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, 2016 and 2017. 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
- 2017 trial site: time replicate 4.

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, Table 3 and Table 4. 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, 2017 (time replicate 4)

Trial details	Trial 1	Trial 2	Trial 3
	Coreen#	Yarrawonga	Dookie
NTSR* (control)	✓	✓	✓
NTSR + 40kg extra nitrogen at sowing	×	✓	×
Cultivated	One pass	One pass	One pass
Cultivated + 40kg N/ha at sowing	One pass	One pass	×
Burnt stubble	✓	✓	✓
NTSR — long stubble	×	39cm	39cm
NTSR — short stubble	×	14cm	18cm
NTSR — straw mown and removed	×	✓	✓
NTSR — stubble mulched and retained	×	×	×
NTSR — faba beans sown for forage	✓	×	×
NTSR — faba beans sown for grain	✓	×	×
Trial plot dimensions (m)	40 x 15	40 x 18	40 x 18
Farm drill used for trial	Aus seeder DBS D-300 tine seeder	Aus seeder DBS tine knife point	Simplicity seeder/knife point
Stubble loading (t/ha)	10.1	7.4	7.1
Stubble height (cm)	42	39	18
Soil type description	Loam over clay	Self-mulching red loam over grey clay	Red loam
Row spacing (cm)	30	32	33.3
Crop and rotation position	Second wheat	Second wheat	Canola

The site was relocated to a paddock near Daysdale in 2014, near Corowa in 2015 and near Coreen in 2016 and 2017 in order to maintain the required rotation position.

* No-till stubble retention (NTSR)

TABLE 2 Site details for 2017 crops sown onto 2016 stubble management trial sites (time replicate 3)

Trial details	Trial 1	Trial 2	Trial 3
	Corowa#	Yarrawonga	Dookie
Crop type/variety	Wheat/Whistler	Oats/Winteroo	Canola/Hyola 575
Paddock burnt	✓	✓	✓
Farmer harvested	✓	✓	✓
Plot harvester	×	×	×
Trial plot dimensions (m)	40 x 15	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
Stubble loading (t/ha)	6.5	10.5	10.9
*Stubble height (cm)**	5	5	3
Soil type description	Loam over clay	Self-mulching red loam over grey clay	Red loam over clay
Row spacing (cm)	30	32	33.3
Crop and rotation position	Wheat following barley	Oaten hay following wheat	Canola following wheat

The site was relocated to a paddock near Daysdale in 2014, near Corowa in 2015 and near Coreen in 2016 and 2017 in order to maintain the required rotation position.

* Stubble height was measured in the retained stubble treatments at sowing time.

TABLE 3 Site details for 2017 crops sown onto 2015 stubble management trial sites (time replicate 2)

Trial details	Trial 1	Trial 2	Trial 3
	Corowa#	Yarrawonga	Dookie
Crop type/variety	Canola/Bonito	Wheat/Corack	Wheat/Trojan
Paddock burnt	×	×	×
Farmer harvested	✓	✓	✓
Plot harvester	×	×	×
Trial plot dimensions (m)	40 x 15	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
Stubble loading (t/ha)	9.2	6.2	6.4
*Stubble height (cm)**	32	7	3
Soil type description	Red brown earth	Self-mulching red loam over grey clay	Red clay
Row spacing (cm)	30	32	33.3
Crop and rotation position	Canola following wheat	Wheat following canola	Wheat following canola

The site was relocated to a paddock near Daysdale in 2014, near Corowa in 2015 and near Coreen in 2016 and 2017 in order to maintain the required rotation position.

* Stubble height was measured in the retained stubble treatments at sowing time.

TABLE 4 Site details for 2017 crops sown onto 2014 stubble management trial sites (time replicate 1)

Trial details	Trial 1	Trial 2	Trial 3
	Daysdale#	Yarrawonga	Dookie
Crop type/variety	Wheat/Beckom	Wheat/Wedgetail	Chickpeas
Paddock burnt	×	✓	✓
Farmer harvested	✓	✓	✓
Plot harvester	×	×	×
Trial plot dimensions	40 x 15m	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
Stubble loading (t/ha)	6.8	6.5	9.5
*Stubble height (cm)**	41	15	4
Soil type description	Heavy grey clay	Self-mulching red loam over grey clay	Red clay
Row spacing (cm)	30	32	33.3
Crop and rotation position	Wheat following canola	Wheat following canola	Chickpeas following Wheat

The site was relocated to a paddock near Daysdale in 2014, near Corowa in 2015 and near Coreen 2016 and 2017 in order to maintain the required rotation position.

* Stubble height was measured in the retained stubble treatments at sowing time.

Trial 1: Coreen, NSW

Sowing date: 18 May 2017
Rotation: Second wheat
Variety: Wheat cv Scepter, faba beans cv Samira
Stubble: Wheat (various treatments applied)
Stubble load at sowing: 10.1t/ha
Rainfall:
GSR: 273mm (April–October)
Summer rainfall: 107mm
Soil nitrogen at sowing: 58kg N/ha NTSR (control) (0–60cm)

Key points

- There were significant increases in dry matter (DM) accumulation, nitrogen (N) uptake and crop canopy greenness where second wheat was established following cultivation with additional nitrogen, however there was no yield benefit.
- Over four years of research (2014–17) at the Coreen focus farm there has been no benefit to either cultivating, burning or additional nitrogen at sowing with cultivation over the no-till stubble retention (NTSR) control.
- 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 and an average of 2t/ha in 2015, however there was no evidence that the legume benefit of the faba beans influenced canola sown two years later (in 2017).
- Burning first wheat stubbles before establishing second wheat has offered no yield benefit, despite indications of better tillering, higher DM and superior yellow leaf spot (YLS) control.

Results

i) Establishment and crop structure

There were no differences in crop establishment five weeks after sowing assessed at the three-leaf stage (GS13) (Table 5). Tiller numbers averaged less than three tillers per plant assessed at the start of stem elongation (GS30–31). Where stubbles were burnt or cultivated with extra nitrogen added, there were significantly more tillers than in the no-till stubble retention (NTSR) control and the cultivated blocks where no additional nitrogen had been added. The higher tiller number in the cultivated blocks with added nitrogen resulted in significantly more heads at harvest, however the higher head number in the burnt treatment was not significantly more than the NTSR control. Head numbers were particularly low in 2017 (mean of 298 heads/m^2) compared with 2016 (mean of 415 heads/m^2), with the 2017 results being similar to 2015 (mean of 306 heads/m^2).

TABLE 5 Plant counts 30 May 2017, one leaf stage (GS11); tiller counts 18 August 2017, start of stem elongation–first node (GS30–31) and head counts 27 November 2017, at physiological maturity (GS95)

Treatment	Crop growth stage		
	GS11	GS30–31	GS95
	Plants/m²	Tillers/m²	Heads/m²
NTSR (control)	125^{a}	300^{c}	282^{ab}
Cultivated (one pass)	121^{a}	316^{bc}	269^{b}
Cultivated (one pass) + 40kg N/ha	123^{a}	364^{a}	323^{a}
Burnt	130^{a}	350^{ab}	316^{ab}
Mean	**125**	**333**	**298**
LSD	21	41	52

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 dry matter (DM) at first node (GS31) compared with both the NTSR (control) and burnt treatment. The cultivated stubbles with additional nitrogen and the burnt treatments also produced significantly more DM at mid-flowering (GS65) compared with the NTSR plots (Table 6). By harvest only the burnt treatment had significantly more DM production than the other treatments.

Similar trends were apparent in the nitrogen uptake figures at first node (GS31), with more nitrogen present in the cultivated plus 40kg N/ha compared with the burnt treatment and the NTSR control plots. At later assessments there was no difference in nitrogen content between the cultivated treatments and the NTSR control, however the burnt stubbles showed significantly higher nitrogen uptake (Table 7).

TABLE 6 Dry matter 9 August 2017, start of stem elongation–first node (GS30–31); 20 September 2017, flag leaf fully emerged (GS39); 9 October 2017, mid-flowering (GS65) and 27 November 2017, at physiological maturity (GS95)

Treatment	Dry matter (t/ha)			
	GS30–31	GS39	GS65	GS95
NTSR (control)	1.34^{b}	6.28^{b}	10.25^{b}	12.28^{b}
Cultivated (one pass)	1.34^{b}	6.70^{b}	9.74^{b}	11.84^{b}
Cultivated (one pass) + 40kg N/ha	1.88^{a}	8.15^{a}	11.67^{a}	12.45^{b}
Burnt	1.48^{b}	7.95^{a}	11.90^{a}	14.02^{a}
Mean	**1.51**	**7.27**	**8.27**	**12.65**
LSD	0.31	1.14	1.14	1.32

Figures followed by different letters are regarded as statistically significant.

TABLE 7 Nitrogen uptake in crop 9 August 2017, start of stem elongation–first node (GS30–31); 20 September 2017, flag leaf fully emerged (GS39); 9 October 2017, mid-flowering (GS65) and 27 November 2017, at physiological maturity (GS95)

Treatment	Nitrogen uptake in dry matter (kg N/ha)			
	GS31	GS39	GS65	GS95
NTSR (control)	65[b]	156[b]	120[c]	130[bc]
Cultivated (one pass)	60[b]	148[b]	141[b]	135[b]
Cultivated (one pass) + 40kg N/ha	89[a]	215[a]	167[a]	116[c]
Burnt	69[b]	169[b]	134[bc]	151[a]
Mean	**71**	**172**	**141**	**133**
LSD	12	23	15	14

Figures followed by different letters are regarded as statistically significant.

iii) Yellow leaf spot

Stubble management resulted in significant differences in yellow leaf spot (YLS) infection (Table 8) in the following wheat crop. Assessment at the start of stem elongation–first node stage (GS30–31) revealed that burning the stubbles gave over 90% control of YLS infection severity on flag-4 and flag-5 compared to the NTSR control. Cultivating the stubbles provided approximately 33–42% control of infection on the same leaf layers.

Disease progression was arrested by drier weather during late August and September and YLS did not move up the crop canopy onto the more important leaf layers — flag-1 and the flag itself. On 20 September at full flag leaf emergence (GS39) there were no differences in disease severity due to stubble management, with infection not exceeding 5% on the top three leaves (Table 9 and 10).

iv) Green leaf retention differences

The NTSR, burnt and cultivated plots were not as green at key assessment growth stages as where additional nitrogen had been added with cultivation; 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 established following cultivation plus additional nitrogen had higher NDVI values, which appear to be correlated to higher DM and nitrogen content up to the middle of flowering (GS65).

TABLE 8 YLS severity and incidence assessed 9 August at start of stem elongation–first node stage (GS30–31) on flag-4 and flag-5

Treatment	YLS severity		YLS incidence	
	Flag-4	Flag-5	Flag-4	Flag-5
NTSR (control)	3.3[a]	20.1[a]	95.0[a]	100.0[a]
Cultivated (one pass)	2.2[a]	12.7[b]	90.0[a]	100.0[a]
Cultivated (one pass) + 40kg N/ha	2.2[a]	11.4[b]	87.5[a]	100.0[a]
Burnt	0.3[b]	1.5[c]	17.5[b]	62.5[b]
Mean	**2**	**11.4**	**72.5**	**90.6**
LSD	1.7	6.8	24.4	12.0

Figures followed by different letters are regarded as statistically significant.

TABLE 9 Yellow leaf spot severity assessed 20 September at full flag leaf emergence (GS39) on flag-1, flag-2 and flag-3

Treatment	YLS severity		
	Flag-1	Flag-2	Flag-3
NTSR (control)	0.45[a]	4.7[a]	19.6[a]
Cultivated (one pass)	0.03[b]	4.7[a]	19.5[a]
Cultivated (one pass) + 40kg N/ha	0.00[b]	4.6[a]	17.1[a]
Burnt	0.00[b]	3.1[a]	12.9[a]
Mean	**0.10**	**4.3**	**17.3**
LSD	0.4	3.1	9.3

Figures followed by different letters are regarded as statistically significant.

TABLE 10 Yellow leaf spot incidence assessed 20 September at full flag leaf emergence (GS39) on flag-1, flag-2 and flag-3

Treatment	YLS incidence		
	Flag-1	Flag-2	Flag-3
NTSR (control)	25.0[a]	87.5[a]	97.5[a]
Cultivated (one pass)	2.5[b]	100[a]	100.0[a]
Cultivated (one pass) + 40kg N/ha	0.0[b]	100[a]	100.0[a]
Burnt	0.0[b]	95.0[a]	100.0[a]
Mean	**6.90**	**95.6**	**99.4**
LSD	18.6	19.6	4.0

Figures followed by different letters are regarded as statistically significant.

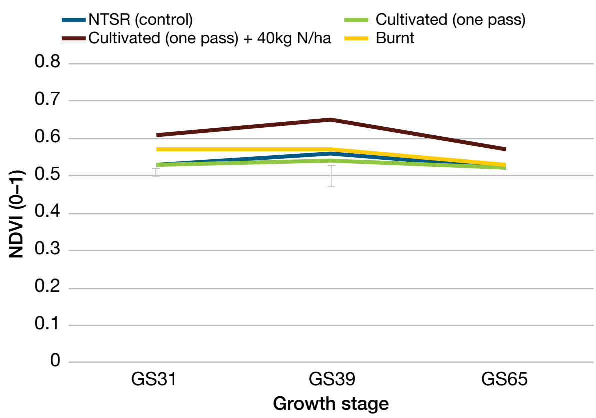


FIGURE 1 Influence of stubble management on wheat crop canopy NDVI assessed 9 August 2017, start of stem extension–first node (GS30–31); 20 September 2017, flag leaf fully emerged (GS39); 9 October 2017, mid-flowering (GS65)
Error bars presented as a measure of LSD.

v) Yield and grain quality

The trial was harvested on 9 December 2017. While the cultivated plus 40kg N/ha treatment recorded greener crop canopies, higher head numbers and higher DM up to mid-flowering (GS65) this offered no significant yield benefit over the other stubble management treatments (Table 11). By way of contrast, the NTSR (control) recorded lower DM and lower head numbers but was significantly higher yielding than cultivated and burnt treatments. Therefore, for the fourth year in succession there were no significant yield advantages of any stubble treatments over the NTSR (control) at this site in the second-wheat rotation position. The only significant difference in grain quality was a lower protein level and fractionally higher screenings in NTSR control plots.

The faba beans harvested as forage and grain alongside the 2017 second wheat trial yielded 1.59t/ha.

vi) Four-year results (time replicates 1, 2, 3 and 4) — yield data 2014–17

For the past four 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**, in the third year it is **time replicate 3** and in the fourth year it is **time replicate 4**. 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 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 four years show the rank order of stubble management treatments has been similar, with significant differences in yield only recorded during 2015 and 2017. During 2015 the cultivated stubbles plus 40kg N/ha significantly out-yielded the burnt treatment but not the NTSR control (Figure 2). In 2017 the NTSR control out-yielded all other stubble management treatments. While similar trends were observed during 2016, the yield differences were not significant. Despite the benefits of earlier DM production and early season disease control (yellow leaf spot) from burning, no yield advantage has been observed over the NTSR (control) at this trial site during the past four seasons of stubble management trials.

During the two higher-yielding seasons (2015 and 2016) there is an indication the additional nitrogen at sowing provided a benefit to the cultivation treatment, however this trend was not present during the years with lower yield potential, despite indicators of better growth. Overall, the benefit during the years of higher yield potential lead to a

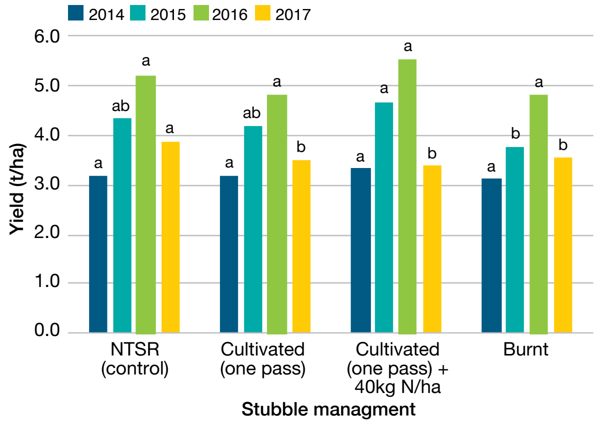


FIGURE 2 Yield data from time replicate trials 1, 2,3 and 4 — the Daysdale (red brown earth), Corowa (heavy grey clay), Coreen (loam over clay) and Coreen (loam over clay) trials for 2014, 2015, 2016 and 2017 — cv Whistler (wheat) in 2014, cv Mace (wheat) in 2015, cv Hindmarsh (barley) in 2016, cv Scepter (wheat) in 2017

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

Note: The four 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, 2016 and 2017 a single pass was used.

TABLE 11 Wheat yield, protein, test weight, screenings and thousand seed weight (TSW) 9 December 2017, at harvest (GS99)

Treatment	Yield and quality				
	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	TSW (g)
NTSR (control)	3.88^{a}	9.0^{b}	77.9^{a}	1.0^{a}	43.2^{b}
Cultivated (one pass)	3.50^{b}	10.2^{a}	78.0^{a}	0.8^{ab}	45.8^{a}
Cultivated (one pass) + 40kg N/ha	3.37^{b}	10.5^{a}	77.9^{a}	0.7^{b}	46.1^{a}
Burnt	3.54^{b}	10.2^{a}	77.8^{a}	0.7^{b}	46.3^{a}
Mean	**3.57**	**10**	**77.9**	**0.8**	**45.4**
LSD	0.33	1.1	0.6	0.3	1.8

Figures followed by different letters are regarded as statistically significant.



trend for additional nitrogen to be beneficial if chopped cereal straw and stubble was incorporated, but in no single year was the difference statistically significant (Figure 3).

vii) 2015 stubble management treatments — influence on 2016 and 2017 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 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 12 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. In 2017 the paddock was established to canola cv Bonito.

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 burning during 2016. During 2017 there was no evidence the different 2015 stubble management treatments influenced canola yields. 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. These increases in wheat productivity one year after faba beans were not evident in the productivity of canola two years after faba beans.

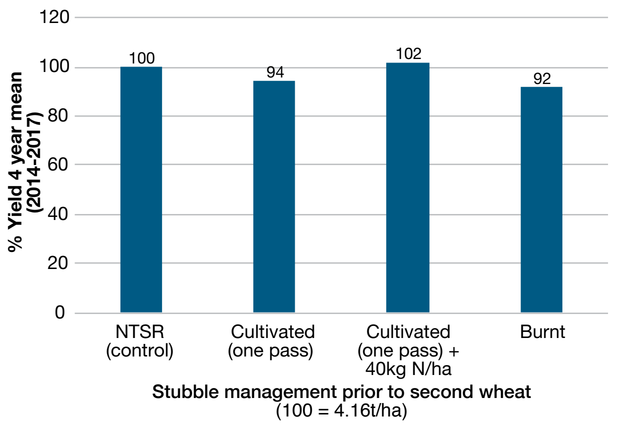


FIGURE 3 Influence of first wheat stubble management on the four-year yield mean percentage of the following wheat crop — Coreen, NSW 2014–17

TABLE 12 Effect of time replicate 2 trial on yield 2015, wheat yield 2016 cv Trojan and canola yield 2017 cv Bonito, Corowa, NSW

	2015	2016	2017
	Wheat and faba beans	Wheat	Canola
2015 stubble treatments	Yield (t/ha)	Yield (t/ha)	Yield (t/ha)
NTSR (control)	4.33^{ab}	6.72^{ab}	2.06^{a}
Cultivated (one pass)	4.18^{ab}	6.53^{ab}	2.14^{a}
Cultivated (one pass) + 40kg N/ha	4.69^{a}	6.66^{ab}	2.18^{a}
Burnt	3.77^{b}	5.90^{b}	2.20^{a}
Faba beans (green manure)	-	7.03^{a}	2.09^{a}
Faba beans (grain)	1.40*	6.96^{a}	2.23^{a}
Mean	**4.24**	**6.63**	**2.15**
LSD	0.67	0.82	0.29

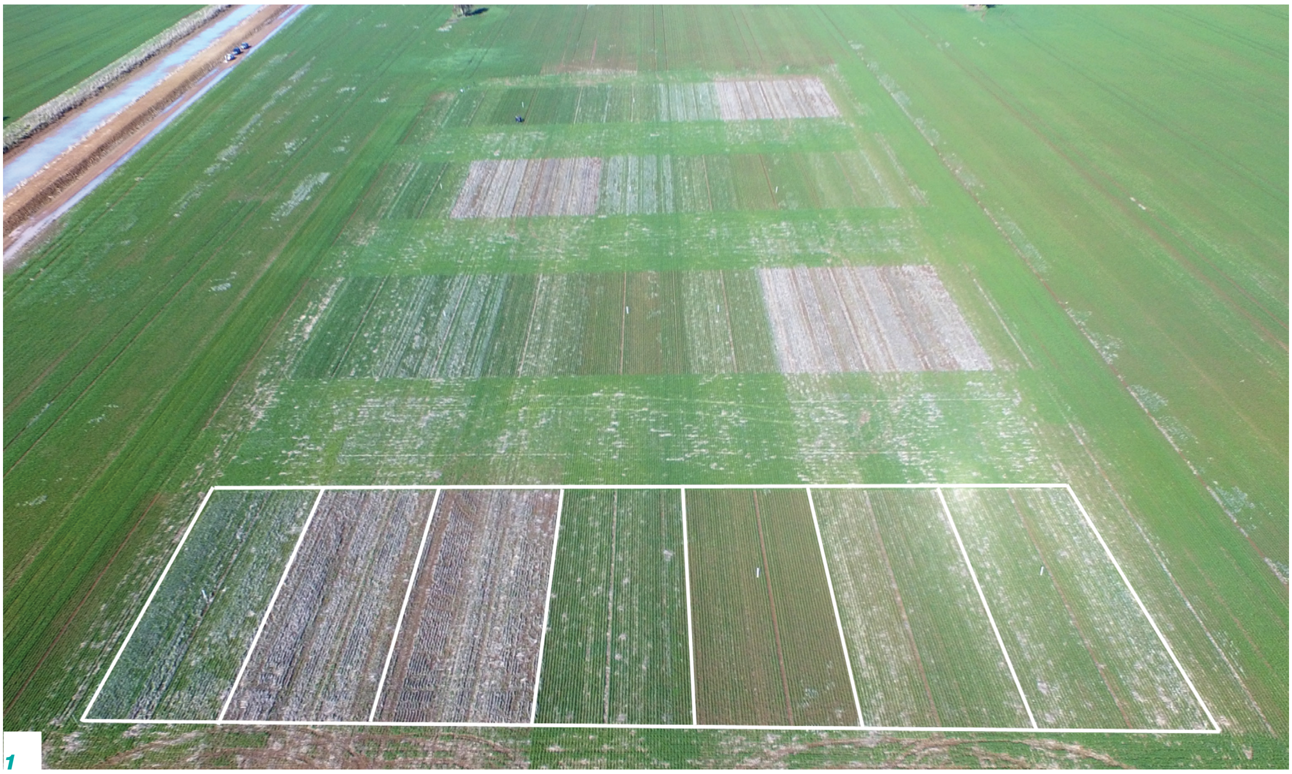
Figures followed by different letters are regarded as statistically significant.
* Beans not statistically analysed alongside wheat.

The stubble management treatments carried out during the 2014 trial (time replicate 1) significantly influenced the following third wheat crop yield (cv Corack). However, the differences were relatively small in comparison to the influence of growing faba beans grown prior to wheat, which gave a 2t/ha advantage over the third wheat crop (Table 13). Unfortunately, the canola crop grown at the site in 2016 was subject to flooding, meaning that harvest was not possible.

TABLE 13 Effect of time replicate 1 trial on yield 2014 and wheat yield 2015 cv Corack, Daysdale, NSW

	2014	2015
	Wheat and faba beans	Wheat
2015 stubble treatments	Yield (t/ha)	Yield (t/ha)
NTSR (control)	3.17^{a}	3.54^{bc}
Cultivated (two pass)	3.18^{a}	3.82^{b}
Cultivated (two pass) + 40kg N/ha	3.31^{a}	3.61^{bc}
Burnt	3.10^{a}	3.38^{c}
Faba beans (forage)	6.68	5.62^{a}
Faba beans (grain)	2.89	5.66^{a}
Mean	**3.19**	**4.27**
LSD	0.53	0.39

Figures followed by different letters are regarded as statistically significant.
* Beans not statistically analysed alongside wheat.
Note: 2016 canola crop was flooded and harvest was not possible.



1 *Coreen trial site on 9 August 2017, marked plots from left to right: NTSR (control), faba beans as grain, faba beans as mulched green manure, cultivated (one pass) + 40kg N/ha, burnt, cultivated as fire break (not analysed) and cultivated (one pass).*

2 *Faba beans (cv Samira) sown alongside second wheat stubble management treatments on 12 October 2017.*

3 *Wheat (cv Scepter) following burnt stubbles on 12 October 2017.*



Trial 2: Yarrawonga, Victoria

Sowing date: 7 May 2017
Rotation: Second wheat
Variety: Corack
Stubble: Wheat (various treatments applied)
Stubble load at sowing: Long stubble 11.2t/ha, short stubble 11.1t/ha
Rainfall:
GSR: 270mm (April–October)
Summer rainfall: 88mm
Soil nitrogen at sowing: 63kg N/ha NTSR (control) (0–60cm)

Key points

- With heavy stubble loads as a result of the 2016 harvest (11t/ha) burning significantly increased second wheat DM production throughout the season and gave a 0.7t/ha yield increase over the NTSR control treatments.
- This is the first year there has been a significant yield advantage with burning. In previous years, with stubble loads of 4–8t/ha, the yield gains have been non-significant or negative (as was the case in 2015).
- The yield response to burning over the four years averaged 6% (range -6% to +20%) compared with NTSR — long stubble.
- With a higher yield potential in 2016, applying nitrogen at sowing significantly increased grain yield and protein when stubble was cultivated, but cultivation has shown no advantage at this research site unless more nitrogen was applied.
- Over the four years the average yield increase from additional nitrogen has been 6% with adding 40kg N/ha to cultivated wheat straw and 3% from adding it to standing straw in NTSR, potentially indicating more nitrogen tie up with chopped wheat stubble when it was incorporated compared with standing stubble.
- The small differential effects of stubble management in year one (time replicates 1 & 2) have not resulted in follow-on effects in commercial crops sown in the following two years at this focus farm.
- Across this project, none of the tested fungicide treatments came close to replicating the level of YLS control achieved by burning stubble.

Results

i) Establishment and crop structure

The NTSR — long stubble treatment significantly reduced plant establishment compared with treatments where stubble (straw) was removed or burnt. Reducing the stubble length in the NTSR — short stubble treatment gave significantly better establishment compared with NTSR — long stubble but establishment was still less than when stubbles were burnt (Table 14). Long stubble significantly reduced tillering recorded at the start of stem elongation (GS30) compared with where stubble height was reduced in the short stubble treatment, burnt or removed.

Overall tiller numbers were low in this trial, although there was a difference of 80 tillers/m^2 between the NTSR — long stubble treatment and the burnt treatment. This difference in tiller numbers was maintained through to harvest, with the burnt treatment having significantly more heads/m^2 than other stubble managements, with the exception of the NTSR — short stubble treatment. At harvest, although the NTSR — long stubble treatment produced the lowest head numbers (237 heads/m^2), there was no statistical difference to other treatments except burning, indicating lower levels of tiller mortality between the start of stem elongation (GS30) and harvest in this treatment.

ii) Dry matter production

The lower tiller number recorded with NTSR — long stubble (control) at the start of stem elongation (GS30) correlated to less DM accumulation at GS30 compared with the NTSR — short stubble and the burnt treatments. The burnt

TABLE 14 Plant counts, 24 May 2017, two leaves (GS12); tiller counts 19 July 2017, start of stem elongation (GS30) and head counts 17 November 2017, physiological maturity (GS95)

	Crop growth stage		
	Plants/m²	Tillers/m²	Heads/m²
Treatment	GS12	GS30	GS95
NTSR — long stubble (control)	102^{c}	223^{c}	237^{b}
NTSR — long stubble + 40kg N/ha	108^{bc}	232^{bc}	249^{b}
NTSR — short stubble	115^{b}	293^{a}	271^{ab}
Straw removed	115^{b}	287^{ab}	247^{b}
Cultivated (one pass)	113^{b}	227^{c}	250^{b}
Cultivated (one pass) + 40kg N/ha	108^{bc}	266^{abc}	250^{b}
Burnt	127^{a}	303^{a}	295^{a}
Mean	**112**	**262**	**257**
LSD	11	60	33

Figures followed by different letters are regarded as statistically significant.

treatment produced significantly more DM throughout the season, however the difference between long stubble and short stubble treatments was not apparent after GS30; a result observed in previous years (Table 15). At the watery ripe grain assessment (GS71) the crop following burnt stubbles had a DM content just under 1t/ha more than the other stubble management treatments. At harvest (GS95) the burnt blocks had significantly higher DM than the NTSR and cultivated blocks. The lag in DM production in the NTSR — long stubble treatment compared with NSTR — short stubble treatment was not apparent at the harvest assessment, indicating later compensation in this treatment from flowering onwards. Cultivating the stubble significantly reduced the following crop DM at harvest compared with NTSR and burnt stubbles. The addition of 40kg N/ha significantly increased canopy DM at flag leaf emergence (GS39) in the NTSR — long stubble, though from flowering onwards there was no DM benefit to the additional nitrogen application.

The reduction in DM accumulation with NTSR — long and short stubble (controls) correlated to decreased nitrogen uptake in the crop canopy at full flag leaf emergence (GS39) compared with the burnt treatments (Table 16). The difference in nitrogen uptake between long and short stubble treatments was not significantly different at the start of stem elongation (GS30) despite there being significantly more DM following short stubble when assessed at the same growth stage. At physiological maturity (GS95) there were no differences in nitrogen uptake between the long and short stubble treatments, but the long stubble treatment had less nitrogen uptake compared with crops where straw was removed or burnt. The burnt stubble treatment had higher nitrogen uptake than all other stubble managements at harvest except for where straw was mown and removed. This indicates the presence of chopped straw reduced nitrogen uptake into the plant relative to those stubble management treatments where straw was mown and removed leaving just the stubble or no residue at all.

TABLE 15 Dry matter 19 July 2017, start of stem elongation (GS30); 5 September 2017, flag leaf fully emerged (GS39); 13 October 2017, watery ripe grain (GS71) and 23 November, physiological maturity (GS95)

Treatment	Dry matter (t/ha)			
	GS30	GS39	GS71	GS95
NTSR — long stubble (control)	0.82^{b}	2.57^{c}	6.62^{b}	7.80^{b}
NTSR — long stubble + 40kg N/ha	0.82^{b}	3.01^{b}	6.72^{b}	7.69^{bc}
NTSR — short stubble	0.96^{a}	2.88^{bc}	6.86^{b}	8.04^{b}
Straw removed	0.88^{ab}	3.01^{b}	6.78^{b}	8.03^{b}
Cultivated (one pass)	0.88^{ab}	2.94^{bc}	6.59^{b}	7.16^{c}
Cultivated (one pass) + 40kg N/ha	0.89^{ab}	2.76^{bc}	6.65^{b}	7.43^{bc}
Burnt	0.98^{a}	3.65^{a}	7.44^{a}	8.97^{a}
Mean	**0.89**	**2.98**	**6.81**	**7.87**
LSD	0.12	0.43	0.45	0.62

Figures followed by different letters are regarded as statistically significant.

TABLE 16 Nitrogen uptake in biomass 19 July 2017, start of stem elongation (GS30); 5 September 2017, flag leaf fully emerged (GS39); 13 October 2017, watery ripe grain (GS71) and 23 November, physiological maturity (GS95)

Treatment	Nitrogen uptake in biomass (kg N/ha)			
	GS30	GS39	GS71	GS95
NTSR — long stubble (control)	43^{bc}	72^{b}	62^{c}	87^{c}
NTSR — long stubble + 40kg N/ha	43^{bc}	79^{b}	69^{b}	94^{ab}
NTSR — short stubble	46^{abc}	70^{b}	72^{ab}	89^{bc}
Straw removed	45^{abc}	80^{b}	69^{ab}	94^{ab}
Cultivated (one pass)	40^{c}	76^{b}	69^{ab}	89^{bc}
Cultivated (one pass) + 40kg N/ha	47^{ab}	79^{b}	73^{a}	89^{bc}
Burnt	50^{a}	93^{a}	68^{b}	100^{a}
Mean	**45**	**78**	**69**	**92**
LSD	6	12	5	7

Figures followed by different letters are regarded as statistically significant.

iii) Photosynthetically active radiation

During the past four seasons (2014–17) 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 the research team looked, for the first time, at differences in light interception by the growing crop canopy; more accurately described as photosynthetically active radiation (PAR). The team assessed the influence of the different stubble management treatments on PAR during June 2017.

The results revealed reductions in PAR of approximately 50% in NTSR — long stubble compared with NTSR — short stubble when measurements were made at 3pm in the afternoon, however there was no difference in PAR when treatments were compared at 12pm midday (Figure 4). 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 are fewer tillers and a lag in DM production with long stubble.

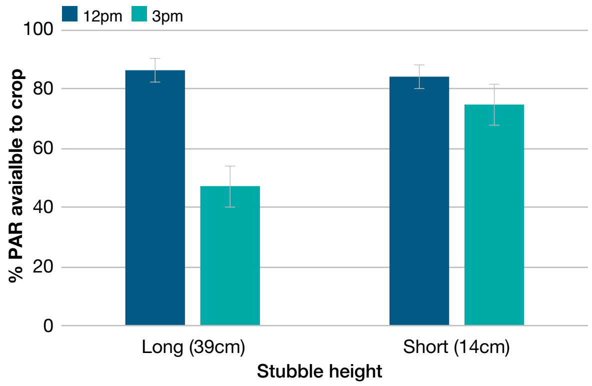


FIGURE 4 Influence of stubble treatment on availability of photosynthetically active radiation on 12pm 20 June 2017 (GS22) and 3pm on 28 June 2016 (GS23) at the Yarrawonga trial site

Error bars are a measure of LSD.

Note: 20 June readings were taken at 12pm with the average above-canopy PAR measuring 865μmol/m^2/s, in the 400–700nm waveband.

28 June readings were taken at 3pm with the average above canopy PAR measuring 651μmol/m^2/s^1, in the 400–700nm waveband.

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

At second node (GS32) and booting (GS45) the burnt and straw removed treatments resulted in higher NDVI crop canopy scores, a result that relates to higher nitrogen uptake in these treatments. The NDVI readings of the burnt plots were significantly higher than the NTSR — long stubble at early grain fill (GS71), but not if additional nitrogen was added to the NTSR treatment at sowing (Figure 5). All NDVI scores declined by the early grain fill stage (GS71) but cultivation with extra nitrogen, straw mown and removed and burnt stubble plots still gave higher NDVI readings than NTSR — short stubble and NTSR — long stubble treatments at this final assessment.

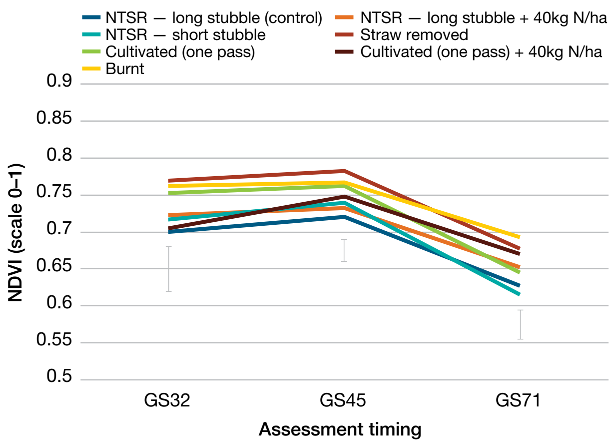


FIGURE 5 Influence of stubble management on resultant crop canopy NDVI (0–1 scale) assessed at stem elongation (GS32), booting (GS45) and early grain fill (GS71)

Error bars are a measure of LSD.

v) Disease levels

With drier conditions prevailing from GS32 onwards, YLS did not progress in the crop canopy, however at the early second node assessment (GS32) burning gave significantly better YLS control on flag-3 and flag-4 than all of the other stubble management treatments. Burning stubble resulted in more than 90% control of YLS severity compared with NTSR — long stubble and NTSR — short stubble (Table 17). Removing the mown and chopped straw and leaving just stubble gave approximately 60% control, while adding 40kg N/ha to NTSR — long stubble resulted in approximately 55% control. Cultivating the soil (one pass) with or without additional nitrogen did not significantly reduce YLS infection.

At flag leaf emergence (GS39) on 6 September the influence of burning on levels of YLS was still apparent on flag-1, flag-2 and flag-3 (Table 18 and Table 19). Although the overall level of control had declined there was evidence that disease had increased on flag-3 between the two assessments. Burning the stubble before sowing was still giving 60–66% control of the disease severity on flag-3 and flag-2 at flag leaf emergence. Within this project, none of the tested fungicide treatments have come close to replicating the level of disease control achieved by burning.

These results on YLS infection are similar to results observed in previous years and in similar rotation positions at other sites.

vi) Grain yield and quality

The trial was harvested on 10 December 2017. There were statistical differences in grain yield and quality as a result of stubble management. Despite a lag in DM accumulation at early stem elongation (GS30) with the NTSR — long

TABLE 17 Yellow leaf spot severity and incidence assessed 16 August at early second node (GS32) on flag-3 and flag-4

Treatment	YLS severity		YLS incidence	
	Flag-3	Flag-4	Flag-3	Flag-4
NTSR — long stubble (control)	2.3^{a}	12.5^{ab}	72.5^{a}	97.5^{a}
NTSR — long stubble + 40kg N/ha	1.1^{c}	4.9^{bc}	85.0^{a}	97.5^{a}
NTSR — short stubble	2.1^{ab}	11.9^{ab}	87.5^{a}	100^{a}
Straw removed	1.0^{c}	5.9^{abc}	47.5^{b}	92.5^{a}
Cultivated (one pass)	1.1^{c}	13.2^{a}	70.0^{ab}	100^{a}
Cultivated (one pass) + 40kg N/ha	1.3^{bc}	10.9^{ab}	79.7^{a}	100^{a}
Burnt	0.1^{d}	0.9^{c}	7.5^{c}	52.5^{a}
Mean	**1.3**	**8.6**	**64.2**	**92.5**
LSD	**0.9**	8	**23.4**	17.3

TABLE 18 Yellow leaf spot severity assessed 6 September at flag leaf emergence (GS39) on flag-1, flag-2 and flag-3

	YLS severity		
Treatment	**Flag-1**	**Flag-2**	**Flag-3**
NTSR — long stubble (control)	0.9^{ab}	7.9^{a}	28.6^{ab}
NTSR — long stubble + 40kg N/ha	0.7^{abc}	9.9^{a}	30.6^{ab}
NTSR — short stubble	1.1^{a}	8.2^{a}	28.6^{ab}
Straw removed	0.4^{cd}	8.9^{a}	22.5^{b}
Cultivated (one pass)	1.1^{a}	7.4^{a}	32.5^{a}
Cultivated (one pass) + 40kg N/ha	0.6^{bc}	7.3^{a}	26.6^{ab}
Burnt	0.2^{d}	3.1^{b}	9.8^{c}
Mean	**0.7**	**7.5**	**25.6**
LSD	0.4	2.8	8.4

TABLE 19 Yellow leaf spot incidence assessed 6 September at flag-leaf emergence (GS39) on flag-1, flag-2 and flag-3

	YLS incidence		
Treatment	**Flag-1**	**Flag-2**	**Flag-3**
NTSR — long stubble (control)	62.5^{ab}	100.0^{a}	100.0^{a}
NTSR — long stubble + 40kg N/ha	40.0^{bc}	100.0^{a}	100.0^{a}
NTSR — short stubble	65.0^{a}	100.0^{a}	100.0^{a}
Straw removed	32.5^{cd}	97.5^{a}	100.0^{a}
Cultivated (one pass)	50.0^{abc}	100.0^{a}	100.0^{a}
Cultivated (one pass) + 40kg N/ha	45.0^{abc}	100.0^{a}	100.0^{a}
Burnt	15^{d}	77.5^{b}	100.0^{a}
Mean	44.3	96.4	100
LSD	23.7	9.9	-

stubble treatment, there was no difference in yield between long and short stubble treatments (Table 20). There was a yield advantage associated with straw removal, burning and adding 40kg N/ha additional nitrogen to the cultivated treatment, however it was the burnt treatment that significantly increased yield in this trial by 0.69–0.70t/ha compared with the NTSR — short stubble treatment. This increase in yield led to a significant decrease in grain protein (approximately 1%) in the burnt treatment compared with the other treatments. In 2016, burning the previous wheat crop residues gave a small, non-significant yield increase (4–5%) over all NTSR treatments, however in 2017 the residue burden at sowing was approximately 11t/ha compared with 4.5t/ha in 2016. Cultivation produced no yield benefits over the NTSR — long stubble (control) treatment and was the lowest yielding treatment in the trial, unless additional nitrogen was applied at sowing.

There were no significant differences in harvest index (HI — the proportion of final DM that is grain).

vii) Four-year results (time replicates 1, 2, 3 and 4) — yield data 2014–17

The stubble management trial has been established in the same crop rotation position (second wheat) on different paddocks during the past four years at the Yarrawonga focus farm. There have been only a few significant yield effects associated with stubble management over the four years of trials. In 2017, yields were significantly higher where the previous wheat residues were burnt compared with NTSR. With higher yield potential in 2016, additional nitrogen applied at sowing significantly increased the yield of crops following NTSR — long stubble and one-pass cultivation, however when the influence of additional nitrogen was removed, there were no significant differences in yield between burning, cultivating and removing straw, compared with NTSR (Figure 6).

Although burning has increased DM production in all four years, it was only in 2017 that it generated a statistical (0.7t/ha) yield advantage over NTSR, with only a small (3–5%), non-significant yield benefits in previous years. The significant yield benefit associated with burning in 2017 can be attributed to the high residue levels (approximately 11t/ha) carried over from the 2016 harvest. In 2015 the harder finish resulted in residue levels of 4.5t/ha and saw the burnt treatment yield significantly less than the NTSR — short stubble treatment, with the greater biomass of the burnt treatment possibly a disadvantage in such a dry season. In 2016 and 2014, there was no difference between the burnt and the NTSR treatments.

If the four year means were expressed as a percentage with NTSR — long stubble set at 100 for the four years, burning at this site has generated a 6.0% yield increase over those years (Figure 7), however only in 2017 were the differences statistically significant. If straw was removed, leaving just the stubble, the yield difference was only 1.5%. Over the four years the average yield increase from 40kg N/ha of additional nitrogen applied at sowing was 6.3% where chopped straw was cultivated with one pass. Yield only increased 3% where the same dose of nitrogen was applied to NTSR — long stubble, indicating potentially greater tie up of nitrogen when chopped straw is cultivated. The need for additional nitrogen was particularly noticeable during 2016 when yield potential was higher.

TABLE 20 Wheat yield, protein, test weight, screenings, harvest index (HI) and thousand seed weight (TSW) 10 December 2017, at harvest (GS99)

Treatment	Yield (t/ha)	Protein (%)	Test weight (kg/hL)	Screenings (%)	TSW (g)	HI (%)
NTSR — long stubble (control)	3.39[b]	11.9[a]	76.1[a]	0.3[a]	44.7[a]	37.9[a]
NTSR — long stubble + 40kg N/ha	3.52[b]	11.6[a]	76.3[a]	0.2[a]	44.8[a]	40.5[a]
NTSR — short stubble	3.38[b]	11.5[a]	76.4[a]	0.2[a]	45.3[a]	36.3[a]
Straw removed	3.65[ab]	11.3[ab]	76.6[a]	0.2[a]	44.1[ab]	38.8[a]
Cultivated (one pass)	3.14[b]	11.3[ab]	76.3[a]	0.2[a]	45.3[a]	39.7[a]
Cultivated (one pass) + 40kg N/ha	3.56[ab]	11.4[a]	76.5[a]	0.2[a]	45.0[a]	43.2[a]
Burnt	4.08[a]	10.7[b]	76.2[a]	0.2[a]	42.4[b]	40.3[a]
Mean	**3.53**	**11.4**	**76.3**	**0.24**	**44.5**	**39.5**
LSD	0.56	0.7	0.6	0.1	2.2	7.7

Figures followed by different letters are regarded as statistically significant.

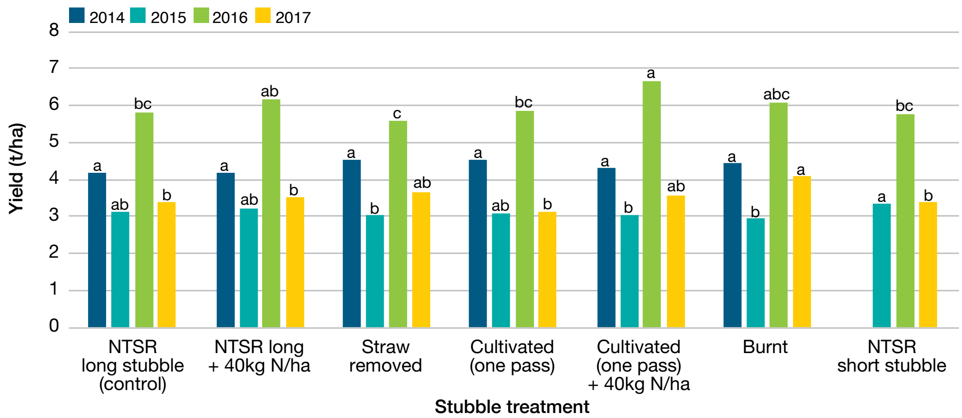


FIGURE 6 Yield data from the four Yarrawonga trials for 2014, 2015 (cv Young), 2016 and 2017 (cv Corack)

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

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

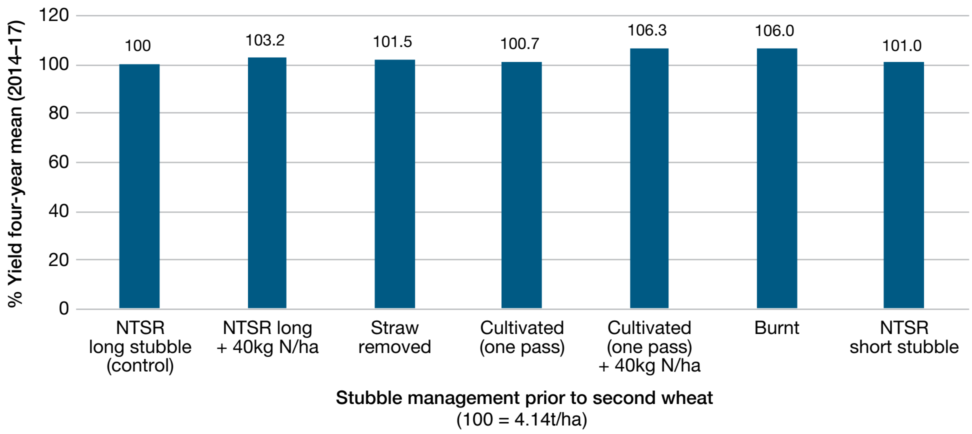


FIGURE 7 Influence of first wheat stubble management on the four-year yield mean percentage of the following second wheat crop — Yarrawonga, Victoria 2014–17

(NTSR — short stubble treatment evaluated for three years from 2015–17).

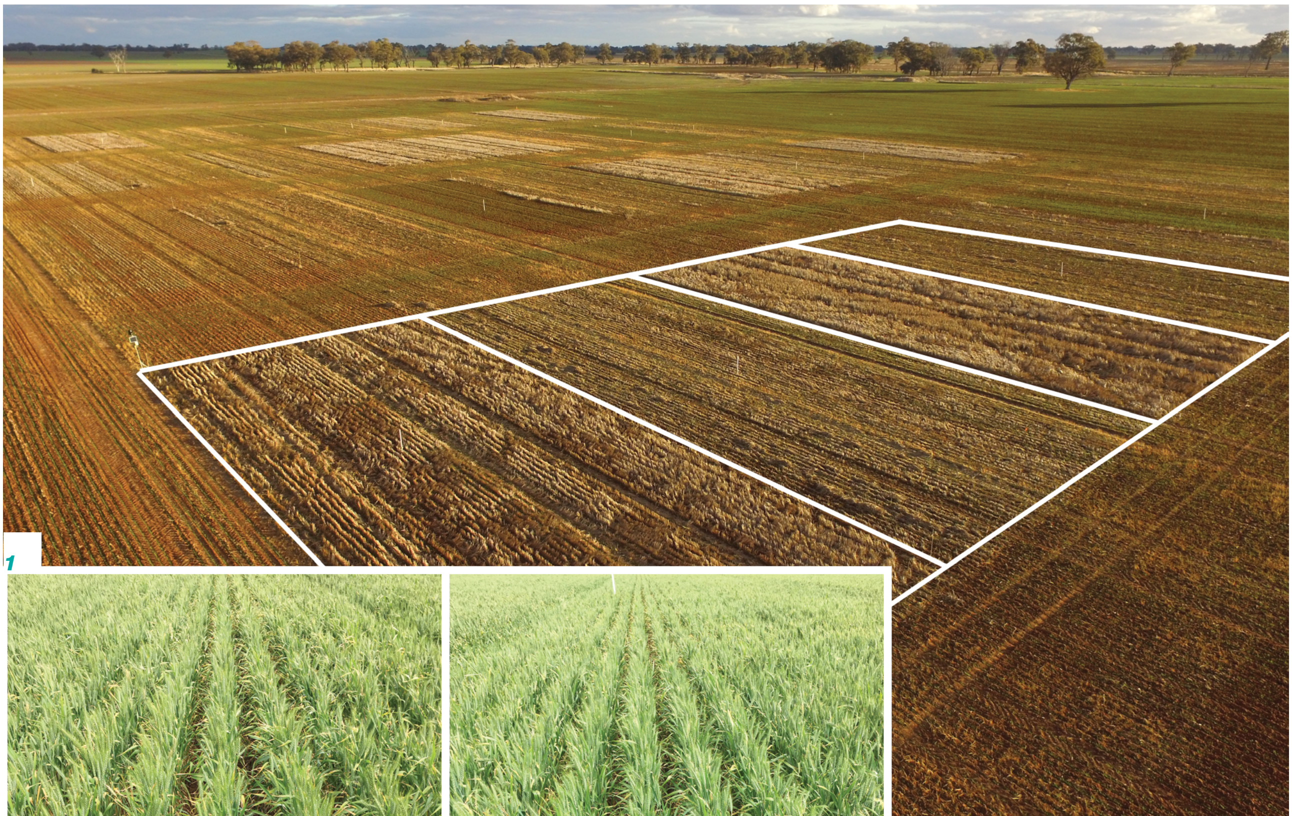
viii) 2015 stubble management treatments — influence on 2016 and 2017 yields

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 or the following wheat crop sown across the site in 2017 (Table 21).

TABLE 21 Effect of time replicate 2 trial on wheat yield 2015 cv Young, canola yield 2016 cv Bonito and wheat yield 2017 cv Trojan, Yarrawonga, Victoria

2015 stubble treatments	2015 Second wheat Yield (t/ha)	2016 Canola Yield (t/ha)	2017 Wheat Yield (t/ha)
NTSR — long stubble (control)	3.13^{ab}	2.76^{a}	4.25^{a}
NTSR — long stubble + 40kg N/ha	3.20^{ab}	2.73^{a}	3.97^{a}
NTSR — short stubble	3.35^{a}	2.84^{a}	4.20^{a}
Straw removed	3.03^{b}	2.72^{a}	4.13^{a}
Cultivated (one pass)	3.10^{ab}	2.75^{a}	4.03^{a}
Cultivated (one pass) + 40kg N/ha	3.05^{b}	2.69^{a}	4.01^{a}
Burnt	2.93^{b}	2.73^{a}	4.07^{a}
Mean	**3.11**	**2.74**	**4.10**
LSD	0.29	0.42	0.36

Figures followed by different letters are regarded as statistically significant.
Note: All blocks were burnt before the 2016 crop.



1 Yarrawonga trial site on 29 May 2017, marked plots in view from left to right are: NTSR — long stubble, NTSR — short stubble, NTSR — long stubble + 40N and cultivated (one pass)

2 Long stubble 13 October 2017

3 Short stubble 13 October 2017



Trial 3: Dookie, Victoria

Sowing date: 20 April 2017
Rotation: Canola following wheat
Variety: ATR Stingray (early-maturing triazine-tolerant variety)
Stubble: Wheat (various treatments applied)
Stubble load at sowing: 7.1t/ha
Rainfall:
GSR: 281mm (April–October)
Summer rainfall: 82mm
Soil nitrogen: 58kg N/ha control NTSR, (0–60cm)

Key points

- A growing season rainfall (GSR) of 281mm resulted in average canola yields of 3.76t/ha.
- Reducing stubble length in NTSR, burning and removing wheat straw treatments significantly increased canola DM production at the greenbud stage (GS3.3) compared with NTSR — long stubble, despite there being no differences in plant establishment due to stubble management.
- The significant reduction in DM in NTSR — long stubble was associated with a delay in the onset of flowering, which was statistically significant.
- The delay in crop development associated with longer stubble length was also observed in wheat at this site during 2015.
- Though there was a trend for the burnt and straw removed treatments to increase DM production compared with NTSR — long stubble, there was no difference in yield among any of the treatments at harvest.
- Across the four years of the trial 2014–17, NTSR — long stubble has reduced early DM production in all four years, however it has only significantly reduced final grain yield during 2014 (0.7t/ha decrease).
- The significant wheat yield reduction in 2014, due to long stubble, resulted in a significant increase in canola yields during 2015.
- The influence of stubble management treatments set up in 2015 (time replicate 2) did not affect the yield of the two subsequent commercial crops; canola in 2016, wheat in 2017.

Results

i) Establishment and crop structure

Neither burning, cultivating or removing the previous wheat straw resulted in any advantage in the following canola establishment over the NTSR control treatments. The average establishment was 52 plants/m^2 with a range in plant population of between 49–56 plants/m^2. There were no differences in crop vigour assessed at the five leaf stage of development (GS1.05) and no difference in stems/m^2 at first flower stage (GS4.1) (Table 22).

NTSR — long stubble significantly delayed the onset of flowering in canola relative to the other establishment treatments (Table 23), a feature also noted in wheat trials at this site during 2015.

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

The NTSR — long stubble treatment had produced significantly less DM at the green bud stage in early stem elongation (GS3.3) compared with the NTSR — short stubble and where straw or straw and stubble had been completely removed or burnt (Table 24). At the flowering (GS4.5) and pod fill (GS5.5) stages the DM accumulation with NTSR — long stubble remained significantly lower than either the burnt treatment at flowering (GS4.5) or

TABLE 22 Plant counts and vigour 30 May 2017, five leaf stage (GS1.05) and stem counts 25 July 2017, first flowers opened (GS4.1)

Treatment	Plants/m^2 GS1.05	Vigour GS1.05	Stems/m^2 GS4.1
NTSR — long stubble	56^{a}	8.5^{a}	119^{a}
NTSR — short stubble	49^{a}	8.5^{a}	110^{a}
Cultivated (one pass)	49^{a}	9.0^{a}	101^{a}
Straw removed	52^{a}	8.3^{a}	115^{a}
Burnt	53^{a}	8.5^{a}	112^{a}
Mean	**52**	**8.6**	**112**
LSD	8	1.4	26

Figures followed by different letters are regarded as statistically significant.

TABLE 23 Flowering scores, percentage of plot with flowers opened 21 July 2107, first flowers opened (GS4.1)

Treatment	Flowering score (%)
NTSR — long stubble	2^{b}
NTSR — short stubble	13^{a}
Cultivated (one pass)	13^{a}
Straw removed	15^{a}
Burnt	17^{a}
Mean	12
LSD	6

Figures followed by different letters are regarded as statistically significant.

TABLE 24 Dry matter 4 July 2017, green bud (GS3.3); 17 August 2014, 50% of all buds on raceme flowering or flowered (GS4.5); 17 September 2017, 50% of potential pods on raceme more than 2cm long (GS5.5), and 9 November 2017, most seeds black but soft (GS6.7)

Treatment	Dry matter (t/ha)			
	GS3.3	GS4.5	GS5.5	GS6.7
NTSR — long stubble	1.40^{b}	4.09^{b}	5.36^{b}	8.10^{a}
NTSR — short stubble	1.70^{a}	4.31^{ab}	5.70^{ab}	8.11^{a}
Cultivated (one pass)	1.64^{ab}	4.33^{ab}	5.44^{ab}	8.20^{a}
Straw removed	1.78^{a}	4.59^{ab}	5.89^{a}	9.08^{a}
Burnt	1.72^{a}	4.65^{a}	5.80^{ab}	8.55^{a}
Mean	**1.65**	**4.39**	**5.64**	**8.41**
LSD	0.26	0.54	0.49	1.08

Figures followed by different letters are regarded as statistically significant.

straw removed treatment at pod fill (GS5.5). Although there was a trend for DM accumulation in the NTSR — long stubble to be lower than other treatments, the difference was not significant. While the short stubble treatment tended to produce more DM than long stubble during the flowering and pod-fill period, these differences were not statistically significant, with no difference between the two treatments at physiological harvest when most seeds are black but soft (GS6.7); a result frequently noted in previous years. There were no significant DM differences among the treatments at harvest, although the trend for DM to be higher where straw was removed was observed at the final assessment.

The lower DM production under the NTSR — long stubble treatment compared with other treatments also equated to lower nitrogen uptake in the canopy at seed ripening (GS6.7). Nitrogen uptake at seed ripening (GS6.7) was significantly greater in the cultivated and straw removed treatments, compared with the burnt and NTSR treatments (Table 25).

TABLE 25 Nitrogen uptake in dry matter 4 July 2017, green bud (GS3.3); 17 August 2014, 50% of all buds on raceme flowering or flowered (GS4.5); and 9 November 2017, most seeds black but soft (GS6.7)

Treatment	Nitrogen uptake (kg N/ha)		
	GS3.3	GS4.5	GS6.7
NTSR — long stubble	76^{ab}	111^{b}	68^{b}
NTSR — short stubble	84^{a}	101^{b}	77^{b}
Cultivated (one pass)	69^{b}	102^{b}	93^{a}
Straw removed	73^{ab}	108^{b}	91^{a}
Burnt	75^{ab}	136^{a}	77^{b}
Mean	**75**	**112**	**81**
LSD	15	14	11

Figures followed by different letters are regarded as statistically significant.
Note: DM samples taken on 17 September were damaged after weighing and it was not possible to undertake nitrogen sampling.

iii) Yield and grain quality

The trial was harvested on 20 November 2017 with an average yield of 3.76t/ha and an average oil content of 46%. There were no significant differences in yield at this site, with treatments yielding between 3.70–3.85t/ha (Table 26). The significant 0.3t/ha difference in DM measured at green bud (GS3.3) between the NTSR — short stubble and NTSR — long stubble treatments resulted in a 0.05t/ha difference in yield, which was not significant (3.70 vs 3.75t/ha). There was no advantage to burning or removing straw, despite advantages in DM content at flowering and pod fill.

iv) Four-year results (time replicate 1, 2, 3 and 4) — yield data 2014–17

For the past three years a replicated large block stubble management trial has been established in a different paddock on the Dookie focus farm. The trial has on each occasion been established following a first wheat crop. 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**. The 2017 trial was set up in the fourth year of the project and is referred to as **time replicate 4.**

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 of the subsequent years 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 year two and three farm crops.

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 four years the trial has run. In the 2014 trial the NTSR — long stubble (45cm) treatment significantly reduced yield by an average of 0.7t/ha, compared with other treatments, including NTSR — short stubble treatment. This equates

TABLE 26 Canola yield, 20 November 2017, at harvest

Treatment	Yield (t/ha)
NTSR — long stubble	3.70^{a}
NTSR — short stubble	3.75^{a}
Cultivated (one pass)	3.85^{a}
Straw removed	3.74^{a}
Burnt	3.74^{a}
Mean	**3.76**
LSD	0.17

Figures followed by different letters are regarded as statistically significant.
Note: The crop in the trial area had an average oil content of 46%.



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 8).

Although a significant yield reduction associated with long stubble was only observed in 2014, there has been evidence in all four years that long stubble has significantly decreased DM production, resulting in slower development, reduced tillering (in wheat) and reduced crop canopy greenness. During the 2015–17 seasons, this reduction in DM accumulation has been reversed later in the season, with NTSR — long stubble treatments producing similar yields to those treatments where straw was removed before sowing.

With four year means expressed as a percentage and NTSR — long stubble set at 100, burning at this site has generated an average yield increase of 8.1% over the four years, however only in 2014 was the advantage over NTSR — long stubble statistically significant (Figure 9). In the same year burning was not statistically better than NTSR — short stubble. If straw was removed, leaving just only the stubble, the yield difference over NTSR — long stubble was an average 4.6%.

v) 2015 stubble management treatments — influence on 2016 and 2017 yields

The 2015 stubble management trial at the Dookie focus farm was sown to a commercial crop of canola during 2016 and wheat during 2017. The 2015 second wheat trial stubbles were burnt in preparation for the commercial canola crop, but for the 2017 wheat crop a uniform method of establishment was applied using NTSR with canola stubbles crunched. 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 the 2015 trial sown to wheat. Neither were there yield differences in the following canola (2016) or wheat (2017) crops sown over the 2015 stubble treatments (Table 27).

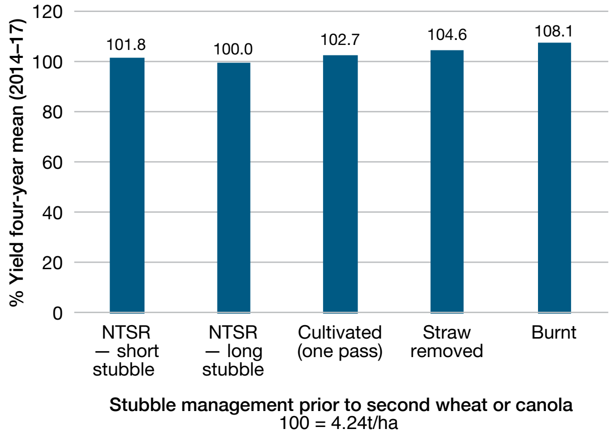


FIGURE 9 Influence of first wheat stubble management on the four year yield mean (%) of the following second wheat crop (2014–16) and canola (2017) — Dookie, Victoria 2014–17

TABLE 27 Effect of time replicate 2 trial on wheat yield 2015 cv Mace, canola yield 2016 cv Bonito and wheat yield 2017 cv Trojan, Dookie, Victoria

2015 stubble treatments	2015	2016	2017
	Second wheat	Canola	Wheat
	Yield (t/ha)	Yield (t/ha)	Yield (t/ha)
NTSR — long stubble	2.41[a]	2.6[a]	4.77[a]
NTSR — short stubble	2.52[a]	2.6[a]	5.30[a]
Cultivated (one pass)	2.39[a]	2.7[a]	5.55[a]
Straw removed	2.32[a]	2.6[a]	4.99[a]
Burn	2.49[a]	2.5[a]	5.46[a]
Mean	**2.42**	**2.6**	**5.21**
LSD	0.22	0.2	0.92

Figures followed by different letters are regarded as statistically significant.

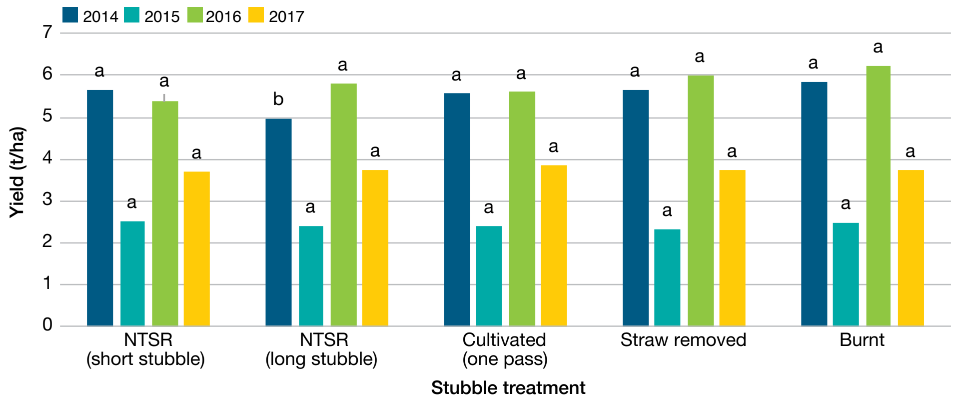
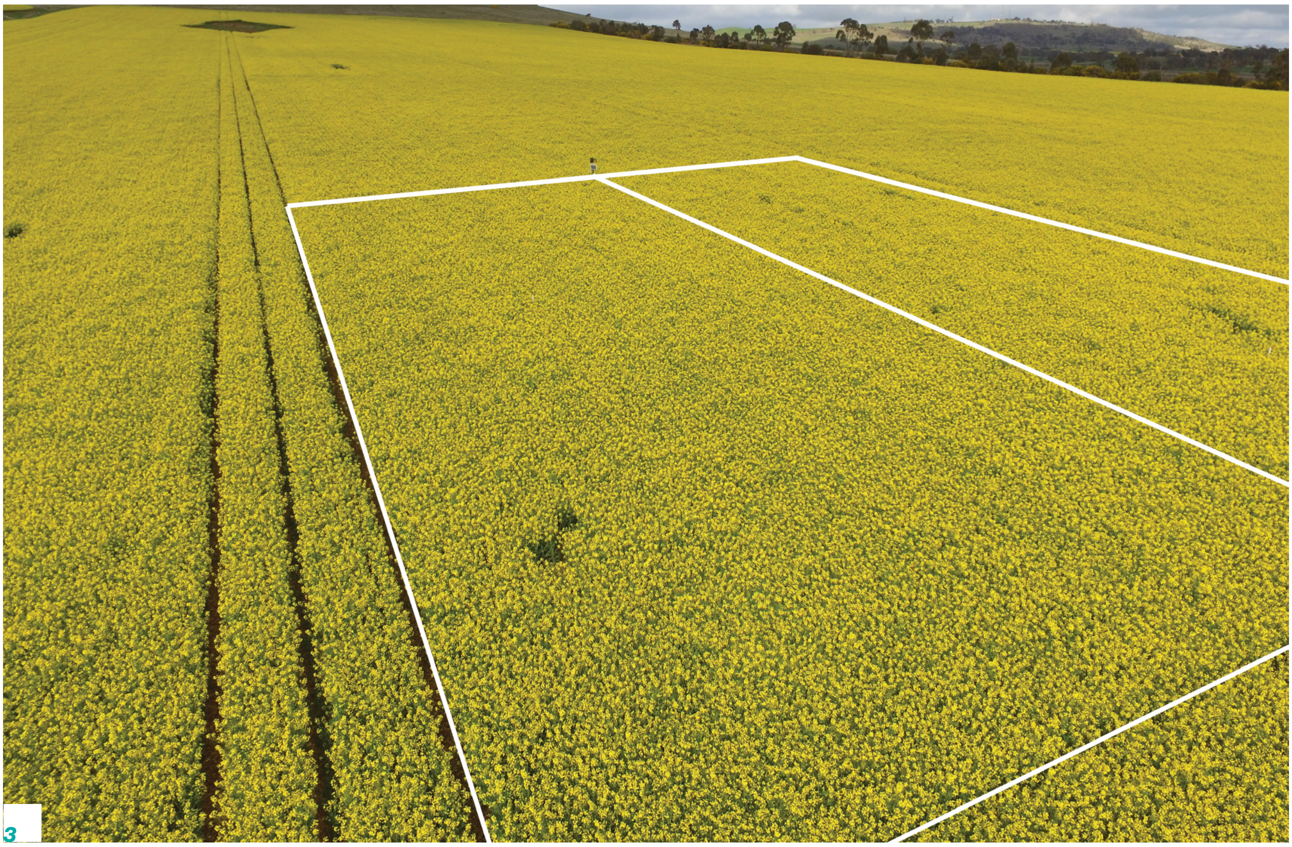


FIGURE 8 Yield data from 2014, 2015, 2016 and 2017 stubble management trials conducted in the wheat-on-wheat rotation position (time replicates 1, 2 and 3) cv Corack (2014), cv Mace (2015) and cv Corack (2016) and in cv ATR Stingray canola following wheat (time replicate 4) (2017)

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



1 Dry matter differences observed on 28 June 2017. Burnt treatment on the left and NTSR — long stubble on the right.

2 Observed flowering differences on 25 July. Cultivated plot in foreground and NTSR — long stubble plot in the background.

3 Dookie site on 5 September 2017 NTSR — short stubble marked plot on the left and NTSR — long stubble marked plot on right. (Note small gaps in canopy where dry matter samples were taken.

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