that we will be farming drier and drier soils. Managing fallow water storage may therefore become a more important feature of future cropping systems in the area. But what strategies will provide the greatest benefit?

We have been conducting field experiments and simulation studies to investigate different aspects of the soil water budget of wheat crops on Red Kandosol soils in southern NSW.

Summer fallow management effects

The effects of different summer fallow management practices on soil water storage were studied using a replicated field trial with five treatments: (1) stubble harvested for straw with strict weed control, (2) stubble left standing after harvest with or (3) without weed control, and (4) stubble flattened (as with Coolamon harrow) with or (5) without weed control. The experiment was located on a Red Kandosol at Charles Sturt University, Wagga Wagga. It was complemented by computer simulations for the same soil and similar management controls, using historical weather data (1960-2006) to explore the effects of different weather conditions.

Experimental results (2003 to 2006)

During 2003-04 and 2004-05 weed control, flattening of stubble and harvest of straw did not have a measurable effect on soil water storage at the end of the summer fallow. Both summers were extremely dry (< 85 mm between January and April). In 2005-06 there was no effect of flattening the stubble, but treatments with stubble finished on average 10 mm wetter than the bare treatment, and treatments in which weeds were not controlled were 12 mm drier than the bare treatment.

Simulated results (years from 1960 to 2006)

Over 46 years of simulations, strict summer fallow weed control was the most effective measure to increase soil water storage with a higher average effect than flattening of stubble (Table 1), and a more frequent occurrence of larger effects of > 20 or 30 mm. Harvesting straw reduced soil water storage by 12 mm on average.

Table 1: Summer fallow management controls and their effect on soil water storage at sowing.

	Average effect*	Proportion of years in which effect is		
		< 5 mm	> 20 mm	> 30 mm
Weed control (standing stubble)	+12 mm	41%	24%	17%
Flattening stubble (with weed control)	+ 6mm	54%	9%	0%
Harvest straw (with weed control)	-12 mm	24%	22%	1%

An analysis of the impact of rainfall amount and distribution on the simulated fallow management impacts showed the following:

- Flattening stubble had a bigger impact on water conservation in years with rainfall distributed over several events (e.g. 1973, 2001) rather than in large single events (e.g. 2002, 2003).
- If a rainfall event is followed by a dry period, soil evaporation under stubble can catch up to that with less stubble cover, minimising its cumulative effect.
- In years with very high summer rainfall (> 300 mm, e.g. 1989, 1994) residue effects were minimised due to full wetting up of the profile.
- In these very wet years, weed control made less difference, except when profile wetting occurred early (by January or early February as in 1971).
- Summers dominated by smaller rainfall events or those with late germinating rain (after February, e.g. 1999) benefited less from weed control.
- In very dry summers (2004, 2005), management impacts on soil water storage were negligible, especially if prolonged dry periods occurred.
- The total amount of rainfall between harvest and sowing on its own was not a good predictor of the benefits of weed control because of carry over of late rainfall from previous cropping seasons (e.g. summers of 1967, 1986, 2006).

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* for the conditions of the simulation scenarios, incl. single flush of grassy weeds germinating on at least 25 mm in December to February or 20 mm in March to April.

Conditions of the simulated scenarios above, such as soil type, location and rainfall, depth of weed roots, and stubble levels influence the *absolute* effects predicted, such as the long term average effect in Table 1. The *relative* effects and the analysis of the impacts of rainfall patterns are less sensitive to the precise definition of the simulated scenarios.

Stored water impacts on yield

The benefits of stored soil water at the end of the summer fallow for subsequent crop yield depends strongly on the growing season rainfall and its distribution. In a rotation experiment at Bethungra in 1994, previous crop and pasture treatments (including fallow) had generated a range of starting soil water contents, and each additional mm was converted to 18 kg/ha/mm of wheat grain yield in that dry season. In 2004, wheat grown on field plots deliberately wet to different depths under a rainout shelter converted the additional stored soil water to grain yield at 29 kg/ha/mm.

We used a simulation study to generate a range of different starting subsoil water contents by changing the simulated weed management during the summer fallow. Weeds were either left un-sprayed, or completely controlled from fortnightly intervals commencing in January. Simulations were carried out for the years from 1960 to 2006 and wheat crops were then simulated on the resulting soil profiles. Figure 1 shows the variation in the response to additional stored water for a selection of 6 years from the 47 simulated. The conversion of the additional water stored varies widely in different seasons although the widely used French and Schultz estimate for WUE provides a reasonable average.

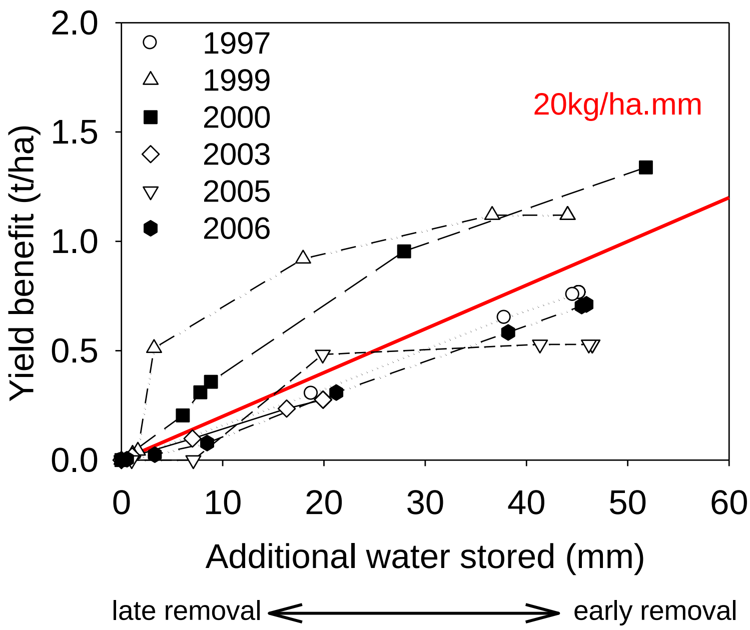

Figure 1. Simulated yield benefit (t/ha) from increased soil water storage (mm) generated by increasing earliness (fortnightly intervals from harvest) of strict fallow weed control in a selection of years at Cootamundra on a Red Kandosol.

Subsoil water – deep and meaningful?

The value of water stored deep in the profile (> 1m) is sometimes overlooked as crops generally utilise water from upper layers preferentially and may not have sufficient time to grow enough roots into the deep soil to extract the available water. Our studies on wheat root growth and water use in the subsoil on Red Kandosols in southern NSW have shown that:

● Wheat roots generally grow down at an average rate of 1.2 cm/day between sowing and anthesis so that on most soils wheat roots reach 1.6 m by anthesis, and can reach 1.8 m in fully wet profiles. In an analysis of 36 field studies, root descent was restricted by incomplete profile wetting in one-third of the studies.

We ran simulations to determine how important the subsoil water would be in different locations and seasons, following either lucerne removed in December (dry soil throughout) or an annual crop (wetter subsoil). We found that;

● At Ardlethan following a lucerne crop removed on 15 December, the soil profile did not wet below 1.2 m in 78% of years compared to only 33% of years at Cootamundra. This changed to 33% and 5% at the sites following an annual crop.
● Root access to the subsoil (1.2 to 1.8 m) increased wheat yield by an average of 0.6 and 0.3 t/ha following an annual crop or lucerne respectively at Cootamundra and by 0.4 and 0.1 t/ha at Ardlethan.
● Subsoil water was used very efficiently (average 30 kg/ha.mm; range 0 to 60 kg/ha/mm), because it was used late in the season when assimilate is being directed to grain. Yield benefits of up to 1 t/ha were gained from extraction of subsoil water at both sites in some seasons.
● Counter-intuitively, the results suggest that subsoil water will be of more value in higher rainfall environments due to its more frequent occurrence, and in above average seasons due to more efficient conversion to grain.
● Strategies designed to improve subsoil water use need to be targeted appropriately according to the frequency of subsoil water availability at the sites of interest as influenced by soil type, rainfall, its variability and local crop sequence practices.

These results indicate that we should not ignore fallow management to enhance subsoil water storage in wetter environments because it is more likely to be present and converted efficiently to grain when present in these environments.

Further Information

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