Management strategies for improved productivity and reduced nitrous oxide emissions

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Key findings

- The nitrogen application strategy that maximised grain yield was not always the same strategy to minimise nitrous oxide (N_2O) emissions.
- While nitrogen applied at GS31 maximised wheat yield following field pea it produced 10 times higher emissions compared to the same application at seeding.
- The pattern and concentration of N_2O emissions were similar for wheat following field pea or canola.

Why do the trial?

Nitrous oxide (N_2O) is a greenhouse gas, primarily produced from agricultural activities such as fertilisation and breakdown of livestock waste. Recent research has shown there are a range of reduction strategies that may benefit growers both environmentally and economically. The objectives of this trial were to measure and demonstrate on-farm strategies that can reduce nitrous oxide by trialling four key practices:

- Use of legumes in the cropping rotation.
- Application of nitrogen fertiliser at key stem elongation growth stages.
- The use of precision farming tools to better measure N mineralisation.
- Use of nitrification inhibitors.

Soils also release dinitrogen (N_2) gas through denitrification however, we cannot measure this as dinitrogen is naturally occurring in the Earth's atmosphere. There is a strong relationship between nitrous oxide emissions and denitrification. In general dinitrogen releases can be 20-30 times greater than N lost from nitrous oxide, though the exact relationship between the two gases depends on the soil water content.

How was it done?

Plot size	9.0 m x 16.5 m	**Fertiliser**	Urea/DAP (22:15) @ 81 kg /ha at seeding (18 kg N/ha). All in-season N applications as specified by treatments below.
Seeding date	3rd May 2015		
Crop	Mace wheat		

The trial was a factorial design with four replicates, two previous crop histories (canola or field pea) and six nitrogen treatments. In 2014 the canola and field pea blocks were sown adjacent to each other on similar soil and using identical management (with the exception of N).

In 2015 the trial was sown with Mace wheat. Six nitrogen treatments were applied as incorporated by sowing (IBS) on 3rd May, start of stem elongation (GS30) on 9th July, first node (GS31) on 16th July, second node (GS32) on 31st July or mid-booting (GS45) on 28th August as follows;

1) Nil nitrogen applied
2) 40 kg N/ha applied as urea at first node (GS31) of the wheat crop
3) 80 kg N/ha applied as urea at first node (GS31) of the wheat crop
4) 80 kg N/ha as urea IBS
5) 80 kg N/ha applied as Entec urea (nitrification inhibitor) at first node (GS31) of the wheat crop
6) Real Time Tactical Treatment - determined using a Greenseeker® to measure crop canopy greenness. The rate for the ex-canola ground was 53 kg N/ha as urea split across GS30, GS32 and GS45. The rate for the ex-field pea ground was 43 kg N/ha as urea split across GS32 and GS45.

Soil assessments

A number of measurements were taken throughout the season including nitrous oxide monitoring in treatments 1 (nil), 3 (80 kg N/ha at GS31) and 4 (80 kg N/ha IBS). Sampling occurred once per week during the growing season and twice per week after seeding and the GS31 nitrogen applications for three weeks. Soil nitrogen was assessed in the canola and field pea blocks prior to seeding (16th April) and in-season at GS32 (20th July) at depths 0-30 cm and 30-60 cm.

Crop structure assessments

Fixed marker points were used for crop structure assessments, 2 markers x 1 m each side per plot. Plant establishment, tiller and head number were all assessed at these fixed marker points. Dry matter and nitrogen content were sampled at GS30 and GS31 for treatments 1 and 4 only and GS32, GS39, GS65 and GS99 for all treatments. Two metres of row were collected at two points in each plot, weighed, subsampled, oven dried at 60°C for 72 hours and dry matter (t/ha) calculated.

Grain yield and quality

The trial was harvested on the 2nd December 2015. All plots were assessed for grain yield, protein, test weight and screenings (<2.0 mm screen).

Results and discussion

Soil nitrogen status

Prior to seeding the block following field pea contained 10 kg of available soil N/ha more compared to the block following canola (Table 1). The use of legume crops such as field peas generally leave higher residual levels of soil nitrogen and the expectation was the legume ground will release more available nitrogen in-season and require less nitrogen fertiliser compared to the canola treatments.

In-season the nil and 80 kg N/ha applied IBS treatment were assessed for available soil nitrogen. For the plots following canola, the soil nitrogen reserves had been run down to 7 kg N/ha where nil was applied, compared to 26 kg N/ha where 80 kg N/ha had been applied at seeding (Table 1). In contrast to this the plots following legume for both the nil and 80 kg N/ha both contained 25 kg N/ha, indicating the ability of the nil legume treatment to mineralise more nitrogen in season compared to the canola treatment.

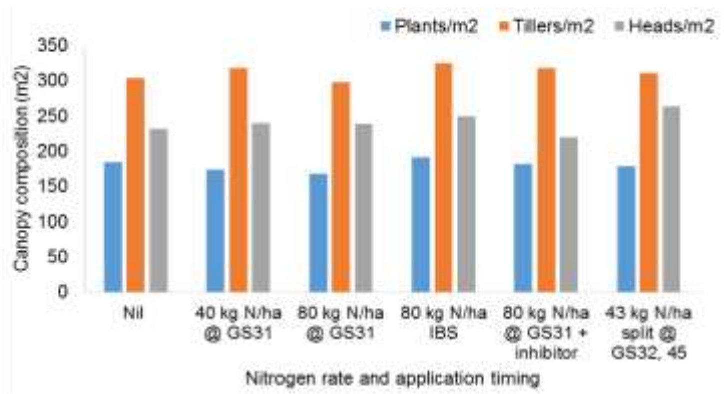
Table 1. Available soil nitrogen (kg N/ha) for ex-field pea and ex-canola ground sampled pre-seeding (16 April) and in-season (20th July), 2015.

Previous crop	Sampling depth (cm)	Pre-seeding	In-season	
		Nil N	Nil N	80 kg N/ha IBS
		Available soil N kg/ha		
Field pea	0-30	27.8	13.7	9.8
	30-60	10.5	10.6	15.4
	Total	**38.4**	**24.3**	**25.2**
Canola	0-30	22.0	1.1	20.7
	30-60	7.6	6.1	4.8
	Total	**29.5**	**7.2**	**25.5**

Crop structure

Plant establishment and tiller number were similar for wheat following field pea or canola, averaging 173 plants/m^2 and 305 tillers/m^2 (Figure 1). In 2014 however, all crop structure assessments were higher for wheat following a legume. Head number was also similar for wheat following field pea and canola at 241 and 231 heads/m^2, respectively. This is not surprising given the difference in yield potential between the seasons with 70 mm less growing season rainfall (25% of long-term average) in 2015.

There was no difference in plant population, tiller number or head number for any of the nitrogen rates and application timings. This result is similar to those obtained in 2014.



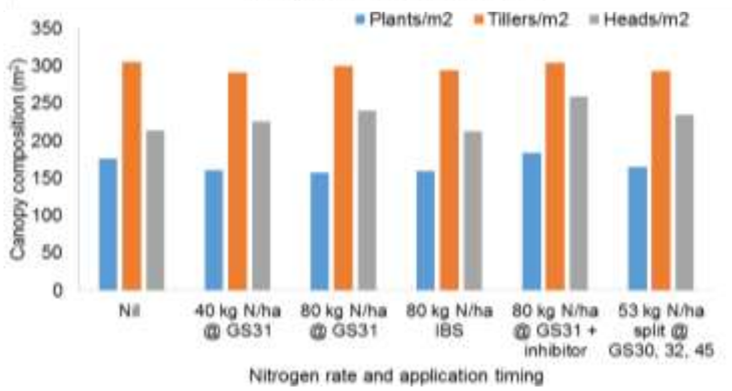


Figure 1. Plant, tiller and final head number/m^2 for Mace wheat following field pea (top) and canola (bottom) for all nitrogen treatments. No significant difference in nitrogen rate or application timing for any canopy structure assessments.

Dry matter production for all nitrogen rates and applications were similar across all sampling dates (data not shown). Nitrogen uptake in the wheat crop was consistent across all N rates and application timings (Table 2). By mid-flowering (GS65) nitrogen uptake was higher where rates of 80 kg N/ha were applied for wheat after canola.

Grain yield and quality

The highest yields in wheat following canola or field peas were measured where 80 kg N/ha was applied at GS31 with or without a nitrification inhibitor and the tactical N treatments (Table 3). In addition to this for the wheat following field peas the 40 kg N/ha applied at GS31 was also high yielding, however protein content was lower compared with the higher nitrogen rates. Application of 80 kg N/ha at seeding was also high yielding however, protein levels were lower. These results are consistent with previous nitrogen research trials which have shown applications of nitrogen prior to stem elongation can be seen as building the foundation of yield and have little or no effect on protein. Later applications can be used to maintain or increase protein, but have little effect on yield.

There was no difference in test weight or 1000 grain weight (data not shown, the average for wheat following canola 34.2 and field pea 38.9 g/1000 grains) for any of the nitrogen rates or application timings (Table 3). Small differences were measured in screenings, however the majority of the treatments were below 5% (requirement for maximum grade).

Table 2. Wheat nitrogen uptake in biomass (kg N/ha) following field pea or canola at various growth stages. Where present, different letters denote significant differences (P≤0.05) within the same timing and previous crop.

Previous crop	Treatment	GS30	GS32	GS39	GS65	GS99
		kg N/ha				
Canola	Nil	21	29	44	46[c]	92
	40 kg N/ha @ GS31		33	47	61[bc]	73
	80 kg N/ha @ GS31		38	44	75[ab]	115
	80 kg N/ha IBS	24	34	52	66[ab]	95
	80 kg N/ha @ GS31 + inhibitor		37	54	84[a]	106
	53 kg N/ha split @ GS30, 32, 45		31	50	63[bc]	103
	LSD (P≤0.05)	ns	ns	ns	20	ns
Field pea	Nil	40	52	66	83	61
	40 kg N/ha @ GS31		48	73	86	67
	80 kg N/ha @ GS31		50	79	104	77
	80 kg N/ha IBS	42	53	80	91	66
	80 kg N/ha @ GS31 + inhibitor		51	78	94	96
	43 kg N/ha split @ GS32, 45		51	76	98	71
	LSD (P≤0.05)	ns	ns	ns	ns	ns

Table 3. Summary of grain yield (t/ha), protein (%), test weight (kg/hL) and screenings (%) for Mace wheat sown following field pea and canola for all nitrogen rates. Where present, different letters denote significant differences (P≤0.05) within the same timing and previous crop.

Previous crop	Nitrogen rate	Grain yield t/ha	Protein %	Test weight kg/hL	Screenings %
Canola	Nil	2.76^{c}	11.6^{c}	77.4	2.1^{c}
	40 kg @ GS31	3.05^{b}	12.2^{bc}	76.6	3.2^{bc}
	80 kg @ GS31	3.10^{ab}	13.2^{ab}	74.1	4.8^{ab}
	80 kg @ IBS	3.05^{b}	12.3^{bc}	77.2	2.9^{bc}
	80 kg @ GS31 + inhibitor	3.30^{a}	13.6^{a}	74.6	5.8^{a}
	53 kg split @ GS30, 32, 45	3.19^{ab}	12.4^{abc}	75.8	3.8^{bc}
	LSD (P≤0.05)	0.24	1.25	ns	2.0
Field pea	Nil	3.85^{c}	11.4^{c}	79.7	1.3
	40 kg @ GS31	4.31^{ab}	12.1^{b}	78.7	1.8
	80 kg @ GS31	4.40^{a}	13.0^{a}	78.0	1.8
	80 kg @ IBS	4.15^{b}	12.4^{ab}	79.5	1.4
	80 kg @ GS31 + inhibitor	4.21^{ab}	13.0^{a}	78.9	1.7
	43 kg split @ GS32, 45	4.13^{b}	12.8^{a}	78.9	1.4
	LSD (P≤0.05)	0.25	0.62	ns	ns

Nitrous oxide emissions

Nitrous oxide emissions were 10-30 times higher when nitrogen was applied at GS31 compared to seeding (Table 4, Figure 2). Applying nitrogen at seeding did not result in emission values higher than the background soil level (nil). This is in contrast to 2014 where highest emissions were observed from nitrogen applications at seeding. The difference in emissions between the two seasons can be attributed to the distribution and amount of growing season rainfall and soil conditions (eg moisture and temperature).

Previous crop	Treatment	g N_2O-N/ ha/ season
Canola	Nil	201
	80 kg/ha GS31	3071
	80 kg/ha IBS	178
Field pea	Nil	103
	80 kg/ha GS31	3300
	80 kg/ha IBS	378

Table 4. Total nitrous oxide emissions (May 4th – December 2nd) for nil, 80 kg N/ha IBS or applied at GS31 for wheat sown after field pea and canola at Hart, 2015.

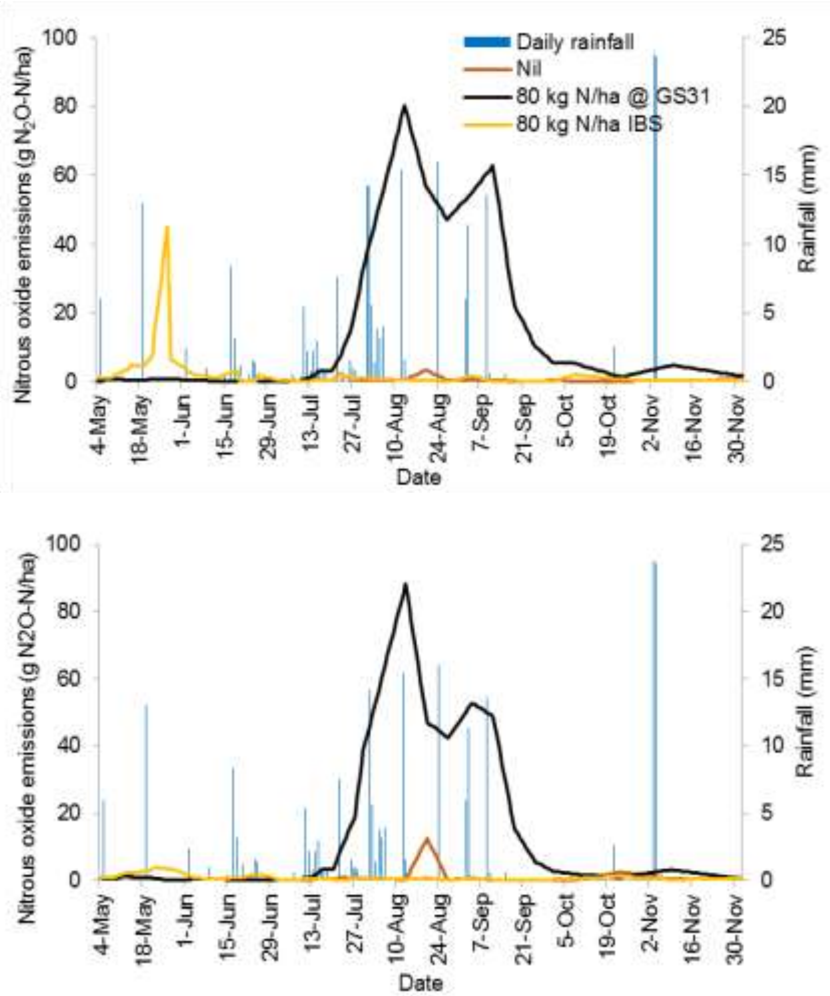


Figure 2. Nitrous oxide emissions (g N_20/ha) for the period of 4th May – 2nd December for nitrogen fertiliser × crop history treatments for wheat following (left) field pea and (right) canola at Hart, 2015.

The 2015 season at Hart, started with an opening break of 60 mm in April followed by below average rainfall in May, June and July totalling 68 mm (Figure 2). In this same period in 2014 the trial received 155 mm and corresponded to the highest emission period. After the GS31 nitrogen application in 2015 (July 16th) the site received 66 mm in August and a sharp increase was seen in N_2O emissions from this treatment. Daily emission values remained high (60-80 g N_2O-N/ha/day) until early September when the soil dried out from the lack of further spring rainfall. During August and September there were also times where the average daily soil temperature was 2-3°C higher compared to 2014 (Figure 3) contributing to higher emissions.

Despite a small increase in emissions for the IBS treatments in late May this treatment did not vary compared to nil applied, indicating the crop and/or soil microorganisms tied the available nitrogen up in other forms.

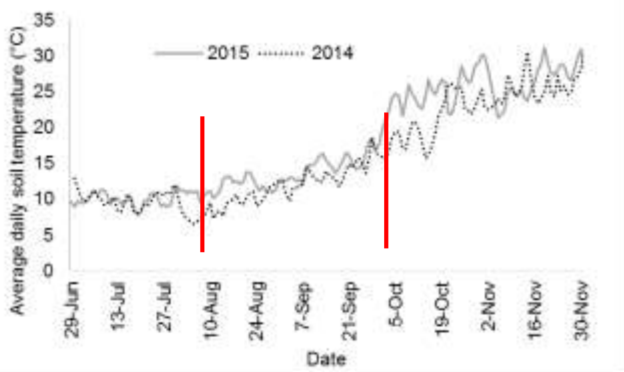


Figure 3. Average daily soil temperature (°C) at 10 cm in 2014 and 2015. The red bars indicate the start and end of the high N_2O emission period in 2015.

Summary

Results from this season have shown that the nitrogen application strategy that maximised yield was not always the same strategy that minimised N_2O emissions. For wheat following field peas nitrogen applied at GS31 maximised yield, but also produced the highest N_2O emissions. However, for wheat following canola, application of nitrogen at seeding resulted in both a high yield and low nitrous oxide emissions.

Acknowledgements

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