Strategic in-crop management supports success in stubble-retained systems

Key points

No-till stubble-retained (NTSR) systems require strategic management to optimise crop nutrition, disease and yield potential.

Nitrogen (N) availability during early crop growth in NTSR systems can be impacted by nitrogen 'tie-up' as microbes use soil nitrogen reserves to fuel stubble breakdown.

Yellow leaf spot (YLS) control in NTSR systems may be best achieved by applying fungicides during node development (GS31–33) to protect the major yield contributing leaves emerging from these growth stages onwards.

No yield benefits have been shown over three years of trials using plant growth regulators (PGR), however, PGRs did influence crop canopy height and leaf orientation.

Normalised difference vegetation index (NDVI) measurements correlate well with crop dry matter (DM) and nitrogen uptake data. This suggests it can be used to support in-crop nitrogen applications, however appropriate ground-truthing is critical.

No-till stubble-retained (NTSR) cropping systems have demonstrated a wide range of benefits for growers across the Riverine Plains region.

These include: improved soil moisture retention during summer, protection from wind and water erosion and increased soil organic matter (SOM) levels, which all have positive impacts on soil structure and fertility. On the flipside, retaining stubble can reduce nitrogen (N) availability during early crop growth stages and increase the risk of stubble-borne diseases, such as yellow leaf spot (YLS), (particularly in second-year wheat crops sown with susceptible varieties).

In recent years, Riverine Plains Inc has carried out a number of trials as part of the GRDC investment in the *Improved Water-Use Efficiency (WUE) in No-Till Cropping and Stubble-Retention Systems in Spatially and Temporally Variable Conditions in the Riverine Plains* project. These trials investigated a range of crop management strategies to support optimal production in NTSR systems. The results from this project are described in the Riverine Plains Inc publication *Between the Rows*, which can be downloaded from: http://riverineplains.org.au.

Nitrogen management

Stubble retention is associated with a temporary nitrogen lag during early crop growth stages, as microbes 'borrow' soil nitrogen to break down the stubble from the previous crop — often referred to as nitrogen 'tie-up' (see boxed section on page 3). This may leave the current crop short on available nitrogen during the initial stages of plant growth if adequate fertiliser nitrogen is not supplied.

Work by Dr James Hunt and others at CSIRO suggests NTSR systems require an extra 5kg N/ha per tonne of canola or cereal stubble at sowing in order to overcome any temporary nitrogen tie-up. As part of the GRDC investment *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region* project, field trials were sown at Daysdale/Corowa, New South Wales and Yarrawonga, Victoria, during the 2014–16 seasons. These trials investigated whether adding extra nitrogen at sowing would compensate for this nitrogen tie-up effect and influence final crop biomass (dry matter) or yield.

Daysdale/Corowa

The Daysdale/Corowa trials have investigated the value of adding an extra 40kg N/ha at sowing where stubble had been cultivated just before sowing. This was to determine whether mixing the stubble into the soil increased the nitrogen requirement during plant establishment due to higher soil-stubble contact.

The dry matter (DM) results from 2015–17 demonstrated that adding nitrogen at sowing to cultivated stubble increased crop DM through the season. However, for all years except 2017 (where the burnt treatment had significantly more biomass at harvest than the other treatments), any differences in DM between the treatments had levelled out by harvest, with all treatments supporting a similar final crop biomass. An example of results is presented in Table 1, showing results from 2015.

Four years of crop yield data (Figure 1) showed no increase in wheat yield when extra nitrogen was added at sowing to offset early nitrogen tie-up. Moreover, there was no difference in yield between the cultivated +40kg N/ha treatment and the NTSR (standing stubble) treatment, except in 2017 where the NTSR control yielded significantly more than the other treatments (Figure 1).

Over the four years of research (2014–17) at the Coreen focus farm there has been no consistent benefit to either cultivating, burning or adding additional nitrogen at sowing with cultivation over the NTSR control. In 2015 burnt treatment yielded less than the other treatments, which was most likely due to a heat stress event during October. In 2017, the NTSR control out-yielded all other treatments.

Yarrawonga

Four years of trials at Yarrawonga from 2014–17 investigated the value of adding extra nitrogen at sowing to both cultivated and NTSR (standing stubble) treatments. While there were some treatment effects on DM, there were no consistent increases in DM production due to extra nitrogen applied at sowing. Results from the 2017 trial are shown in Table 2.

Over the four years of the trial, there was also no yield benefit in applying extra nitrogen at sowing, compared with the NTSR control or the cultivated treatments, except in 2016, where the addition of nitrogen significantly increased the yield of the cultivated treatment (Figure 2). Although burning has increased DM production in all four years of trials, it was only in 2017 that it generated a significant yield advantage over the NTSR treatments. This relates to high levels of stubble residue carried over with the NTSR treatments from 2016.

Wheat growing through lightly incorporated stubble as part of the stubble management trials at Yarrawonga.

TABLE 1 Dry matter at Daysdale/Corowa 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)

Treatment	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.

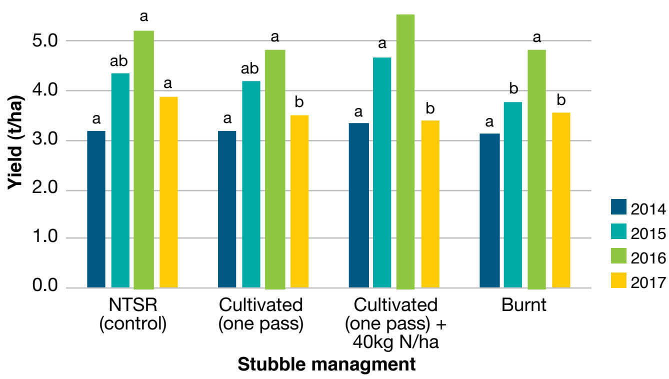


FIGURE 1 Yield data from time replicate trials 1, 2,3 and 4 — the Daysdale (red brown earth), Corowa (heavy grey clay), Coreen (loam over clay) and Coreen (loam over clay) trials for 2014, 2015, 2016 and 2017 — cv Whistler (wheat) in 2014, cv Mace (wheat) in 2015, cv Hindmarsh (barley) in 2016, cv Scepter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

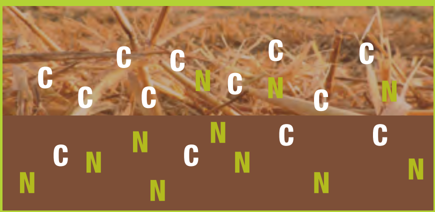
While applying extra fertiliser at sowing to offset nitrogen tie-up may not always result in higher wheat yields for the Riverine Plains region, it may provide other benefits, such as increased early vigour. Early vigour may be of particular value if the winter turns wet and cold or if waterlogging becomes an issue. Such effects were observed in the Yarrawonga region in the wet winter of 2015, where crops that received more nitrogen up front were better established and recovered more quickly from extended waterlogging than those having less early-season nitrogen.

Disease management

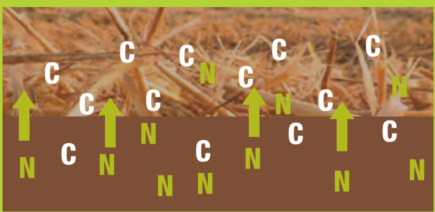
The carryover of stubble between seasons presents a disease challenge in many NTSR systems. While there are several diseases of importance in cereal crop production systems, yellow leaf spot (YLS) (*Pyrenophora tritici repentis*), is of particular interest to wheat growers in the Riverine Plains region because it survives on stubble between seasons.

Nitrogen tie-up explained

1. Soil naturally contains carbon (C) and nitrogen (N), with soil organic matter (SOM) having a C:N ratio of about 10:1. This ratio is optimum for microbial function. Wheat stubble contains lots of carbon and only a little nitrogen; with a C:N ratio of at least 80:1.



2. When the autumn break comes and microbial activity fires up, the soil microbes start breaking down carbon in the stubble and converting it to SOM. The microbes use some of the soil nitrogen reserves as 'fuel' to undertake this process.



3. A young plant growing in a stubble-retained system might not have much nitrogen available as the microbes have borrowed it to break down stubble. This is why young plants in wheat stubble may show nitrogen deficiency or have less vigour.

4. As the stubble breaks down, the microbes return nitrogen to the soil reserves. This extra nitrogen provides a boost for plant growth. Nitrogen tie-up in the early growth stages doesn't always correlate to a yield penalty, as the plant compensates by building biomass later in the season.

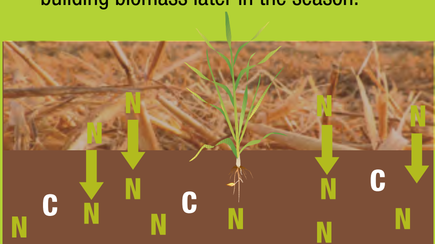


TABLE 2 Dry matter at Yarrawonga 19 July 2017, start of stem elongation (GS30); 5 September 2017, flag leaf fully emerged (GS39); 13 October 2017, watery ripe grain (GS71) and 23 November, physiological maturity (GS95)

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.

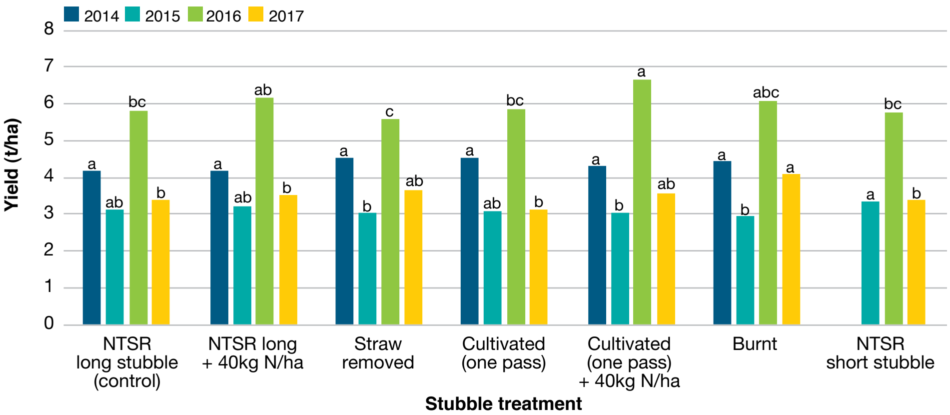
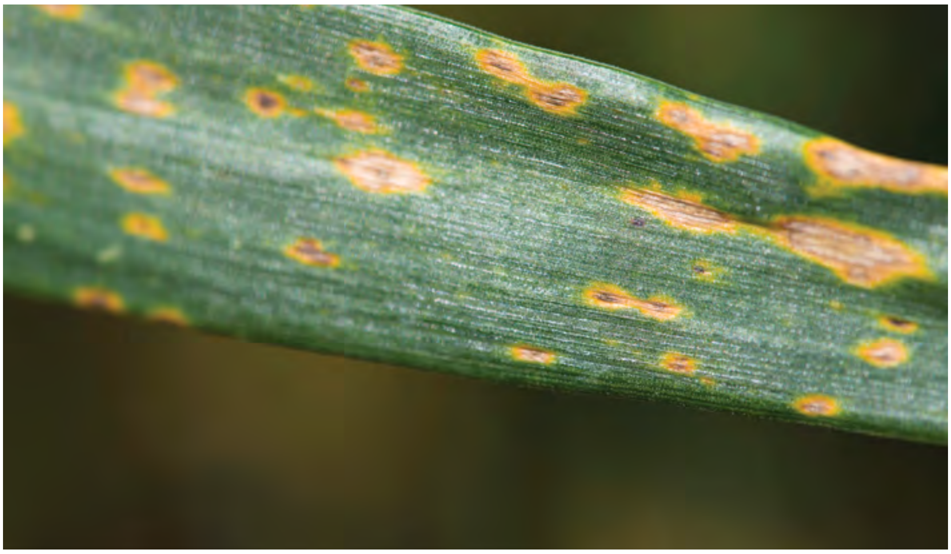


FIGURE 2 Yield data from the four Yarrawonga trials for 2014, 2015 (cv Young), 2016 and 2017 (cv Corack)

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.



Yellow leaf spot (YLS) (Pyrenophora tritici repentis)*. Photo courtesy: Evan Collis.*

The control of YLS through different fungicide and nitrogen application strategies has been evaluated through the GRDC-funded *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region Project* (2013–18).

Four years of field trials (2013–16) were carried out to determine the value of using fungicides (product and timing of application) and nitrogen to control YLS in early-sown second wheat crops.

For three successive years a response to foliar fungicides for YLS control was observed. This was despite yields being less than 4t/ha during 2015 and less than 3t/ha the previous two seasons, with disease levels being relatively low (less than 20% on the top three leaves) (Table 3). In 2016, despite the high incidence of YLS throughout the season, there was no significant yield response to fungicide due to the effect of severe waterlogging on the trial.

Over the four years of this trial the key messages are:

- Timing of nitrogen application did not influence yield when applied in conjunction with fungicide during 2014 and 2015. When nitrogen timing was delayed until third node (GS33) in 2016, yield was significantly reduced compared with the first node (GS31) timing.
- A single fungicide application for YLS at late tillering is of limited value, with greater control and yield benefit from a later fungicide application
- During 2013 and 2014 a two-spray fungicide program achieved the best YLS control.
- During 2014 Prosaro® performed better than Tilt®, with no difference between the two products in 2013, 2015 or 2016.

Varietal susceptibility, disease pressure, environmental factors and fungicide choice all play a role in determining the value of fungicide application for YLS control. As a general rule, the use of fungicides for YLS early in the season may not be economic, however in a wet spring there may be benefit in protecting the top leaves from disease.

The use of resistant varieties and rotations that include break crops such as canola and pulses, will also aid in managing YLS. While barley doesn't display symptoms of YLS, barley stubble can host the disease and provide a source of infection for the following crop.

TABLE 3 Yield of treatments for the control of YLS, with nitrogen and fungicide applications targeted for tillering (GS22–25) and first node (GS31–33), 2013–16

	Grain yield (t/ha)			
	Yarrawonga, Victoria	Coreen, NSW	Corowa, NSW	Yarrawonga, Victoria
Treatment	2013	2014	2015	2016*
Target nitrogen timing				
GS22		2.71[a]	3.81[a]	3.78[a]
GS31		2.70[a]	3.64[a]	3.26[b]
LSD		0.04	0.19	0.18
Target fungicide timing				
Untreated control	1.79[b]	2.58[c]	3.57[b]	3.42[a]
GS23–25	1.88[b]	2.72[b]	3.62[b]	3.52[a]
GS32–33	1.89[b]	2.71[b]	3.97[a]	3.55[a]
GS23–25 and GS32–33	2.06[a]	2.81[a]	3.74[ab]	3.59[a]
LSD	0.15	0.07	0.26	0.25
Product				
Prosaro	1.96[a]	2.73[a]	3.65[a]	3.54[a]
Tilt	1.85[a]	2.67[b]	3.8[a]	3.5[a]
LSD	0.77	0.03	0.19	0.18
Mean	**1.91**	**2.70**	**3.73**	**3.52**

* As a result of the wet conditions experienced during winter 2016, nitrogen and fungicide applications targeted for GS22-25 and GS32-33 were delayed until GS31 and GS33 respectively
Figures followed by different letters are regarded as statistically significant.

Large plot stubble management trials, Yarrawonga.

What is NDVI and how is it measured?

Normalised Difference Vegetation Index (NDVI) is a measure of the amount of live green vegetation, or the greenness of a crop canopy.

Live green plants absorb visible light (solar radiation) as part of photosynthesis. At the same time, plants reflect solar energy in the near infra-red range.

Measuring the difference between the visible and near infra-red light above a plant canopy provides a measure of greenness, which is converted to an index of between -1 and +1. Values are commonly between 0.1 and 0.7 with higher values associated with greater density and greenness of the plant canopy.

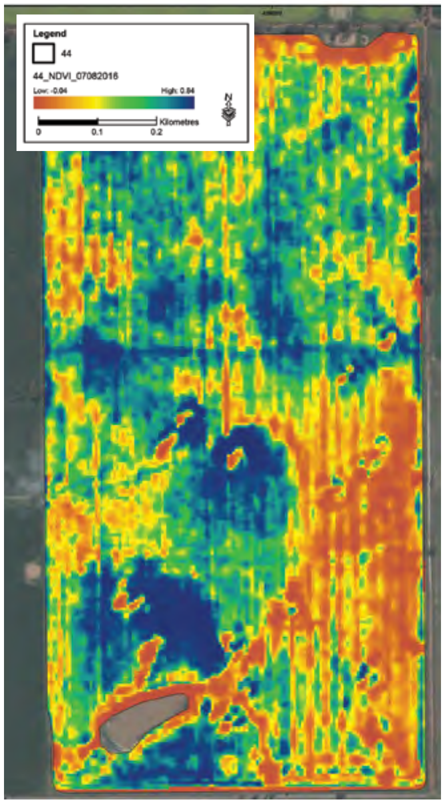
NDVI decreases as leaves come under water stress, become diseased or die.

Two ways of measuring NDVI

NDVI can be measured in-crop using a handheld device (e.g. GreenSeeker), which provides a numerical value on crop greenness at a specified point, or across a paddock if GPS referenced. This can be used through the vegetative stage to assess nutrition status, and determine the requirement for extra nitrogen.

NDVI maps can also be accessed from satellite data, which comes from instruments on board the National Oceanic and Atmospheric Administration (NOAA) series of satellites operated by the United States. Paddock-scale NDVI maps, taken at specific time points, can be purchased and used for both in-season fertiliser decisions, and for providing additional spatial data to interpret variability shown by yield maps.

Source of NDVI information: Australian Government, Bureau of Meteorology 2016.



NDVI image collected as part of paddock-scale experiments conducted within the Riverine Plains Inc Stubble Project, August 2016. Copyright Precision Agriculture.

Sowing varieties within their recommended sowing window and supplying adequate nutrition ensures crop development occurs at the appropriate time and that plants are vigorous. Healthy, vigorous crops are better able to resist or outgrow the effects of disease, limiting the potential for yield losses. Choosing a variety with YLS resistance and burning infected stubble will also help reduce the inoculum source.

Plant growth regulators in stubble-retained systems

Plant growth regulators (PGRs) are routine inputs for high-yielding cereal crops grown elsewhere in the world to shorten the crop, prevent crop lodging and avoid associated yield penalties.

Six trials were carried out across four years in the Riverine Plains region (2013–16) to determine if the larger crop canopies associated with early sowing, higher rates of nitrogen, or both, would benefit from PGR application.

During the four years of trials, it was found that applying a PGR (Chlormequat + Moddus®) decreased crop height by up to 8cm without influencing DM except in 2016, where harvest DM was significantly lower compared to the untreated control. This suggests crop biomass was redistributed, not decreased.

NDVI readings (see boxed section) taken with a handheld GreenSeeker® were lower with PGR application. This suggests the PGR either altered the greenness of the crop canopy, or changed the orientation of the leaves, making them more upright (and so producing less reflectance).

Applying a PGR did not affect yield in any of the trials, and did not interact with additional nitrogen applied above the standard farm application rate. This was shown at a representative trial at Dookie during 2015, where nitrogen was applied above the farm standard of 142kg N/ha (Figure 3).

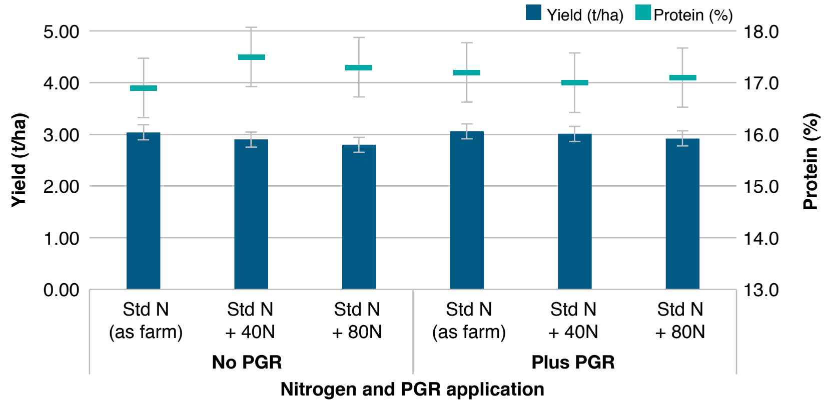


FIGURE 3 Influence of nitrogen application and PGR application on yield and protein at Dookie, 2015

The error bars are a measure of LSD.

Using in-crop NDVI to measure nitrogen requirements

Trials carried out as part of the GRDC-funded *Maintaining Profitable Farming Systems with Retained Stubble in the Riverine Plains Region* Project (2013–18) measured in-crop NDVI through the season to determine the responsiveness of wheat crops to nitrogen applications. The trial results from the 2014 Dookie site demonstrate how NDVI values correlate with other measurements (Figure 4).

The Dookie trial evaluated three rates of nitrogen application, (0, 60kg N/ha, 120kg N/ha), with the fertiliser either applied all at first node (GS31) or split between the first fully-unfolded leaf (GS11) and first node (GS31) stages. As there was little difference between the two nitrogen timings, the NDVI results are presented as an average across both timings.

As seen in Figure 4, additional nitrogen fertiliser increased the NDVI readings, with the greatest difference seen in NDVI values at the start of ear emergence (GS51) and mid-flowering (GS65). As shown in Table 4, the differences in NDVI measured in the field at GS51 and GS65 with a GreenSeeker correspond well to differences in DM, nitrogen uptake and yield.

While trial work is continuing to refine the relationships between NDVI and different growth parameters, results to date suggest an increase in NDVI up to mid-flowering may correlate with greater biomass and yield potential.

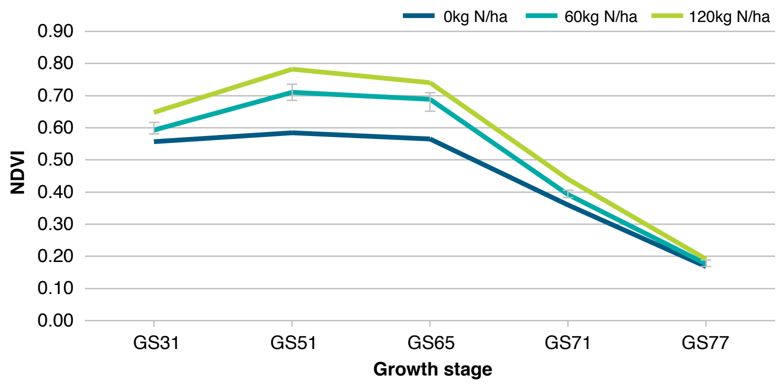


FIGURE 4 Influence of applied nitrogen rate on NDVI scale 0–1* at Dookie, 2014
* The error bars are a measure of LSD.

TABLE 4 A comparison of different growth parameters measured 11 September 2014 at Dookie, start of ear emergence (GS51) and 3 October 2014, mid-flowering (GS65)

Measurement timing, nitrogen rate	DM (t/ha)	Nitrogen uptake (kg N/ha)	NDVI scale (0–1)	Yield (t/ha)
GS51				
0kg N/ha	5.63^{b}	66^{c}	0.58^{c}	4.83^{b}
60kg N/ha	6.65^{a}	111^{b}	0.71^{b}	5.97^{a}
120kg N/ha	6.41^{a}	130^{a}	0.78^{a}	6.17^{a}
GS65				
0kg N/ha	8.15^{c}	57^{b}	0.57^{b}	
60kg N/ha	10.10^{b}	100^{a}	0.69^{a}	
120kg N/ha	11.31^{a}	113^{a}	0.74^{a}	

The yield is recorded for the three nitrogen rates applied

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The Stubble Initiative involves farming systems groups in Victoria, South Australia and southern and central New South Wales, collaborating with research organisations and agribusiness, to address challenges associated with stubble retention.

The GRDC, on behalf of growers and the Australian Government, is investing $17.5 million in the initiative that has been instigated by the GRDC Southern Regional Panel and the four Regional Cropping Solutions Networks that support the panel.

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