Management strategies for improved productivity and reduced nitrous oxide emissions

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Key findings

- The amount of nitrogen lost as nitrous oxide was small, 0.4 kg N/ha after 204 days (seeding-harvest).
- Highest emissions came from applications of 80 kg N/ha applied IBS compared to the same rate applied at GS31 and the nil N applied.
- In adjacent blocks Mace wheat sown on canola produced higher emissions and lower grain yields than wheat sown on lentils.

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 was 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 be better measure N mineralisation.
- Use of nitrification inhibitors.

Soils also release dinitrogen (N_2) gas through denitrification however, we cannot measure this as dinitrogen naturally occurs 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 water content of the soil.

How was it done?

Plot size	12.5 m x 22.5 m	**Fertiliser**	Urea/DAP (22:10) @ 10 kg N/ha at seeding
Seeding date	13th May 2014		
Crop	Mace wheat		All in-season N applications as specified by treatments below.

The trial was a factorial design with four replicates, two previous crop histories (2013 - 44C79 canola or Blitz lentils) and six N treatments. In 2013 the canola and lentil blocks were sown adjacent to each other on the same soil type and using identical management (with the exception of N).

In 2014 the trial was sown with Mace wheat. The six nitrogen treatments were applied as incorporated by sowing (IBS) on 13th May or at first node (GS31) on 21st July as follows;

1) Nil nitrogen applied (zero nitrogen control)
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. At GS31 25 kg N/ha (as urea) was applied to the ex-lentil plots and 51 kg N/ha (as urea) to ex-canola plots.

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 the GS31 nitrogen applications for three weeks. Soil moisture content and temperature was also measured in the top 12 cm of the soil using a hand held time domain reflectometer (TDR) soil moisture metre and HOBO® temperature logger. Soil nitrogen was assessed in the canola and lentil blocks prior to seeding (8th May) 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 (1st node) for treatments 1 and 4 only and GS32, GS39 (flag leaf), GS65 (flowering) and GS99 for all treatments. Two metres of row were collected at two points in each plot, weighed, subsampled, oven dried at 60°C and final dry matter calculated.

Grain yield and quality

The trial was harvested on the 5th December 2014. All plots were assessed for grain yield, protein, test weight, screenings (<2.0 mm screen) and 1000 grain weight.

Results and discussion

The use of legume crops such as lentils generally leave higher residual levels of soil nitrogen. Prior to seeding the previous lentil and canola trials were assessed for soil nitrogen and the ex-lentil ground had 10 kg N/ha greater residual nitrogen compared to the canola (Table 1). The hypothesis was the lentil ground (with higher nitrogen reserves) will require less nitrogen fertiliser compared to the canola treatments, leading to better nitrogen use efficiency (NUE) and reduced nitrous oxide emissions.

Table 1. Soil nitrogen (kg N/ha) for ex-lentil and ex-canola ground sampled 8th May 2014.

Treatment	Soil nitrogen (kg N/ha)
Ex Lentils: Nil N 0-30cm	20.7
Ex Lentils: Nil N 30-60cm	18.9
Ex Lentils: Nil N Total	**39.6**
Ex Canola: Nil N 0-30cm	16.8
Ex Canola: Nil N 30-60cm	13.0
Ex Canola: Nil N Total	**29.9**

Previous crop history affected all crop structure assessments. On average between the two crop histories lentils always had greater establishment (17 plants/m^2), tiller number (175 tillers/m^2) and final head number (86 heads/m^2) compared to the canola (Figure 1a and b). Early in the season the 80 kg N/ha IBS did not affect crop establishment for wheat following lentils or canola. At GS31 the tiller number for nitrogen treatments following lentils were different. At this growth stage the IBS 80 kg N/ha had a higher tiller number compared to the control. The percentage of tillers which produced heads was higher for wheat sown after canola (76%) compared to wheat following lentils (68%).

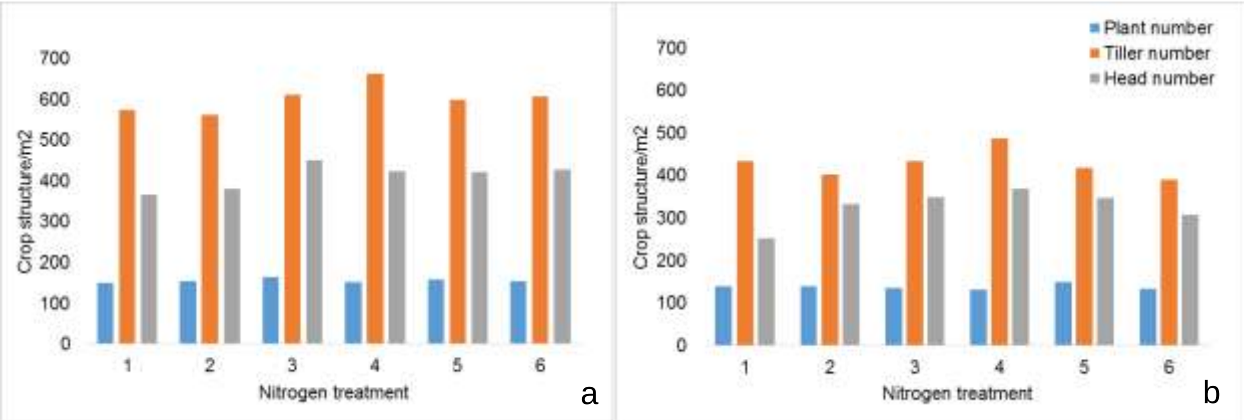

Figure 1. Plant, tiller and final head number/m^2 for Mace wheat following (a) lentils and (b) canola for all nitrogen treatments.

Dry matter production varied more for wheat after canola compared to lentils. This could be seen visually throughout the season and become more prominent as the season progressed. The early nitrogen up front (80 kg N/ha IBS) consistently had higher dry matter production compared to all other treatments (Figure 2b). While this did not affect grain yield, grain protein content was lower for this treatment (Table 2).

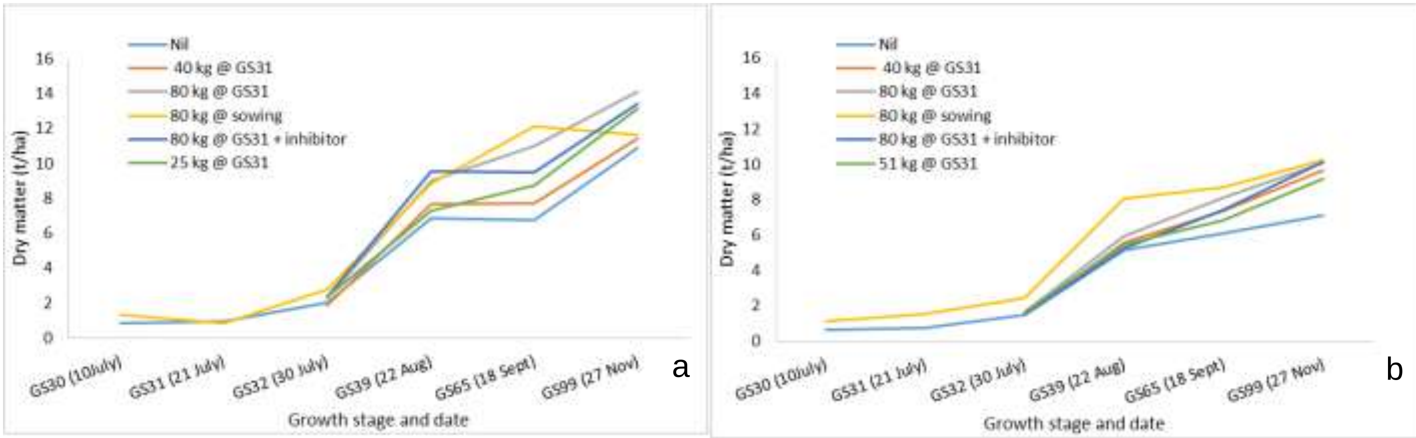

Figure 2. Dry matter production of Mace wheat following (a) lentils or (b) canola for all nitrogen treatments.

The effect of nitrogen application on grain yield and grain protein varied according to the time of application. Generally applications of N up to mid-stem elongation can be seen as building the foundation of yield and have relatively little effect on protein while later applications of N can be used to maintain or increase protein, but have little or no effect on yield. The highest yielding nitrogen treatments were 80 kg N/ha applied IBS, GS31, GS31 with nitrification inhibitor and tactical treatment (Table 2). Application of only 40 kg N/ha yielded less than these treatments however, was significantly higher (0.96 t/ha) compared to the control. Similar trends were seen for grain protein however, for both crop histories the GS31 application of N as urea or Entec urea had higher protein (Table 2). Test weight and 1000 grain weight were not affected by nitrogen treatment and all screening levels were below 5% (maximum level for AH and APW).

Table 2. Summary of grain yield (t/ha), protein (%), test weight (kg/hl), screenings (%) and 1000 grain weight (g) for Mace wheat sown following lentils and canola for all nitrogen rates.

Previous crop	Nitrogen rate	Grain yield t/ha	Protein %	Test weight kg/hL	Screenings %	1000 grain wt g
Lentils	Nil	3.77c	7.3c	80.3	0.6d	45.6
	40 kg @ GS31	4.73b	8.8b	80.5	1.0cd	44.5
	80 kg @ GS31	6.07a	10.6a	79.8	1.5a	44.2
	80 kg @ sowing	5.49a	9.6ab	81.4	0.8cd	43.5
	80 kg @ GS31 + inhibitor	6.04a	10.8a	80.0	1.4ab	43.0
	25 kg @ GS31	5.54a	9.0b	80.5	1.0bc	44.2
	LSD (P≤0.05)	0.74	1.3	ns	0.4	ns
Canola	Nil	2.77d	6.5c	79.6	0.6	46.8
	40 kg @ GS31	4.12c	7.7b	81.0	1.0	46.2
	80 kg @ GS31	5.14a	10.2a	81.3	1.2	45.9
	80 kg @ sowing	4.39abc	8.4b	81.0	1.2	46.2
	80 kg @ GS31 + inhibitor	5.01ab	9.6a	80.9	1.4	45.2
	51 kg @ GS31	4.33bc	8.3b	80.8	1.2	46.2
	LSD (P≤0.05)	0.81	1.0	ns	ns	ns

Nitrous oxide emissions

Initial nitrous oxide losses from the first 17 days shows the impact of nitrogen application (80 kg N/ha) at seeding after 25 mm of rainfall was received by the end of May (Table 3). Emissions were higher following canola compared to the lentils. From June through to July the trial received 120 mm of rainfall, increasing soil moisture in the surface soil (Figure 3). Soil moisture is an important driver of nitrous oxide emissions through both the nitrification and denitrification process. Nitrification mostly occurs when soils are at field capacity. Denitrification occurs when soils are above field capacity and starting to become waterlogged.

Table 3. Nitrous oxide emissions (g N_20/ha) for the period of 15th May – 4th December for nitrogen fertiliser × crop history treatments at Hart, 2014.

		May 15-31 (17 days)	June 1-30 (3 days)	July 1-23 (23 days)	July 24-31 (7 days)	August 1-31 (31 days)	Sept 1-30 (30 days)	Oct 1-31 (31 days)	Nov 1 - Dec 4 (34 days)	**Total (204 days)**
Ex-Crop	Trt					g N_2O/ha				
Canola	1	15.2	7.2	13.5	7.5	22.1	7.8	1.4	19.5	**94.4**
Canola	4	34.9	162.2	149.8	8.0	5.5	0.0	0.0	0.0	**360.4**
Canola	3				6.2	50.3	23.4	0.0	9.6	**89.6**
Lentils	1	0.0	28.7	16.6	17.3	53.0	5.6	0.4	13.1	**134.7**
Lentils	4	33.1	50.3	26.0	28.1	94.6	1.7	0.0	37.5	**271.3**
Lentils	3				23.1	44.8	4.9	5.3	28.0	**106.1**

**total N_2O emissions for treatment 3 assume emissions were same as nil prior to 24th of July.*

The GS31 application of nitrogen 21st July resulted in increased nitrous oxide emissions for 80 kg at GS31 (Figure 4). However, the emissions were not as high compared to 80 kg N/ha IBS which can be attributed to the drier soil conditions after the GS31 application (Figure 4). From early August the season conditions changed and for the majority of August, September and October the trial received only 11 mm, 11 mm and 2 mm, respectively.

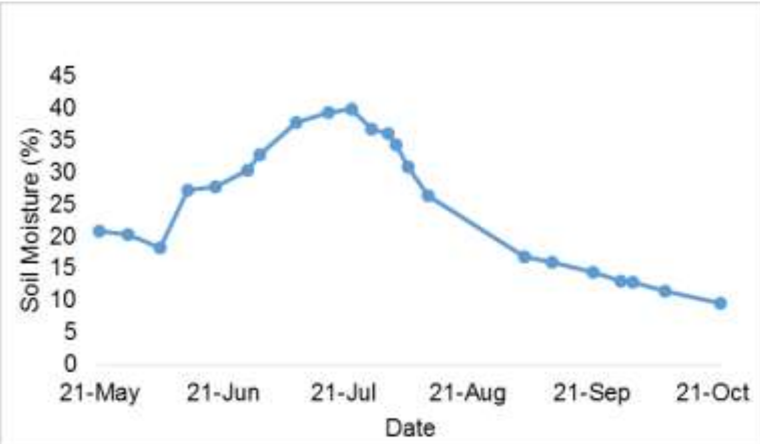

Figure 3. Average soil moisture (%) as recorded by a portable time domain reflectance (TDR) metre in the top 12 cm of the soil.

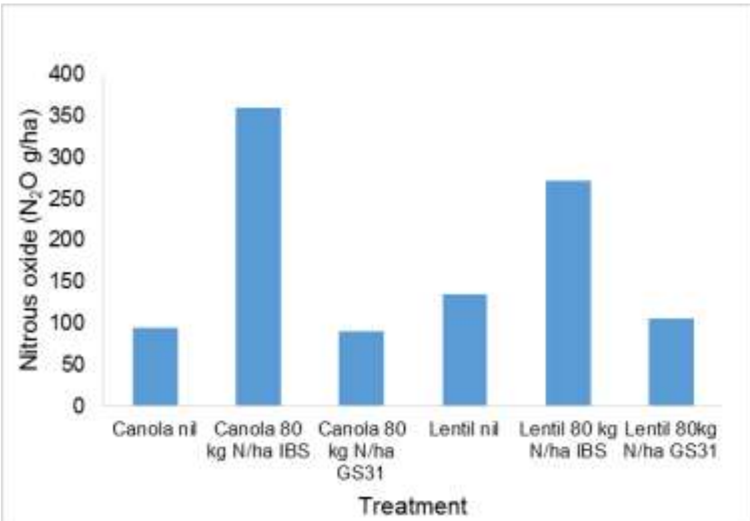

Figure 4. Total nitrous oxide emissions for nil, 80 kg N/ha IBS or applied at GS31 for lentil and canola treatments.

Actual nitrogen losses from the Hart nitrous oxide trial were small, maximum of 0.4 kg of nitrous oxide per hectare after 204 days (seeding – harvest). However, as mentioned previously nitrous oxide losses are strongly correlated to dinitrogen gas loss which is the main form of soil nitrogen gas lost. If dinitrogen emissions were calculated to be 20-30 times high than nitrous oxide, a loss of 0.4 kg nitrous oxide/ha might equate to 8-12 kg N/ha.

An identical trail was also established in Yarrawonga, Victoria (Riverine Plains) with the exception of a different legume sown in 2013 (field peas instead of lentils). Similar to Hart, nitrous oxide emissions were greatest after fertiliser application (Table 4). The IBS 80 kg N/ha also produced higher emissions compared to the 80 kg N/ha at GS31 in the first 115 days of this trial (Table 4). Interestingly, the Yarrawonga site had 4.5 times higher nitrous oxide emissions compared to Hart in just over half the trial time (205 day Hart compared to 115 days Yarrawonga). We suspect the differences between the sites are attributed to rainfall and differences in soil type (eg. drainage and soil structure).

Table 4. Nitrous oxide emissions (g N_20/ha) for the period of 9th May – 31st August for nitrogen fertiliser × crop history treatments at Yarrawonga, 2014

		May (23 Days)	June (30 days)	July (23 Days)	July Post App (8 Days)	August (31 Days)	Total for 115 days
Ex-Crop	Trt			g N20/ha			
Canola	1	61.3	106.2	8.0	-1.6	18.5	**192.4**
Canola	4	812.4	897.9	48.4	20.1	66.1	**1844.8**
Canola	3				8.1	77.2	**260.8**
Peas	1	41.5	179.2	12.4	6.8	12.2	**252.1**
Peas	4	472.1	1108.4	27.8	10.3	26.6	**1645.2**
Peas	3				47.6	57.4	**338.0**

**total N_2O emissions for treatment 3 assume emissions were same as nil prior to 24th of July.*

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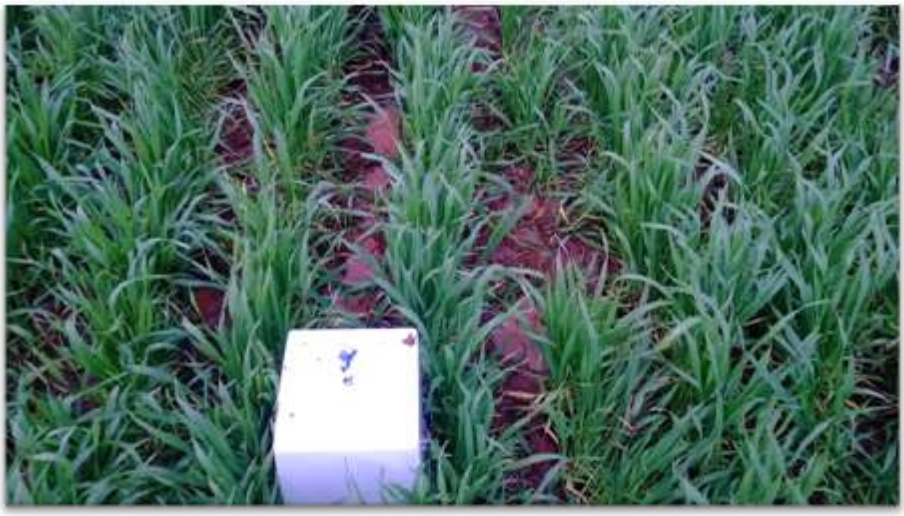

Photo: Nitrous oxide chamber in 2014 wheat crop at Hart.