“Buying a spring” – the water and nitrogen cost of poor fallow weed control

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Abstract
Research in southern NSW demonstrated that 50% of yield potential can be attributed to summer rainfall and summer fallow management as a result of increased stored water (increased by 49 mm) and nitrogen (N) (increased by 49 kgN/ha). This paper reports experiments conducted near Forbes in central NSW (2011 & 2012) to further evaluate the impact of summer weed control on subsequent crop yield, to investigate interactions with other macro-nutrients (P, K and S) and assess the profitability of replacing lost N (via summer weed uptake) with N fertiliser. Controlling summer weeds increased canola grain yield by 1.0 t/ha due to increased stored water (85 mm PAW) and mineral N (69 kgN/ha) at sowing. For every 1mm of stored water stored through summer weed control, soil mineral N increased by 0.6 kgN/ha. Summer weeds had no significant impact on topsoil P and K levels, or S to a depth of 90cm. Every $/ha invested in fallow herbicides returned $8/ha. Despite poor topdressing conditions, profitability of applying N fertiliser improved from $1 return on every $1 invested when weeds were not controlled to $3 return on every $1 invested in the complete weed control treatment. The study demonstrates the value of strict summer weed control to improve productivity and resource-use efficiency in southern cropping systems.

Key words
Water use efficiency, summer fallow management, summer weed control, nitrogen use efficiency.

Introduction
This experiment was part of a series of summer fallow management experiments funded by GRDC through the Central West Farming Systems “Rain & Grain” project. In three experiments conducted in a single year (2010), Haskins and McMaster (2012) found that complete control of summer fallow weeds increased subsequent wheat crop yield by 50%. Summer weed control was more important than stubble management as weed-free fallows increased both water and N availability. A dollar invested in herbicide to maintain fallows weed free averaged a $ 3.90 gross return across three experiments (Haskins and McMaster, 2012).

The aim of this experiment was to evaluate the impact of summer weed control during the summer fallow period on stored soil water and N, and the impact on subsequent grain yield over a further two years (2011 and 2012) as seasonal interactions on the value of stored water are likely. In addition, previous studies on effects of summer fallow weed control (Haskins and McMaster 2012, Hunt *et al*. 2013) considered effects on water and N, but not impacts on other macronutrients (P, K and S).

Methods
The experiment was conducted over two seasons (2011 and 2012) at a site located 30 km north west of Forbes NSW. A factorial design with three replications, four weed control treatments (Table 1) and three N fertiliser rates (0, 70,140 kg/ha N in 2011 and 0, 50, 100 kg/ha N in 2012). The weed control treatments ranged from no control (Nil) to complete control, with intermediate levels including missed or delayed treatments (Table 1). Individual plot size for each weed control treatment was 12m x 12m and all experiments were sown on 29 April (575CL canola - 2011) and 5 May (Bounty wheat - 2012) using a commercial seeder with narrow points and press wheels. The N fertiliser treatments (2m x 12m) were applied at early budding with urea ammonium nitrate (streaming nozzles) in 2011 and predrilled with urea in 2012 (plot seeder). Fertiliser (80 kg/ha MAP) was applied with seed. But no further nutrients were applied.

Table 1. Protocol for summer weed control treatments

Weed control treatment	Protocol
Nil	No summer spray (knockdown applied just prior to sowing)
Miss first	The first initial spray of the fallow period was not applied
Complete weed control	Herbicides applied approx 10 days after significant rainfall event (>20mm)
Delayed	Herbicides applied approx 24 days after a significant rainfall event (>20 mm)

Results

The seasonal conditions at the site were close to average in terms of long-term mean rainfall and both years experienced above-average February and March rainfall, but relatively low in-crop rainfall (Table 2). This rainfall pattern was likely to highlight the value of summer fallow management as significant rain occurred in summer while spring rainfall for crop growth was low.

Table 2. Monthly rainfall (mm) at Gunningbland.

Year	Rainfall (mm)												Total (mm)	In-crop (mm)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
2011	8	70	83	25	34	12	17	57	23	56	139	102	626	136
Decile	1	7	9	4	4	1	2	7	3	6	10	9		
2012	35	179	128	37	60	44	43	15	33	7	18	14	613	202
Decile	4	10	9	6	7	5	5	1	5	0	2	2		

Effects of fallow management on soil water

Complete control of summer weeds increased the amount of water available to the subsequent crop by 86 mm in 2011 and 50 mm in 2012 relative to the nil treatment (Table 3). Stored soil water in 2011 for the full (201 mm) or delayed (167 mm) treatment was greater than either the missed first (122 mm) or nil (115 mm) spray treatments (Table 3). The complete, delayed and miss first spray treatments also stored more water than the nil spray in 2012 with 147, 159, 155 and 97 mm PAW, respectively (Table 3). This may have been influenced by the higher rainfall over the summer fallow period in 2012 (Table 2).

Table 3. Effect of weed control treatment on plant available water (mm) and mineral N (kgN/ha)

Weed control treatment	Plant available water (mm)		Mineral N (kgN/ha)	
	2011	2012	2011	2012
Nil	116	97	44	80
Miss first	122	155	72	121
Complete	201	147	114	126
Delayed	168	159	82	113
l.s.d (P=0.05)	43	37	36	21

In both 2011 and 2012 the additional PAW was conserved between 15cm and 105cm depth. Summer weeds in the nil spray treatment reduced PAW to a depth of 120 cm (Figures 1, and 3 4). Soil water was measured after the 2011 harvest (115 mm PAW) with no difference between the spray treatments (data not shown).

Effect of fallow management on macronutrients

Summer weeds had a significant effect on available soil nitrogen at sowing in 2011 (P=0.02) and 2012 (P=0.007) (Table 3). Complete control increased the level of mineral nitrogen by 69 and 45 kg N/ha in 2011 and 2012, respectively. Nitrogen losses increased as weed control was delayed, missed or not applied in 2011, when compared to full spray treatment (Table 3). The nil spray treatment had lower mineral nitrogen levels in the soil when compared to the other three spray treatments. Increased nitrogen levels were evenly distributed throughout the whole soil profile (Figure 2 and 4). A strong relationship (R^2=0.62) was observed between PAW and nitrogen availability at sowing. For every millimetre of moisture that was lost through summer fallow weed growth, mineral nitrogen levels reduced by 0.56 kg/ha (Figure 5). The additional nitrogen benefit was likely due to a combination of increased mineralisation as the soil stayed wetter for longer where weeds were controlled, as well as reduced nitrogen loss through uptake by summer weeds.

Control of summer weeds did not influence the level of soil phosphorus (Colwell P), potassium (Colwell K) or sulphur (KCl) in either 2011 or 2012 (data not shown).

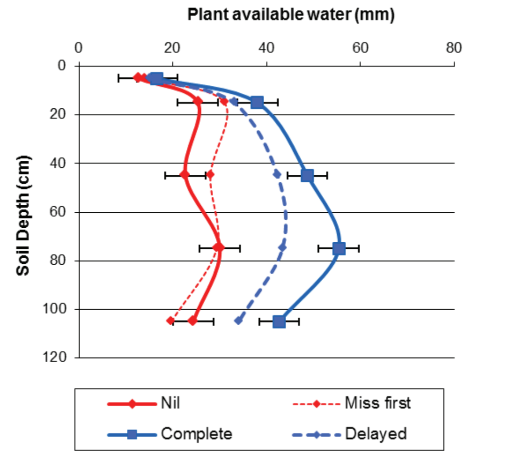

Figure 1. Plant available water profiles (mm) and standard error in 2011

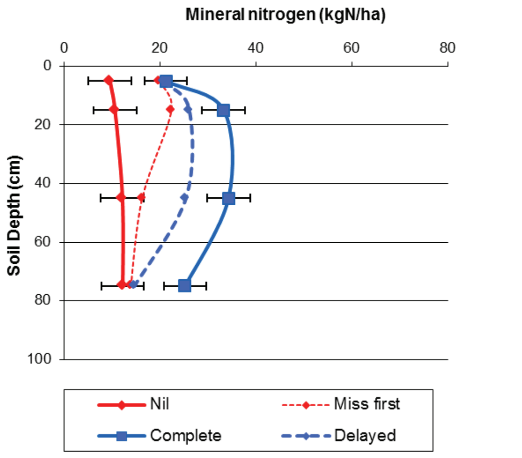

Figure 2. Mineral N (kgN/ha) profiles and standard error in 2011

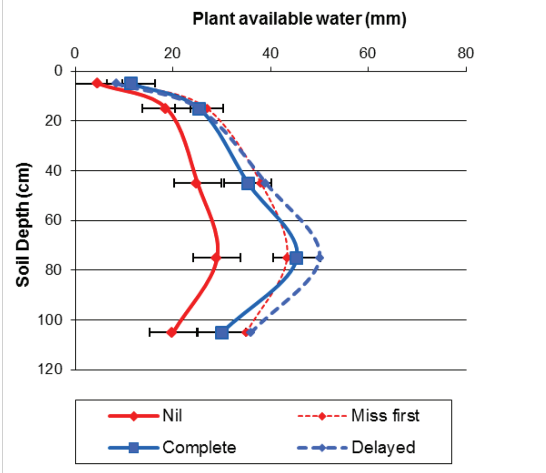

Figure 3. Plant available water profiles (mm) and standard error in 2012

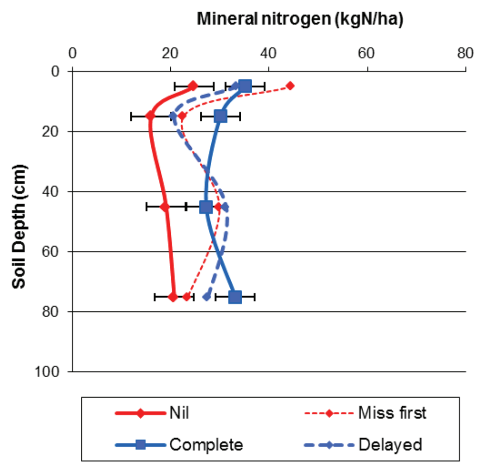

Figure 4. Depth and quantity of mineral N (kgN/ha) and standard error in 2012

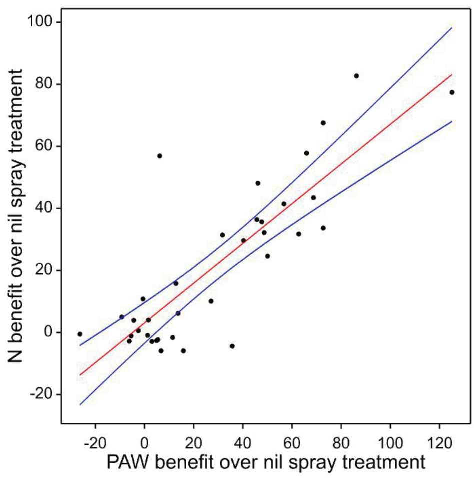

Figure 5. Fitted and observed relationship between PAW (mm) and mineral N (kgN/ha) loss by summer weed growth with 95% confidence intervals (across 2011-2012)

Impact of summer weed control and additional N fertiliser on grain yield and profitability

Grain yield was affected by summer weed control ($P<0.001$), additional N fertiliser ($P<0.001$) and their interaction ($P=0.004$) in 2011. In 2012, the experiment was accidently harvested by a commercial contractor at night. Canola grain yields for complete and delayed spray treatments (1.8 t/ha) were higher than the missed first (1.3 t/ha) or nil (1 t/ha) spray treatments (Table 4). Additional N fertiliser increased grain yield from 1.1 t/ha to 1.4 t/ha and 1.8 t/ha respectively for 0 kgN/ha, 70 kgN/ha and 140 kgN/ha treatments. The effectiveness of additional fertiliser on grain yield varied with summer weed control. N fertiliser coupled with good summer weed control (increased stored moisture) gave the highest grain yields. For every dollar invested in fallow herbicides, the miss first spray treatment returned $1.90 /ha, the delayed spray treatment $3.90 /ha and full spray treatment $7.20 /ha (Table 4). The application of N fertiliser was not profitable in all treatments (Table 4) and did not match the returns of full weed control alone. Addition of N fertiliser with weed control increased return by a range of -$1.20 to $0.80 (Table 4). Seasonal conditions would strongly influence N uptake and hence ROI as no rain fell for 20 days after N application.

Table 4: Grain yield and economic analysis of summer weed control and additional nitrogen fertiliser treatments in 2011 Canola crop.

Spray treatment	Trt 1 - Spray treatment			Trt 2 - N fertiliser		Partial analysis			Total variable costs ($/ha)	Yield (t/ha)	Income ($/ha)	Gross margin ($/ha)
	No of sprays	Herbicide rate (low or high)	Cost ($/ha)	Rate (kgN/ha)	Cost ($/ha)	Cost ($/ha)	Benefit ($/ha)	Benefit cost ratio				
Nil	1	H	$24	0	$0	$24			$406	0.65	$323	-$83
				70	$119	$143	$196	1.4	$580	1.04	$519	-$61
				140	$238	$262	$267	1.0	$699	1.18	$590	-$109
Miss first	2	H, L	$42	0	$0	$42	$120	2.9	$479	0.89	$443	-$36
				70	$119	$161	$179	1.1	$598	1.25	$623	$25
				140	$238	$280	$381	1.4	$717	1.65	$825	$108
Complete	3	L, L, L	$54	0	$0	$54	$441	8.2	$491	1.53	$764	$273
				70	$119	$173	$59	0.3	$610	1.65	$823	$213
				140	$238	$292	$327	1.1	$729	2.18	$1,091	$362
Delayed	3	H, H, H	$72	0	$0	$72	$352	4.9	$509	1.35	$675	$166
				70	$119	$191	$220	1.1	$628	1.79	$895	$267
				140	$238	$310	$375	1.2	$747	2.10	$1,050	$303

Discussion

Summer weed control is a key profit driver for cropping systems in central NSW. Consistent with the results of Sadras et al. (2012) for South Australia and Hunt et al. (2013) for Victoria, crop profitability was maximised by complete control of summer weeds as a result of increased water and N availability. Controlling summer weeds provided 0.56 kgN/ha of nitrogen for every extra 1 mm of stored water in the soil profile (Figure 5). Water and N increase grain yield through grain number (more tillers and more grains per head) and grain size, and the ROI for controlling summer weeds in this and other reports (Haskins and McMaster, 2012) has been consistently between $2.20 - $7.20 ha for every dollar invested. The stored water was especially valuable because it was stored throughout the profile (>30 cm) and so available to the crops during the yield determining stage in the 30 days leading up to anthesis. Summer weed control would also presumably enhance early sowing opportunities in some seasons, which could increase grain yield by a further 21-31% (Kirkegaard & Hunt 2010). Summer weeds should be controlled when small and actively growing, as this lowers the rate of herbicide required and generally increases herbicide efficacy.

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