Performance of canola under no-till full stubble retention (NTSR) using different drill openers and row spacings at Coreen

Location: Coreen, NSW

Growing season rainfall:
- **Annual:** 331mm
- **GSR:** 234mm (Apr–Oct)

Soil:
- **Type:** Clay loam
- **pH (H_2O):** 5.9
- **pH ($CaCl_2$):** 4.9

Sowing information:
- **Sowing date:** 1 June 2009
- **Sowing rate:** 2.5kg/ha
- **Sowing fertiliser:** Superfect @ 170kg/ha
- **Sowing equipment:** Single disc opener, Janke tine and press wheel
- **Varieties:** Hyola 50, canola

Row spacing: 22.5cm, 30cm and 37.5cm

Paddock history:
- **2008** — triticale
- **2007** — wheat

Plot size: 44 x 3m

Replicates: 4 disc and 8 tine

KEY POINTS

- **A 30cm row spacing for canola produced significantly higher yields than crops grown at 22.5cm and 37.5cm row spacings ($p<0.001$).**
- **In this first-year trial the disc opener produced significantly higher canola yields than the tine based opener ($p=0.05$).**
- **Yield results represented water use efficiencies (WUE) ranging from 6.4 kilograms per millimetre to 7.3kg/mm.**
- **Dry matter (DM) calculations revealed that a 30cm row spacing produced greater transpiration efficiency than a 22.5cm row spacing.**

WRITTEN BY

Nick Poole Foundation for Arable Research, New Zealand in conjunction with Riverine Plains Inc

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.

Trial aim

The aim of this trial was to evaluate the performance of different drill openers at a range of row spacings in two no-till rotations.

Method

A replicated experiment was established to test the effect of a range of drill openers and row spacings in two no-till canola rotations.

Crop stubble from the previous commercial triticale crop was chopped and spread at right angles to the direction of plots.

Results

Crop establishment:

Establishment was significantly better with the disc opener than with the tine when assessed 18 and 38 days after sowing. There was no significant difference in establishment between 22.5 centimetre and 30cm rows. However, plant populations were lower where row spacing moved out to 37.5cm (see Table 1 and Figure 1).

As row width increased using the disc opener, the established plant populations declined (see Figure 2), indicating a significant linear relationship between the two. For reasons that are not clearly understood, the establishment with the tine opener was significantly better at the 30cm rather than the 22.5cm row spacing, which also had been the case with disc opener.

TABLE 1 Plant establishment at the cotyledon stage and the two-leaf fully-unfolded stage assessed 18 and 38 days after establishment

Row spacing (cm)	Drill opener[1]					
	Plant establishment (plants/m²)					
	19 June 2009			8 July 2009		
	Disc	Tine	Mean	Disc	Tine	Mean
22.5	73.5	43.7	**58.6**	68.6	47.0	**57.8**
30	61.7	54.6	**58.2**	55.8	56.7	**56.3**
37.5	53.2	39.6	**46.7**	48.3	42.4	**45.4**
Mean	**63**	**46**		**58**	**49**	
LSD (row spacing)	7.5			5.3		
LSD (drill opener)	6.5			4.6		
LSD (disc) (tine) LSD (disc vs tine)	12.9 11.2	9.12		9.3 8.0	6.54	
Interactions — drill opener x row spacing						
Linear	*			**		
Quadratic	ns			*		

[1] Tine treatments had eight replicates compared with four for the disc treatment
* Significant at p = 0.05
**Significant at p=0.005

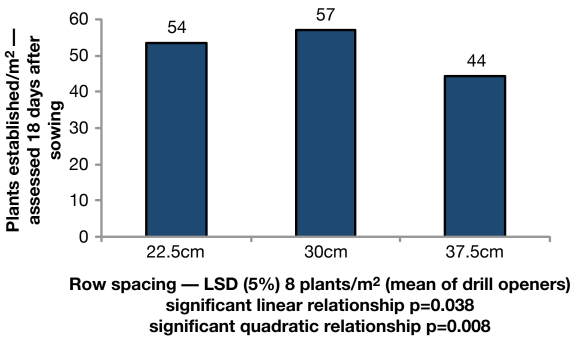

FIGURE 1 Influence of row spacing on plant establishment at the cotyledon stage (GS10) 18 days after sowing

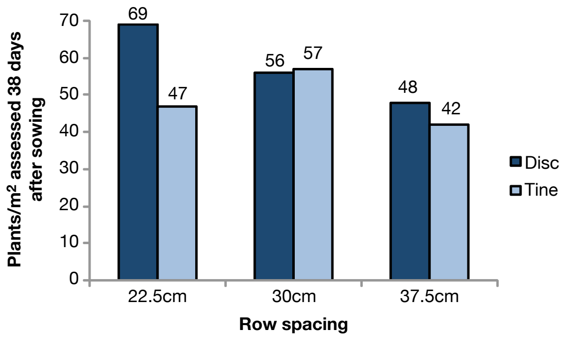

FIGURE 2 Influence of row spacing and opener method on plant establishment at the two-leaf stage (GS12), assessed 38 days after sowing

Dry matter production

i) Row spacing

Dry matter (DM) assessments of the treatments (three row spacings with discs and tines) were made at five assessment dates (green bud — 20 August 2009, early flower — 7 September 2009, mid flower — 21 September 2009, podding — 7 October 2009 and maturity — 11 December 2009).

At green bud there was a significant difference in DM production as a result of the row spacing (see Figure 3). Later assessments revealed no difference in DM production as a result of row spacing, but the trend was for a 22.5cm row spacing to produce more biomass than a 37.5cm spacing.

ii) Drill opener

There was a significant effect on DM production at green bud and crop maturity when the two openers were compared; however there was a trend for the disc to produce the higher DM across all assessments (see Figure 4).

Yield

Canola grown on 30cm rows was significantly higher yielding than that grown on 22.5cm or 37.5cm rows, between which there was no difference (see Figure 5). The results indicated that the relationship between row spacing and yield was not linear, with an indication that a 22.5cm spacing was too narrow and a 37.5cm spacing was too wide.

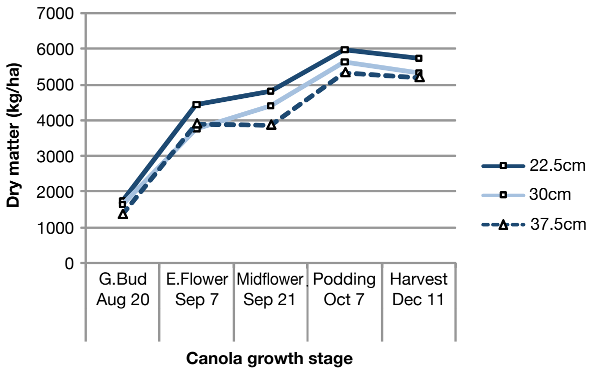

FIGURE 3 Influence of row spacing on dry matter production*

*Mean of both drill openers, assessed from green bud (20 August 2009) to maturity (11 December 2009)

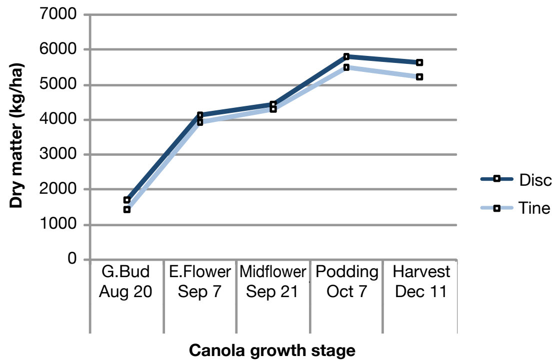

FIGURE 4 Influence of opener on dry matter production*

*Mean of three row spacings assessed from green bud (20 August 2009) to maturity (11 December 2009)

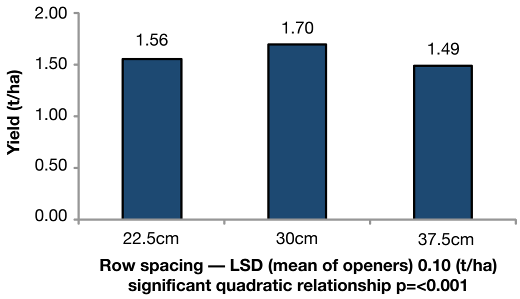

FIGURE 5 Influence of row spacing on seed yield*

*Mean of both drill openers

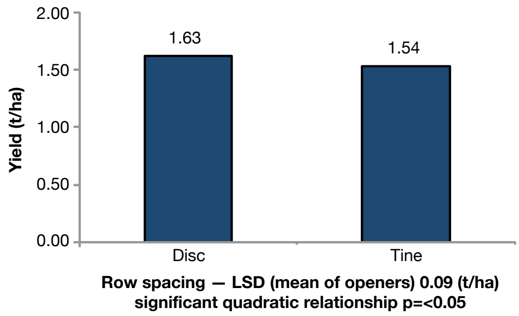

FIGURE 6 Influence of drill openers on seed yield*

*Mean of three row spacings

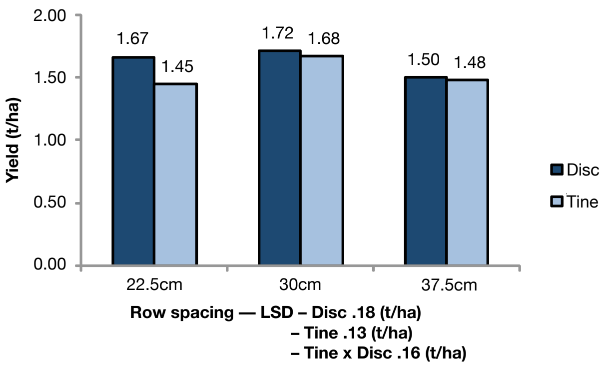

FIGURE 7 Influence of row spacing and drill opener on seed yield

TABLE 2 Maximum biomass at podding, seed yield, harvest index (HI), WUE, transpiration, estimated soil evaporation/other soil losses and transpiration efficiency (TE)

Row spacing (cm)	Biomass (kg/ha)	Yield (t/ha)	HI (%)	WUE[1] (kg/mm)	Transpiration[2] (mm)	Evaporation[3] (mm)	TE[4] (mm)
22.5	5987	1.56	**26**	6.7	120	**114**	**13.0**
30	5652	1.69	**30**	7.3	113	**121**	**15.0**
37.5	5347	1.49	**28**	6.4	107	**127**	**13.9**

[1] Based on 234mm of GSR (Apr–Oct) with no soil evaporation term included.
[2] Transpiration through the plant based on a maximum 50kg biomass/ha.mm transpired.
[3] Difference between transpiration through the plant and GSR (mm).
[4] Transpiration efficiency based on kg/ha grain produced/mm of water transpired through the plant.

The disc opener (when all row widths were considered) produced significantly higher crop yields than the tine (p=0.05) (see Figure 6), with the same trends in yield exhibited in terms of row spacing — 30cm being the highest yielding treatments (see Figure 4). However the disc opener showed no statistical difference in yield between the 22.5cm and 30cm row spacings, both being superior to the 37.5cm spacing.

Observations and comments

The results were very similar to those observed in the wheat trial (see pages 14–17), which was part of the same national WUE project. The drop in yield from exceeding a 30cm row spacing and moving to a 37.5cm spacing was just over 12 per cent — the same as that recorded in the wheat. However, in the wheat there was little difference in productivity between the 22.5cm and 30cm spacings, whereas in the canola there was a penalty at the narrower spacing.

In terms of overall WUE, a 30cm row spacing gave slightly better WUE than either 22.5cm or 37.5cm spacings (7.3 kilograms per millimetre vs 6.4–6.7kg/mm with no soil evaporation/run-off/drainage factor included) (see Table 2).

While a 22.5cm row spacing produced superior DM per unit area at podding (maximum DM recorded) and harvest compared with a 30cm spacing, less DM was turned into seed yield. As a consequence the 22.5cm spacing produced a lower harvest index than the 30cm row spacing (26% vs 30%). There was slightly greater water loss through soil surface evaporation with a wider row spacing, but this estimated loss was small compared with the benefit of a superior harvest index.

Sponsors

This trial is part of a nationwide project funded by the Grains Research and Development Corporation (GRDC) aimed at improving WUE in broadacre cropping systems.

Farmer co-operator: Hanrahan family, Coreen and Peracto Pty Ltd as trial manager.

CONTACT

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Performance of wheat under no-till full stubble retention (NTSR) using different drill openers and row spacings at Coreen

Location: Coreen, NSW
Growing season rainfall: **Annual:** 331mm **GSR:** 234mm (Apr–Oct)
Soil: **Type:** Clay loam **pH (H_2O):** 5.8 **pH ($CaCl_2$):** 4.9
Sowing information: **Sowing date:** 29 May 2009 **Sowing rate:** 85kg/ha **Sowing fertiliser:** 70kg/ha MAP **Sowing equipment:** Single disc opener, Janke tine and press wheel **Varieties:** Gladius, wheat
Row spacing: 22.5cm, 30cm and 37.5cm
Paddock history: **2008** — canola **2007** — wheat
Plot size: 44 x 4m
Replicates: 4 disc and 8 tine

KEY POINTS

- **Gladius wheat following canola (residue retained) yielded 2.5 tonnes per hectare.**
- **Crops with 22.5cm and 30cm row spacings yielded 0.33–0.34t/ha more than crops established at 37.5cmspacings.**
- **Crops established with the disc opener yielded 0.19t/ha more than those established with the tine opener. This correlated to similar findings with plant establishment and dry matter (DM) production.**
- **Water use efficiency (WUE) was similar for 22.5 and 30cm row spacings, giving superior performance to the 37.5cm row spacing.**

WRITTEN BY

Nick Poole Foundation for Arable Research, New Zealand in conjunction with Riverine Plains Inc

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.

Trial aim

The aim of this trial was to evaluate the performance of different drill openers at a range of row spacings for their performance in two no-till rotations.

Method

A replicated experiment was established to test the effect of a range of drill openers and row spacings in two no-till wheat rotations.

Crop residue from previous commercial canola crop was chopped and spread at right angles to the direction of plots.

Results

Crop establishment:

Row spacing (22.5cm, 30cm and 37.5cm) had a significant effect (linear $p=<0.001$) on establishment 21 days after sowing (see Table 1 and Figure 1), with the 22.5cm row spacing achieving significantly higher plant populations than both 30cm and 37.5cm spacings. The 30cm spacing also established significantly more plants per square metre than the 37.5cm spacing.

There was still a significant difference in plant establishment when assessed 40 days after sowing (linear $p=<0.001$), the data showed the same trend as the assessment 21 days after sowing.

There was a non-significant effect of drill openers on plant establishment at both assessment timings (21 days after sowing $p=0.056$, and 40 days after sowing $p=0.082$). However, disc treatments gave a trend for better crop establishment than tine treatments (see Figure 2).

TABLE 1 Plant establishment at the one-leaf stage (GS11) and the three-leaf stage (GS13) assessed 21 and 40 days after establishment

Row spacing (cm)	Drill opener [1] Plant establishment (plants/m²)					
	19 June 2009			8 July 2009		
	Disc	Tine	Mean	Disc	Tine	Mean
22.5	191.2	189.3	**190**	205.9	194.2	**198**
30	155.8	153.6	**154**	164.2	153.6	**157**
37.5	154.1	126.5	**136**	129.7	126.6	**128**
Mean	**167**	**157**		**167**	**158**	
LSD (row spacing)	13			11		
LSD (drill opener)	11			10		
LSD (disc) (tine) LSD (disc vs tine)	21.7 18.8	15.3		19.3 16.7	13.6	
Interactions — drill opener with row spacing was not significant						

[1] Tine treatments had eight replicates compared with four for the disc treatment

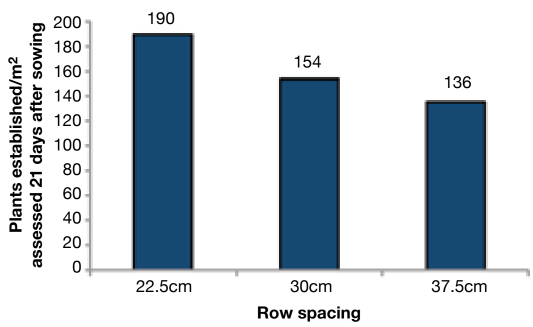

FIGURE 1 Influence of row spacing on plant establishment at the one-leaf stage (GS11) 21 days after sowing

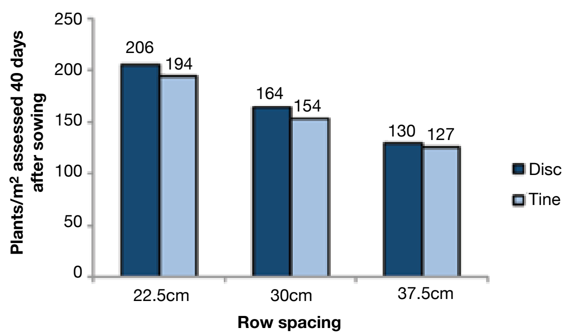

FIGURE 2 Influence of row spacing and opener method on plant establishment at the three-leaf stage (GS13) assessed 40 days after sowing

Dry matter production

i) Row spacing

Dry matter (DM) assessments were conducted while the crop was at first node (GS31 — 20 August 2009), flag leaf emergence (GS39 — 7 September 2009), early flower (GS61 — 21 September 2009) and at harvest (GS99 — 16 November 2009). Across all four assessment timings there were significant differences in the DM production as a result of the row spacing (treatments ranging from p=<0.001 (GS31) to p=0.016 (GS99)). The 22.5cm row spacing produced significantly more DM than 30cm and 37.5cm row spacings at harvest but was always significantly better than the 37.5cm spacing (see Figure 3).

ii) Drill opener

There was significantly more DM produced throughout the growing season in those plots established with the disc opener rather than the tine opener (see Figure 4).

Yield

The mean yield across the trial was 2.51 tonnes per hectare. Comparing the three row spacings (mean of both drill openers) Gladius crops established at 22.5cm and 30cm spacings yielded significantly more (0.33–0.34t/ha) than equivalent crops sown with 37.5cm row spacing (see Figure 5). Despite the trend in DM suggesting a 22.5cm row spacing was superior to a 30cm spacing, there was no difference in yield.

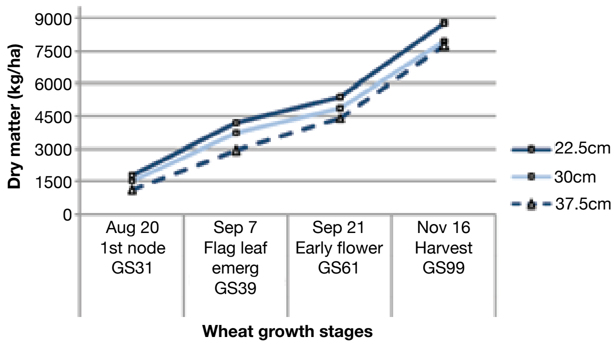

FIGURE 3 Influence of row spacing on dry matter production*

* Mean of both drill openers assessed from first node (GS31 — 20 August 2009) to maturity (GS99 — 16 November 2009)

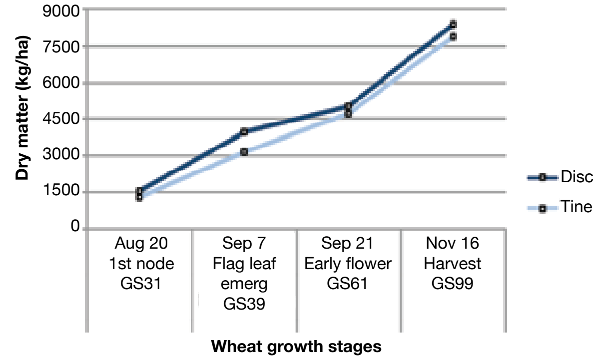

FIGURE 4 Influence of opener on dry matter production*

* Mean of three row widths assessed from first node (GS31 — 20 August 2009) to maturity (GS99 — 16 November 2009)

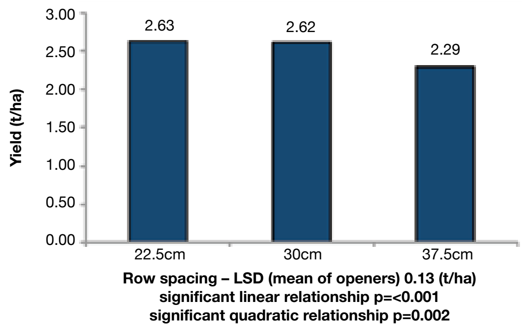

FIGURE 5 Influence of row spacing on yield*

* Mean of both drill openers

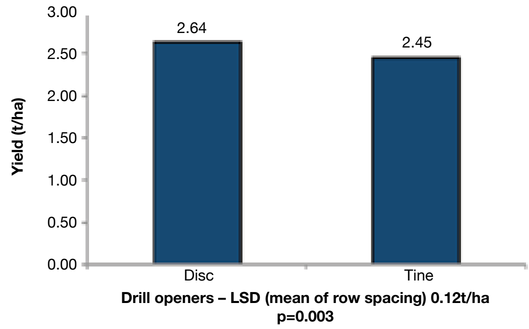

FIGURE 6 Influence of drill openers on yield*

* Mean of three row spacings

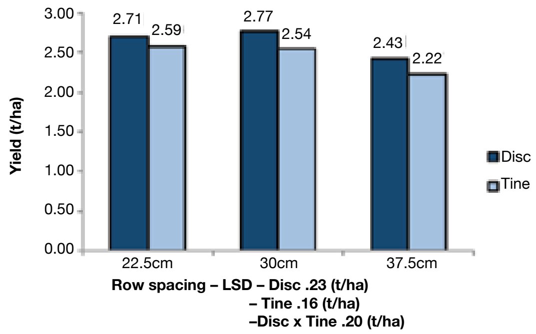

FIGURE 7 Influence of row spacing and drill opener on yield

TABLE 2 Biomass at maturity, yield, harvest index, water use efficiency, transpiration, estimated soil evaporation and transpiration efficiency for wheat (mean of both openers)

Row spacing (cm)	Biomass (kg/ha)	Yield (t/ha)	HI (%)	WUE[1] (kg/mm)	Transpiration[2] (mm)	Evaporation[3] (mm)	TE[4] (mm)
22.5	8799	2.63	**29.9**	11.2	160	**74**	**16.4**
30	7945	2.62	**33.0**	11.2	144.5	**89.5**	**18.1**
37.5	7738	2.29	**29.6**	9.8	140.7	**93.3**	**16.2**

[1] Based on 234mm of GSR (Apr–Oct) with no soil evaporation term included.
[2] Transpiration through the plant based on a maximum 55kg biomass/ha.mm transpired.
[3] Difference between transpiration through the plant and GSR (mm).
[4] Transpiration efficiency based on kg/ha grain produced per mm of water transpired through the plant.

When drill openers were compared (mean of three row spacings), crops established with the disc openers yielded significantly (0.19t/ha) more than those established with the tine openers (see Figure 6). There were no significant interactions between drill opener and row spacing.

Disc openers tended to be higher yielding than tine openers and wheat at the 37.5cm row spacing was inferior to the 22.5cm and 30cm row spacings, between which there was no difference (see Figure 7).

Quality

There were no significant differences in the protein or test weight as a result of the treatments, the mean protein was 14.6 per cent with a mean test weight of 72.7 kilograms per hectalitre. All grain screenings were below 2%, however there was a significant effect of row spacing (linear p=0.12) with the 22.5cm row spacing recording lower screenings (1.5%) than the 37.5cm (1.9%) with the 30cm spacing intermediate (1.8%).

Observations and comments

Moving to wider row spacing in order to improve the logistics (for example, residue flow) and economics (for example, reduced number of openers) of no-till establishment under full stubble retention showed little effect on grain yields and resultant WUE, provided row spacing did not exceed 30cm. In this trial the yield loss associated with moving from a 30cm to 37.5cm row spacing was more than 12% (0.33t/ha).

It is accepted that for the benefit of the whole sowing system there may still be advantages to moving to wider row spacings even with some degree of yield decrease, but this trial, which is only one year of results, does illustrate a substantial penalty to moving to 37.5cm spacings from 30cm spacings in this environment.

In terms of WUE, 22.5cm and 30cm row spacings gave the same figures, both being superior to 37.5cm spacings. However, from examining the DM figures at harvest it would appear that the water lost through transpiration and soil evaporation differed such that 30cm spacings lost slightly more from the soil and slightly less through the plant while with the 22.5cm spacing it was the other way around (see Table 2).

Sponsors

The trial is part of a nationwide project funded by the Grains Research Development Corporation (GRDC) aimed at improving WUE in broadacre cropping systems.

Farmer co-operator: Hanrahan family, Coreen and Peracto Pty Ltd as trial manager.

CONTACT

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Performance of wheat under no-till full stubble retention (NTSR) using different drill openers and row spacings at Bungeet

Location: Bungeet, Victoria	
Growing season rainfall:	
Annual: 397mm	
GSR: 286mm (Apr–Oct)	
Soil:	
Type: Loam over clay wattville number 205	
pH (H_2O): 6.74	
Sowing information:	
Sowing date: 4 June 2009	
Sowing rate: 85kg/ha	
Sowing fertiliser: 70kg/ha MAP	
Sowing equipment: Single disc opener, Janke tine and press wheel	
Varieties: Livingston, wheat	
Row spacing: 22.5cm, 30cm and 37.5cm	
Paddock history:	
2008 — wheat (farm crop)	
2007 — faba beans	
Plot size: 44 x 3m	
Replicates: 4 disc and 8 tine	

KEY POINTS

- **Livingston wheat following wheat (residue retained) produced an average yield of 2.86 tonnes per hectare.**
- **Crops with 22.5cm and 30cm row spacings yielded 0.49–0.45t/ha more than crops established at a 37.5cm row spacing.**
- **Crops established with the disc opener produced identical yields to those established with the tine opener when averaged over the three planting widths.**
- **The 22.5cm row spacing was estimated to have lost more water through the plant than the 30cm row spacing due to higher biomass at harvest.**

WRITTEN BY

Nick Poole Foundation for Arable Research, New Zealand in conjunction with Riverine Plains Inc

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.

Trial aim

The aim of this trial was to evaluate the performance of different drill openers at a range of row spacings for their performance in two no-till rotations.

Method

A replicated experiment was established to test the effect of a range of drill openers and row spacings in two no-till wheat rotations.

Crop residue from the previous commercial wheat crop was chopped and spread at right angles to the direction of plots, before sowing the 2009 wheat with the use of 2cm guidance.

Results

Crop establishment:

Row spacing had a significant effect (linear $p=<0.001$) on establishment 19 days after sowing (see Figure 1), with the 22.5cm row spacing achieving significantly higher plant populations (plants per square metre) than both 30cm and 37.5cm spacings. The 30cm spacing also produced significantly more plants/m^2 than the 37.5cm spacing.

There was still a significant difference in plant establishment when assessed 33 days after sowing (linear $p=<0.001$) between the 22.5cm and 30cm spacings, however there was no longer a significant difference between 30cm and 37.5cm spacings.

There was no significant effect of drill openers on plant establishment at both assessment timings (19 days after sowing $p=0.099$, 33 days after sowing $p=0.270$) however disc treatments gave a trend for higher establishment than tine treatments (see Figure 2).

TABLE 1 Plant establishment at the one-leaf stage (GS11) and the three-leaf stage (GS13) assessed 19 and 33 days after establishment

Row spacing (cm)	Drill opener [1]					
	Plant establishment (plants/m²)					
	25 June 2009			7 July 2009		
	Disc	Tine	Mean	Disc	Tine	Mean
22.5	190	202	**198**	208	176	**187**
30	114	149	**137**	138	137	**137**
37.5	117	118	**118**	115	104	**108**
Mean	**140**	**156**		**154**	**139**	
LSD (row spacing)	22			31		
LSD (drill opener)	19			27		
LSD (disc) (tine) LSD (disc vs tine)	38 33	27		54 47	37	
Interactions — drill opener with row spacing was not significant						

[1] Tine treatments had eight replicates compared with four for the disc treatment.

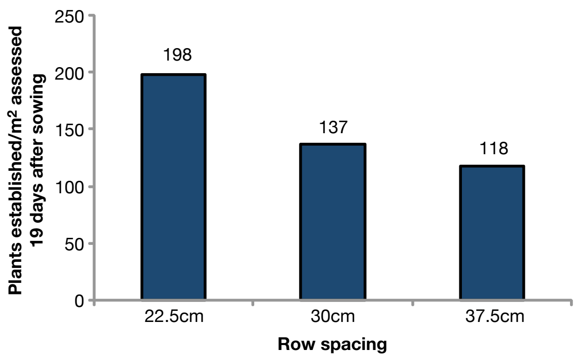

FIGURE 1 Influence of row spacing on plant establishment at one-leaf stage (GS11) 19 days after sowing (mean of both openers)

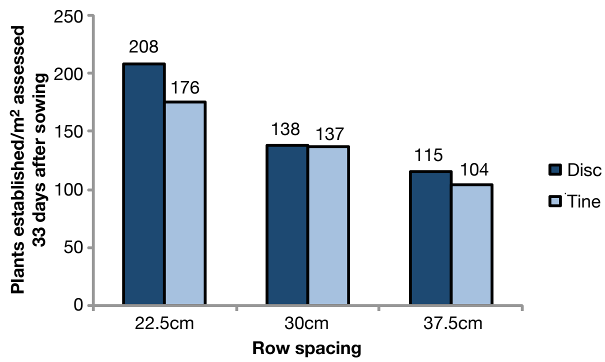

FIGURE 2 Influence of row spacing and drill opener on plant establishment at the three-leaf stage (GS13) assessed 33 days after sowing

Dry matter production

i) Row spacing

Dry matter (DM) assessments were carried out at first node (GS31 — 7 September 2009), flag leaf emergence (GS39 — 28 September 2009), early flower (GS61 — 14 October 2009) and ripening (GS90 — 18 November 2009).

Across all four assessment timings there were significant differences in DM production as a result of the row spacing (p=<0.001). The 22.5cm row spacing produced significantly more DM than the 30cm and 37.5cm row spacings at first node and flag leaf emergence. The 22.5cm spacing produced significantly more DM than the 37.5cm spacing at all assessment timings except 30cm at early flower. A 30cm spacing at early flower and early ripening was significantly higher yielding than the 37.5cm spacing (see Figure 3).

ii) Drill opener

The DM production thoughout the growing season was not significantly different as a result of using the drill opener method (see Figure 4).

Yield

The mean yield across the trial was 2.86 tonnes per hectare. Comparing the three row spacings (mean of both drill openers), crops established at 22.5cm and 30cm spacings yielded 0.49–0.45t/ha more than equivalent crops sown with a 37.5cm row spacing (see Figure 5). There was no difference in yield between 22.5cm and 30cm spacings.

When drill openers were compared (mean of three row spacings) there was no significant difference in yield (see Figure 6).

Examining individual treatments revealed no significant interactions between drill opener and row spacing (see Figure 7).

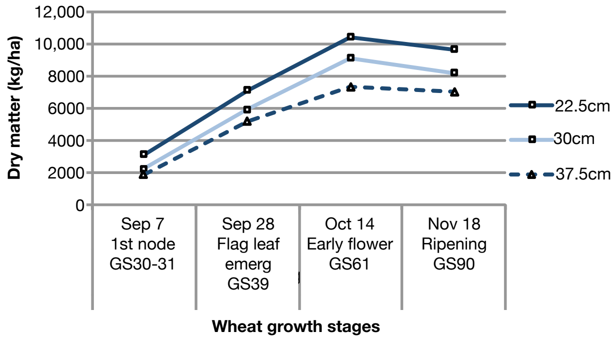

FIGURE 3 Influence of row spacing on dry matter production*
* Mean of both drill openers, assessed from first node (GS31 — 7 September 2009) to early ripening (GS90 — 18 November 2009)

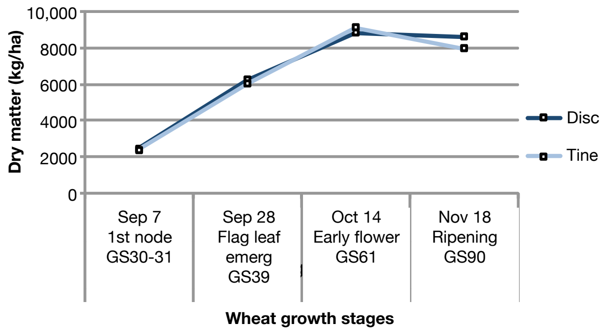

FIGURE 4 Influence of drill opener on dry matter production*
* Mean of three row widths, assessed from first node (GS31 — 7 September 2009) to early ripening (GS90 — 18 November 2009)

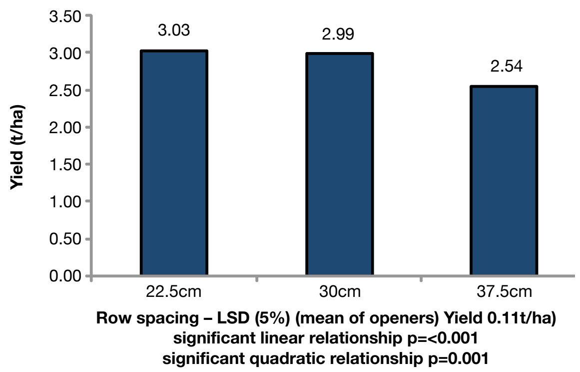

FIGURE 5 Influence of row spacing on yield*
* Mean of both drill openers

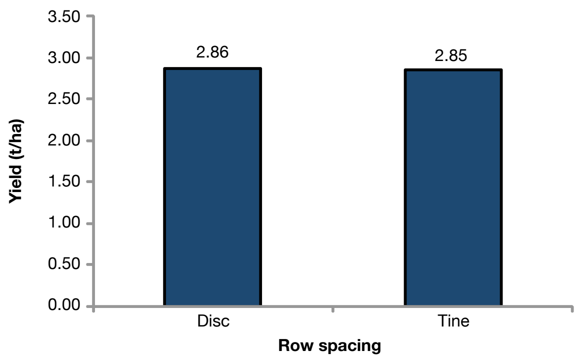

FIGURE 6 Influence of drill openers on yield*
* Mean of three row spacings

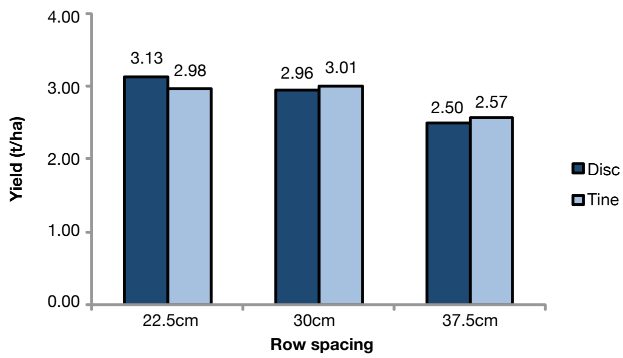

FIGURE 7 Influence of row spacing and drill opener on yield

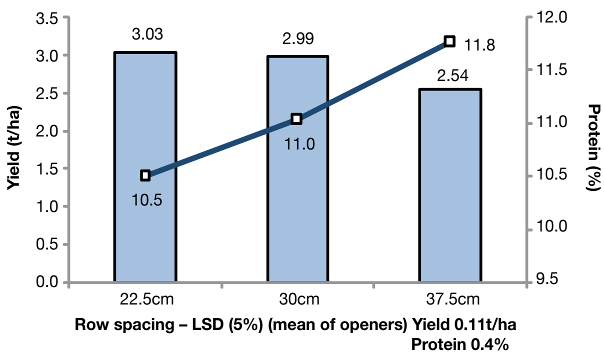

FIGURE 8 Influence of row spacing on yield and protein*
* Mean of both drill openers

TABLE 2 Biomass at flowering (GS61), yield, harvest index (HI), water use efficiency, transpiration, estimated soil evaporation and transpiration efficiency (TE) (mean of both openers)

Row spacing (cm)	Biomass (kg/ha)	Yield (t/ha)	HI (%)	WUE[1] (kg/mm)	Transpiration[2] (mm)	Evaporation[3] (mm)	TE[4] (mm)
22.5	10476	3.03	**28.9**	10.6	190.5	**95.5**	**15.9**
30	9141	2.99	**32.7**	10.4	166.2	**119.8**	**18.0**
37.5	7333	2.54	**34.7**	8.9	133.3	**152.7**	**19.1**

[1] Based on 286mm of GSR (Apr–Oct) with no soil evaporation term included.
[2] Transpiration through the plant based on a maximum 55kg biomass/ha.mm transpired.
[3] Difference between transpiration through the plant and GSR (mm).
[4] Transpiration efficiency based on kg/ha grain produced per mm of water transpired through the plant.

Quality

There were significant differences in the thousand seed weight, test weight, protein and screenings as a result of row spacing. Significant differences in the grain protein percentage as a result of row spacing were evident (linear p=<0.001) with wider rows significantly increasing protein (see Figure 8).

There was also a significant effect of row spacing (linear p=0.012) on the test weights with 22.5cm and 37.5cm row spacings recording higher test weights (66.1 kilograms per hectalitre) than the 30cm spacing (64kg/hl). The 30cm row spacing also had a significantly higher screening percentage than the 22.5cm and 37.5cm spacings, although this was not significant at the individual treatment level.

Observations and comments

In terms of water use efficiency (WUE), the near identical grain yields of the 22.5cm and 30cm row spacings resulted from different breakdowns as regards water loss (see Table 2). The narrower 22.5cm row spacing was estimated to have lost more water through the plant as a consequence of higher biomass at flowering (and harvest) than the wider 30cm row spacing.

The poorer translation of biomass into grain with a 22.5cm row spacing (harvest index 29%) compared with a 30cm row spacing (harvest index 33%) led to inferior transpiration efficiency (15.9 vs 18.0kg grain per hectare per millimetre). However the wider 30cm rows lost the benefit of better transpiration efficiency with an estimated increase of 24mm soil surface evaporation.

As a consequence overall WUE was similar with the 22.5cm and 30cm row spacings, though both were superior to the 37.5cm row spacing, where inferior grain yields significantly reduced overall WUE.

Sponsors

The trial is part of a nationwide project funded by the Grains Research and Development Corporation (GRDC) aimed at improving WUE in broadacre cropping systems.

Farmer co-operator: John Alexander, Bungeet and Peracto Pty Ltd as trial manager.

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Riverine Plains 2009 crop reflectance measurements and implications

WRITTEN BY
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Aim

During 2009 three paddocks were selected for intensive broadacre studies of the validity of crop sensing technology and its integration into commercial crop conditions in the Riverine Plains area. Two paddocks were located at Yarrawonga and one at Dookie.

The aim of the studies was to validate the technology for use in the Riverine Plains area and to investigate ways of integrating the technology into local cropping systems to help support better input decisions during the growing season and potentially improve crop canopy management across a variable paddock.

KEY POINTS

- **Research trials investigating the use of crop sensing technology revealed a strong correlation between Normalised Difference Vegetation Index (NDVI) values in surveys taken three weeks apart, showing the general validity of the technology.**
- **A strong correlation between NDVI and dry matter (DM) was found during the trials, but the correlation was better with earlier surveys.**
- **Trial results suggest a strong correlation between NDVI and shoots per square metre (shoots/m^2).**
- **While there was not a high correlation between NDVI and nitrogen content, the correlation was better with later surveys.**
- **There is a strong correlation between NDVI and total nitrogen due to the high correlation with DM. This also meant the correlation was better with earlier surveys.**
- **The nitrogen use efficiency (NUE) of nitrogen stored at growth stage Z30 decreases as the total amount of nitrogen stored increases.**
- **The NUE plateaus at between 550 and 600 shoots/m^2 and between 19 and 27 kilograms of grain/kg nitrogen.**

Method

Four crop circle reflectance sensors were spread equally across a boom and driven on a 20 metre swath survey within the paddock. The distribution of the observed Normalised Difference Vegetation Index (NDVI) values was split into 7–10 classes and three sampling sites in each class were identified.

Measurements were taken of: crop nitrogen (%), dry matter (DM) (tonnes per hectare), shoots (m^2) and deep soil nitrogen (0-50 centimetres). Total crop nitrogen (kilograms per hectare) was calculated by:

$$\text{Total N}_{(kg/ha)} = \frac{N\%}{100} \times (DM_{t/ha} \times 1000)$$

Soil electrical conductivity (EC_a) and elevation data for the sample points was extracted from historical data sets. Final yield data was obtained from crop yield sensor data. Correlation analysis was performed on all sample observations.

Stepwise regression was used to discern whether the addition of elevation or soil information to the NDVI data could improve the ability to predict soil nitrogen (%) and total nitrogen at the sample sites. The best prediction formula was then used to estimate total nitrogen at all locations in the survey.

Crop nitrogen use efficiency (NUE) (kilograms of grain/kg nitrogen in crop at growth stage Z30) was calculated to explore relationships between production efficiencies and the parameters affecting the NDVI readings at Z30.

A map of NDVI across the paddock was created. Crop yield for the season, as well as elevation and soil EC_a were also mapped onto the same grid for whole field correlation analysis. Local correlation analysis of yield and NDVI was used to identify areas where the relationship changed significantly across the paddock. Total nitrogen and NUE was also mapped for the paddock.

TABLE 1 Paddock average NDVI values with paddock average yield

Paddock	Average yield (t/ha)	Coefficient of variation (%)	Average NDVI	Coefficient of variation (%)	Correlation
8	2.70	12	0.26	7	-0.36
39	2.93	21	0.25	10	0.06
7	2.35	11	0.29	8	0.13
B1 survey 1	3.27	19	0.27	13	0.42
survey 2	3.27	19	0.31	10	0.38
3	3.14	18	0.24	8	0.45
30 survey 1	1.62	15	0.25	11	0.57
survey 2	1.62	15	0.23	9	0.56

Correlation coefficient interpretation: 1 = perfect positive correlation - as the value of one attribute rises, so does the other by the same relative amount; -1 = perfect negative correlation – as the value of one attribute rises, the other falls by the same relative amount. For n = >100 samples: values greater than +/- 0.20 significant at p = 0.05. Values greater than +/- 0.25 significant at p = 0.01.

Results

Whole paddock data:

Simple paddock average data provide a first glimpse at the potential validity of this technology for use in the Riverine Plains area. Results are shown in Table 1.

Table 1 illustrates the variable nature of the relationship between in-season NDVI and crop yield that has been seen during previous years. Predicting the relationship from averages or the variability of either property is not possible.

Importantly though, 66% of the paddocks show a significant relationship (one of those is negative). While the aim of in-season monitoring is not to predict yield per se, a relationship between NDVI and yield means that any in-season management operations based on the NDVI maps should (not withstanding extreme events) impact final yield.

Practical application

The whole-field correlation value 'averages out' differences in the relationship between NDVI and yield across a paddock. Figure 1 however, shows the local correlation of the two properties by looking at the relationship in a moving window of 100 points. There are substantial areas across all paddocks where the relationship is significant, and in all paddocks there are coherent areas of positive and negative correlation.

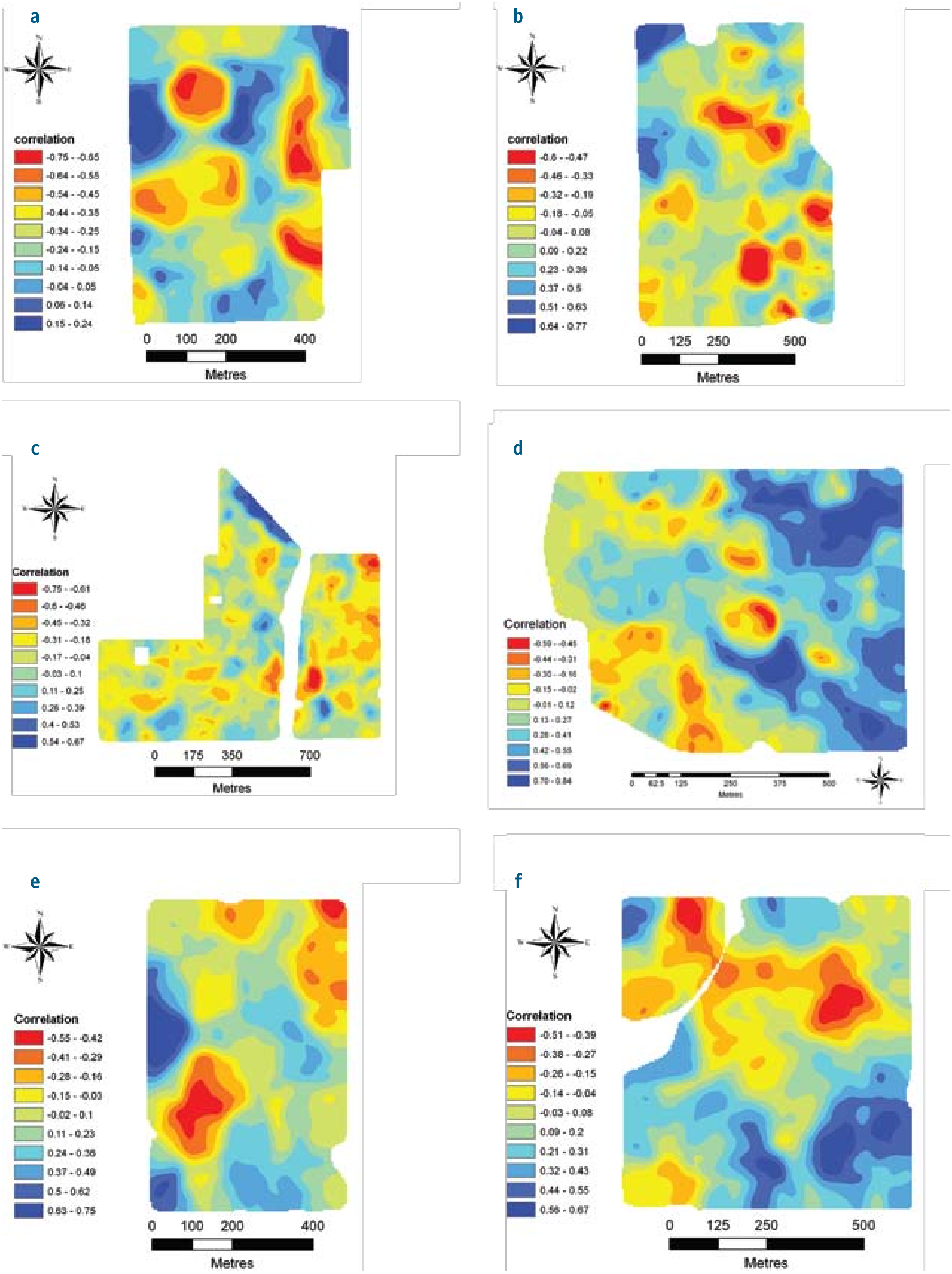

FIGURE 1 Local correlation maps of NDVI and yield showing significant areas of both positive and negative relationships in each paddock

TABLE 2 Correlation coefficients (r) for crop and soil sample data from paddock 30 at Yarrawonga

	NDVI 1	NDVI 2	NDVI difference	Nitrogen %	DM	Shoots/m²	Total N	DSN	Elevation	Yield
NDVI 1	1	0.85	-0.76	-0.13	0.86	0.68	0.85	-0.16	0.47	0.74
NDVI 2	0.85	1	-0.30	0.11	0.78	0.62	0.80	0.08	0.14	0.75
NDVI difference (survey 2 – survey 1)	-0.76	-0.30	1	0.38	-0.60	-0.47	-0.56	0.41	-0.68	-0.41
Nitrogen (%)	-0.13	0.11	0.38	1	-0.21	-0.15	-0.04	0.10	-0.18	-0.19
DM	0.86	0.78	-0.60	-0.21	1	0.80	0.98	-0.12	0.25	0.70
Shoots/m²	0.68	0.62	-0.47	0.15	0.80	1	0.80	0.33	-0.04	0.51
Total N	0.85	0.80	-0.56	0.04	0.98	0.80	1	-0.14	0.22	0.66
DSN	-0.16	0.08	0.41	0.10	-0.12	0.33	-0.14	1	-0.75	0.19
Elevation	0.47	0.14	-0.68	-0.18	0.25	-0.04	0.22	-0.75	1	0.24
Yield	0.74	0.75	-0.41	-0.19	0.70	0.51	0.66	0.19	0.24	1

Correlation coefficient interpretation: 1 = perfect positive correlation — as the value of one attribute rises, so does the other by the same relative amount;
-1 = perfect negative correlation — as the value of one attribute rises, the other falls by the same relative amount.
For n = 27 samples: values greater than +/- 0.38 significant at p = 0.05. Values greater than +/- 0.49 significant at p = 0.01.

TABLE 3 Correlation coefficients (r) for crop and soil sample data from paddock B1 at Dookie

	NDVI 1	NDVI 2	NDVI difference	Nitrogen %	DM	Shoots/m²	Total N	DSN	Soil EC_a	Elevation	Yield
NDVI 1	1	0.97	-0.28	0.25	0.74	0.77	0.78	0.68	-0.02	-0.30	0.66
NDVI 2	0.97	1	-0.05	0.38	0.66	0.78	0.73	0.65	-0.04	-0.41	0.65
NDVI difference (survey 2 – survey 1)	-0.29	-0.05	1	0.45	-0.43	-0.10	-0.30	-0.07	0.23	-0.38	-0.15
Nitrogen (%)	0.25	0.38	0.45	1	-0.04	0.06	0.21	0.43	-0.12	-0.13	0.24
DM	0.74	0.66	-0.43	-0.04	1	0.63	0.96	0.51	-0.17	-0.01	0.39
Shoots/m²	0.77	0.78	-0.10	0.06	0.63	1	0.62	0.52	0.33	-0.34	0.42
Total N	0.78	0.73	-0.31	0.21	0.96	0.62	1	0.56	-0.21	-0.02	0.43
DSN	0.68	0.65	-0.07	0.43	0.51	0.52	0.56	1	-0.26	-0.06	0.67
Soil EC^a	-0.02	-0.04	0.23	-0.12	-0.17	0.33	-0.21	-0.26	1	-0.56	-0.02
Elevation	-0.30	-0.41	-0.38	-0.13	-0.01	-0.34	-0.02	-0.06	-0.56	1	-0.38
Yield	0.66	0.65	-0.15	0.24	0.39	0.42	0.43	0.67	-0.02	-0.38	1

Correlation coefficient interpretation: 1 = perfect positive correlation — as the value of one attribute rises, so does the other by the same relative amount;
-1 = perfect negative correlation — as the value of one attribute rises, the other falls by the same relative amount.
For n = 30 samples: values greater than +/- 0.36 significant at p = 0.05. Values greater than +/- 0.46 significant at p = 0.01.

Individual paddock data

The results shown in Tables 2 and 3 illustrate results of more intensive studies conducted on the three paddocks during 2009. In this example results from only two paddocks are shown.

As expected, Tables 2 and 3 shows that NDVI has a strong positive relationship with shoots/m² (r = 0.68-0.78) and DM (r = 0.74–0.86). It demonstrates a poor relationship with nitrogen (%) (r = 0.11–0.38). A strong positive relationship with total nitrogen (r = 0.78–0.85) can be seen due to the incorporation of the DM figure in the calculation.

In paddock 30, the deep soil nitrogen (DSN) is not well predicted but overall the NDVI shows a strong positive relationship with the final crop yield (r = 0.75). This improvement in the relationship compared with the whole field is due to the targeted sampling procedure.

In B1, the DSN is reasonably well predicted (r = 0.68) and overall the NDVI shows a strong positive relationship with the final crop yield (r = 0.66).

Curiously, the difference in NDVI between the two surveys shows an improved positive relationship with nitrogen (%) in the paddock (r = 0.38–0.45), but a negative relationship with DM (r = -0.43–

-0.60), shoots/m² (-0.47 – -0.1) and crop yield (-0.41 - -0.15). This suggests that in places where there is a bigger change in NDVI between the two surveys, the nitrogen (%) in the crop is higher because there are less shoots/m² and more significantly the crop is producing less biomass. The inference here is that the level of change in NDVI being picked up during the three-week period is being driven by the nitrogen in the plant and not the biomass.

So while the general relationship of more shoots/m² : more biomass : more yield is evident across the paddock, changes in NDVI over short periods within the season may be useful in identifying for examination, areas of sub-optimal development early in the season. It also has implications for the decision on nitrogen fertiliser quantities and spatial applications at this time. More nitrogen in these areas of highest change may be detrimental or at best a waste.

Including extra spatial data in calculations

Given the use of the sensors is to help manage nitrogen application, improving the prediction of total nitrogen would be useful. This is possible by combining some basic information that should be available to most farmers using precision agriculture (elevation and soil EC_a) with the NDVI data.

In this paddock, the soil EC_a data did not improve the predictive ability of the NDVI. However, the inclusion of elevation did significantly improve the predictive ability (see Figure 2).

Efficiency of converting crop nitrogen at Z30 to final grain yield

A side benefit of these studies is the consolidation of our understanding of some important canopy management principles.

Figure 3(a) shows the conversion rate of crop nitrogen into crop yield decreases as the total amount of in-crop nitrogen increases. Or to put it another way, Figure 4(b) shows the amount of nitrogen in the crop required to produce 1kg of grain increases linearly as the amount of nitrogen in the plant increases. So the more nitrogen the crop takes up, the less efficient the plant is at using nitrogen to photosynthesise and produce grain.

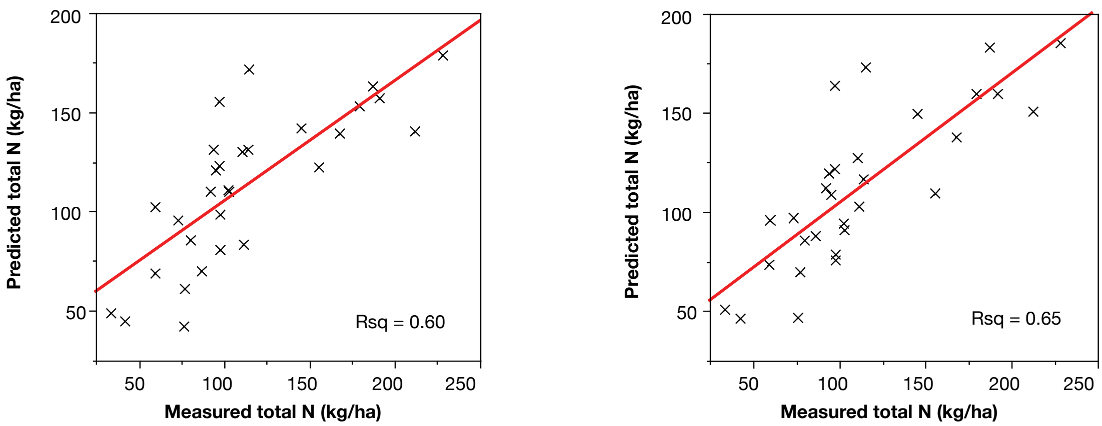

FIGURE 2 Improved prediction of in-crop total nitrogen by including elevation with NDVI in paddock B1

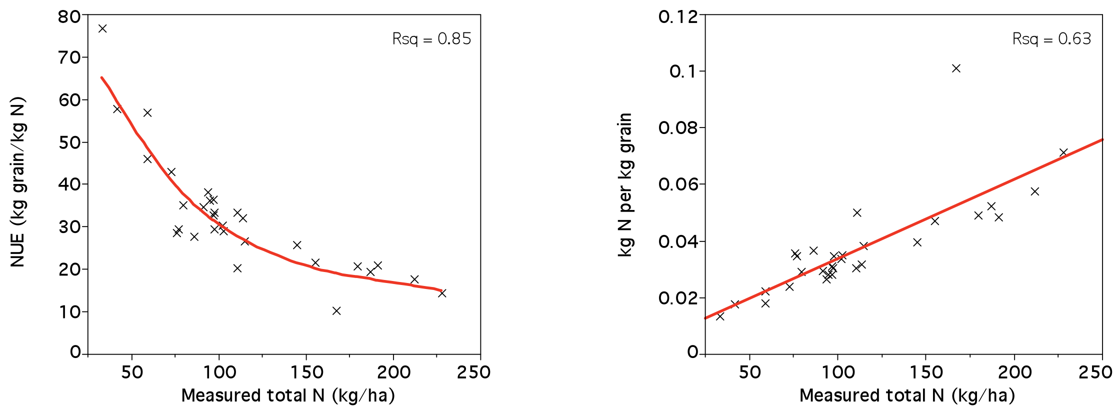

FIGURE 3 (a) Nitrogen use efficiency of nitrogen in crop as at Z30 relative to the total nitrogen in the crop at that growth stage; (b) amount of nitrogen required at Z30 to produce 1kg grain relative to the total nitrogen in the crop at that growth stage

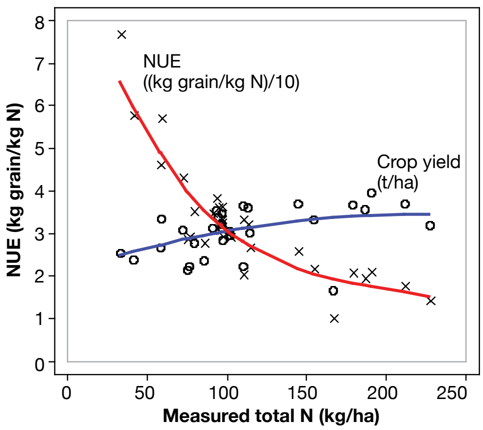

FIGURE 4 Efficiency of converting nitrogen in crop as at Z30 to grain yield compared with total grain yield across the range of total nitrogen observed in the crop at Z30

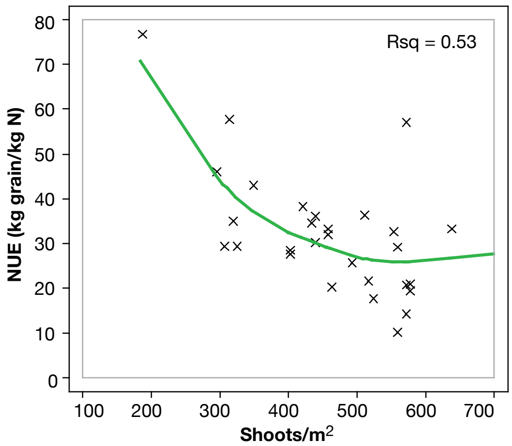

FIGURE 5 Nitrogen use efficiency of nitrogen in crop as at Z30 relative to the shoots/m^2 in the crop at that growth stage.

Figure 4 compares crop yield and nitrogen use efficiency (NUE) as crop nitrogen increases and it shows the yield increases as the total nitrogen increases, but starts to plateau with the NUE.

Interestingly, Figure 5 shows that NUE plateaus at 550 shoots/m^2 and 25kg grain for every kilogram of nitrogen in the crop. Hitting 550 shoots/m^2 should optimise yield/nitrogen ratio.

Comments and observations

Firstly, the 'variable' correlations between NDVI and yield means that in all paddocks there are areas where the NDVI may be more useful than others. This highlights the need to consider different management options for different portions of the paddock.

If considering in-season NDVI as a management aid, compiling these maps for a season may well prove to be useful to direct some sampling investigations to understand the differences before moving onto using NDVI to change management.

After this, the next step is probably to use NDVI to predict total nitrogen/ha in a crop canopy. Making maps of total nitrogen could show areas in paddocks where it can be seen there is adequate nitrogen in the canopy to reach a target yield and protein, and other areas where there is not. This information could further direct nitrogen inputs later during the season.

However, some understanding of the soil nitrogen status at the start of the season or a comparison with some area of nitrogen sufficiency may still be required at present if maps alone are to be used for accurate nitrogen rate determination.

To that end, 'change maps' (maps showing the change in NDVI values from one scan to the next during a growing season) may be an important addition to the suite of knowledge gained from using this technology.

It has been shown this year, for instance, that areas undergoing the most positive change when no fertiliser nitrogen was applied, were the areas with plenty of nitrogen in the canopy. Taking just one NDVI map at one stage during the growing season is dangerous.

There is much potential in crop sensing technology, but there is much still to learn. Further investigations under the Riverine Plains *WUE* project will shed more light on the use of the technology to improve input decisions and canopy management across paddocks.

Sponsors

This project is funded by the Grains Research and Development Corporation (GRDC) as part of Riverine Plains' *Improved WUE in no-till cropping and stubble retention systems in spatially and temporally variable conditions in the Riverine Plains* project.

Crop sensing hardware was donated by gps-Ag.

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Wheat inputs experiment

WRITTEN BY
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Location: Balldale, NSW

Growing season rainfall:
Annual: 355mm (average 504mm)
GSR: 281mm (average 319mm)
Stored moisture: 72mm

Soil:
Type: Red chromosol
pH ($CaCl_2$): 5.2
Colwell P: 46mg/kg
Deep soil nitrogen: 110kg/ha

Sowing information:
Sowing date: 23 May 2009
Variety: Ventura, wheat

Row spacing: 18cm

Paddock history:
2008 — canola (hay)
2007 — pasture

Plot size: 1.5 x 16m

Replicates: 3

KEY POINTS

- **Trials reveal that 70 plants per square metre (about 35kg/ha seed) and 5–10 kilograms per hectare of phosphorus represent the optimal target plant density and phosphorous input level for wheat.**
- **Similar yield results can be obtained using a number of combinations of seed and fertiliser.**
- **Low tiller numbers can be recovered by using light amounts of nitrogen.**

Aim

The aim of this trial was to assess the effect of varying the seed rates and fertiliser inputs on wheat yields.

Method

A replicated experiment was established to test the effect of varying seed and phosphorus and nitrogen fertiliser inputs.

Results

See Table 1 for results.

Observations and comments

- The minimum number of plants required to produce average yields for wheat in this trial was 70 plants per square metre (about 35 kilograms per hectare of seed).
- The optimum phosphorus rate is 5–10kg/ha at sowing (depending on original phosphorus soil test levels).
- The optimum tiller numbers were between 250–350 tillers/m^2 (t/m^2).
- A rate of 35kg/ha of seed and 5kg/ha of phosphorus can produce 500t/m^2 by using early nitrogen fertiliser to boost tiller numbers. Early nitrogen in this treatment boosted tiller numbers to nearly the same level as that produced by the 70kg/ha of seed and 5kg/ha of phosphorus treatment. The experiments show that tillers can be boosted by either using more seed or extra nitrogen applied early (prior to Z31).
- This trial (2009) shows that 500 tillers/m^2 may not be necessary to produce a 4t/ha crop. Further efforts are required to see what occurs at higher yield targets.
- There may be opportunities to split the phosphorus use by using lower phosphorus inputs at sowing and applying phosphorus in crop.
- Using lower inputs produces the optimal result due to the lower cost of production and higher gross margin in about average growing season rainfall (GSR) years. This strategy also lowers risk and increases yield in low-rainfall years.
- Using lower inputs may increase the quality of wheat at similar yields.

Sponsors

Grains Research and Development Corporation (GRDC), Mr C Cay, Mrs S Cay, Mr O Smith.

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TABLE 1 2009 Results for the wheat inputs experiment

Treatment description	Plant count (plants/m²)	Tillers (Z15 t/m²)	Tillers (Z30 t/m²)	Yield (t/ha)	GM ($/ha)
70S 0P 0N	156	308	346	1.9	243
70S 5P 0N	163	423	403	2.4	297
70S 10P 0N	141	414	442	2.9*	361
70S 20P 0N	154	541	550	3.2*	383
70S 20P 20N	141	549	485	2.8	287
35S 0P 0N	70	152	166	1.9	244
35S 5P 0N	70	178	235	2.6	341
35S 10P 0N	74	213	242	3.0*	406
35S 20P 0N	74	259	298	3.2*	403
35S 5P 20N+20N[1]	71	190	401	2.6	289
35S 5P 20N	78	178	190	2.7	310
35S 10P 20N+20N[1]	64	224	449	3.4*	414
35S 10P 40N	68	219	247	3.0	332
35S 20P 20N+20N[1]	66	242	497	3.5*	391
35S 20P 40N	70	239	283	3.6*	410
35S 5P+15P[2] 20N+20N[1]	70	213	523	3.5*	389
35S 5P+15P[2] 40N	67	224	262	3.5*	387
150S 20P 0N	258	708	953	1.4	27
15S 20P 20+20N[1]	35	150	391	2.4	202
70S 0P 20N at sowing[3]	140	463	490	2.3	267
70S 10P as SS[4] 20N	143	506	487	2.5	270
LSD (preliminary analysis) (0.05)	48	139	154	0.4	
CV				16.9%	

S = Sowing rate of Ventura (kg/ha), P = rate of phosphorus (kg/ha) applied at sowing as triple super unless otherwise stated, N = rate of nitrogen applied as urea at Z31 unless otherwise stated.

1 — Nitrogen applied as a split application of urea at Z15 and Z31 (first and second nitrogen figures refers to rate applied at Z15 and at Z31 respectively. 2 — Phosphorus applied as triple super split application at sowing and at Z15. 3 — Nitrogen as urea applied at sowing. 4 — SS – Single Super instead of triple to supply sulphur as well as phosphorus. * — These treatments were not significantly different in yield to the 70S 20P 0N treatment. The 70S 20P 0N treatment was the most commonly recommended sowing treatment for the region prior to 2005.

Opportunistic summer cropping for increased water use under wheat-based dryland winter cropping systems

WRITTEN BY

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Location: Pine Lodge South, east of Shepparton, Victoria

Growing season rainfall 2009-2010:
326mm September 2009 to April 2010

Soil:
Type: Sandy clay loam
pH (H_2O): 4.9–6.8 (0–20cm)

Paddock history:
2008 — wheat
2007 — canola
2006 — wheat

Plot size: 1.2ha

Replicates: 3

KEY POINT

- **Opportunistic summer cropping can make use of summer rainfall that may otherwise be lost to evaporation.**

Aim

The aim of this trial is to investigate how different summer crops influence soil moisture throughout their growing seasons and in the subsequent wheat crop.

Method

A replicated experiment was established to investigate the effect of various summer crops on soil moisture and subsequent wheat crop yields in comparison to a chemical summer fallow (see Table 1).

Permanent soil moisture probes were located in two of the three replicates of each treatment (a total of 12 probes) to measure moisture, temperature and electrical conductivity (EC).

At installation of the probes, soil was sampled every 20 centimetres for moisture content, pH and EC.

A total of 42 neutron probe access tubes were installed and readings continue to be taken about every two weeks.

Crop growth stages were monitored weekly.

Measurements were being taken of crop emergence (plants per square metre) dry matter (DM) and grain yield.

A soil survey was carried out and soil bulk density has been measured.

Results (to date)

See Tables 2 and 3 for crop development, dry matter and grain yield results to date.

See Figure 1 for soil moisture results.

TABLE 1 Summer cropping trial species sowing and crop emergence information

Crop (variety)	Sowing date	Sowing rate (kg/ha)	Row spacing (cm)	Fertiliser (kg MAP/ha)	Emergence (plants/m^2)
Safflower (Sironaria)	4 September 2009	9, 12.5 & 16	62	50	16.2
Sunflower (Aussie gold 62)	20 October 2009	2.4	124	30	3.1
Millet (French white)	1 December 2009	9	31	75	8.8
Lablab (Rongai)	1 December 2009	28.5	62	75	20.2
Mung beans (Emerald)	4 December 2009	16	62	60	5.0

FIGURE 1 Average soil moisture for all probes against rainfall

Observations and comments

Water use (early observations need to be confirmed with soil bulk densities):

- Most crops are drawing moisture to 80cm (millet drawing deeper at 100cm).
- Soil moisture in paddock seems to depend more on soil type rather than crop present with average soil moistures varying with location not crop type. Differences between replicates are apparent.
- Crop soil moisture usage decreases dramatically with the end of vegetative production and the start of flowering.
- Rain during November 2009 and the New Year was quickly lost from all blocks.
- Rain during February 2010 filtered to between 30 and 80cm with most being lost. Slight improvement in soil moisture in fallow and safflower blocks.
- Rain during March 2010 has moved deeper into the soil profile with the exception of millet, where it appears rapid plant uptake hindered infiltration.

Cropping:

- Establishment was patchy in the sunflower blocks.
- Millet was showing symptoms of drought stress from the middle of January 2010 until February rain. Just before the rain the crop looked like it was going to fail. This was especially true in Replicate 3, which falls into an old creek bed.
- There is variation in the crop performance across the replicates. This could be due to the varying soil across the paddock. There has also been a different level of weed establishment between the replicates.

TABLE 2 Dry matter results for forage crops

Cut – 8 March 2010	Millet (t/ha)	Lablab (t/ha)
Replicate 1	8.50	3.32
Replicate 2	5.03	2.68
Replicate 3	4.96	2.29
Average yield	6.16	2.76

TABLE 3 Grain yield

	Safflower (kg/ha)	Mung Beans (kg/ha)	Millet (t/ha)
Replicate 1	358	546	2.85
Replicate 2	766	574	2.68
Replicate 3	398	399	1.53
Average yield	507	506	2.35

Sponsors

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