Poor Wheat Yield Response to Conservation Cropping – Causes and Consequences during 10 years of the Harden Tillage Trial

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ABSTRACT

A long-term tillage trial was established in 1989 on a red earth soil at Harden on the southern slopes of NSW, which has been cropped continuously in a breakcrop/wheat rotation. Stubble retention and direct-drilling (SR/DD) consistently reduced the early vigour and yield of wheat compared with late stubble burning and minimum cultivation (B/C) despite similar plant populations and improvements in a range of soil attributes often associated with "soil health." These effects did not diminish over time. Inhibitory Pseudomonads, and to a lesser extent *Rhizoctonia,* have been implicated in reducing the early vigour of direct-drilled wheat, and foliar diseases (e.g. yellow leaf spot) often survived on stubble through the breakcrop year and infected the following wheat crop. A consequence of both the reduced vigour and yield of wheat and the increased water infiltration on the SR/DD plots was an increase in residual subsoil water (up to 70 mm) remaining at harvest. In 2000, drainage during winter below 1.1 m was 77 mm on SR/DD compared with 25 mm in B/C. On permeable soils in high-rainfall areas, the risk of increased drainage may be an unfortunate but important consequence of adopting conservation farming systems if the attendant growth constraints cannot be overcome.

Key words

Conservation cropping, wheat, soil health, direct drill, stubble, drainage.

INTRODUCTION

Direct-drilling and stubble retention are widely promoted throughout the Australian grains industry as components of conservation cropping systems to sustain soil fertility and crop production. Despite the established benefits in terms of erosion control and improvements in a range of soil properties, crop yield responses to conservation cropping are small in south-eastern Australia (8). The failure of crops to respond to the improved soil conditions not only discourages and slows adoption, but may also have significant impacts on other aspects of the cropping system. Cropping systems which promote greater water infiltration and storage but do not increase the use of that water by crops may increase the risk of deep drainage and N leaching, particularly on highly permeable soils in higher rainfall areas. We established a tillage trial in the higher rainfall zone at Harden (600 mm) in 1989, to investigate the effects of stubble and tillage management on soil conditions and crop growth. We have previously reported reduced early vigour and yield and associated increases in residual subsoil water and N under SR/DD treatments (7). This paper summarises results from a further 10 years at the site and considers the causes and consequences of poor yield response to conservation cropping, in particular the potential for increased drainage and N leaching.

METHODS

The site was established on a red earth soil at Harden on the southern slopes of NSW and has been continually cropped in a wheat/breakcrop rotation since 1989 as follows: Oat/Wht/Lup/Wht/Can/Wht/Lup/Wht/Pea/Wht/Can/Wht. A factorial combination of stubble burning (April) or stubble retention (bashed flat immediately following harvest), and cultivation (one pass 2 weeks prior to sowing) or direct-drill treatments (no pre-sowing cultivation) have been maintained and monitored at the site. In this paper we present data for wheat crops under the Burn/Cultivate (B/C) and Stubble retain/Direct drill (SR/DD) treatments only. During the wheat phase, soil Min-N and water were measured gravimetrically at sowing and harvest and routine plant growth measurements included: establishment counts; biomass at DC30, anthesis and final harvest; maximum rooting depths; yield components; and grain protein. Detailed descriptions of the site, soil type and the general methods used have been reported previously as follows; treatment description, plant growth, root growth, root disease, soil Min-N and soil water (7); soil N and C, microbial biomass (3); soil biota (5, 10, 11); inhibitory activity of Pseudomonads (12).

In 2000, soil drainage below 1.1 m was measured in the B/C and SR/DD treatments using a new instrument called a “tube tensiometer”, the installation and operation of which is described by Hutchinson and Bond (6). Pairs of these instruments were buried at a depth of 1.0 m and 1.2 m where soil water potential and hydraulic gradient were continually measured. Deep drainage was estimated from these data using Darcy’s law, and an estimate of hydraulic conductivity for subsoils typical of the area (2). The model for hydraulic conductivity was that of van Genuchten (13) with Ks = 3 cm/hr, α =0.08, n = 1.1, m = 0.091 and l=0.5.

RESULTS AND DISCUSSION

Soil conditions

A range of soil physical, chemical and biological measurements have been taken at the site during the course of the experiment. The bulk density of the seedbed (0-10 cm) measured in winter was higher in SR/DD plots (1.48) compared with B/C (1.35) which led to higher soil strengths measured during establishment (7,9). There were no differences in a range of chemical properties including EC, pH, Min-N, P, K, CEC, Cu, Fe, Mn, Zn, after 6 years (11), nor in soil Min-N at sowing in any year (data not shown). Although Min-N did not differ, the total N in the 0-5 cm layer after 10 years had declined from 0.185% to 0.118% in the B/C treatment and 0.151% in the SR/DD treatment. This represents decline rates of 45.2 and 25.2 kg N/ha/yr which are greater than those reported for similar treatments at a long-term tillage trial at Wagga (4), possibly due to fewer legumes in the rotation. In association with the maintenance of higher total N and C on SR/DD treatments, there were generally higher levels of different classes of soil biota including microbial biomass (3,11), earthworms (1), and the abundance of nematodes, mites and collembola (5,10,11). *Rhizoctonia solani* infection was evident at the site in 1990 (7), with minor incidence in DD plots only since that time. Yellow leaf spot (*Pyrenophora tritici-repentis*) was severe in 1996 and infection was more severe on SR treatments.

Poor seedling vigour

A feature of the study has been a consistent reduction in the early vigour of the wheat crops in the SR/DD treatment compared with B/C treatment. This occurred in all years despite no differences in the established plant populations. More detailed studies using intact cores taken from the site have demonstrated that these effects could not be overcome with added water or nutrients but could be completely alleviated with irradiation or fumigation, indicating a biological limitation (9). Although the increased incidence of *Rhizoctonia* contributed to this effect in some years, the poor vigour occurred in its absence. Recently it has been shown that the poor early vigour in direct-drilled crops at sites throughout southern NSW is highly correlated with growth inhibition by *Pseudomonas* spp. on DD soil (12). In 1998 and 2000, microbial measurements on wheat rhizosphere soil at the Harden site showed few effects on general soil organism groups, but increased inhibitory activity of the pseudomonad populations in SR/DD soil. (Table 1).

Table 1. Effect of tillage treatments on rhizosphere microbial counts and the inhibitory activity of *Pseudomonas* spp. isolated from wheat roots at 5-leaf stage at Harden in 1998 and 2000.

Year	Treatment	Organism counts (lnCFU/g dry root)					Inhibitory activity[A] (%)	
		Total Bacteria	Total Fungi	Gram -ve	Bacilli	*Pseudomonas.*	*Pseudomonas* Root	Shoot
1998	B/C	9.58	6.42	8.68	6.46	8.24	4.0	16.9
	SR/DD	9.99	6.79	8.77	6.20	8.96*	39.5*	36.8*
2000	B/C	9.74	6.85	9.16	na	8.03	17.0	16.5
	SR/DD	9.71	6.64	9.44	na	8.49*	26.8*	27.7*

[A]Inhibition of root (seminal root length) and shoot growth (leaf area) of wheat cv. Janz grown in agar tubes inoculated with whole communities of Pseudomonads isolated from each treatment as % of uninoculated tubes. * Means different at P=0.05; CFU=colony forming units.

Crop growth, water and N use

The reduced early vigour in SR/DD treatment persisted in most years and was reflected in reduced DC30 biomass and yield (Table 2). The exceptions for yield were the 1994 drought and the early sown crop in 1996. In the 1994 drought, the SR/DD treatment utilised residual stored water resulting from poorer growth in the previous seasons to outyield the B/C crop. In 1996 the split sowing time revealed that earlier sown crops compensated for reduced early vigour while the later sown crops did not. The average yield reduction for the SR/DD treatment compared with B/C was 9.4% while grain protein content did not differ. Although rooting depth differed in some years, the average maximum rooting depth was similar in both treatments.

A consequence of the reduced growth and yield of SR/DD treatment was higher levels of residual water left in the subsoil at harvest in some years. The difference, first reported in 1990 (21mm) (7) was higher in 1992 (71mm) and 1998 (28mm) but was not evident in the 1994 drought or in any of the 1996 sowings. The magnitude of the difference is highly dependent on the distribution of rainfall but indicates that a combination of improved infiltration, less evaporation and reduced crop growth results in less water use and greater residual water in some seasons, potentially increasing the risk of drainage in subsequent seasons. There was some evidence that increased residual subsoil water coincided with residual subsoil Min-N in 1990 and 1994, however significantly more Min-N remained in the B/C treatment in 1996 (Table 2). This appears to have resulted from cultivation-induced mineralisation of N from the 1995 lupin residues followed by leaching by the high rainfall in autumn and late spring in 1996. Thus despite potential for greater drainage in the SR/DD treatment, N leaching may be exacerbated by cultivation, particularly following legumes.

Table 2. Effect of tillage treatment on growth, yield, rooting depth and residual water and N in the subsoil (50-160cm) for wheat crops at Harden from 1990-2000. *Means different at P=0.05.

Year harvest (SD)	GSR (mm)	Var.	Treat.	DC30 (g/m2)	Grain yield (t/ha)	Grain protein (%)	Root depth (cm)	Available water[A] and N at 50 – 160 cm depth Water (mm)	Min-N (kg/ha)
1990	474	$bird	B/C	52	3.2	12.7	150	45	51
(16/5)			DD	37*	2.4*	13.7	130*	66*	78*
1992	343	Rosella	B/C	105	8.3	9.3	135	34	46
(5/5)			DD	83*	7.6*	9.3	135	107*	58
1994	176	Janz	B/C	170	0.7	18.2	115	35	54
(15/6)			DD	133*	1.2*	15.4*	105	40	73*
1996S1	517	Janz	B/C	232	6.1	10.9	125	88	116
(9/5)			DD	172*	6.2	10.3	110	84	67*
1996S2	517	Janz	B/C	150	6.0	10.5	105	86	115
(20/5)			DD	121*	5.2*	10.8	120	96	86*
1996S3	517	Janz	B/C	92	5.3	11.4	100	103	129
(31/5)			DD	88	4.6	11.2	110	100	78*
1998	453	Janz	B/C	153	7.5	10.9	110	59	79
(19/5)			DD	116*	6.2*	10.2	125	87*	69
2000	na	Janz	B/C	129	na	na	na	na	na
(19/5)			DD	96*	na	na	na	na	na
Mean			**B/C**	**135**	**5.3**	**12.0**	**120**	**53**	**84**
			DD	**106**	**4.8**	**11.6**	**120**	**79**	**73**

[A] water present above the lower limit of 190mm; GSR=April-October rainfall; Long-term GSR mean for Harden = 385mm; SD=sowing date.

Drainage in 2000

At the time of sowing wheat on 21 May 2000, there was more water in the profile (0-160cm) in the SR/DD treatment (435 mm) compared with B/C treatment (387 mm) and the difference was greatest in the 80-120cm layer. The mean soil water potential at 110 cm was also marginally higher in the SR/DD treatment (-4.93 kPa cf -5.15 kPa) and the hydraulic gradient was five times larger, resulting in an increase in drainage in week 1 (Table 3). This trend continued throughout winter, and by week 16 when the wheat had reached DC30, the total drainage was 77 mm for SR/DD, compared with 26 mm for B/C. Rainfall during this period (256mm) exceeded the long term mean (202mm), however 256 mm or more for the period could be expected in 20% of years.. Although the initial difference in water content (48 mm) contributed to the early differences in drainage, both profiles were above field capacity by week 5. The higher drainage from the SR/DD treatment which persisted beyond week 5 appears to have resulted from higher infiltration due to water entrapment by stubble, and the improved macroporosity of the soil, which reduced surface runoff.

Table 3. Rainfall and weekly drainage below 1.1 m estimated using tube tensiometers at Harden in 2000.

	21/5								Week						10/9		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	**TOTAL**
Rain (mm)	6	20	7	1	26	9	10	16	22	12	1	12	15	38	42	19	**256**
Drainage (mm)																	
B/CC	0.1	0.5	0.8	0.9	0.8	1.0	1.4	2.2	2.2	2.0	1.9	1.2	0.7	1.6	5.0	3.0	**25.5**
SR/DD	1.3	1.3	2.2	2.4	2.2	5.6	4.5	6.9	5.1	5.9	4.6	3.3	3.8	9.4	11.6	6.6	**76.7**

CONCLUSIONS

On permeable soils in high rainfall areas, the risk of increased drainage may be an unfortunate but important consequence of adopting conservation farming systems which improve the infiltration of water, but reduce water use by crops as a result of constraints to vegetative growth. Further research to overcome these constraints, and to develop other agronomic options to increase water use by crops is required.

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