Active stubble management to enhance residue breakdown and subsequent crop management — focus farm trials

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Background

This report presents the results from the large plot focus farm trials of the *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region* project, as described in the project overview on page 10.

Method

Different methods of stubble management were trialled in four large (farm-scale) replicated trials during 2014, 2015 and 2016. All results were statistically analysed using analysis of variance (ANOVA), with means separated using the unrestricted least significant difference (LSD) procedure. The different trial treatments are outlined in Table 1.

As the trial sites are moved each year to reflect a one-off change in the system, each year of trials is referred to as a 'time replicate':

- 2014 trial site: time replicate 1
- 2015 trial site: time replicate 2
- 2016 trial site: time replicate 3.

After each year of field trials the site is returned to the farming co-operator and blanket-sown with a crop of their choice, as described in Table 1, Table 2 and Table 3. At some sites the yield of the subsequent crop is also measured to determine whether a one-off strategic change has any long-term impacts through the rotation.

TABLE 1 Stubble management project trial details, 2016 (time replicate 3)

Trial details	Trial 1 Coreen#	Trial 2 Yarrawonga	Trial 3 Dookie	Trial 4 Henty
Treatments				
NTSR* (control)	✓	✓	✓	✓
NTSR + 40kg N/ha at sowing	×	✓	×	✓
Cultivate	One pass	One pass	One pass	One pass
Cultivate + 40kg N/ha at sowing	One pass	One pass	×	One pass
Burn stubble	✓	✓	✓	×
NTSR — long stubble	×	36cm	34cm	×
NTSR — short stubble	×	15cm	15cm	×
NTSR — straw mown and removed	×	✓	✓	×
NTSR — stubble mulched and retained	×	×	×	✓
NTSR — stubble mulched + 40kg extra nitrogen at sowing	×	×	×	✓
NTSR — lupins sown for forage	✓	×	×	×
NTSR — lupins sown for grain	✓	×	×	×
Trial plot dimensions (m)	40 x 15	40 x 18	40 x 18	40 x 15
Farm drill used for trial	Aus seeder DBS D-300 tine seeder	Aus seeder DBS tine knife point	Simplicity seeder/ knife point	John Deere 1590 disc seeder
Stubble loading (t/ha)	7.0	4.7	7.9	6.6
Stubble height (cm)	26	36	15	47
Soil type description	Loam over clay	Self-mulching red loam over grey clay	Red loam over clay	Yellow brown earth
Row spacing (cm)	30	32	33.3	19
Crop and rotation position	Second cereal (barley)	Second wheat	Second wheat	Canola following wheat

The site was relocated to a paddock near Daysdale in 2014, near Corowa in 2015 and near Coreen in 2016 in order to maintain the required rotation position.
* No-till stubble retention (NTSR)



TABLE 2 Site details for 2016 crops sown onto 2015 stubble management trial sites (time replicate 2)

Trial details	Trial 1	Trial 2	Trial 3	Trial 4
	Corowa#	Yarrawonga	Dookie	Henty
Treatments				
Crop type/variety	Wheat/Trojan	Canola/45Y25	Canola/Bonito	Wheat/Gregory
Paddock burnt	✓	✓	✓	×
Farmer harvested	×	✓	✓	✓
Plot harvester	✓	×	×	×
Trial plot dimensions (m)	40 x 15	40 x 18	40 x 15	40 x 15
Farm drill used for trial	Aus seeder DBS D-300 tine seeder	Aus seeder DBS tine knife point	Simplicity seeder/ knife point	John Deere 1590 disc seeder
Stubble loading (t/ha)	5.8	4.3	5.6	3.2
*Stubble height (cm)**	5	3	3	20
Soil type description	Red brown earth	Self-mulching red loam over grey clay	Red clay	Red brown earth
Row spacing (cm)	30	32	33.3	19
Crop and rotation position	Third wheat	Canola following wheat	Canola following wheat	Wheat following canola

The site was relocated to a paddock near Daysdale in 2014, near Corowa in 2015 and near Coreen in 2016 in order to maintain the required rotation position.
* Stubble height was measured post burn at sowing time.

TABLE 3 Site details for 2016 crops sown onto 2014 stubble management trial sites (time replicate 1)

Trial details	Trial 1	Trial 2	Trial 3	Trial 4
	Daysdale#	Yarrawonga	Dookie	Henty^
Treatments				
Crop type/variety	Canola/Bonito	Canola/Bonito	Wheat/Corack	Wheat/Wedgetail
Paddock burnt	×	✓	×	×
Farmer harvested	✓	✓	✓	×
Plot harvester	×	×	×	×
Trial plot dimensions	40 x 15m	40 x 18m	40 x 15m	40 x 15m
Farm drill used for trial	Aus seeder DBS D-300 tine seeder	Aus seeder DBS tine knife point	Simplicity seeder/ knife point	John Deere 1590 disc seeder
Stubble loading (t/ha)	7.0	5.9	3.0	5.8
*Stubble height (cm)**	26	4	8	35
Soil type description	Heavy grey clay	Self-mulching red loam over grey clay	Red clay	Yellow podzol-yellow brown earth
Row spacing (cm)	30	32	33.3	19
Crop and rotation position	Canola following wheat	Canola following barley	Wheat following canola	Grazing wheat following oats

The site was relocated to a paddock near Daysdale in 2014, near Corowa in 2015 and near Coreen 2016 in order to maintain the required rotation position.
^ The Henty site was affected by waterlogging and was grazed off and left (not harvested).
* Stubble height was measured post burn at sowing time.

Trial 1: Coreen, NSW

Sowing date: 4 May 2016

Rotation: Second cereal (barley)

Variety: Barley cv Hindmarsh, lupins cv Mandelup

Stubble: Wheat (various treatments applied)

Stubble load at sowing: 7.0t/ha

Rainfall:

GSR: 567mm (April–October)

Summer rainfall: 80mm

Soil nitrogen at sowing: 111kg N/ha NTSR (control) and 103kg N/ha multidisc (0–60cm)

Key points

- There were significant increases in dry matter (DM) accumulation, nitrogen (N) uptake and crop canopy greenness where barley was established following cultivation with one pass of the multidisc, which was most evident where additional nitrogen was added at sowing.
- Although there was a trend for cultivated stubble with additional sowing nitrogen to yield more than burning, there were no significant yield differences in the trial.
- Growing a faba bean crop instead of a second wheat crop increased the yield of the following wheat by 0.34–0.47t/ha in 2016 compared with a 2t/ha advantage in the following wheat crop in 2015.
- Adequate nitrogen availability in the third wheat crop, combined with higher yield potential, and poor nodulation in the faba beans, appears to be partly the reason for the smaller yield benefit in 2016.
- Across three years of field trials, none of the different stubble management treatments have been superior to the no-till stubble retention (NTSR) control, despite differences in DM production.

Results

i) Establishment and crop structure

With sufficient moisture levels at sowing there were no differences in crop establishment five weeks after sowing (Table 4). Tiller numbers were relatively high and differed between the treatments. Tiller numbers varied from 3.9 tillers per plant in burnt plots to 5.3 tillers per plant in cultivated plots, when assessed at the second node stage (GS32). However, there were no differences in head numbers between treatments, with an average of just more than 400 heads/m².

TABLE 4 Plant counts 9 June 2016, three-leaf stage (GS13); tiller counts 28 July 2016, second-node stage (GS32) and head counts 19 November 2016, harvest (GS99)

	Crop growth stage		
	GS13	GS32	GS99
Treatment	Plants/m²	Tillers/m²	Heads/m²
NTSR (control)	97^{a}	483^{ab}	406^{a}
Cultivated (one pass)	108^{a}	568^{a}	429^{a}
Cultivated (one pass) + 40kg N/ha	107^{a}	497^{ab}	440^{a}
Burnt	103^{a}	406^{b}	387^{a}
Mean	**103**	**488**	**415**
LSD	17	116	121

Figures followed by different letters are regarded as statistically significant.

ii) Dry matter production and nitrogen uptake

Plots that had been cultivated with additional nitrogen at sowing produced significantly more DM at first node (GS31), compared with both the NTSR (control) and burnt treatment. The cultivated treatments also produced significantly more DM at flowering (GS69) compared with the NTSR plots (Table 5). By harvest there were no significant differences in DM production between any of the treatments.

Similar trends were apparent in the nitrogen uptake figures at first node (GS31), with more nitrogen present in the cultivated and cultivated plus 40kg N/ha compared with the burnt treatment and the control plots. At later assessments there were no significant differences in nitrogen content between the different stubble treatments (Table 6).

iii) Green leaf retention differences

The NTSR plots were not as green at key assessment growth stages as the burnt and cultivated plots; observations confirmed by normalised difference vegetation index (NDVI) readings (Figure 1). The presence of stubble (brown vegetation) in the NTSR plots may have partly influenced earlier NDVI readings, compared with the burnt treatment readings. Crops

TABLE 5 Dry matter 15 July 2016, first node (GS31); 18 August 2016, flag leaf fully emerged (GS39); 26 September 2016, end of flowering (GS69) and 21 November 2016, at physiological maturity (GS95–99)

	Dry matter (t/ha)			
Treatment	GS31	GS39	GS69	GS95–99
NTSR (control)	1.17^{bc}	2.97^{a}	7.30^{b}	9.37^{a}
Cultivated (one pass)	1.49^{ab}	3.40^{a}	8.92^{a}	9.27^{a}
Cultivated (one pass) + 40kg N/ha	1.56^{a}	3.37^{a}	8.44^{a}	9.22^{a}
Burnt	1.06^{c}	2.89^{a}	8.42^{ab}	8.41^{a}
Mean	**1.32**	**3.15**	**8.27**	**9.07**
LSD	0.36	0.98	1.12	2.17

Figures followed by different letters are regarded as statistically significant.

TABLE 6 Nitrogen uptake in crop 15 July 2016, first node (GS31); 18 August 2016, flag leaf fully emerged (GS39); 26 September 2016, end of flowering (GS69) and 21 November 2016, at physiological maturity (GS95–99)

Treatment	Nitrogen uptake in dry matter (kg N/ha)			
	GS31	GS39	GS69	GS95–99
NTSR (control)	55[ab]	64[a]	102[a]	51[a]
Cultivated (one pass)	69[a]	64[a]	132[a]	51[a]
Cultivated (one pass) + 40kg N/ha	62[a]	85[a]	122[a]	58[a]
Burnt	42[b]	77[a]	118[a]	46[a]
Mean	**57**	**73**	**118**	**52**
LSD	16	22	59	14

Figures followed by different letters are regarded as statistically significant.

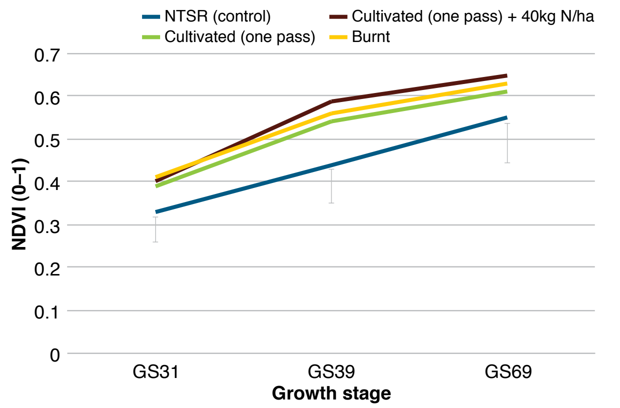

FIGURE 1 Influence of stubble management on barley crop canopy NDVI assessed July 15 2016 first node (GS31); 18 August 2016, flag leaf fully emerged (GS39) and 26 September 2016, end of flowering (GS69)

Error bars presented as a measure of LSD

established following cultivation had higher NDVI values, which appear to be correlated to higher DM and nitrogen content up to the end of flowering (GS69).

iv) Yield and grain quality

The trial was harvested on 9 December 2016. While the cultivated plus 40kg N/ha treatment recorded the highest yield, and the burnt treatment recorded the lowest, these yields were not significantly different. Therefore, there were no significant yield advantages of any stubble treatments over the NTSR (control) for barley at this site (Table 7); a result consistent with previous years of field trials in second wheat in this region. The only significant difference in grain quality was a lower protein level in cultivated plots that did not receive nitrogen at sowing.

v) Three-year results (time replicates 1, 2 and 3) — yield data 2014–16

For the past three years a replicated large block stubble management trial has been established in a different paddock on the Coreen focus farm. The trial set-up in 2014 (year one of the experiment) is referred to as the time replicate 1 in the trial series, the trial set-up in year two is time replicate 2 and in the third year it is time replicate 3. After each trial has been completed the trial area reverts to being a commercial farm crop undergoing uniform management. The stubble management for all subsequent years has therefore been uniform across all trial plots and dictated by commercial farm operations. In each subsequent year the trial area has then been revisited in order to assess any carryover yield effects of the stubble management treatments set up in year one on yields of the farm crop in the following years.

The results from this focus farm during the past three years show the rank order of stubble management treatments has been similar, with significant differences in yield only recorded during 2015 when the cultivated plus 40kg N/ha treatment significantly outyielded the burnt treatment (Figure 2). While similar trends were observed during 2016, the yield differences were not significant. Despite benefits of earlier DM production and disease control (yellow leaf spot) from burning, no yield advantage has been observed due to burning over NTSR (control) at this trial site during the past three seasons of stubble management trials.

vi) 2015 stubble management treatments — influence on 2016 wheat yields

The stubble management trial has not only been set up to examine the influence of different stubble management techniques on the subsequent crop, but also to assess

TABLE 7 Wheat yield, protein, test weight, screenings and thousand seed weight (TSW) 9 December 2016, at harvest (GS99)

Treatment	Yield and quality				
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	TSW (g)
NTSR (control)	5.24[a]	9.5[a]	63.9[a]	4.2[a]	38.0[a]
Cultivated (one pass)	4.82[a]	8.5[b]	59.8[a]	4.3[a]	35.4[a]
Cultivated (one pass) + 40kg N/ha	5.54[a]	9.7[a]	61.9[a]	4.6[a]	37.9[a]
Burnt	4.81[a]	9.5[a]	63.7[a]	4.5[a]	37.0[a]
Mean	**5.11**	**9.3**	**62.4**	**4.4**	**37.1**
LSD	1.15	0.7	7.4	1.9	4.1

Figures followed by different letters are regarded as statistically significant.

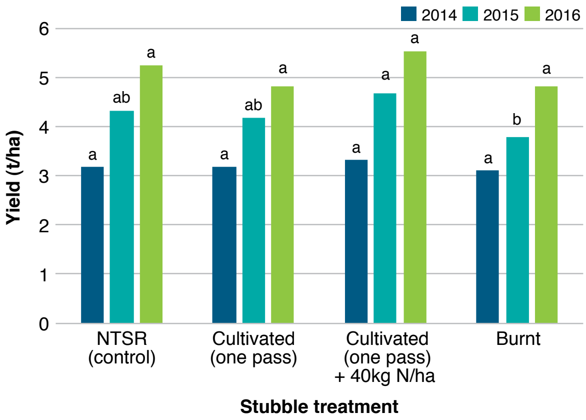

FIGURE 2 Yield data from time replicate trials 1, 2 and 3 — the Daysdale (red brown earth), Corowa (heavy grey clay) and Coreen (loam over clay) trials for 2014, 2015 and 2016 — cv Whistler (wheat) in 2014, cv Mace (wheat) in 2015, cv Hindmarsh (barley) in 2016

Yield bars for the same year with different letters are regarded as statistically different.

Note: The three trials were carried out on the same farm but not on the same trial site. During 2014 the cultivation treatments were established with two passes of a multidisc, while in 2015 and 2016 a single pass was used.

whether there are any rotational effects on following crops. For example, does burning or cultivating between the first and second wheat crop impact yield performance the year after the second wheat? Table 8 shows the performance of a commercial wheat crop (cv Trojan) sown during 2016 into the large block 2015 stubble management trial. As the faba bean crops sown in 2015 suffered from poor nodulation they do not represent an effective legume break crop.

The stubble management treatments carried out during the 2015 trial (time replicate 2) did not significantly influence the following third wheat crop (cv Trojan), although there was a trend for crops established by cultivation or NTSR to yield more than crops following

TABLE 8 Wheat yield, protein, test weight and screenings at Corowa, 2016

2015 stubble treatments	2016 yield and quality			
	Yield (t/ha)	**Protein (%)**	**Test weight (kg/hL)**	**Screenings (%)**
NTSR (control)	6.72^{ab}	8.8^{a}	79.9^{ab}	2.4^{a}
Cultivated (one pass)	6.53^{ab}	8.8^{a}	78.6^{b}	2.5^{a}
Cultivated (one pass) + 40kg N/ha	6.66^{ab}	9.1^{a}	80.5^{ab}	2.2^{a}
Burnt	5.90^{b}	8.7^{a}	80.4^{ab}	1.6^{a}
Faba beans (green manure)	7.03^{a}	8.9^{a}	81.0^{a}	2.1^{a}
Faba beans (grain)	6.96^{a}	9.3^{a}	80.2^{ab}	1.7^{a}
Mean	**6.63**	**8.9**	**80.1**	**4.4**
LSD	0.82	0.8	2.3	1.9

Figures followed by different letters are regarded as statistically significant.

burning during 2016. Wheat yields following faba beans, which nodulated poorly, were 0.34–0.47t/ha higher yielding than a third continuous wheat crop, as compared with a 2t/ha advantage in the 2014 (time replicate 1) trial. Although wheat yields were higher following faba beans, there was no difference in protein levels between treatments. This indicates a greater nitrogen offtake, although the extra nitrogen offtake is relatively small and statistically insignificant in the 2015–16 trial sequence. The nitrogen offtake in grain following faba beans equated to 112kg N/ha (average of forage and grain faba bean treatments) versus 104kg N/ha in the third wheat established with NTSR (control). The difference in the previous year's research (2015 commercial crop sown over 2014 trial site) was 111kg N/ha offtake following faba beans versus 57kg N/ha following wheat, however in 2016 the host farmer applied 108kg N/ha across his wheat crop compared with 53kg N/ha during 2015.

Faba beans sown alongside second wheat stubble management treatments in July and then September in 2015.



Trial 2: Yarrawonga, Victoria

Sowing date: 28 April 2016

Rotation: Second wheat

Variety: Corack

Stubble: Wheat (various treatments applied)

Stubble load at sowing: Long stubble 4.7t/ha, short stubble 4.3t/ha

Rainfall:
GSR: 604mm (April–October)
Summer rainfall: 125mm

Soil nitrogen at sowing: 64kg N/ha NTSR (control) and 60kg N/ha multidisc (0–60cm)

Key points

- Despite differences in DM production early in the season, there were no differences in yield or grain protein due to stubble management treatments (burning, removing straw, cultivating or NTSR).
- There was a non-significant trend for burning to produce small yield gains (4–5%) over NTSR, a result seemingly linked to higher DM production.
- With a higher yield potential for 2016, applying nitrogen at sowing significantly increased grain yield and protein when stubble was cultivated. However this may be due to optimal nitrogen management rather than stubble management.
- In all three seasons of trials (2014–16), there was more DM accumulation earlier in the season and small non-significant yield gains (3–5%) when stubbles were burnt; however with a sharp finish to the 2015 season, burning significantly reduced yield compared with NTSR (12.5% yield decrease).
- Stubble management options that support high DM production earlier in the season (i.e. stubble removal) can be beneficial when yield potential is higher (2014 and 2016) and either neutral or disadvantageous in seasons when yield potential is lower (2015).

Results

i) Establishment and crop structure

The NTSR — short stubble treatment significantly reduced plant establishment compared with treatments where stubble (straw) was removed or burnt. As the short stubble was prepared by cutting the long stubble after harvest (late March/early April), the cut straw on the ground may have created a mulching effect, which may have impeded plant emergence. Other treatments, such as the NTSR — long stubble and cultivation treatments, were not significantly different from the straw removed or burnt plots (Table 9). By second node (GS32) the long stubble treatments had significantly reduced tiller numbers relative to the other treatments, which followed through to a significant reduction in head number in the long stubble plus nitrogen treatment.

ii) Dry matter production

The lower tiller number recorded with NTSR — long stubble (control) at second node (GS32) correlated to less DM accumulation compared with the other treatments. The burnt treatment produced significantly more DM throughout the season (Table 10). Up until grain fill there was a lag in DM production in the NTSR — long stubble treatment compared with NSTR — short stubble treatment, which was not apparent at the harvest assessment; indicating later compensation in these treatments.

The reduction in DM accumulation with NTSR — long stubble (control) correlated to decreased nitrogen uptake in the crop canopy at GS32 compared with the burnt or cultivated treatments (Table 11). The difference in nitrogen uptake between long and short stubble treatments was not significantly different despite there being significantly more DM following short stubble when assessed at the same growth stage.

At early grain fill (GS71) all the NTSR treatments had significantly lower crop canopy nitrogen contents compared with the other stubble treatments, although this was offset in the NTSR — long stubble + 40kg N/ha treatment. The additional nitrogen at sowing generated a small increase in nitrogen offtake compared with the

TABLE 9 Plant counts and vigour 10 June 2016, one tiller (GS21); tiller counts 2 August 2016, second node (GS32) and head counts 6 December 2016, harvest (GS99)

	Crop growth stage		
	Plants/m²	Tillers/m²	Heads/m²
Treatment	GS11	GS32	GS99
NTSR — long stubble (control)	151^{ab}	248^{b}	266^{bc}
NTSR — long stubble + 40kg N/ha	153^{ab}	271^{b}	225^{c}
NTSR — short stubble	140^{b}	334^{a}	304^{ab}
Straw removed	159^{a}	371^{a}	300^{ab}
Cultivated (one pass)	146^{ab}	335^{a}	304^{ab}
Cultivate (one pass) + 40kg N/ha	152^{ab}	354^{a}	327^{a}
Burnt	158^{a}	373^{a}	325^{ab}
Mean	**151**	**327**	**293**
LSD	16	62	60

Figures followed by different letters are regarded as statistically significant.

TABLE 10 Dry matter 2 August 2016, second node (GS32); 5 September 2016, mid-booting (GS45); 12 October 2016, watery ripe grain (GS71) and 6 December, harvest (GS99)

Treatment	Dry matter (t/ha)			
	GS32	GS45	GS71	GS99
NTSR — long stubble (control)	1.57^{b}	5.13^{b}	8.82^{d}	11.83^{bc}
NTSR — long stubble + 40kg N/ha	1.53^{b}	5.74^{ab}	9.65^{cd}	10.85^{c}
NTSR — short stubble	1.91^{a}	5.45^{ab}	10.57^{bc}	11.89^{bc}
Straw removed	2.10^{a}	6.72^{a}	10.55^{bc}	11.68^{bc}
Cultivated (one pass)	2.02^{a}	5.63^{ab}	11.10^{b}	11.94^{bc}
Cultivate (one pass) + 40kg N/ha	2.12^{a}	6.49^{ab}	12.31^{a}	12.93^{ab}
Burnt	2.13^{a}	6.69^{a}	12.22^{a}	14.41^{a}
Mean	**1.91**	**5.98**	**10.75**	**12.22**
LSD	0.22	1.41	1.08	1.96

Figures followed by different letters are regarded as statistically significant.

TABLE 11 Nitrogen uptake in biomass 2 August 2016, second node (GS32); 5 September 2016, mid-booting (GS45); 12 October 2016, watery ripe grain (GS71) and 6 December, harvest (GS99)

Treatment	Nitrogen uptake in biomass (kg N/ha)			
	GS32	GS45	GS71	GS99
NTSR — long stubble (control)	49^{c}	72^{a}	79^{b}	93^{b}
NTSR — long stubble + 40kg N/ha	51^{c}	75^{a}	87^{ab}	95^{b}
NTSR — short stubble	54^{bc}	63^{a}	72^{b}	98^{b}
Straw removed	55^{bc}	84^{a}	105^{a}	105^{b}
Cultivated (one pass)	61^{ab}	66^{a}	105^{a}	124^{a}
Cultivate (one pass) + 40kg N/ha	65^{a}	86^{a}	101^{a}	122^{a}
Burnt	60^{ab}	71^{a}	108^{a}	100^{b}
Mean	**56**	**74**	**94**	**105**
LSD	8	24	22	15

Figures followed by different letters are regarded as statistically significant.

NTSR (control), but where the stubble was cultivated there was no increase in nitrogen offtake at harvest due to extra nitrogen at sowing compared with the cultivation only treatment.

iii) Photosynthetically active radiation (PAR)

During the past three seasons (2014–16) one of the most consistent effects of the stubble management treatments in NTSR systems has been the influence of stubble length on DM production. There is a consistent reduction in tillering and DM production in longer stubble. In part this appears to be linked with nitrogen availability and temperature, but as these factors could not completely explain this effect, in 2016 for the first time the research team looked at differences in light interception by the growing crop canopy; more accurately described as photosynthetically active radiation (PAR). During the winter months (June and July 2016) the influence of the different stubble management treatments on PAR was assessed.

The results revealed reductions in PAR of more than 50% compared with short stubble NTSR (Figure 3). Burnt plots captured the most PAR, but this was only slightly more than the cultivation and NTSR — short stubble treatments. Although the PAR will be influenced by the Sun's zenith (high point in the sky) the results clearly show the ability to capture available sunlight is a key difference between long and short stubble treatments and could be the major factor in why there is reduced tillers and a lag in DM production with long stubble.

iv) Green leaf retention at the stem elongation and early grain-fill stages

At second node (GS32) and booting (GS45) the burnt and cultivated treatments resulted in higher NDVI crop canopy scores (Figure 4). This increased greenness of the canopy was evident in the NDVI assessments (conducted with the Greenseeker®) at GS32 and GS45. All NDVI scores declined at early grain fill (GS71) but cultivation with extra nitrogen and burnt stubble plots still gave higher NDVI readings than NTSR — short stubble and NTSR — long stubble treatments.

v) Disease levels

There were no appreciable levels of disease in the trial, a result that is linked to the better resistance of Corack to yellow leaf spot (YLS) compared with Young, a variety used in previous years.

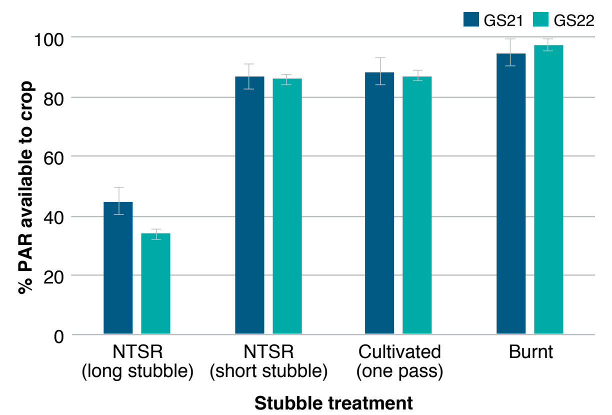

FIGURE 3 Influence of stubble treatment on availability of photosynthetically active radiation (PAR) on 10 June 2016 (GS21) and 15 June 2016 (GS21/22) at the Yarrawonga trial site

*The error bars are a measure of LSD

Note: 10 June readings were taken at 1pm with the average above-canopy PAR measuring 866μmol/m^2/s, in the 400–700nm waveband

15 June readings were taken at 10am with the average above canopy PAR measuring 733μmol/m^2/s^1, in the 400–700nm waveband

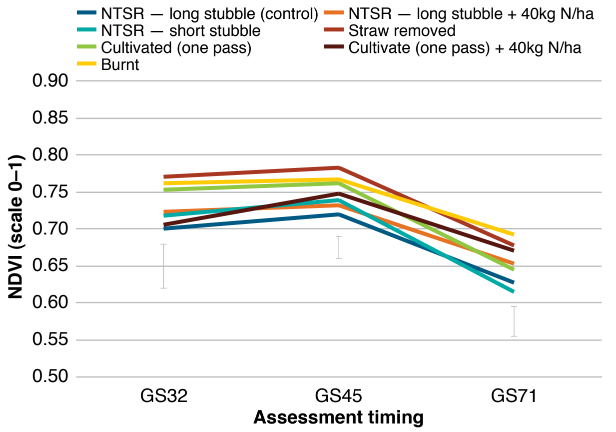

FIGURE 4 Influence of stubble management on resultant crop canopy NDVI (0–1 scale) assessed at stem elongation (GS32), booting (GS45) and early grain fill (GS71)

*The error bars are a measure of LSD

vi) Grain yield and quality

The trial was harvested on 12 December 2016. There were statistical differences in grain yield and quality as a result of stubble management. Despite a lag in DM accumulation at stem elongation (GS32) with the NTSR — long stubble treatment there was no difference in yield between long and short stubble treatments (Table 12). There was also no yield advantage associated with straw removal. Burning the previous wheat crop residues gave a small, non-significant yield increase (4–5%) over all NTSR treatments,— a result similar to that observed during 2014. Cultivation produced no yield benefits over the NTSR — long stubble (control) treatment.

The high in-season rainfall and high yield potential meant crops responded to extra nitrogen applied at sowing, which is evident in both the NTSR and cultivated plots. In both cases applying 40kg N/ha at sowing resulted in significantly higher grain protein and significantly more yield with cultivation (0.79t/ha). Where no extra nitrogen was applied at sowing the effect of the different stubble management treatments (burnt, cultivated, straw removed and NTSR) had no impact on grain quality.

vii) Three-year results (time replicates 1, 2 and 3) — yield data 2014–16

The stubble management trial has been established in the same crop rotation position on different paddocks during the past three years. There have been only a few significant yield effects associated with stubble management over the three years of trials. In 2016 there were significant yield increases when additional nitrogen was applied at sowing, however removing the influence of treatments with additional nitrogen, there were no significant differences in yield between burning, cultivating and straw removal, compared with NTSR (Figure 5).

Although burning has increased DM production in all three years it has not generated any statistical yield advantages, with only a small, non-significant trend suggesting a 3–5% yield benefit. With the harder finish during 2015, the burnt treatment had significantly less grain yield compared with NTSR — short stubble, with the greater biomass of the burnt treatment possibly being a disadvantage in such a season.

viii) 2015 stubble management treatments — influence on 2016 canola yields

Different stubble management treatments established pre-sowing during 2015 resulted in significant differences in wheat yields during 2015, with the NTSR — short stubble treatment significantly increasing wheat yields compared with straw removal and burning. However, these treatment effects did not follow through to have any effect on the yield of a commercial crop of canola sown across the 2015 site during 2016 (Table 13).

TABLE 12 Wheat yield, test weight, protein, screenings, harvest index (HI) and thousand seed weight (TSW) 12 December 2016, at harvest (GS99)

Treatment	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	HI (%)	TSW (g)
NTSR — long stubble (control)	5.86^{bc}	8.5^{c}	79.9^{a}	2.9^{a}	50.3^{abc}	46.6^{c}
NTSR — long stubble + 40kg N/ha	6.19^{ab}	9.7^{ab}	80.1^{a}	2.5^{ab}	57.1^{a}	47.3^{bc}
NTSR — short stubble	5.81^{bc}	8.9^{c}	79.9^{a}	2.1^{b}	49.3^{abc}	48.7^{ab}
Straw removed	5.6^{c}	8.6^{c}	79.8^{a}	2.5^{ab}	48.3^{bc}	49.0^{a}
Cultivated (one pass)	5.9^{bc}	9.1^{bc}	80.4^{a}	2.2^{b}	49.7^{abc}	49.3^{a}
Cultivate (one pass) + 40kg N/ha	6.69^{a}	10.0^{a}	80.4^{a}	2.5^{ab}	52.0^{ab}	49.9^{a}
Burnt	6.12^{abc}	8.9^{c}	80.3^{a}	2.2^{b}	42.8^{c}	50.0^{a}
Mean	**6.03**	**9.1**	**80.1**	**2.4**	**49.9**	**48.7**
LSD	0.58	0.7	0.9	0.6	8.6	1.4

Figures followed by different letters are regarded as statistically significant.

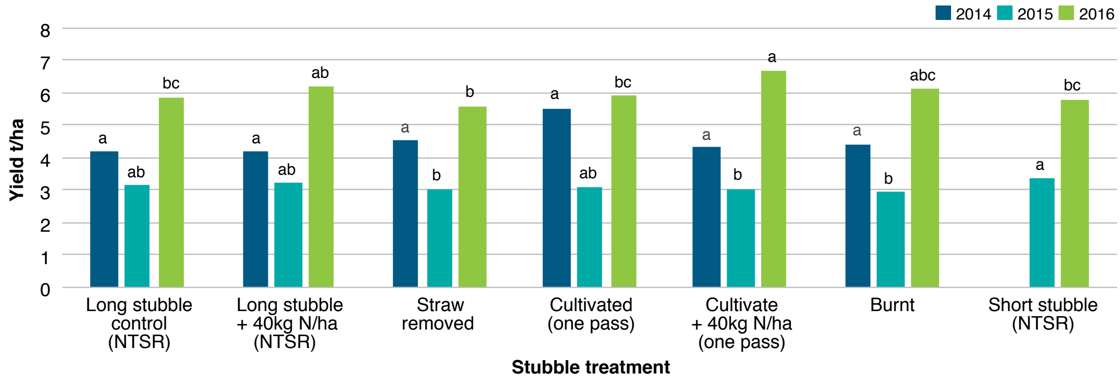

FIGURE 5 Yield data from the three Yarrawonga trials for 2014, 2015 (cv Young) and 2016 (cv Corack).

Note: The NTSR — short stubble was not part of the 2014 list of treatments.

Yield bars across treatments for the same year with different letters are regarded as statistically different.

TABLE 13 Canola yield in the 2016 commercial crop following different stubble management treatments set up in the 2015 stubble management site and the 2015 wheat yield

2015 stubble management treatments (all blocks were burnt before the 2016 crop)	2015 second wheat yield (t/ha)	2016 canola yield (t/ha)
NTSR — long stubble (control)	3.13[ab]	2.76[a]
NTSR — long stubble + 40kg N/ha	3.20[ab]	2.73[a]
NTSR — short stubble	3.35[a]	2.84[a]
Straw removed	3.03[b]	2.72[a]
Cultivated (one pass)	3.10[ab]	2.75[a]
Cultivate (one pass) + 40kg N/ha	3.05[b]	2.69[a]
Burnt	2.93[b]	2.73[a]
Mean	**3.11**	**2.74**
LSD	0.29	0.42

Figures followed by different letters are regarded as statistically significant.

Influence of stubble height on sunlight interception in the NTSR — long stubble (left) and NTSR — short stubble (right) at the Yarrawonga site, 20 May, 2016.



Trial 3: Dookie, Victoria

Sowing date: 12 May 2016
Rotation: Second wheat
Variety: Corack
Stubble: Wheat (various treatments applied)
Stubble load at sowing: 7.9 t/ha
Rainfall:
GSR: 509mm (April–October)
Summer rainfall: 130mm
Soil nitrogen: 110kg N/ha control NTSR, 102kg N/ha multidisc (0–60cm)

Key points

- A growing season rainfall of 509mm resulted in average yields of 5.8t/ha compared with 2.4t/ha in 2015 and 5.5t/ha in 2014 for the equivalent trial in a second wheat rotation position.
- Transient waterlogging influenced the results of the trial and gave variable yield effects resulting in a high LSD of 1.02t/ha.
- As a consequence, there were no yield differences during 2016 due to stubble management, with all treatments achieving 5–6t/ha yields, screenings less than 1% and grain protein levels above 10.5%.
- Though there was a trend for the burnt and straw removed treatments to increase plant establishment and early DM production compared with NTSR — long stubble (control), the trend for these treatments to be higher yielding (3–7%) was not statistically significant.
- Across the three years of the trial, NTSR — long stubble has reduced early DM production in all years, however it has only significantly reduced yield compared with other stubble treatments during 2014 (0.7t/ha decrease).
- The significant yield reduction in 2014, due to long stubble, resulted in a significant increase in canola yields during 2015.
- However, the influence of stubble management treatments set up in 2014 had no effect on the yield of wheat in 2016, following canola.

Results

i) Establishment and crop structure

Burning the straw resulted in a significantly higher plant population than all NTSR and cultivation treatments, however the differences were relatively small (less than 20 plants/m^2). At first node (GS31), the NTSR — long stubble treatment had significantly fewer tillers compared with the short stubble and other treatments (Table 14). Burning stubble produced the highest tiller number (445 tillers/m^2), however the advantage over the NTSR — short stubble treatment was not significant. At maturity there were no significant differences in head numbers between the different treatments and the large range in tiller number (approximately 150 tillers/m^2) was narrowed with only an approximate range of 50 heads/m^2 between treatments.

ii) Dry matter production and nitrogen uptake in the crop canopy

The NTSR long stubble treatment produced significantly less DM at first node (GS31), a result that correlates to observations on tiller numbers (Table 14 and 15). At early grain fill (GS71) the burnt treatment still maintained an increase in DM over NTSR — long stubble. Although the short stubble treatment tended to produce more DM than long stubble during ear emergence (GS55) and at early grain fill (GS71), these differences were not statistically significant, with no difference between the two treatments at physiological maturity (GS95–99); a result noted in previous years.

The lower DM production under the NTSR — long stubble treatment compared with other treatments also equated to lower nitrogen uptake in the canopy at first node (GS31), however there were no differences in nitrogen uptake at later assessment times (Table 16).

iii) Disease levels

Assessments for disease revealed only trace levels of yellow leaf spot (YLS), a result similar to that seen at the Yarrawonga site. Again, this is thought to be linked to greater resistance rating of Corack to this disease. There

TABLE 14 Plant counts and vigour 8 June 2016, two leaf (GS12); tiller counts 2 August 2016, first node (GS31) and head counts 30 November 2016, physiological maturity (GS95–99)

	Crop growth stage		
	Plants/m^2	Tillers/m^2	Heads/m^2
Treatment	GS12	GS31	GS99
NTSR — long stubble	135^{b}	296^{c}	356^{a}
NTSR — short stubble	133^{b}	389^{ab}	383^{a}
Cultivated (one pass)	136^{b}	363^{bc}	391^{a}
Straw removed	141^{ab}	378^{ab}	343^{a}
Burnt	152^{a}	445^{a}	378^{a}
Mean	**139**	**374**	**370**
LSD	14	77	52

Figures followed by different letters are regarded as statistically significant.

TABLE 15 Dry matter 2 August 2016, first node (GS31); 19 September 2014, head half emerged (GS55); 17 October, watery ripe grain (GS71) and 30 November, physiological maturity (GS95–99)

Treatment	Dry matter (t/ha)			
	GS31	GS55	GS71	GS95–99
NTSR — long stubble	0.76^{b}	6.6^{a}	10.3^{b}	14.1^{a}
NTSR — short stubble	1.12^{a}	7.3^{a}	11.2^{ab}	14.0^{a}
Cultivated (one pass)	1.04^{a}	6.6^{a}	11.1^{ab}	12.5^{a}
Straw removed	1.10^{a}	6.6^{a}	10.5^{ab}	12.9^{a}
Burnt	1.17^{a}	7.1^{a}	11.5^{a}	12.6^{a}
Mean	**0.86**	**6.8**	**10.9**	**13.2**
LSD	0.22	1.3	1.2	1.7

Figures followed by different letters are regarded as statistically significant.

TABLE 16 Nitrogen uptake in dry matter 2 August 2016, first node (GS31); 19 September 2014, head half emerged (GS55); 17 October, watery ripe grain (GS71) and 30 November, physiological maturity (GS95–99)

Treatment	Nitrogen uptake (kg N/ha)			
	GS31	GS55	GS71	GS95–99
NTSR — long stubble	32^{b}	139^{a}	116^{ab}	71^{a}
NTSR — short stubble	49^{a}	138^{a}	142^{a}	80^{a}
Cultivated (one pass)	45^{a}	116^{a}	106^{b}	73^{a}
Straw removed	52^{a}	124^{a}	124^{ab}	52^{a}
Burnt	50^{s}	149^{a}	112^{b}	79^{a}
Mean	**46**	**133**	**120**	**71**
LSD	10	45	30	31

Figures followed by different letters are regarded as statistically significant.

were traces of leaf rust at the end of the season, but no observable differences in disease between treatments.

iv) Green leaf retention

The soft finish to the season produced conditions suitable for an extended grain fill period, unlike the heat stress of 2015, although it was evident that transient waterlogging in parts of the trial precluded this from happening to the extent that might be suggested by available water and temperatures. Assessments of the crop canopy, using NDVI, revealed initial differences at first node (GS31), however these differences were not measured later in the season, at half head emerged (GS55) and early grain fill (GS71) (Figure 6). Long and short stubble NTSR recorded lower crop canopy greenness compared with the burnt plots at first node (GS31), but not when assessed later.

v) Yield and grain quality

The trial was harvested on 13 December 2016. The yield results at this site were highly variable as parts of the trial site were subject to waterlogging during the growing season. As a result, there were no significant differences between the different stubble management treatments (Table 17). Yield results and grain quality were based on three replicates as the fourth replicate was badly affected by waterlogging. The yield range in the trial was 5.37–6.23t/ha, which is similar to results achieved in 2014 at this site. There were no statistical differences in grain quality (Table 17).

vi) Three-year results (time replicate 1, 2 and 3) — yield data 2014–16

For the past three years a replicated large block stubble management trial has been established in a different

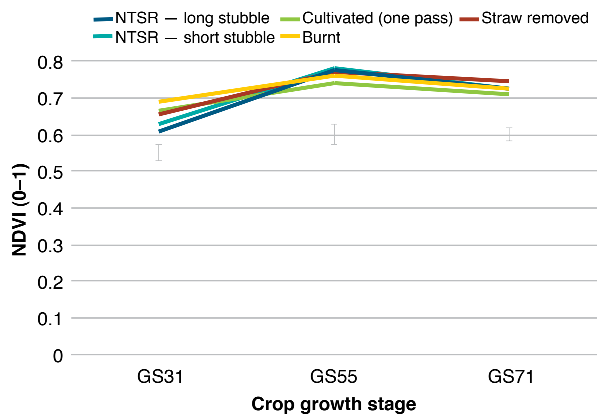

FIGURE 6 Influence of stubble management on crop canopy NDVI (0–1 scale)*
*The error bars are a measure of LSD

TABLE 17 Wheat yield, protein, test weight, screenings and thousand seed weight (TSW) 13 December 2016, at harvest (GS99)

Treatment	Yield and quality				
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	TSW (g)
NTSR — long stubble	5.80^{a}	10.7^{a}	76.5^{a}	0.7^{a}	53.9^{a}
NTSR — short stubble	5.37^{a}	10.7^{a}	79.4^{a}	0.6^{a}	54.4^{a}
Cultivated (one pass)	5.60^{a}	11.3^{a}	79.4^{a}	0.7^{a}	53.2^{a}
Straw removed	6.00^{a}	10.5^{a}	80.5^{a}	0.7^{a}	52.5^{a}
Burnt	6.23^{a}	11.1^{a}	79.7^{a}	0.6^{a}	52.8^{a}
Mean	**5.80**	**10.9**	**79.1**	**0.7**	**53.3**
LSD	1.02	1.6	5.0	0.2	4.6

Figures followed by different letters are regarded as statistically significant.

Dookie site on 8 June 2016 (GS12)

paddock on the Dookie focus farm. The trial set-up in 2014 (year one of the experiment) is referred to as time replicate 1 in the trial series, the trial set up in year two is time replicate 2 and in the third year it is time replicate 3.

After each trial has been completed the trial area reverts to being a commercial farm crop undergoing uniform management. The stubble management for all subsequent years has been uniform across the trial area and dictated by commercial farm operations. In each subsequent year the trial area has then been remarked in order to assess any yield effects of stubble management set-up in year one on yields in the year two and three farm crop.

The yield results from each time replicate trial at the Dookie focus farm have shown only one significant yield difference due to stubble management over the three years the trial has run. In 2014 the NTSR — long stubble (45cm) treatment significantly reduced yield by approximately 0.7t/ha, compared with other treatments, including NTSR — short stubble treatment. This equates to a yield reduction of 0.25t/ha for every 10cm increase in stubble height above 15cm, assuming it is a linear response between yield and stubble height (Figure 7).

Although a significant yield reduction associated with long stubble was only observed in 2014, there has been evidence in all three years that long stubble has significantly decreased DM production, resulting in less tillering and reduced crop canopy greenness. In some seasons, this reduction in crop canopy greenness has been reversed later in the season, with NTSR treatments being greener at grain fill. This was most pronounced during 2015, and was also associated with slower phenological development of the crop. In a stressed season with yields of 2.5t/ha these greenness/ phenological differences did not influence yield.

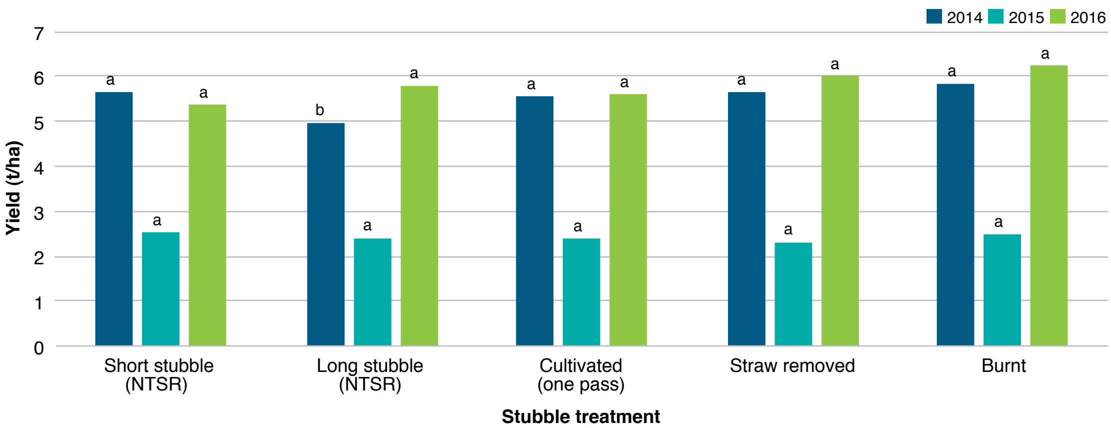

FIGURE 7 Yield data from 2014, 2015 and 2016 stubble management trials conducted in the wheat-on-wheat rotation position (time replicate 1, 2 and 3), cv Corack (2014), cv Mace (2015) and cv Corack (2016)

Yield bars for the same year with different letters are regarded as statistically different.

vii) Time replicate 1 — yield data 2014–16

Looking at crop productivity on the same trial site over three years revealed that stubble management treatments during 2014 significantly influenced canola yields in 2015 but had no effect on wheat yields in 2016. The significant reduction in yield caused by NTSR — long stubble in 2014 significantly increased commercial canola yields during 2015, even though the site was burnt following the 2014 trial, before sowing the canola. The higher canola yields in 2015 are likely due to greater stored water or unused nitrogen retained in the lower-yielding NTSR — long stubble plots. There were no flow-on effects from stubble management in 2014 on 2016 wheat yields (Table 18).

viii) 2015 trial treatments — 2016 canola yield data

The 2015 stubble management trial at the Dookie focus farm was sown to a commercial crop of canola during 2016. The 2015 second wheat trial stubbles were burnt in preparation for the commercial canola crop. Despite large visual differences in crop appearance in 2015 with NTSR — long stubble plots being greener (*Research for the Riverine Plains 2016*, p22) and slightly less developed, there were no yield differences due to stubble management treatments in either the 2015 trial, sown to wheat or the following canola crop, when sown over the 2015 stubble treatments with a yield range of 0.2t/ha across the site in both seasons (Table 19).

TABLE 18 2015 canola yields and 2016 wheat yields, on the site of the 2014 stubble management trial, which was sown to second wheat (time replicate 1)

2014 stubble management (2015 all trial blocks burnt prior to canola)	2014 trial results, second wheat yield	2015 canola yield	2016 wheat yield
NTSR — long stubble	5.0^{b}	1.4^{a}	7.1^{a}
NTSR — short stubble	5.7^{a}	1.3^{ab}	7.1^{a}
Cultivated (one pass)	5.6^{a}	1.4^{ab}	7.2^{a}
Straw removed	5.7^{a}	1.3^{ab}	6.9^{a}
Burnt	5.9^{a}	1.2^{b}	7.1^{a}
Mean	**5.5**	**1.3**	**7.1**
LSD	0.5	0.2	0.7

TABLE 19 2016 canola yields, on the site of the 2015 stubble management trial, which was sown to second wheat (time replicate 2)

2015 stubble management (2016 all trial blocks burnt prior to canola)	2015 trial results, second wheat yield	2016 canola yield
NTSR — long stubble	2.41^{a}	2.6^{a}
NTSR — short stubble	2.52^{a}	2.6^{a}
Cultivated (one pass)	2.39^{a}	2.7^{a}
Straw removed	2.32^{a}	2.6^{a}
Burn	2.49^{a}	2.5^{a}
Mean	**2.42**	**2.6**
LSD	0.22	0.2

Figures followed by different letters are regarded as statistically significant.

NTSR — long stubble 2 August 2016 (GS31)

Burnt stubble 2 August 2016 (GS31)



Trial 4: Henty, NSW

Sowing date: 10 April 2016
Rotation: Wheat stubble
Variety: Canola 650 TT
Stubble: Wheat (various treatments applied)
Stubble load at sowing: 6.6t/ha
Rainfall:
GSR: 619mm (April–October)
Summer rainfall: 145mm
Soil nitrogen at sowing: 106kg N/ha NTSR (control), 101kg N/ha multidisc (0–60cm)

Key points

- Trial results were highly variable, with no significant differences in canola yield although there was a trend for the cultivation treatments to be higher yielding.
- Canola 650TT showed higher DM accumulation at flowering where the seedbed had been cultivated (multidisc) compared with the NTSR control, although adding nitrogen to the NTSR treatment negated this effect.
- The 2016 results were similar to 2014 when cultivation before sowing significantly increased canola yields.

Results

i) Establishment and crop structure

There were no significant differences in crop establishment in terms of crop and weed plant populations, however plant establishment was significantly more vigorous where the seedbed had been cultivated (Table 20).

TABLE 20 Plant and weed counts 3 May 2016, three leaves unfolded (GS13) and vigour score 17 July 2016, green bud stage (GS51)

Treatment	Canopy composition		
	GS13		GS51
	plants/m^2	weeds/m^2	Vigour
NTSR (control)	31^{a}	0.4^{a}	4.3^{bc}
NTSR + 40kg N/ha	35^{a}	0.6^{a}	5.4^{ab}
Mulched	31^{a}	0.4^{a}	4.9^{abc}
Mulched + 40kg N/ha	25^{a}	0.4^{a}	3.8^{c}
Cultivate (one pass)	34^{a}	0.0^{a}	6.0^{a}
Cultivate (one pass) + 40kg N/ha	28^{a}	1.0^{a}	5.1^{abc}
Mean	**31**	**0.5**	**4.9**
LSD	14	1.2	1.6

ii) Dry matter production and nitrogen uptake in the crop canopy

While the results were highly variable, the NTSR (control) and mulched treatments generally produced less DM than the cultivated treatment, up to the mid-flower assessment (Table 21). Early DM production was increased by either cultivation and/or adding nitrogen to the NTSR (control), but by harvest there were no significant differences in DM between treatments (Table 21). Similar trends are observed in the nitrogen uptake data (Table 22).

iii) Yield

There were no significant yield differences due to stubble management, with variable yield results due to transient waterlogging across the trial site. There was a non-significant trend for crops in the cultivated treatment to yield more, a result that was significant in 2014 when cultivated crops significantly out-yielded the NTSR (control) blocks (Table 23).

TABLE 21 Dry matter 11 July 2016, green bud (GS51); 9 August 2016, mid-flower (GS65); 26 September 2016, 50% pods reached final size (GS75) and 11 November, harvest (GS99)

Treatment	Dry matter (t/ha)			
	GS51	GS65	GS75	GS99
NTSR (control)	1.64^{b}	3.70^{c}	6.90^{b}	9.76^{a}
NTSR + 40kg N/ha	2.15^{a}	4.51^{abc}	6.09^{b}	7.98^{a}
Mulched	1.69^{b}	3.91^{bc}	7.58^{ab}	8.31^{a}
Mulched + 40kg N/ha	1.58^{b}	4.19^{abc}	9.11^{a}	9.59^{a}
Cultivate (one pass)	1.84^{ab}	5.17^{a}	6.64^{b}	8.33^{a}
Cultivate (one pass) + 40kg N/ha	1.75^{ab}	5.12^{ab}	7.49^{ab}	8.87^{a}
Mean	**1.78**	**4.43**	**7.30**	**8.81**
LSD	0.46	1.23	1.78	2.99

TABLE 22 Nitrogen uptake in dry matter 11 July 2016, green bud (GS51); 9 August 2016, mid-flower (GS65); 26 September 2016, 50% pods reached final size (GS75) and 11 November, harvest (GS99)

Treatment	Nitrogen uptake (kg N/ha)			
	GS51	GS65	GS75	GS99
NTSR (control)	86^{bc}	117^{bc}	141^{b}	151^{a}
NTSR + 40kg N/ha	112^{a}	130^{bc}	114^{b}	153^{a}
Mulched	96^{abc}	94^{c}	161^{b}	91^{b}
Mulched + 40kg N/ha	82^{c}	167^{ab}	227^{a}	130^{ab}
Cultivate (one pass)	111^{ab}	132^{bc}	132^{b}	98^{b}
Cultivate (one pass) + 40kg N/ha	94^{abc}	201^{a}	164^{b}	165^{a}
Mean	**97**	**140**	**157**	**131**
LSD	26	61	51	52

NTSR (control) treatment, 3 June 2016, 4–6 leaves

Cultivated treatment, 3 June 2016, 4–6 leaves

TABLE 23 Canola yield and % of trial site mean 6 December 2016, at harvest (GS99)

Treatment	Yield (t/ha)
NTSR (control)	2.40[a]
NTSR + 40kg N/ha	2.26[a]
Mulched	2.48[a]
Mulched + 40kg N/ha	2.53[a]
Cultivate (one pass)	2.80[a]
Cultivate (one pass) + 40kg N/ha	2.72[a]
Mean	**2.53**
LSD	0.72

iv) Three-year results (time replicates 1, 2 and 3) — yield data 2014–16

The yield results from year one of each trial run at the Henty focus farm (time replicates 1, 2 and 3) have shown variable results, but similar trends (Figure 8). This trend has been for canola crops to yield more following cultivation compared with the NTSR (control) treatment, though it was only in 2014 that the yield advantage of cultivation (by multidisc) was statistically significant. In all three years the trial site has been subjected to variable amounts of waterlogging, which was particularly problematic in early spring across all three years.

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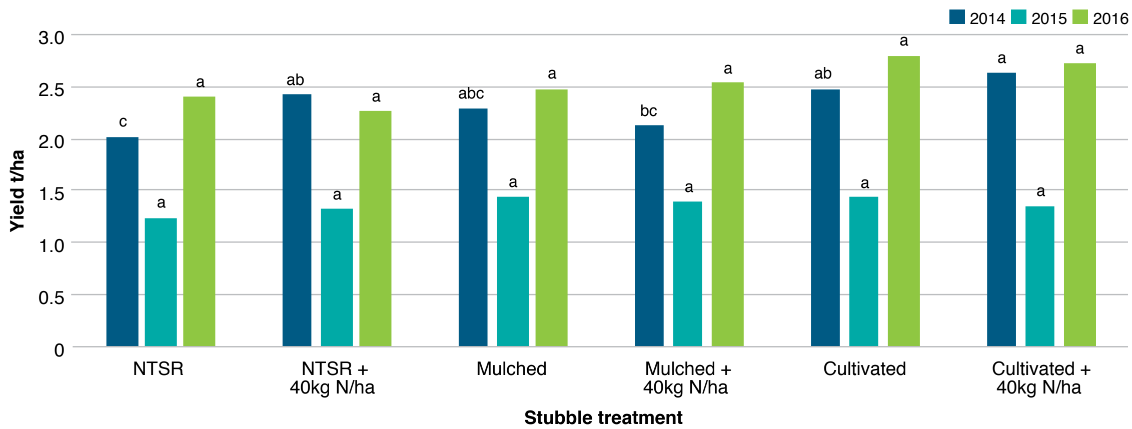

FIGURE 8 Yield data from 2014, 2015 and 2016 stubble management trials carried out in canola following wheat (time replicates 1, 2 and 3), cv GT50 RR (2014), cv 314 TT Monola (2015) and cv Hyola 650 TT (2016)