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 pages 10–11.

Method

Different methods of stubble management were trialled in four large (farm-scale) replicated trials during 2014 and 2015. 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.

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 2. 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, 2015 (time replicate 2)

Trial details	Trial 1 Corowa	Trial 2 Yarrawonga	Trial 3 Dookie	Trial 4 Henty
Treatments				
NTSR (control)	✓	✓	✓	✓
NTSR + 40kg extra nitrogen 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	×	38cm	42cm	×
NTSR — short stubble	×	15cm	15cm	×
NTSR — straw mown and removed	×	✓	✓	×
NTSR — stubble mulched and retained	×	×	×	✓
NTSR — stubble mulched + 40kg extra nitrogen at sowing	×	×	×	✓
NTSR — faba beans sown for forage	✓	×	×	×
NTSR — faba beans sown for grain	✓	×	×	×
Trial plot dimensions	40 x 15m	40 x 18m	40 x 18m	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)	6.4	6.3	8.7	8.3
Stubble height (cm)	35	38	15	50
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	Second wheat	Wheat following barley	Second wheat	Monola following triticale



TABLE 2 Site details for 2015 crops sown onto 2014 stubble management trial sites (time replicate 1)

Trial details	Trial 1 Daysdale#	Trial 2 Yarrawonga	Trial 3 Dookie	Trial 4 Henty
Treatments				
Crop type/variety	Wheat/Corack	Barley/Latrobe	Canola/43Y23	Oats/Matika
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)	6.1	6.4	7.4	7.9
Stubble height (cm)	26	35	30	47
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	Third wheat	Barley following wheat	Canola following wheat	Oats following wheat

The site was relocated from a paddock near Daysdale in 2014 to a paddock near Corowa in 2015 in order to maintain the required rotation position.

Trial 1: Corowa, NSW

Sowing date: 7 May 2015
Rotation: Second wheat
Variety: Wheat cv Mace, faba beans cv Fiesta
Stubble: Wheat (various treatments applied)
Stubble load at sowing: 6.4t/ha
Rainfall:
GSR: 329mm (April – October)
Summer rainfall: 152mm
Soil nitrogen at sowing: 50kg N/ha NTSR (control) and 54kg N/ha multidisc (0–60cm)

Key points

- There were significant differences in dry matter (DM) accumulation, nitrogen (N) uptake, disease control and yield between treatments.
- Burning stubble increased wheat dry matter (DM), but limited yield, likely due to earlier senescence causing lower harvest indices (HI).
- Growing faba beans, instead of a second wheat, increased the yield of the following wheat by about 2t/ha compared with growing a third wheat using no-till full stubble retention (NTSR).
- Wheat following faba beans resulted in significantly higher protein compared with third wheat with more than 50kg N/ha additional nitrogen offtake in the grain.
- Cultivation in the 2014 trial resulted in significantly higher yields during 2015 compared with burning.

Results

i) Establishment and crop structure

With sufficient moisture levels at sowing there were no differences in crop establishment at three and six weeks after sowing with no increase in plant numbers between the two assessments (Table 3). Rates of tillering were relatively low and uniform at 2.3–2.4 tillers per plant when assessed at the end of tillering/start of stem elongation (GS31). There was also no difference in head numbers between treatments, which was about 300/m^2.

ii) Dry matter production and nitrogen uptake

Where the previous wheat stubble was burnt the DM production at flowering was greater than with the NTSR and cultivated plots (Table 4). At harvest there were no significant differences in DM production between burning and NTSR. Similar trends were apparent in the nitrogen uptake figures with more nitrogen present in the burn treatment and the treatment receiving an extra 40kg N/ha at sowing. The higher nitrogen content in the burnt treatment was not statistically superior to the NTSR (Table 5 and Figure 1). Nitrogen uptake did not increase in the crop canopy after flag leaf emergence (GS39).

iii) Disease levels

Yellow leaf spot (YLS) caused by the pathogen *Pyrenophora tritici repentis* was present at high levels early in the season but never exceeded 5–10% on flag-2, the first of the important leaves. Under these conditions burning the previous wheat stubble gave significantly better disease control in the lower crop canopy (flag-3 to flag-5) when assessed at stem elongation (GS31 and GS39). There were no significant differences in disease

TABLE 3 Plant counts 1 June 2015, two-leaf stage (GS12); plant counts 24 June 2015, one-tiller stage (GS21); tiller counts 15 July 2015, first node (GS31) and head counts 19 November, harvest (GS99)

	Crop growth stage			
	GS12	GS21	GS31	GS99
Treatment	**Plants/m²**	**Plants/m²**	**Tillers/m²**	**Heads/m²**
NTSR (control)	114^{a}	114^{a}	270^{a}	312^{a}
Cultivated (one pass)	118^{a}	113^{a}	265^{a}	321^{a}
Cultivated (one pass) + 40kg N/ha	114^{a}	115^{a}	276^{a}	294^{a}
Burnt	126^{a}	131^{a}	295^{a}	297^{a}
Mean	**118**	**118**	**277**	**306**
LSD	28	32	54	85

Figures followed by different letters are regarded as statistically significant.

TABLE 4 Dry matter 15 July 2015, first node (GS31); 9 September 2015, flag leaf fully emerged (GS39); 9 October 2015, mid-flowering (GS65) and 19 November, harvest (GS99)

	Dry matter (t/ha)			
	GS31	GS39	GS65	GS99
NTSR (control)	0.66^{a}	3.81^{ab}	6.94^{b}	8.90^{a}
Cultivated (one pass)	0.71^{a}	3.47^{b}	7.59^{b}	9.12^{a}
Cultivated (one pass) + 40kg N/ha	0.70^{a}	4.42^{a}	8.01^{ab}	8.77^{a}
Burnt	0.73^{a}	4.35^{a}	9.34^{a}	8.79^{a}
Mean	**0.70**	**4.01**	**7.97**	**8.90**
LSD	0.18	0.69	1.45	1.89

Figures followed by different letters are regarded as statistically significant.

TABLE 5 Nitrogen uptake in crop 15 July 2015, first node (GS31); 9 September 2015, flag leaf fully emerged (GS39); 9 October 2015, mid-flowering (GS65) and 19 November, harvest (GS99)

	Nitrogen uptake in dry matter (kg N/ha)			
	GS31	GS39	GS65	GS99
NTSR (control)	32^{a}	77^{bc}	70^{a}	79^{a}
Cultivated (one pass)	33^{a}	67^{c}	68^{a}	61^{a}
Cultivated (one pass) + 40kg N/ha	32^{a}	98^{a}	89^{a}	87^{a}
Burnt	35^{a}	83^{ab}	94^{a}	79^{a}
Mean	**33**	**81**	**80**	**77**
LSD	10	16	26	42

Figures followed by different letters are regarded as statistically significant.

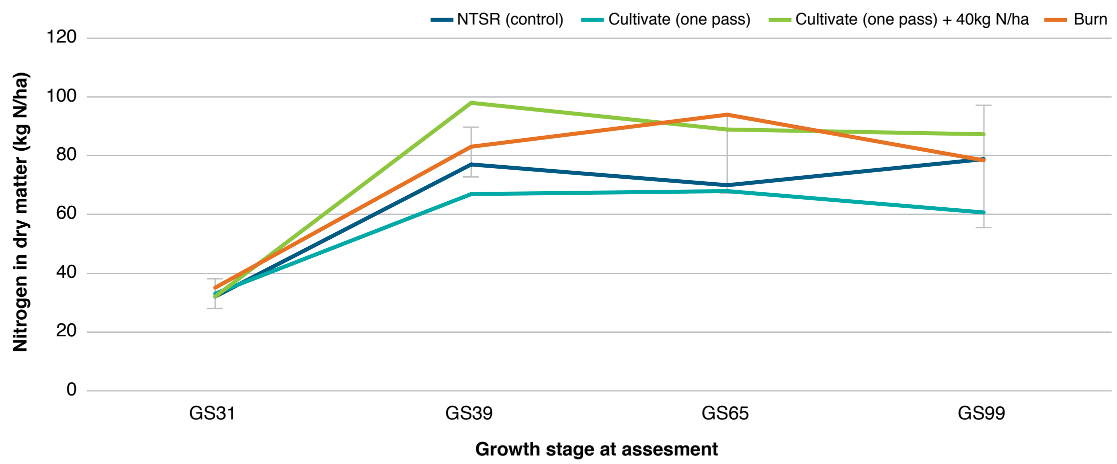

FIGURE 1 Nitrogen uptake in dry matter across the four stubble management treatments



levels due to other stubble management treatments (Table 6 and Table 7).

iv) Green leaf retention differences

The largest visual differences in the large block plots were observed during mid-October after a period of extreme heat (35–37°C) during the first week of October. The NTSR plots were visibly greener at this stage than the burn plots and observations at grain fill suggested the burn plots were slightly more developmentally advanced. How the stubble treatments affect the timing of crop phenology will be studied in more detail during the 2016 season.

v) Yield and grain quality

The trial was harvested on 25 November 2015. The different stubble management treatments resulted in significantly different yields (Table 8). Where stubble was burnt the yields were significantly lower than cultivated crops, which received 40kg N/ha before sowing. There were no significant yield advantages of any stubble treatments over the NTSR control treatments at this site.

TABLE 6 Yellow leaf spot severity and incidence of the two newest fully-emerged leaves (flag-4, flag-5) assessed 15 July 2015, first-node stage (GS31)

	YLS (%) at GS31			
	Severity (% leaf area infected)		Incidence (% leaves infected)	
	Flag-4	Flag-5	Flag-4	Flag-5
NTSR (control)	1.93[a]	5.83[ab]	75[a]	85[a]
Cultivated (one pass)	2.20[a]	5.78[ab]	88[a]	95[a]
Cultivated (one pass) + 40kg N/ha	2.30[a]	6.58[a]	78[a]	95[a]
Burnt	0.18[b]	0.68[b]	15[b]	48[b]
Mean	**1.65**	**4.71**	**64**	**81**
LSD	1.55	5.90	30	23.28

Figures followed by different letters are regarded as statistically significant.

TABLE 7 Yellow leaf spot severity and incidence on the three newest fully-emerged leaves (flag-1, flag-2, flag-3) assessed 9 September 2015, flag leaf fully emerged (GS39)

	YLS (%) at GS39					
	Severity (% leaf area infected)			Incidence (% leaves infected)		
	Flag-1	Flag-2	Flag-3	Flag-1	Flag-2	Flag-3
NTSR (control)	0.2[a]	2.8[a]	35.4[a]	18[a]	88[a]	100[a]
Cultivated (one pass)	0.2[a]	6.3[a]	42.2[a]	15[a]	80[ab]	100[a]
Cultivated (one pass) + 40kg N/ha	0.2[a]	2.9[a]	28.2[a]	23[a]	76[ab]	100[a]
Burnt	0.3[a]	1.4[a]	12.9[b]	25[a]	63[b]	98[a]
Mean	**0.2**	**3.3**	**29.7**	**20**	**77**	**99**
LSD	0.2	5.5	15.1	23	19	4

Figures followed by different letters are regarded as statistically significant.

TABLE 8 Wheat yield, protein, test weight, screenings, harvest index (HI) and thousand seed weight (TSW) 25 November 2015, at harvest (GS99)

	Yield and quality					
	Yield (t/ha)	Protein (%)	Test weight (kg/hl)	Screenings (%)	HI (%)	TSW (g)
NTSR (control)	4.33[ab]	10.9[a]	78.8[a]	3.5[a]	42.8[ab]	31.3[b]
Cultivated (one pass)	4.18[ab]	11.4[a]	78.7[a]	3.2[a]	40.4[b]	36.1[a]
Cultivated (one pass) + 40kg N/ha	4.69[a]	11.5[a]	78.7[a]	3.5[a]	46.8[a]	28.9[b]
Burnt	3.77[b]	11.4[a]	79.8[a]	3.6[a]	37.7[b]	35.2[a]
Mean	**4.24**	**11.3**	**79.0**	**3.5**	**41.9**	**32.9**
LSD	0.67	1.2	1.8	1.2	5.9	3.2

Figures followed by different letters are regarded as statistically significant.

The only significant difference in grain quality was a lower thousand seed weight (TSW) when extra nitrogen was applied at sowing.

The faba bean treatments, when cut for forage on 23 October, had a DM yield of 3.5t/ha. The bean crop taken through to grain harvest yielded 1.4t/ha and was harvested on the same day as the wheat treatments.

vi) Combined results over two years

The results from this focus farm across the past two years show that for both 2014 and 2015 the rank order of treatments has been similar, although with significant differences in yield only recorded during 2015 (Figure 2). Despite benefits in terms of earlier DM accumulation and disease control (YLS) from burning, no yield advantage has been observed over NTSR at this trial site.

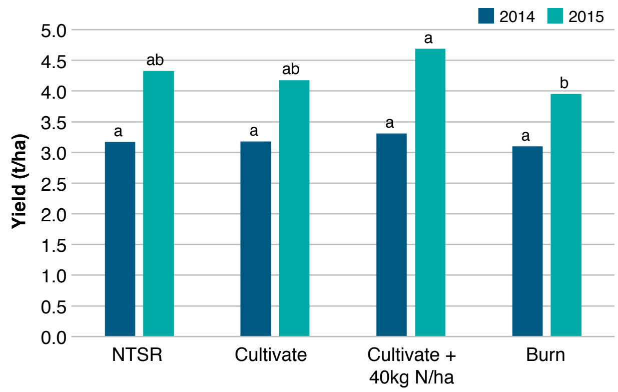

FIGURE 2 Yield data from the Daysdale (red brown earth) and Corowa (heavy grey clay) trials for 2014 and 2015 — cv Whistler in 2014 and cv Mace in 2015.

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

Notes: The two trials were carried out in the same region, but not on the same trial site. During 2014 the cultivation treatments were established with two passes while a single pass was used in 2015.

vii) 2014 stubble management treatments — influence on 2015 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 to assess whether there are any rotational effects on these crops. For example, whether burning or cultivating between the first and second wheat crop impact yield performance the year after the second wheat. Table 9 shows the performance of a commercial wheat crop (cv Corack) sown during 2015 into the 2014 stubble management trial.

The stubble management carried out during the 2014 stubble management trial, where a second wheat crop and faba beans were grown, significantly influenced the commercial crop established in 2015. The 2015 wheat crop was established using NTSR. Wheat yields following faba beans yielded 2t/ha more than a third continuous wheat crop. Higher yields were clearly associated with greater nitrogen availability as wheat protein was significantly higher following faba beans. The nitrogen offtake in grain following faba beans equated to 111kg N/ha (average of forage and grain faba bean treatments) versus 57kg N/ha in the third wheat established with NTSR. Light cultivation during 2014 offered no advantage to NTSR crops during 2015, although burning during 2014 resulted in significantly lower-yielding 2015 crops than cultivating during 2014. Screenings from the 2015 harvest following burning during 2014 were significantly higher.

TABLE 9 Wheat yield, protein, test weight and screenings at Daysdale, 2015

2014 stubble treatments	2015 yield and quality			
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screening (%)
Burnt	3.38[c]	9.1[b]	82.7[b]	5.8[a]
NTSR (control)	3.54[bc]	9.2[b]	83.6[a]	4.8[b]
Cultivated	3.82[b]	9.7[b]	82.9[ab]	4.7[b]
Cultivated + 40kg N/ha	3.61[bc]	9.4[b]	82.7[b]	4.4[b]
Faba beans (forage)	5.62[a]	11.4[a]	82.8[b]	3.7[c]
Faba beans (grain)	5.66[a]	11.1[a]	83.1[ab]	3.5[c]
Mean	**4.27**	**10.0**	**83.0**	**4.5**
LSD	0.39	0.8	0.7	0.6

Figures followed by different letters are regarded as statistically significant.

Trial 2: Yarrawonga, Victoria

Sowing date: 13 May 2015
Rotation: Second cereal
Variety: Young
Stubble: Barley (various treatments applied)
Stubble load at sowing: 6.3t/ha
Rainfall:
GSR: 266mm (April–October)
Summer rainfall: 120mm
Soil nitrogen at sowing: 98kg N/ha NTSR (control) and 60kg N/ha multidisc (0–60cm)

Key points

- Retaining short stubble with no-till full stubble retention (NTSR — short stubble) resulted in significantly higher wheat yields than where stubble was burnt, cultivated with extra nitrogen (N) or straw removed.
- No-till full stubble retention with long stubble (NTSR — long stubble), and to a lesser extent NTSR — short stubble, gave better green leaf retention than other stubble management treatments; a result that may be linked to slower development earlier in the season.
- The stubble treatments set up during the 2014 season (burning, cultivating, removing straw) had no impact on the yield of the following barley crop compared with the NTSR control, although removing straw during 2014 produced significantly superior barley crops in 2015 compared with cultivating the straw.

Results

i) Establishment and crop structure

The different stubble management treatments did not influence plant establishment, however the NTSR — long stubble (control) crops had less vigour compared with where straw was removed, cultivated, burnt or where stubble was kept short (NTSR — short stubble) (Table 10). By the start of stem elongation (GS31) the NTSR — long stubble treatments had significantly fewer tiller numbers per square metre compared with the straw removed, cultivation and burn treatments. The differences in tillering did not result in any significant difference in head number.

ii) Dry matter production

The lower tiller number recorded with NTSR — long stubble at first node (GS31) correlated to less dry matter (DM) accumulation, which was also seen in the NTSR — short stubble treatment (Table 11). However the lag in DM production with NTSR treatments was not apparent at the harvest assessment, indicating later compensation in these treatments. The burn treatment had significantly higher DM than the NTSR — long stubble treatment up to and including flowering (GS65).

The differences in DM accumulation at first node (GS31) were related to nitrogen uptake in the crop canopy, with significantly higher nitrogen content where there was more DM (Table 12). Again there were few differences in nitrogen contents of the canopy at later assessments, although an extra 40kg N/ha at sowing did result in more nitrogen in the crop at harvest.

TABLE 10 Plant counts and vigour 2 June 2015, one-leaf stage (GS11); plant counts 25 June 2015, three-leaf stage (GS13); tiller counts 6 August 2015, first-node stage (GS31) and head counts 25 November, harvest (GS99)

	Crop growth stage				
	Plants/m^2	Vigour	Plants/m^2	Tillers/m^2	Heads/m^2
Treatment	GS11		GS13	GS31	GS99
NTSR — long stubble (control)	167^{a}	6.0^{b}	165^{a}	338^{d}	289^{a}
NTSR — long stubble + 40kg N/ha	178^{a}	6.0^{b}	175^{a}	354^{cd}	294^{a}
NTSR — short stubble	164^{a}	8.0^{a}	163^{a}	379^{bcd}	313^{a}
Straw removed	185^{a}	8.0^{a}	185^{a}	406^{bc}	300^{a}
Cultivated (one pass)	179^{a}	8.0^{a}	177^{a}	440^{ab}	314^{a}
Cultivated (one pass) + 40kg N/ha	177^{a}	8.0^{a}	181^{a}	471^{a}	289^{a}
Burnt	185^{a}	9.0^{a}	188^{a}	486^{a}	301^{a}
Mean	**176**	**7.5**	**177**	**411**	**300**
LSD	31	0.8	29	64	45

Figures followed by different letters are regarded as statistically significant.

TABLE 11 Dry matter 6 August 2015, first node (GS31); 15 September 2015, flag leaf fully emerged (GS39); 7 October 2015, mid-flowering (GS65) and 17 November, harvest (GS99)

Treatment	Dry matter (t/ha)			
	GS31	GS39	GS65	GS99
NTSR — long stubble (control)	0.86[b]	4.01[b]	6.52[b]	6.88[a]
NTSR — long stubble + 40kg N/ha	1.01[b]	4.61[ab]	7.40[a]	6.79[a]
NTSR — short stubble	1.00[b]	4.21[ab]	6.84[ab]	6.82[a]
Straw removed	1.36[a]	4.61[ab]	6.80[ab]	6.81[a]
Cultivated (one pass)	1.37[a]	5.01[a]	6.78[ab]	7.05[a]
Cultivated (one pass) + 40kg N/ha	1.50[a]	4.84[ab]	6.71[ab]	7.14[a]
Burnt	1.34[a]	4.87[a]	7.42[a]	6.92[a]
Mean	**1.21**	**4.60**	**6.92**	**6.91**
LSD	0.27	0.85	0.73	1.01

Figures followed by different letters are regarded as statistically significant.

TABLE 12 Nitrogen uptake in crop 6 August 2015, first node (GS31); 15 September 2015, flag leaf fully emerged (GS39); 7 October 2015, mid-flowering (GS65) and 17 November, harvest (GS99)

Treatment	Nitrogen uptake in biomass (kg N/ha)			
	GS31	GS39	GS65	GS99
NTSR — long stubble (control)	47.0[b]	121[a]	117[a]	90[ab]
NTSR (long) + 40kg N/ha	54.0[b]	122[a]	120[a]	86[b]
NTSR — short stubble	56.0[b]	113[a]	111[ab]	98[ab]
Straw Removed	77.0[a]	114[a]	95[b]	91[ab]
Cultivated (one pass)	74.0[a]	116[a]	101[ab]	81[b]
Cultivated (one pass) + 40kg N/ha	82.0[a]	125[a]	108[ab]	109[a]
Burnt	74.0[a]	117[a]	111[ab]	77[b]
Mean	**66.3**	**118**	**109**	**90**
LSD	13.3	26	20	22

Figures followed by different letters are regarded as statistically significant.

iii) Green leaf retention at the early grain-fill stage

During mid-October there were large visual differences in the treatment blocks with the NTSR blocks being greener, but with slightly less-developed grain. These differences followed a period of extreme heat (35–37°C) during the first week of October that 'cooked' many of the crops. The burn blocks were notably more senesced with more-developed grain when observed during mid-October.

iv) Soil water monitoring

Monitoring of deep soil moisture at this site indicated water was unavailable to the crop below 50cm, which may help explain the premature senescence in the crop following the dry spring and excessive heat events during October.

v) Grain yield and quality

The trial was harvested on 25 November 2015. There were statistical differences in grain yield and quality as a result of stubble management. Despite a lag in DM accumulation in the NTSR — short stubble treatment, it significantly out yielded the burn treatment (3.35t/ha versus 2.93t/ha). The premature senescence of the burn treatment is evident in the higher level of screenings (averaged 21%) compared with the NTSR — short stubble treatment.

Visual differences in green leaf retention due to different stubble management treatments photographed 13 October 2015 (NTSR — long stubble plot in the foreground). Inset: Grain from burn plots (left) and NTSR — long stubble plots (right).

TABLE 13 Wheat yield, protein, test weight, screenings, harvest index (HI) and thousand seed weight (TSW) 25 November 2015, at harvest (GS99)

Treatment	Yield and quality					
	Yield (t/ha)	Protein (%)	Test wt (kg/hL)	Screenings (%)	HI (%)	TSW (g)
NTSR — long stubble (control)	3.13^{ab}	15.6^{ab}	78.8^{ab}	19.9^{ab}	42.8^{a}	21.1^{a}
NTSR — long stubble + 40kg N/ha	3.20^{ab}	15.6^{abc}	78.5^{ab}	21.0^{ab}	44.0^{a}	21.1^{a}
NTSR — short stubble (2015 only)	3.35^{a}	14.8^{d}	79.2^{a}	17.7^{b}	46.8^{a}	22.3^{a}
Straw removed	3.03^{b}	14.9^{bcd}	78.3^{ab}	22.6^{ab}	41.7^{a}	21.1^{a}
Cultivated (one pass)	3.10^{ab}	14.8^{cd}	79.0^{ab}	19.1^{b}	41.0^{a}	21.3^{a}
Cultivated (one pass) + 40kg N/ha	3.05^{b}	15.7^{a}	78.9^{ab}	22.0^{ab}	40.0^{a}	21.3^{a}
Burnt	2.93^{b}	15.0$^{a\text{-}d}$	77.9^{b}	25.2^{a}	39.8^{a}	20.8^{a}
Mean	**3.11**	**15.2**	**78.7**	**21.1**	**42.3**	**21.3**
LSD	0.29	0.8	1.2	5.7	7.7	1.5

Figures followed by different letters are regarded as statistically significant.

vi) Two-year results — yield

In two trials set up in the same crop rotation position on different paddocks during 2014 and 2015, changing stubble management only had a significant effect on yield during 2015 (Figure 3). There was a trend during the 2014 season, when ground conditions were wetter at establishment, for those treatments that removed or cultivated straw to perform better than during 2015. The lag in DM production observed with NTSR compared with other treatments was evident in both years, persisting up to flowering in both 2014 and 2015. The DM results indicate a growth compensation occurred in the NTSR treatments later in the season from flowering to grain fill.

vii) 2014 stubble management treatments — influence on 2015 barley yields

Different stubble management treatments carried out during autumn 2014 resulted in no significant differences in 2014 second wheat yields but did produce significant differences in the commercial barley crop yields during 2015 (Table 14). Retaining the stubble, but removing the straw during 2014, then burning wheat stubble during 2015 resulted in significantly higher barley yields compared with cultivating during 2014 and burning wheat stubble during 2015. This treatment however was not significantly greater than NTSR or burning in both years.

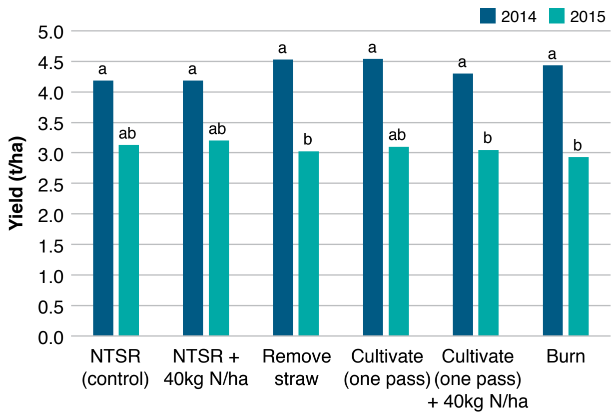

FIGURE 3 Yield data (cv Young) from the Yarrawonga trials during 2014 and 2015

Yields for the same year with different letters are regarded as statistically different. Refer to Table 14 for NTSR — short stubble result (2015 only), which completes the dataset.

TABLE 14 Barley yield in the 2015 commercial crop following different stubble management treatments set up in the 2014 stubble management site and the 2014 wheat yield

2014 stubble management treatments (all blocks were burnt before the 2015 crop)	2014 second wheat yield (t/ha)	2015 barley yield (t/ha)
Burnt	4.43^{a}	2.60^{ab}
NTSR — long stubble (control)	4.18^{a}	2.49^{ab}
NTSR — long stubble + 40kg N/ha	4.18^{a}	2.70^{ab}
Straw removed	4.53^{a}	2.73^{a}
Cultivated (one pass)	5.54^{a}	2.43^{b}
Cultivated + 40kg N/ha	4.30^{a}	2.40^{b}
Mean	**4.36**	**2.56**
LSD	0.46	0.30

Figures followed by different letters are regarded as statistically significant.

Trial 3: Dookie, Victoria

Sowing date: 12 May 2015

Rotation: Second wheat

Variety: Mace

Stubble: Wheat (various treatments applied)

Stubble load at sowing: 8.7t/ha

Rainfall:
GSR: 233mm (April–October)
Summer rainfall: 76mm

Soil nitrogen at sowing: 56kg N/ha NTSR (control), 35kg N/ha multidisc in 0–60cm (21 April 2015)

Key points

- Heat and moisture stress during spring resulted in average yields of 2.4t/ha compared with 5.5t/ha for the equivalent trial and rotation position during 2014.
- There were no differences in the 2015 yields due to stubble management, all stubble treatments resulted in low yields, high screenings and high protein levels.
- There were visual differences in green leaf retention due to stubble management and evidence of slightly delayed maturity in the no-till stubble retention (NTSR) treatments.
- Although the NTSR— long stubble treatment decreased yields during 2014, this effect was not seen under the more stressful conditions of 2015.
- Canola sown during 2015 across the 2014 trial site yielded significantly higher in the 2014 long stubble treatment, presumably due to either water or nitrogen (N) saving.

Results

i) Establishment and crop structure

Removing or burning straw resulted in significantly higher crop vigour and tiller numbers at first node (GS31), although at harvest there were no significant differences in head numbers between any of the stubble treatments (Table 15).

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

Despite having the same plant populations, where straw was removed or burnt there were 0.75–1.0t/ha extra dry matter (DM) production by flag leaf emergence (GS39), compared with the NTSR and cultivation treatments (Table 16). After flag leaf emergence (GS39) there were no differences in DM. The same trends in DM production correlated to nitrogen uptake into the crop canopy with more nitrogen present in crops with more DM (straw removed and burnt blocks). Nitrogen content in the crop canopy peaked at the flag leaf growth stage (GS39), while DM production peaked at the end of flowering (GS69) (Table 17).

iii) Disease levels

Yellow leaf spot (YLS) was assessed at first node (GS31) and flag leaf emergence (GS39) with low levels recorded in the trial on both occasions. There were no significant differences at first node (GS31) but at flag leaf emergence (GS39) there was evidence of higher levels of YLS in the long stubble compared with the short stubble, straw removed and burnt treatments (Table 18).

iv) Green leaf retention

Following the heat shock during early October the plots showed visual differences in green leaf retention with the NTSR plots being greener than the burnt plots.

The grain in the NTSR plots also appeared to be less physiologically mature than grain taken from the burn plots.

TABLE 15 Plant counts and vigour 10 June 2015, two-leaf stage (GS12); plant counts 23 June 2015, one-tiller stage (GS21); tiller counts 29 July 2015, first-node stage (GS31) and head counts 20 November, harvest (GS99)

	Crop growth stage				
	Plants/m^2	Vigour	Plants/m^2	Tillers/m^2	Heads/m^2
	GS12		GS21	GS31	GS99
NTSR — long stubble	154[a]	8.3[b]	153[ab]	298[b]	317[a]
NTSR — short stubble	143[a]	9.0[a]	141[b]	309[b]	333[a]
Cultivated (one pass)	143[a]	9.0[a]	151[ab]	349[ab]	340[a]
Straw removed	146[a]	8.8[a]	146[ab]	389[a]	354[a]
Burnt	163[a]	9.0[a]	162[a]	394[a]	325[a]
Mean	**150**	**9.0**	**151**	**348**	**334**
LSD	25	0.5	21	76	60

Figures followed by different letters are regarded as statistically significant.



TABLE 16 Dry matter 29 July 2015, first node (GS31); 11 September 2014, flag leaf fully emerged (GS39); 9 October, end of flowering (GS69) and 20 November, harvest (GS99)

	Dry matter (t/ha)			
	GS31	GS39	GS69	GS99
NTSR — long stubble	0.92^{bc}	3.67^{b}	6.67^{a}	6.35^{a}
NTSR — short stubble	0.89^{c}	3.66^{b}	6.82^{a}	6.87^{a}
Cultivated (one pass)	0.92^{bc}	3.86^{b}	6.56^{a}	6.76^{a}
Straw removed	1.13^{ab}	4.75^{a}	6.72^{a}	6.66^{a}
Burnt	1.15^{a}	4.46^{a}	6.77^{a}	6.74^{a}
Mean	**1.00**	**4.08**	**6.71**	**6.68**
LSD	0.22	0.59	0.63	0.63

Figures followed by different letters are regarded as statistically significant.

TABLE 17 Nitrogen uptake in dry matter 29 July 2015, first node (GS31); 11 September 2014, flag leaf fully emerged (GS39); 9 October, end of flowering (GS69) and 20 November, harvest (GS99)

	Nitrogen uptake (kg/ha)			
	GS31	GS39	GS69	GS99
NTSR — long stubble	39^{ab}	90^{abc}	81^{a}	89^{ab}
NTSR — short stubble	35^{b}	87^{bc}	84^{a}	82^{ab}
Cultivated (one pass)	33^{b}	79^{c}	73^{a}	85^{ab}
Straw removed	44^{a}	103^{a}	76^{a}	90^{a}
Burnt	44^{a}	94^{ab}	83^{a}	74^{b}
Mean	**39**	**91**	**79**	**84**
LSD	8	13	12	16

Figures followed by different letters are regarded as statistically significant.

TABLE 18 Yellow leaf spot severity and incidence of the two newest fully-emerged leaves (flag-2, flag-3) assessed 11 September 2015, flag leaf fully emerged (GS39)

	Severity (% leaf area infected)		Incidence (% leaves infected)	
	Flag-2	Flag-3	Flag-2	Flag-3
NTSR — long stubble	1.3^{a}	5.6^{a}	70.0^{a}	83.3^{ab}
NTSR — short stubble	0.5^{b}	2.7^{bc}	36.7^{b}	83.3^{ab}
Cultivated (one pass)	0.6^{b}	3.8^{ab}	50.0^{ab}	86.7^{a}
Straw removed	0.3^{b}	1.5^{c}	34.1^{b}	65.2^{b}
Burnt	0.6^{b}	2.7^{bc}	56.7^{ab}	80.0^{ab}
Mean	**0.6**	**3.3**	**49.5**	**79.7**
LSD	0.6	1.9	27.3	19.7

Figures followed by different letters are regarded as statistically significant.

Green leaf retention differences resulting from the 2015 stubble management treatments at Dookie. Outlined block on right is NTSR — long stubble, and the slightly less green block outlined to the left is NTSR — short stubble. In other plots where straw was removed or cultivated the crops were more senesced. Note: two replicates further up the paddock showing similar differences. (Drone image from Tony Ludeman, with thanks).

Physiological development of grain from NTSR — long stubble treatment on the left and from burn blocks on the right observed 13 October 2015 — cv Mace.

v) Yield and grain quality

The trial was harvested on 27 November 2016. There were no statistical differences in grain yield with all treatments showing high levels of screenings (averaged almost 50%) (Table 19). The only significant differences were measured in the grain quality. Grain protein from NTSR — long stubble treatments was significantly higher than the other treatments, including NTSR — short stubble. When straw was removed the screenings were increased relative to the NTSR — short stubble treatment

vi) Two-year results — yield data

The results from this focus farm across the past two years have shown the main difference in crop productivity has been associated with long stubble in NTSR (Figure 4). The heat stress experienced during early October 2015, with resultant low yields, may have negated any treatment differences compared with 2014. The differences in green leaf retention associated with NTSR were the most visual differences recorded during 2015, but were not



TABLE 19 Wheat yield, protein, test weight, screenings, harvest index (HI) and thousand seed weight (TSW) 27 November 2015, at harvest (GS99)

	Yield and quality					
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	HI (%)	TSW (g)
NTSR — long stubble	2.41^{a}	15.0^{a}	69.8^{a}	45.8^{ab}	33.2^{a}	17.3^{a}
NTSR — short stubble	2.52^{a}	13.6^{b}	70.6^{a}	43.7^{b}	32.1^{a}	17.1^{a}
Cultivated (one pass)	2.39^{a}	12.9^{c}	68.1^{ab}	47.3^{ab}	31.1^{a}	16.4^{a}
Straw removed	2.32^{a}	13.5^{bc}	66.4^{b}	57.7^{a}	30.5^{a}	16.1^{a}
Burnt	2.49^{a}	13.3^{bc}	68.6^{ab}	50.3^{ab}	32.4^{a}	16.5^{a}
Mean	**2.42**	**13.6**	**68.7**	**49.0**	**31.9**	**16.7**
LSD	0.22	0.6	2.8	12	4.1	1.9

Figures followed by different letters are regarded as statistically significant.

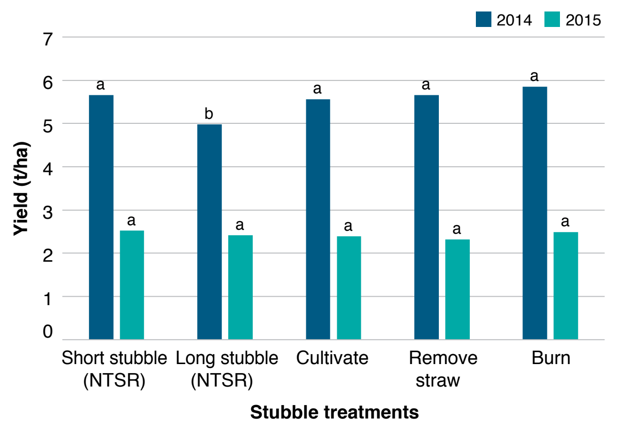

FIGURE 4 Yield data from the Dookie wheat-on-wheat trials, 2014 and 2015 — cv Corack (2014) and cv Mace (2015)

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

Notes: The two trial sites were on the same farm in the same rotation position, but not on the same trial site. During 2014 the cultivation treatments were carried out twice and during 2015 a single pass was carried out.

evident in 2014 when yields were almost double at this site There was also evidence that longer stubble in the NTSR blocks retarded the phenological development of the crop at this site during 2015, which may explain why despite the increased green leaf retention relative to other blocks the NTSR — long stubble treatment conferred no significant yield benefit. The influence of stubble length on subsequent crop development will be studied in more detail during 2016.

vii) 2014 trial treatments — 2015 canola yield data

The 2014 stubble management trial at the Dookie focus farm was sown to a commercial crop of canola during 2015. The 2014 second-wheat trial stubbles were burnt in preparation for the canola crop. The NTSR — long stubble plots that produced the lowest wheat yields during 2014 produced significantly higher canola yields than the burnt plots from 2014 (Table 20). It is unclear if the higher yields in the 2015 canola crop were the result of moisture and/or nutrient saving due to the lower-yielding wheat the season before.

TABLE 20 2015 Canola yields grown on the 2014 second wheat blocks where different stubble management treatments were performed

2014 stubble management (2015 all trial blocks burnt)	2014 second wheat yield	2015 canola yield
Burn	5.85^{a}	1.2^{b}
NTSR — long stubble	4.98^{b}	1.4^{a}
NTSR — short stubble	5.66^{a}	1.3^{ab}
Straw removed	5.66^{a}	1.3^{ab}
Cultivated (one pass)	5.56^{a}	1.4^{ab}
Mean	**5.54**	**1.3**
LSD	0.45	0.2

Figures followed by different letters are regarded as statistically significant.

Trial 4: Henty, NSW

Sowing date: 21 April 2015
Rotation: Monola following triticale/arrowleaf clover
Variety: 314 TT Monola
Stubble: Triticale (various treatments applied)
Stubble load at sowing: 8.3 t/ha
Rainfall:
GSR: 391mm (April–October)
Summer rainfall: 114mm
Soil nitrogen at sowing: 44kg N/ha NTSR (control), 37kg N/ha cultivate 0–60cm (21 April 2015)

Key points

- A highly variable trial with no significant differences in monola dry matter (DM) accumulation, nitrogen (N) uptake or yields due to stubble management.
- The 2014 cultivation treatments carried out before sowing the canola crop during the first year of the project significantly increased the yield of the following oat crop established using no-till stubble retention (NTSR).
- The yield increase in the following oat crops was reflected in significantly more biomass accumulation by the flag leaf.

Results

i) Establishment and crop structure

There were no significant differences in crop establishment in terms of crop and weed plant populations, which were highly variable. However, extra nitrogen applied at sowing improved crop vigour where cereal straw was cultivated (Table 21).

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

The different stubble management treatments produced no differences in DM production, as the waterlogging through winter resulted in large variation between replicates (Table 22). The variable nature of the DM data is also represented in the nitrogen uptake data (Table 23).

iii) Disease levels

Although there was a high level of blackleg (phoma) incidence in the trial (more than 70% of plants at each assessment timing showed infection across all treatments) infection severity never exceeded more than 20%. Significant differences in blackleg levels were recorded due to stubble management in the trial at mid-flowering only (Figure 5) with mulched stubble plus 40N being more severely infected than NTSR.

iv) Yield and grain quality

Periodic waterlogging produced highly variable yields with no significant differences due to stubble management (Table 24). The moisture content of the oilseed was higher with NTSR. Extra nitrogen at sowing significantly decreased oil content in the NTSR plots.

v) 2014 stubble management treatments — influence on 2015 oat yields cv Matika

The 2014 canola stubble management trial at the Henty focus farm was sown to a commercial crop of oats during 2015 using NTSR. From the exact same areas in the trial the 2015 oat yields were recorded to assess if the 2014 stubble management treatments put in place before the canola had any rotational effect on the following oat crop. The 2014 stubble management treatments set up before canola produced significant differences in the following 2015 oat crop (Table 25). The 2014 cultivation

TABLE 21 Plant counts, vigour and weed counts 21 May 2015, three leaves unfolded (GS13) and plant counts 5 August 2015, yellow bud stage (GS59)

	Canopy composition			
	GS13			GS59
Treatment	Plants/m²	Vigour	Weeds/m²	Plants/m²
NTSR (control)	42[ab]	4.0[b]	2.0[a]	29[ab]
NTSR + 40kg N/ha	43[ab]	5.0[b]	4.0[a]	35[ab]
Mulched	34[b]	5.0[b]	2.0[a]	24[b]
Mulched + 40kg N/ha	39[ab]	5.0[b]	2.0[a]	36[ab]
Cultivated (one pass)	59[a]	7.0[a]	6.0[a]	33[ab]
Cultivated (one pass) + 40kg N/ha	62[a]	8.0[a]	6.0[a]	42[a]
Mean	**47**	**5.7**	**3.8**	**33**
LSD	23	0.7	6.2	17

Figures followed by different letters are regarded as statistically significant.

TABLE 22 Dry matter 2 July 2015, green bud stage (GS51); 5 August 2015, yellow bud stage (GS59); 27 August, full flowering (GS65); 8 September 2015, 50% pods reached final size (GS75); 8 October 2015, 10% pods ripe (GS81) and 17 November 2015, harvest (GS99)

Treatment	Dry matter (t/ha)					
	GS51	GS59	GS65	GS75	GS81	GS99
NTSR (control)	0.90^{a}	2.04^{a}	2.78^{a}	4.91^{a}	6.38^{a}	4.79^{a}
NTSR + 40kg N/ha	1.07^{a}	2.18^{a}	2.84^{a}	3.98^{a}	6.67^{a}	3.52^{a}
Mulched	0.95^{a}	2.04^{a}	2.60^{a}	5.29^{a}	6.47^{a}	3.88^{a}
Mulched + 40kg N/ha	0.96^{a}	2.33^{a}	2.87^{a}	4.54^{a}	7.79^{a}	4.04^{a}
Cultivated (one pass)	1.07^{a}	2.20^{a}	2.69^{a}	4.52^{a}	6.21^{a}	3.27^{a}
Cultivated (one pass) + 40kg N/ha	1.22^{a}	2.23^{a}	3.09^{a}	4.38^{a}	5.60^{a}	3.54^{a}
Mean	**1.03**	**2.17**	**2.81**	**4.60**	**6.52**	**3.84**
LSD	0.46	0.83	0.98	2.38	3.53	1.55
Figures followed by different letters are regarded as statistically significant.						

TABLE 23 Nitrogen uptake in dry matter 2 July 2015, green bud stage (GS51); 5 August 2015, yellow bud stage (GS59); 27 August, full flowering (GS65); 8 September 2015, 50% pods reached final size (GS75); 8 October 2015, 10% pods ripe (GS81) and 17 November 2015 harvest (GS99)

Treatment	Nitrogen uptake (kg N/ha)					
	GS51	GS59	GS65	GS75	GS81	GS99
NTSR (control)	30^{b}	83^{a}	47^{a}	80^{a}	68^{a}	42^{a}
NTSR + 40kg N/ha	44^{ab}	71^{a}	50^{a}	64^{a}	79^{a}	44^{a}
Mulched	39^{ab}	65^{a}	47^{a}	80^{a}	61^{a}	48^{a}
Mulched + 40kg N/ha	36^{ab}	78^{a}	58^{a}	76^{a}	81^{a}	66^{a}
Cultivated (one pass)	34^{ab}	82^{a}	55^{a}	87^{a}	67^{a}	43^{a}
Cultivated (one pass) + 40kg N/ha	50^{a}	85^{a}	55^{a}	76^{a}	57^{a}	51^{a}
Mean	**39**	**77**	**52**	**77**	**69**	**49**
LSD	17	29	17	43	54	31
Figures followed by different letters are regarded as statistically significant.						

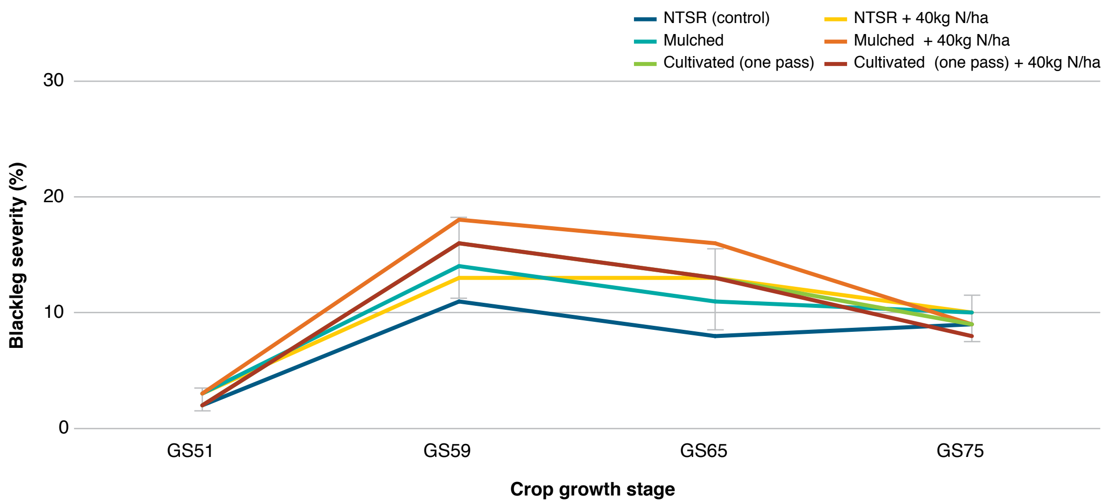

FIGURE 5 Blackleg severity of the whole plant 2 July 2015, green bud stage (GS51); 5 August 2015, yellow bud stage (GS59); 27 August, full flowering (GS65) and 8 September 2015, 50% pods reached final size (GS75)
Error bars presented as a measure of LSD

TABLE 24 Monola yield, oil, protein and moisture 28 November 2015, harvest (GS99)

Treatment	Yield and quality			
	Yield (t/ha)	Oil (%)	Protein (%)	Moisture (%)
NTSR (control)	1.24^{a}	44.5^{a}	19.1^{b}	5.4^{a}
NTSR + 40kg N/ha	1.32^{a}	41.0^{b}	21.7^{a}	5.1^{ab}
Mulched	1.44^{a}	43.6^{a}	20.6^{ab}	5.0^{b}
Mulched + 40kg N/ha	1.39^{a}	43.6^{a}	20.4^{ab}	4.8^{b}
Cultivated (one pass)	1.43^{a}	44.3^{a}	20.3^{ab}	4.9^{b}
Cultivated (one pass) + 40kg N/ha	1.35^{a}	43.7^{a}	20.8^{ab}	4.8^{b}
Mean	**1.36**	**43.4**	**20.5**	**5.0**
LSD	0.63	1.6	1.7	0.4

Figures followed by different letters are regarded as statistically significant.

TABLE 25 2015 oat yields recorded on the 2014 Henty stubble management site

2014 stubble management treatments	2014 canola yields	2015 oat yields
NTSR (control)	2.02^{c}	2.71^{b}
NTSR + 40kg N/ha	2.42^{ab}	3.24^{ab}
Mulched	2.29^{abc}	3.21^{ab}
Mulched + 40kg N/ha	2.21^{bc}	3.29^{ab}
Cultivated	2.48^{ab}	3.48^{a}
Cultivated + 40kg N/ha	2.63^{a}	3.49^{a}
Mean	**2.34**	**3.24**
LSD	0.36	0.71

Figures followed by different letters are regarded as statistically significant.

blocks with and without nitrogen significantly increased oat yields in the year following compared with the NTSR treatments. There was also a non-significant trend that oat yields following mulching were higher than NTSR.

The 2014 cultivation carried out before the canola significantly increased the yield of the 2015 oat crop both with and without additional nitrogen at sowing (applied at sowing during autumn 2014). This yield increase was reflected in DM increases (Table 26).

TABLE 26 2015 oat dry matter following the 2104 Henty stubble management treatments — assessed early booting (GS41), 8 September 2015

2014 stubble management treatments	Dry matter GS41
	(t/ha)
NTSR (conrol)	6.03^{bc}
NTSR + 40kg N/ha	5.75^{c}
Mulched	6.30^{bc}
Mulched + 40kg N/ha	6.57^{bc}
Cultivated	7.39^{b}
Cultivated + 40kg N/ha	9.72^{a}
Mean	**6.96**
LSD	1.55

Figures followed by different letters are regarded as statistically significant.

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