How important is straw for yield of no-till crops on heavy soils in the low-rainfall southern Mallee?

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Abstract

This paper tests the hypothesis that no-till crops, grown on clay soils in the low rainfall Southern Mallee environment would yield better, if more straw/biomass could be retained from the previous crop. The evaporation rate from small rainfall events on clay soils is high, so using stubble to reduce evaporation may be important in no-till systems especially on wide (30 cm) row spacings. Wheat straw (5 t/ha) was added over summer to no-till plots in a rotation trial, and ground cover, straw dry matter, soil water and nitrogen and crop growth measured over the following growing season. Crops with straw grew 81 g/m^2 more after anthesis ($p=0.036$), and yielded 0.26 t/ha more than no-till crops without straw (0.72 t/ha, $p=0.001$). Soil throw at sowing covered stubble but it was still a large proportion of ground cover in straw plots. Stubble in control plots had mostly decayed or been buried by late August, whereas added straw mostly decayed between late August and harvest. Straw increased surface soil water, and early in the season reduced surface soil mineral nitrogen, but crops had similar nitrogen offtake in grain. While straw did increase yield, there would not be enough straw in the following season to have a similar effect. Lack of straw residue caused by low rainfall and crop yield may in turn reduce yield in no-till cereal crops in the area. Farmers should consider management that minimises the burial and breakdown of residue from the previous crop to maximise the benefits.

Key Words

Soil moisture, nitrogen immobilisation, cracking calcarosol soil, farming system trial

Introduction

No-till in the southern Mallee describes the practice of weed control with herbicides, low-disturbance sowing with knife-points and press-wheels, and retention of crop residue (apart from grazing). No-till has been poorly adopted in the southern Mallee, which combines clay soils (high evaporation) with low rainfall (ca. 340 mm average annual). No-till adoption has been rapid since 2002 in the sandier, lower rainfall Mallee to the north, and has been a feature of cropping practice since the 1980s on the clay soil, medium rainfall (370-450 mm) Wimmera to the south. There is a need to understand whether there are biophysical reasons for this, or whether the causes are socioeconomic and cultural.

The Birchip Cropping Group Farming Systems Trial was established in 1999 to compare four ‘farming systems’ used by farmers in surrounding areas, on a typical southern Mallee site. The site has low April-October rainfall (177 mm average since 1999, 252 mm long-term median) and cracking, calcarosol soil with high salt (EC1:5 av. 1.0, up to 1.4 dS/m) and boron (av. 16, up to 33 mg/kg) in the rootzone (40-60 cm). A feature of the early years of the trial was the relatively poor early performance of the ‘No Till’ system, which was championed by a Wimmera farmer. Although much of the poor economic performance could be attributed to crop choice, the No Till champion also proposed that the yield gains that might be expected from implementing no-till in other areas were limited by the combination of low rainfall, high evaporation on clay soils, and inability of crops to produce stubble loads similar to those in the Wimmera (4-8 t/ha). Stubble may be important to reduce evaporation, but could also affect nitrogen nutrition *via* mineralisation/immobilisation in surface soil. Previous studies in the area have been in rotations with long fallow, at narrower row spacing, on unconstrained soils in wetter years and have measured inconsistent yield responses to stubble (O'Leary and Connor 1997b). This paper reports the results of an in-practice test of the No Till champion’s hypothesis.

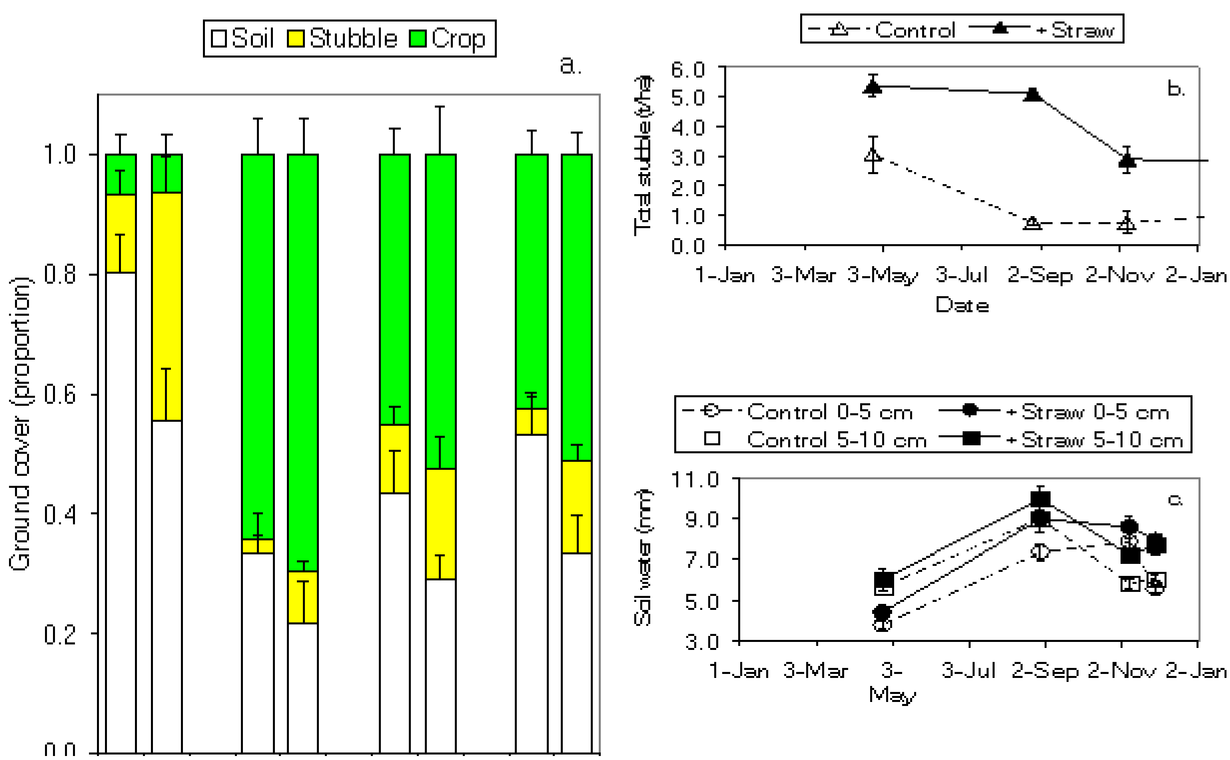
Methods

Treatments were applied in Jan-Mar 2007 to five 2006 cereal crop plots from the ‘reduced till’ and ‘no till’ systems in the BCG FS Trial. Plots in the ‘reduced till’ system had since 2003 been managed with the same weed control and establishment methods as ‘no till’ and were included to expand the range of available plots. Wheat straw at 5 t/ha was applied to a randomly selected half of each plot, with the other half retained as a control. Whole plots formed the blocks of a randomised complete block design. Each plot half (treatment unit) had been monitored separately since harvest 2005. There was small-scale spatial variation at the site associated with gilgais (crab-holes), and 2005/6 soil measurements showed reasonably large differences between plot halves before treatments were applied. To account for this, soil nitrogen and water were analysed in terms of change since sowing 2006, rather than the absolute values.

Straw treatments received an extra glyphosate spray to control volunteer wheat growth in early April. Four of the five plots were sown to wheat and barley in May 2007 (the champion left one fallow). Crops were sown with knife points and press-wheels at 305 mm spacing (225 mm in 2006). All five plots were included in analysis to May 2007, with crop plots only used thereafter. A sowing error in plot 16 required resowing of the plot, but in-crop herbicide damaged strips of the original sowing left for this experiment, hence not all measurements were made on this plot and only results from the resown crop (mid-June) were presented. There was no evidence of significant root or leaf disease during crop inspections in September.

Soil volumetric water content and available nitrogen were measured pre-sowing (2006 and 2007) and post-harvest (2007), with 4 soil cores to a depth of 1 m (0-10, 10-40, 40-70 and 70-100 cm) per plot. Volumetric water was calculated using estimates of bulk density for the site, and ‘available’ nitrogen measured as nitrate + ammonium. Ground cover was measured on digital photographs taken at waist height. Crop dry matter was measured at growth stages 31, 65 and 99, with ten 50 cm lengths of row harvested per half plot. Stubble dry matter and soil water content 0-5 and 5-10 cm was measured using the same transects. Grain yields were measured with 6 plot-harvester swaths per plot (1.6 m in width).

Results



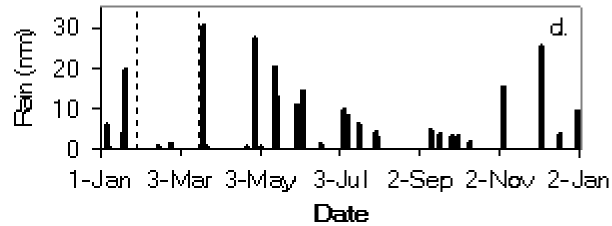


Figure 1a-d. (a) Proportion of crop (green), soil and straw as ground cover (a) in normal crops (control) and crops with 5 t/ha straw (+straw). (b) Stubble dry matter in control and straw treatments. (c) Surface soil water 0-5 and 5-10 cm under control and straw treatments, and (d) rainfall events during the study, with the period during which straw was applied in windrows and spread marked by dashed lines. Error bars are standard error of the mean, data from all plots excluding 6 (no crop).

The straw treatments affected the surface and soil water properties of crops throughout the growing season. Straw treated crops had less soil ground cover in mid-June, 0.55 compared with 0.79 in the control (Figure 1a, p=0.012). Soil throw from sowing partly covered the straw early in the season, and crop canopy further covered straw later in the season. The ground cover classification did not record dead crop separately from straw, hence mid-season straw/soil measurements were not significantly different. More crop (0.51 vs 0.42, p=0.028), less soil (0.33 vs 0.53, p=0.012) and more straw covered the ground in straw treatments at harvest. More (at least 2.1 t/ha) stubble dry matter was maintained on straw plots throughout the season (Figure 1b), decreasing with sowing-related burial in control treatments, and during September on +straw treatments.

Soil water for straw plots was generally higher (Figure 1c), both at the soil surface (0-5 cm) and just below (5-10 cm). The differences were not significant when measured on April 25, just before the breaking rain (p>0.257). Significant differences were measured 0-5 cm in late August following a relatively dry period (p=0.025; p=0.07 in the 5-10 cm layer), at 5-10 cm following early harvest rain (p=0.01), and at both depths (p<0.009) just before rain at the start of December. The size of the differences was not large (1.0 – 4.0 mm 0-10 cm) but may have had a cumulative effect on infiltration in the 2007 season, with many smaller winter/spring rainfall events (Figure 1d).

Table 1. Effect of straw treatment (in windrows 29/1/2007, spread by 19/3) on change (Δ) in soil water and mineral nitrogen between 7/4/2006 and 27/3/2007. Between 29/1 and 27/3/2007 there was 30.5 mm rain on 21/3.

	Δ Soil water (mm)			Δ Soil mineral nitrogen (kg/ha)		
Depth	Control	Straw	LSD[a]	Control	Straw	LSD[a]
0-10 cm	+16.1	+16.8	n/s	-0.5	-7.1	6.7
10-40 cm	+3.2	+10.9	6.2	+20.9	+18.6	n/s
40-70 cm	-1.5	+5.5	n/s	+4.7	+1.6	m/v

70-100 cm	+3.4	+5	n/s	-1.7	-1.7	n/s
Total (0-100 cm)	+21.3	+38.2	n/s	+22.0	+11.5	n/s
			Absolute (27/3/2007)			
Total (0-70 cm)	174	175	n/s	115	89	25

a. LSD = Least Significant Difference at p=0.05. n/s = not significant, m/v = 1 missing value (which leads to discrepancy between the total and sum of means presented).

Table 2. Growth and yield components of cereal (barley and wheat) crops on control and 5 t/ha straw plots in 2007.

			Treatment (3 reps)			Inc. resown (4 reps)		
Measurement	Unit	Timing	Control	Straw	LSD[a]	Control	Straw	LSD[a]
Plant density	(/m^2)	GS30	138	145	n/s			
Dry matter	(g/m^2)	GS30	99	89	n/s	86	84	n/s
		GS65	351	326	n/s			
		GS99	416	472	n/s	367	426	n/s
		99-65	+65	+146	68			
Spike DM	(g/m^2)	GS65	47	42	n/s			
		GS99	162	198	n/s	141	173	n/s
Spikes	(/m^2)	GS65	283	301	n/s			
		GS99	309	383	n/s	282	361	75
Yield (hand)	(g/m^2)	GS99	124	154	n/s	108	135	n/s
Yield (machine)	(t/ha)		0.85	1.11	0.08	0.72	0.98	0.04

Protein (machine)	(%)	16.7	14.2	n/s	16.5	14.9	n/s
N removal (machine)	(kg/ha)	22.7	25.2	n/s	19.1	22.8	n/s
Grain weight (machine)	(mg)	34.3	34.8	n/s			
Harvest Index (hand)		0.31	0.33	n/s	0.30	0.32	n/s

a. LSD = Least Significant Difference at p=0.05. n/s = not significant.

Significantly more water was conserved in straw plots in the 10-40 cm soil layer in late March 2007 (+7.7 mm, p=0.027, Table 1), compared to early April 2006 when there were no treatment differences between plot halves. The straw treatments also led to a near-significant reduction in surface soil nitrogen (-6.6 kg N/ha, p=0.053, Table 1). In absolute terms straw plots 0-70 cm had significantly less mineral nitrogen (p=0.043, Table 1) and similar water, but the straw effect must be considered in the context of pre-existing (though non-significant) mineral nitrogen and soil water differences (both lower for straw plots) measured in 2006.

Crop growth and yield were analysed across the three plots with complete measurements (19, 24, 27) and where possible all crop plots (including resown plot 16, Table 2). The straw treatments had significantly higher machine harvested yields (+0.26 t/ha, p=0.001,Table 2), and more spikes at maturity (+79/m^2, p=0.044). Dry matter growth on straw plots between anthesis and maturity was significantly higher (+81g/m^2, p=0.036), but up to anthesis was quite similar. Grain weight was similar, implying yield difference mostly related to grain number. The only difference evident at anthesis was consistently more spikes per unit of spike dry matter (all straw treatments rank higher but too variable to be significant, p=0.182). Grain protein was much lower in some, but not all straw plots. There was a negative association between the effect of straw on grain protein and dry matter: plots with much higher dry matter in the straw treatment also had much lower protein at harvest, and *vice versa* (not shown).

Discussion and Conclusion

The No-Till farmer champion's hypothesis seems plausible and may highlight a biophysical factor affecting no-till cropping on constrained soils in the southern Mallee. Amounts of straw residue similar to that produced by a reasonable crop did increase yields in no-till cereal crops in 2007, but the crops themselves would have produced insufficient straw residue to have the same effect again in 2008. Farmers using no-till techniques in the Southern Mallee need to find ways of maximising the benefits from the available straw residue in their cropping system.

The main effect of the straw on crop growth came around and after anthesis. This timing reflected mainly a water conservation effect of straw, probably mostly before anthesis because there was little spring rainfall. Differences in soil water storage were measurable both 10-40 cm soon after applying the straw (Table 1) and at the surface through the season, even after a relatively dry period during spring (Figure 1c). Previous studies have measured stubble-related water stored at up to 1.5-2.0 m but generally in association with higher rainfalls and a long fallow period (O'Leary and Connor 1997a).

The seasonal patterns of ground cover (Figure 1a) and stubble dry matter (Figure 1b) demonstrate the variable importance and effects of straw residue in this environment. Stubble made up a large proportion of ground cover as the crop established but was less important with a large crop canopy after good winter rains. Stubble again became important in spring as the crop senesced. Soil throw (sowing) was an important factor reducing stubble ground cover, although stubble under and mixed with loose soil may still have been a barrier to evaporation. There was some stubble at sowing in control plots, but little of this remained in late August (Figure 1b), possibly because of disturbance/burial during the sowing process and subsequent decomposition. Inter-row sowing to reduce disturbance of standing stubble may be important for maximising the effects of the small amounts of straw residue available in these environments.

Better balance of nitrogen supply and hence pre/post-anthesis growth was unlikely as a mechanism for yield increase in 2007 but did have measurable effects. Small reductions in soil mineral nitrogen were measured early in the season (Table 1), but overall nitrogen nutrition was adequate relative to yield. Any nitrogen-driven reduction in pre-anthesis growth was insufficient to explain the increased post-anthesis growth with straw, and was not accompanied by the significant decrease in harvest index expected in control plots if they had too much pre-anthesis growth. Net nitrogen removal in grain was finally slightly higher in the straw treatments, with increased yield offsetting decreased protein.

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