Performance of first wheat under no-till full stubble retention (NTSR) using in-crop nitrogen, plant population and row spacing at Yarrawonga

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Key points

- First wheat following canola yielded between 3.65–5.35t/ha depending on row spacing, plant population and nitrogen (N) application.
- A narrow row spacing of 22.5cm produced higher dry matter (DM), grain yields and water use efficiency (WUE) than a wider row spacing of 37.5cm.
- Higher grain yields were associated with plant populations of 150–165 plants/m^2.
- Wide row spacing reduced grain yields by an average of 6.5% and DM by 15% compared with narrow row spacing.

Location: Yarrawonga, Victoria

Rainfall:
Annual: 378mm
GSR: 222mm (April–October)
Stored moisture: 32mm (estimated at 35% fallow efficiency)

Soil:
Type: Loamy clay

Sowing information:
Variety: Gregory
Sowing date: 15 May 2013
Sowing equipment: Janke tine with Janke presswheel
Treatments: Row spacing x nitrogen application x plant population

Row spacing: 22.5cm and 37.5cm

Paddock history:
2012 — canola
2011 — wheat
2010 — pasture

Plot size: 16m x 2m

Replicates: 4

Overall goal

Improved water use efficiency (WUE) in no-till cropping and stubble retention systems in spatially and temporally variable conditions in the Riverine Plains.

Aim

The aim of this trial was to evaluate the performance of in-crop nitrogen (N), plant population and row spacing interaction in a first wheat no-till full-stubble-retention (NTSR) scenario.

Method

A replicated experiment was established to test the effect of four nitrogen timing strategies across four combinations of: two row spacings (22.5cm and 37.5cm) and two target plant populations (100 and 200 plants/m^2).

The four nitrogen timing treatments were based on 50kg N/ha timed at: sowing in the seedbed, early stem elongation (pseudo stem erect to first node — GS30–31), a 50% split of 25kg N/ha between both timings and nil nitrogen fertiliser.

Nitrogen application in these treatments was based on prilled urea fertiliser (46% nitrogen by weight).

A further four nitrogen strategies (25kg N/ha in the seedbed, 25kg N/ha at GS30–31, 100kg N/ha in the seedbed and 100kg N/ha at GS31) were applied to additional plots established on a 22.5cm row spacing and the higher crop density target of 200 plants/m^2.

The trial was sown in fully-retained canola stubbles that were approximately 45cm in length.

Statistical analysis was carried out using Statistix (version 9.0).

The trial was analysed as two trials: row spacing, plant population and nitrogen timing was analysed as a factorial design and nitrogen rate by timing (22.5cm row spacing and 200 plants/m^2 population target) was analysed separately as a factorial and a randomised complete block.

Reference to significant differences in the text denotes a p value equal to or <0.05.



Results

Crop establishment

Plant establishment differed significantly as a result of target plant population and row spacing. The 22.5cm row spacing established significantly more plants/m² than the 37.5cm spacing for the same sowing rate. The plant populations were greater than the target of 100 plants/m² and 200 plants/m² for the narrow row spacing but not for the wide row spacing.

Applying nitrogen to the seedbed did not significantly affect plant establishment, regardless of the nitrogen rate applied (25 and 50kg N/ha), when averaged across the two target plant populations and two nitrogen timings (see Table 1).

Nitrogen (0, 25, 50, 100kg N/ha) applied at sowing (established at 22.5cm row spacing with the higher target population) had no significant effects on plant establishment (see Figure 1).

Dry matter production

i) Plant population

Higher plant populations produced significantly more DM (larger canopies) than the lower plant populations until harvest, at which time there was no difference between the two target populations (see Figure 2).

TABLE 1 Plant establishment at three-leaves-unfolded stage (GS13), 37 days after sowing

Nitrogen treatment	Plant establishment (plants/m²)					
	Target 100 plants/m²			Target 200 plants/m²		
Row spacing (cm)	**22.5**	**37.5**	**Mean**	**22.5**	**37.5**	**Mean**
Nil nitrogen	167	96	**132**	272	152	**212**
50kg N/ha seedbed (SB)	163	88	**126**	273	157	**215**
50kg N/ha GS30–31*	159	87	**123**	270	151	**211**
50:50 seedbed:GS30–31 split*	164	86	**125**	269	146	**208**
Mean	**163**	**89**		**271**	**151**	
LSD [plant population]	10					
LSD [row spacing]	10					
LSD [nitrogen treatment]	14					
LSD [popⁿ x row spacing]	14					
LSD [popⁿ x nitrogen treatment]	19					
LSD [popⁿ x row x nitrogen treatment]	27					
Interaction — plant population x row spacing p value <0.001						

*At the time of assessment the GS31 nitrogen application had not been applied
Popⁿ — plant population

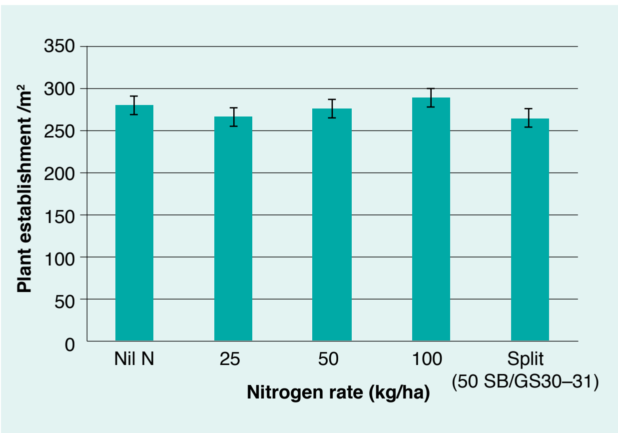

FIGURE 1 Influence of different nitrogen rates at sowing on plant establishment at a targeted plant population of 200 plants/m² sown on 22.5cm row spacings*

* Error bars presented as LSD value

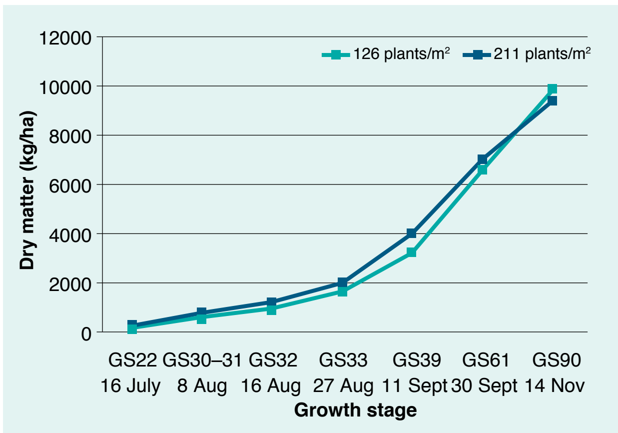

FIGURE 2 Influence of plant population on dry matter production*

LSD (5%): GS22; 55 , GS30–31; 85, GS32; 124, GS33; 196, GS39; 270, GS61; 373, GS90; 479kg DM/ha

* Mean of two row spacings and two nitrogen strategies (16 July – 27 August), mean of two row spacings and four nitrogen strategies (11 September – 14 November 2013)

The growth rate between flag leaf emergence (GS39) and harvest was significantly greater where the lower plant population was established (103kg DM/day) versus the higher population (84kg DM/day).

ii) Row spacing

Sowing the crop at the narrow row spacing (22.5cm) produced significantly more DM/ha than establishing the crop at the wider row spacing (37.5cm) at each of the seven assessment timings (see Figure 3).

The narrow row spacing averaged a growth rate of 98kg DM/day, which was significantly greater than growth at the wider spacing of 84kg DM/day between GS39 and harvest.

iii) Plant population and row spacing

With a wider row spacing, increasing plant population (density) from less than 100 plants/m^2 to 150 plants/m^2 increased DM production until GS39, after which the difference was not statistically significant.

At higher plant populations (163 increased to 271) with the narrow row spacing, the same effect was observed; the higher plant population produced more DM until GS39, after which there was increased growth by the lower plant population, which significantly increased DM by harvest (see Figure 4).

Overall, increasing plant population with a wide row spacing did not allow the crop to achieve the levels of DM production measured with a narrow row spacing.

iv) Nitrogen application: timing and rate

Applying nitrogen at sowing did not significantly influence DM production at the first assessment at

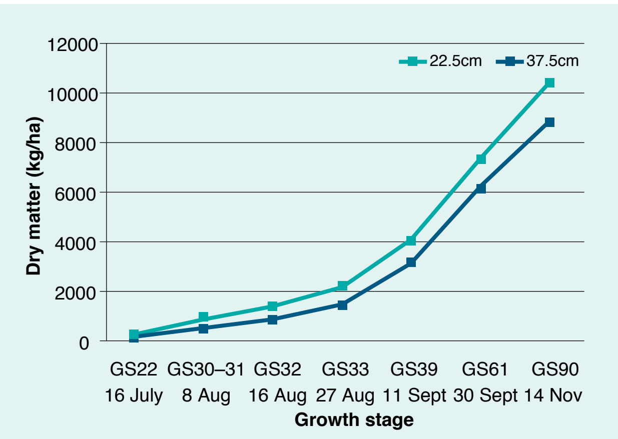

FIGURE 3 Influence of row spacing on dry matter production*

LSD (5%): GS22; 55, GS30–31; 85, GS32; 124, GS33; 196, GS39; 270, GS61; 373, GS90; 479kg DM/ha

* Mean of two plant populations and two nitrogen strategies (16 July — 27 August), mean of two plant populations and four nitrogen strategies (11 September — 14 November 2013)

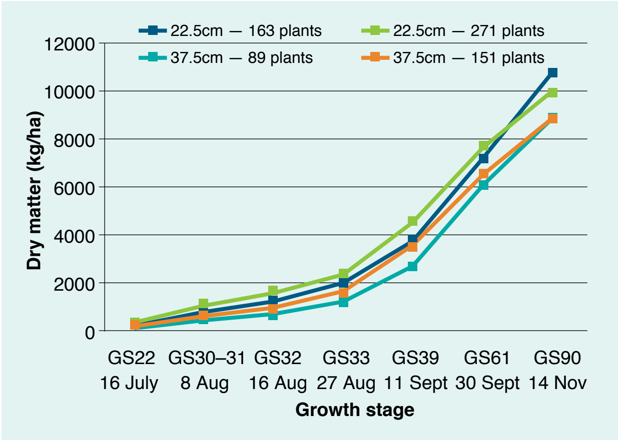

FIGURE 4 Influence of plant population and row spacing on dry matter production*

LSD (5%): GS22; 77, GS30–31; 125, GS32; 175, GS33; 277, GS39; 382, GS61; 527, GS90; 677kg DM/ha

* Mean of two nitrogen strategies (16 July — 27 August), mean of four nitrogen strategies (11 September — 14 November 2013)

tillering (GS22 main stem and two tillers). However, from the pseudo-stem erect stage (GS30) assessment through to third node (GS33) the addition of 50kg N/ha in the seedbed significantly increased the amount of DM compared with the untreated and GS30–31 nitrogen-fertilised plots.

When assessed at GS39 the 50kg N/ha applied at sowing also produced significantly more DM than the split nitrogen application (where 25kg N/ha was applied in the seedbed with a further 25kg N/ha at GS30–31). At the same assessment (GS39) there was no difference in DM production between the split application (25kg N/ha seedbed and 25kg N/ha GS30–31), the stem elongation application (GS30–31) or the untreated treatments.

Between the nitrogen application on 6 August at GS30–31 and sampling at GS39 on the 11 September there was 31mm of rain.

Assessments at the start of flowering (GS61) showed that applying nitrogen at sowing resulted in significantly more DM compared with where nitrogen application was delayed until GS30–31. However, both nitrogen application strategies produced significantly more DM than the nil-nitrogen treatment.

At harvest there was no statistical difference in DM between the three nitrogen strategies (100% seedbed, 100% GS30–31 and split 50%:50% between the two timings) with a range of DM from 9600–10,100kg/ha DM (see Figure 5). However, all three nitrogen treatments significantly increased DM production over the nil-nitrogen treatment (8800kg/ha DM).

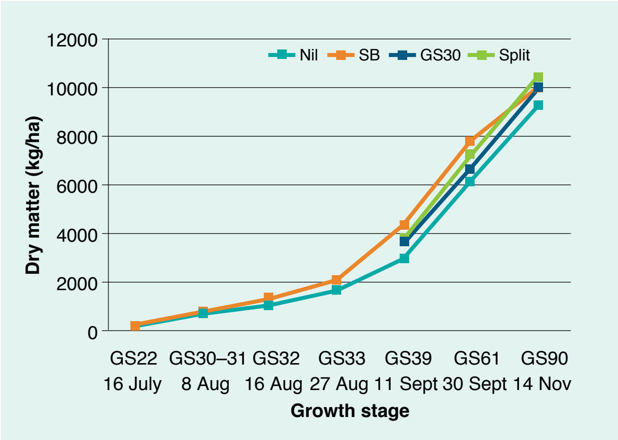

FIGURE 5 Influence of 50kg N/ha applied to the seedbed at sowing, at GS30–31 and 50:50 split between seedbed and GS30–31 on dry matter production (16 July – 14 November)*

LSD (5%): GS22; 55, GS30–31; 85, GS32; 124, GS33; 196, GS39; 382, GS61; 528, GS90; 677kg Dm/ha

* Mean of two row spacing and two plant populations

The rate of nitrogen applied, when averaged across two application timings (seedbed and start of stem elongation: GS30–31), generated significant differences in DM production at harvest. All levels of nitrogen application increased DM production significantly over the unfertilised treatment.

There was no difference in DM between the 100 and 50kg N/ha rates of application, and no difference between 50 and 25kg N/ha treatments. However, the trend was that more nitrogen produced more DM (see Figure 6).

v) Nitrogen uptake

As was measured with DM production, there were no differences in nitrogen uptake in the crop between treatments when assessed at the early growth stages.

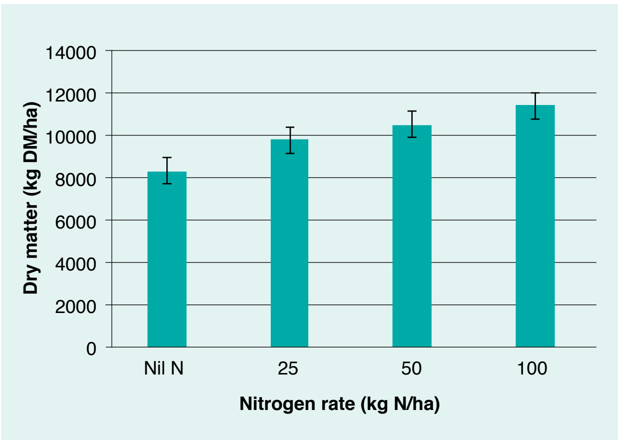

FIGURE 6 Influence of nitrogen rates applied on dry matter production at harvest (14 November) when sown at 22.5cm row spacings at a target plant population of 200 plants/m^2*

* Mean of two application timings: seedbed and GS30–31

(Error bars presented as LSD value)

However, at second node (GS32) there was significantly more nitrogen in the plant shoot biomass (canopy) where nitrogen was applied to the seedbed at sowing.

From the GS39 assessment through to harvest, the nil-nitrogen treatment had significantly less biomass nitrogen than when nitrogen was applied (see Figure 7).

Note that at crop maturity (GS90) the unfertilised crop had taken up 145kg N/ha compared with those crops that had been fertilised (with 50kg N/ha), which had taken up 168–186kg N/ha, indicating the crop had access to a relatively large soil nitrogen reserve.

Crop structure

Tiller production was greatest where 50kg N/ha was applied at sowing, though there was no statistical advantage over 25kg N/ha applied at the same time when assessed at GS30–31. Both nitrogen application rates promoted significantly more tillers than the nil-nitrogen control treatment.

The 50kg N/ha at sowing treatment also produced the most heads at harvest, however the advantage was not significant over the other two nitrogen application timings.

Tiller mortality was relatively low in the trial at 6–11% (see Figure 8).

Overall, relatively high nitrogen uptake in the unfertilised crop treatment and dry conditions during spring have restricted the overall nitrogen response.

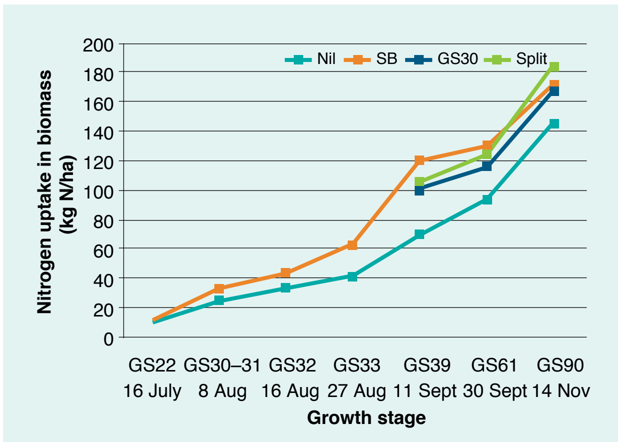

FIGURE 7 Addition of 50kg N/ha applied in the seedbed at: GS30–31 and 50:50 split between seedbed and GS30–31 on nitrogen uptake, compared with the nil-N control (16 July – 14 November)*

LSD (5%): GS22; 3, GS30–31; 4, GS32; 4, GS33; 6, GS39; 11, GS61; 13, GS90; 13kg N/ha

* Mean of two row spacings and two plant populations

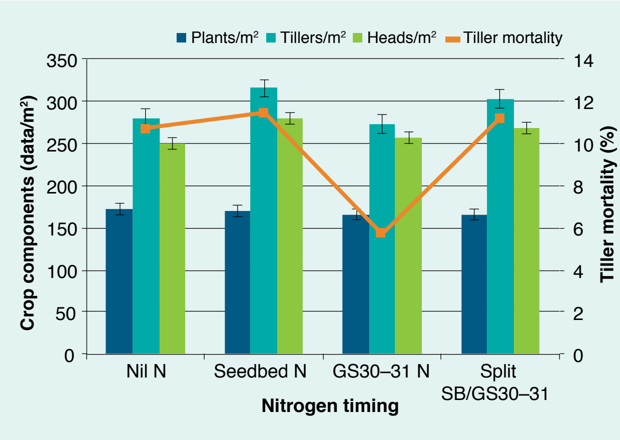

FIGURE 8 Influence of nitrogen application (50kg N/ha) on crop structure (plants 24 June, tillers 14 August, heads 14 November)*

* Mean of two row spacings and two plant populations
Error bars presented as LSD value

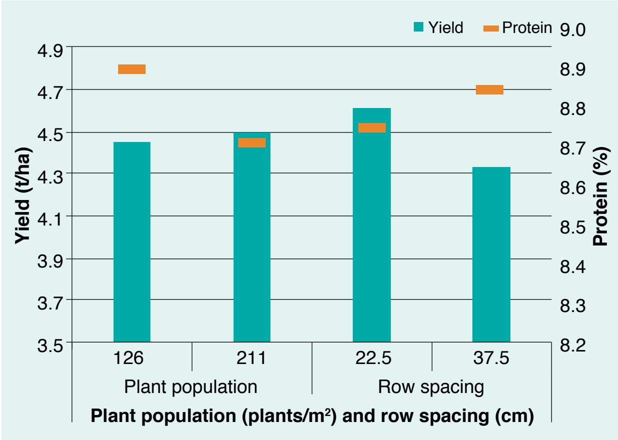

FIGURE 9 Influence of target plant population* and row spacing^ on yield and protein.

* Plant population is the mean of two row spacings and four nitrogen timings. ^ Row spacing data is the mean of two plant populations and four nitrogen timings.
LSD (5%); plant population and row spacing yield 0.11t/ha, protein 0.12%, compare plant population and row spacing separately

Yield and quality

i) Influence of row spacing and plant population

The narrow row spacing significantly out-yielded the wider row spacing by 0.3t/ha when averaged across all treatments, with no difference recorded in protein content due to row spacing (see Figure 9). There was also no effect of plant population on yield (see Table 2).

The influence of row spacing and plant population on yield is consistent with the differences recorded in DM production.

There was significantly higher protein content in the lower plant population (8.9% in the 100 plants/m² treatment versus 8.7% in the 200 plants/m² treatment) (see Figure 9). This result is the same as that recorded during the 2012 trial year.

There was a significant interaction between plant population and row spacing, which is probably the result of the actual plant population ranges established. There was no significant difference in yield between the two plant populations established (271 versus 163 plant/m²) with the narrow row spacing (22.5cm), while at the wider row spacing (37.5cm) increasing plant population from 89 plants/m² to 151 plants/m² significantly increased yield (see Figure 10).

Note that the comparison of plant population at the narrow row spacing was assessed at higher populations than the wider row spacing; a factor that is likely to have influenced this interaction.

TABLE 2 Yield at harvest (10 December 2013)

	Yield (t/ha)					
Nitrogen treatment	Target 100 plants/m²			Target 200 plants/m²		
Actual plant population (m²)	163	89		271	151	
Row spacing (cm)	22.5	37.5	Mean	22.5	37.5	Mean
Nil N	3.93	3.65	**3.79**	3.90	3.70	**3.80**
50kg N/ha seedbed	4.85	4.55	**4.70**	4.68	4.68	**4.68**
50kg N/ha GS30–31	4.93	4.30	**4.61**	4.80	4.58	**4.69**
50:50 seedbed GS30–31 split	5.00	4.38	**4.69**	4.83	4.83	**4.83**
Mean	**4.68**	**4.22**		**4.44**	**4.55**	
LSD [plant population]	0.11					
LSD [row spacing]	0.11					
LSD [nitrogen treatment]	0.16					
LSD [popⁿ x row spacing]	0.16					
LSD [popⁿ x nitrogen treatment]	0.23					
LSD [popⁿ x row x nitrogen treatment]	0.32					

Significant interaction — plant population x row spacing p = 0.003
Popⁿ — plant population

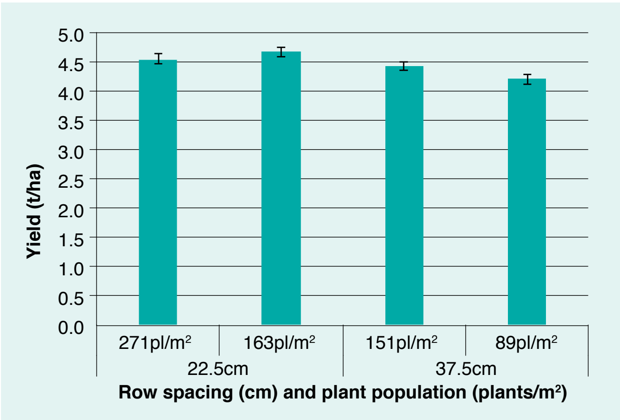

FIGURE 10 Interaction of plant population and row spacing on yield*

* Mean of four nitrogen timings
Error bars presented as LSD value

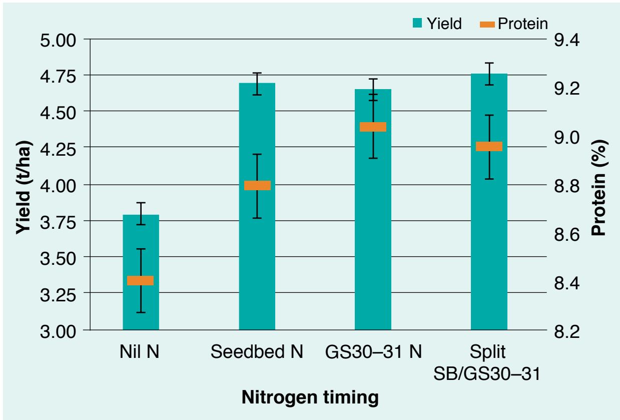

FIGURE 11 Influence of nitrogen application timing (50kg N/ha) on yield and protein content *

* Mean of two row spacings and two plant populations
Error bars presented as LSD value

The optimum combination of row spacing and plant population (22.5cm at 163 plants/m²) yielded 0.25t/ha more than the nearest equivalent population (151 plants/m²) at the wider 37.5cm row spacing and 0.47t/ha more than the wide spacing at the lower population of 89 plants/m².

ii) Influence of nitrogen timing and rate

Irrespective of timing, the application of 50kg N/ha significantly increased yield and protein content over the unfertilised plots (mean of two row spacings and two plant populations) (see Figure 11).

There was no yield difference due to the timing of nitrogen applications when 50kg N/ha was applied; a result that concurs with DM assessments at maturity.

Grain protein was highest with GS30–31 applied nitrogen, indicating greater nitrogen use efficiency in grain nitrogen uptake, since overall nitrogen uptake in the crop canopy as a whole was the same with all nitrogen timing strategies at maturity (see Figure 7). The nitrogen uptake in the grain of the split application was intermediate, as might be expected.

When comparing the influence of nitrogen rate at the higher plant population and 22.5cm row spacing, all nitrogen rates gave a significant yield advantage over the nil-nitrogen control. The application of 100kg N/ha yielded significantly more grain than all other treatments, with no difference in the two 50kg N/ha treatments (applied as a single or split application) (see Figure 12).

Grain protein content followed similar trends to yield, with higher nitrogen application rates delivering higher grain protein levels (see Figure 13).

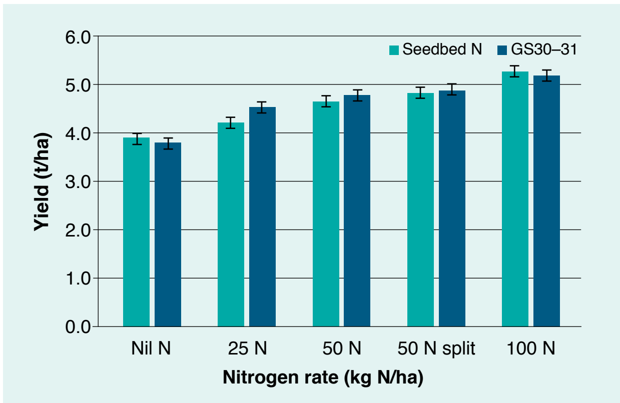

FIGURE 12 Influence of nitrogen rate and timing on yield when sown at a 22.5cm row spacing and 270 plants/m²*

* Error bars presented as LSD value

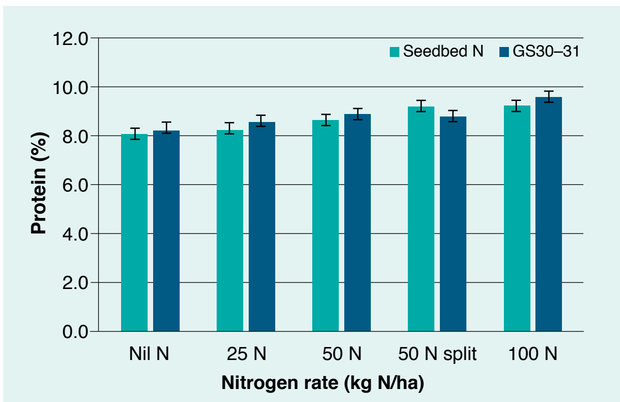

FIGURE 13 Influence of nitrogen rate and timing on protein when sown at a 22.5cm row spacing and 270 plants/m²*

* Error bars presented as LSD value

TABLE 3 Biomass at harvest, yield, harvest index (HI), water use efficiency (WUE), transpiration, evaporation/drainage and transpiration efficiency (TE)

	Biomass (kg/ha)	Yield[5] (kg/ha)	HI (%)	WUE[1] (kg/mm)	Transpiration[2] (mm)	Evaporation[3] (mm)	TE[4] (kg/mm)
Plant population (plants/m^2)							
100 (target)	9807	3891	**40**	15.3	178	76	**21.8**
200 (target)	9394	3935	**42**	15.5	171	83	**23.0**
LSD	479	100	**2.5**	0.39	8.7	8.7	**1.37**
P value	0.089	0.345	**0.153**	0.345	0.089	0.089	**0.153**
Row spacing (cm)							
22.5	10,369	4036	**39**	15.9	189	66	**21.4**
37.5	8833	3790	**43**	14.9	161	94	**23.6**
LSD	479	100	**2.5**	0.39	8.7	8.7	**1.37**
P value	<0.001	<0.001	**0.003**	<0.001	<0.001	<0.001	**0.003**
Nitrogen treatments (50kg N/ha)							
Nil nitrogen	9202	3320	**36**	13.1	167	87	**19.8**
Seedbed	9947	4102	**41**	16.1	181	73	**22.7**
GS30–31	9873	4069	**41**	16.0	180	73	**22.7**
50:50 split	10407	4162	**40**	16.4	189	65	**22.0**
LSD	677	142	**3.5**	0.56	12.3	12.3	**1.94**
P value	0.003	<0.001	**0.040**	<0.001	0.003	0.003	**0.040**

[1] Based on 222mm of GSR (April – October) + 35% fallow efficiency (32mm) for January – March rainfall (total GSR + stored = 254mm) with no soil evaporation term included and assuming no drainage in periods of excessive rainfall.
[2] Transpiration through the plant based on a maximum 55kg harvest biomass/ha/mm transpired.
[3] Unproductive water (evaporation, drainage and water left unused at harvest) is the difference between transpiration through the plant and GSR (mm) + stored water at sowing.
[4] Transpiration efficiency based on kg/ha grain produced per mm of water transpired through the plant.
[5] Note that yields have been presented at 0% moisture content rather than 12.5% moisture as is the case in Table 2.

The highest yields were achieved with 100kg N/ha (at sowing and at GS31) (5.25–5.35t/ha), however at this nitrogen level only the narrow row spacing at the 270 plants/m^2 was examined. When the treatments that covered all of the combinations of nitrogen application, row spacing and plant population were considered, the highest grain yield (5.00t/ha) was produced with a combination of narrow row spacing, 164 plants/m^2 and a split nitrogen approach with 50% nitrogen applied at sowing and 50% at GS30–31 where 50kg N/ha had been applied. This combination also produced the highest WUE, as a result of higher DM production and a relatively high harvest index (HI) — proportion of biomass partitioned (harvested) as grain.

Observations and comments

The widest row spacing (37.5cm) produced the highest HI and the greatest transpiration efficiency (see Table 3). However this result was principally a feature of the lower overall levels of biomass produced (8800kg/ha DM) and as a result less water loss (transpiration) from that biomass. Although the HI was lower with the narrow row spacing, the higher biomass produced offset this disadvantage resulting in higher grain yields and overall significantly higher WUE (which takes into account the losses from the soil and the plant).

The calculations suggest that wider rows led to greater water loss either through evaporation from the soil or as water left unused. Water use efficiency rates were higher during the 2013 season compared with 2012.

The WUE peaked with the split nitrogen application at 16.4kg grain/mm (presented as an average of row spacing and plant population).

Sponsors

This trial was carried out as part of the Riverine Plains Inc GRDC-funded project *Improved WUE in no-till cropping and stubble retention systems in spatially and temporally variable conditions in the Riverine Plains* (RP100007).

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