Optimising crop nutrition in canola

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Key points

- The Coreen trial was not harvested due to dry conditions.
- While harvest results at Howlong were compromised due to dry conditions, early dry matter (DM) and tissue nitrogen (N) and sulphur (S) results indicate an interaction between nitrogen and sulphur.
- While early DM production increased with added nitrogen, there was a trend for further early biomass production when sulphur was also added.
- As tissue nitrogen concentrations increased, sulphur concentrations also increased, as measured at harvest.
- There were no differences in yield due to applied nitrogen or sulphur treatments, likely due to the dry conditions.
- Protein levels increased with added nitrogen, while oil levels decreased.

Background

Following the discovery of sulphur deficiency in canola in southern NSW during the late 1980s, the application of 20–30kg S/ha has been recommended when sowing canola (GRDC Canola guide, 2009). Since then, the wheat–canola rotation has become established, meaning growers are applying 20–30kg S/ha as frequently as every second year. With some sulphur moving to depth, growers are questioning whether they can reduce their sulphur application rates to their canola crops.

Furthermore, a variable response to sulphur has been observed, depending on background nutrition levels, (e.g. soil nitrogen status — where nitrogen supply is sub-optimal, plant uptake of sulphur can be inhibited, leading to a confounded yield response).

This Grains Research and Development Corporation (GRDC) investment, *Optimising crop nutrition in canola* is investigating the interactions between nitrogen supply and sulphur uptake, to ensure sulphur uptake is not limited by sub-optimal soil nitrogen levels.

Aims

This project aims to determine if nitrogen supply is limiting the uptake of sulphur in canola crops grown in the Riverine Plains region and whether sulphur uptake and yield are increased when nitrogen is available in non-limiting quantities.

The 2017 and 2018 trials assessed the response to nitrogen and sulphur in canola crops of the Riverine Plains by determining:

- the influence of nitrogen and sulphur application on canola tissue content, yield and oil
- the fluctuation in nitrogen and sulphur content and nitrogen:sulfur ratio in the plant from stem elongation (GS2.0) to harvest (GS6.9), and
- the optimum available soil nitrogen level for the region's canola crops at varying sulphur application rates.

Method

During 2018, two trial sites were established at Coreen and Howlong in southern NSW.

A randomised block design was used, with plots measuring 3m x 18m long, with four replicates. The Coreen site was sown on 18 April 2018 to canola cv Bonito. The Howlong site was sown on 29 April 2018 to canola cv Roundup Ready® 45Y25.

After sowing, combinations of nitrogen and sulphur treatments were applied to both trial sites. The Coreen site was severely affected by dry conditions and was not harvested. As a result, data from Coreen is not presented in this report.

Nitrogen (as urea) was applied in a split application at the 6 leaf stage (GS1.06) and greenbud (GS3.3) at five rates (0, 40, 80, 120, 160kg N/ha), with 40kg N/ha applied at the 6 leaf stage, and the remainder applied at green bud. Sulphur was applied as sulphate of ammonia (SOA) at four rates (0, 10, 20, 30kg S/ha), which was applied with the first application of in-crop nitrogen, with urea added to balance the nitrogen applied in the SOA. Sulphur treatments were applied across the suite of nitrogen treatments to determine the interaction between nitrogen and sulphur (Table 1).

The trial site was managed as part of the surrounding commercial crop, with the exception of the sulphur and nitrogen applications.

Tissue sulphur and nitrogen testing and DM sampling both occurred at early flowering (GS4.1–GS4.2), pod set (GS5.8) and harvest (GS6.9). Yield, oil and protein content was also measured.

TABLE 1 Treatment list: Nitrogen applied as urea (46% N) and sulphur applied as ammonium sulphate (21% N and 24% S)

No.	6 leaf stage GS1.06	Green bud GS3.3	Total S (kg/ha S)	Total N (kg/ha N)
1	0	0	0	0
2	40N 0S	0	0	40
3	40N 10S	0	10	40
4	40N 20S	0	20	40
5	40N 30S	0	30	40
6	0	0	0	0
7	40N 0S	40N	0	80
8	40N 10S	40N	10	80
9	40N 20S	40N	20	80
10	40N 30S	40N	30	80
11	0	0	0	0
12	40N 0S	120N	0	160
13	40N 10S	120N	10	160
14	40N 20S	120N	20	160
15	40N 30S	120N	30	160
16	0	0	0	0
17	40N 0S	200N	0	240
18	40N 10S	200N	10	240
19	40N 20S	200N	20	240
20	40N 30S	200N	30	240

Treatments at six-leaf stage (GS1.06) applied as ammonium sulphate with residual nitrogen application applied as urea

The first 40kg N/ha of all nitrogen treatments was applied at the six-leaf stage, with the remainder applied at green bud (GS3.3).

Treatment list excludes MAP applied at sowing with the commercial crop

Trial 1: Howlong, NSW

Sowing date: 29 April 2018
Rotation: Canola after wheat
Variety: Canola, cv 45Y25
Rainfall:
GSR: 172.6mm (April – October):

i) Soil sampling results

Incremented soil samples (0–30cm, 30–60cm, 60–90cm) were collected on 28 May 2018 and analysed for nitrogen and sulphur content.

Field sites were selected based on previous cropping history and associated high levels of production and nutrient export. While the soil nitrogen values were high in the top 30cm, they decreased significantly at depth; this is as expected given the dry finish experienced during 2017 and the limited rainfall received during the 2017–18 summer before sowing the 2018 canola crop (Table 2). Low sulphur levels at depth suggest a sulphur response would be expected at this site.

ii) Dry matter (DM)

Due to the large number of treatments in this trial, only selected treatments (i.e. the nil-sulphur and high-sulphur treatments at each rate of nitrogen) received an in-crop assessment for DM production.

The DM measurement at 20% flowering (GS4.2) showed the 120N:30S treatment had the greatest biomass and this was 3.28t/ha higher than that measured in the untreated controls (UTC). However, no significant differences were observed in biomass production at either the 80% pods filled stage (GS5.8) or at harvest (GS6.9). This was likely due to the dry spring conditions contributing to both a limited nutrient response and the high variance observed in the trial (as seen by the 1.59t/ha difference in biomass between the two UTC treatments at harvest) (Table 3).

iii) Plant tissue nitrogen and sulphur content

The nitrogen content of the canola at 20% flowering (GS4.2) showed increased nitrogen uptake at higher application rates, which is expected. However, there was also trend

TABLE 2 Soil nitrogen and sulphur contents at the Howlong, NSW site, sampled 28 May 2018

Depth (cm)	Mineral N (kg/ha)	Mineral S values (kg/ha)
0–30	48.0	2.65
30–60	9.04	8.25
60–90	8.05	8.35
Total (0–90)	**65.1**	**19.3**

TABLE 3 Dry matter assessment at the Howlong, NSW site

	6 Sep 2018	18 Oct 2018	20 Nov 2018
	Dry matter (t/ha)		
	20% flower (GS4.2)	80% pods filled (GS5.8)	Harvest (GS6.9)
UTC	4.07^{d}	3.63	3.23
UTC	4.23^{cd}	4.46	4.82
40N:0S	6.49^{ab}	5.10	4.78
40N:30S	5.01^{bcd}	6.70	5.07
80N:0S	5.43^{a-d}	6.58	4.88
80N:30S	6.40^{abc}	5.37	6.31
120N:0S	6.53^{ab}	6.28	6.43
120N:30S	7.51^{a}	5.38	4.90
160N:0S	6.12^{a-d}	6.36	5.93
160N:30S	7.00^{ab}	5.61	4.58
Mean	**5.88**	**5.55**	**5.09**
LSD P=0.05	2.24	2.14	1.89
P value	0.05	n.s.	n.s.
CV	26.27	26.55	25.61
SD	1.54	1.47	1.30

UTC: Untreated control

Figures followed by different letters are regarded as statistically different.

for increased nitrogen uptake with sulphur addition, a trend which was statistically significant at the highest level of nitrogen addition (Table 4). Such a trend suggests a readily available supply of sulphur could facilitate increased nitrogen uptake early in the season.

There was less variance in canola nitrogen content at the 80% pods filled stage (GS5.8), with all treatments except 40N:0S having significantly more tissue nitrogen than the untreated controls. The significant increase in plant nitrogen content at 40N:30S compared with the equivalent nitrogen treatment with no sulphur (40N:0S) again indicates sulphur could aid nitrogen uptake, however, this trend was not evident at higher nitrogen application rates.

While differences in nitrogen uptake were even less evident at harvest (GS6.9), the highest nitrogen content was measured in the 80N:30S treatment, which was almost double the tissue nitrogen measured in the 160N:30S treatment.

While the 2017 results at Howlong showed an increase in nitrogen uptake over the season from an average of 129 to 181kg N/ha, the 2018 results show an overall depletion in plant tissue nitrogen from 20% flower (mean of 200kg N/ha) to harvest (mean of 54kg N/ha). As these results also correlate with a lack of increase in DM over the season, it is likely the dry conditions caused a large amount of leaf matter to die prematurely.

The range in tissue sulphur content at 20% flowering (GS4.2) significantly increased with additions, with strong interaction between additional sulphur and additional nitrogen (Table 4). As nitrogen addition increased, so did the tissue sulphur content, with a trend for higher sulphur contents when sulphur was added.

As the season progressed through to the 80% pods filled (GS5.8) and harvest (GS6.9) stages, there were no significant differences in sulphur content between treatments. This is likely due to the poor DM production caused by the dry seasonal conditions.

There was not a strong relationship between sulphur addition and DM production, which meant there was no clear connection between sulphur addition and plant growth (as water was the most limiting factor for growth). However there was a strong relationship between plant tissue nitrogen and sulphur content at harvest (Figure 1).

iv) Normalised difference vegetation index

Normalised difference vegetation index (NDVI) was measured in each plot 10 times throughout the season. While there were differences in plant greenness, as estimated by NDVI throughout the season, there were no statistically significant differences in NDVI between treatments (Figure 2). Hence, the average NDVI values are presented for each time period. Plant greenness peaked between green bud (GS3.3) and 20% flower (GS4.2).

TABLE 4 Plant tissue nitrogen and sulphur contents at Howlong, NSW

	Nitrogen content			Sulphur content		
	6 Sep 2018	18 Oct 2018	20 Nov 2018	6 Sep 2018	18 Oct 2018	20 Nov 2018
	kg N/ha			kg S/ha		
Treatment	20% flower (GS4.2)	80% pods filled (GS5.8)	Harvest (GS6.9)	20% flower (GS4.2)	80% pods filled (GS5.8)	Harvest (GS6.9)
UTC	81^{e}	45^{b}	22^{c}	10^{f}	18	19
UTC	95^{e}	62^{b}	32^{bc}	18^{def}	24	28
40N:0S	165^{cde}	59^{b}	34^{bc}	15^{ef}	22	25
40N:30S	109^{e}	138^{a}	47^{bc}	24^{def}	40	28
80N:0S	148de	130^{a}	37^{bc}	26^{c-f}	36	24
80N:30S	230^{bcd}	142^{a}	117^{a}	43^{abc}	40	37
120N:0S	264^{b}	140^{a}	93^{a}	35^{bcd}	33	32
120N:30S	302^{ab}	122^{a}	47^{bc}	57^{a}	30	25
160N:0S	246^{bc}	161^{a}	54^{bc}	28^{cde}	60	25
160N:30S	360^{a}	141^{a}	59^{b}	47^{ab}	36	24
Mean	**200**	**114**	**54**	**30**	**34**	**27**
LSD P=.05	86	52	33	18	30	10
P value	<0.001	<0.001	<0.001	<0.001	n.s.	n.s.
CV	29.5	31.7	41.6	40.9	60.9	26.3
SD	59	36	23	12	21	7

UTC: Untreated control
Figures followed by different letters are regarded as statistically different.

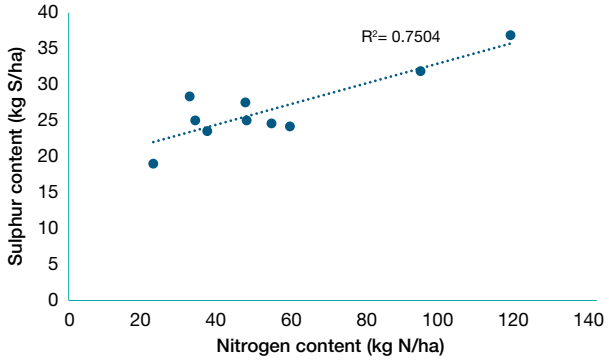

FIGURE 1 Relationship between tissue nitrogen and sulphur content at Howlong NSW, measured at harvest (GS6.9), 20 November 2018

v) Yield, oil and protein

During 2018, there were no significant differences in yield across the various treatments due to the dry conditions, with a total yield range of 0.89–1.51t/ha (Table 5). By comparison, the Howlong trial site yields ranged from 2.46–3.04t/ha during 2017.

While oil content decreased significantly as nitrogen application rates increased, protein content increased as nitrogen application rates increased. The rate of sulphur addition had minimal influence on oil and protein levels.

vi) Grain nitrogen and sulphur

The amount of nitrogen in the grain was not significantly increased with increased nitrogen addition (Table 6), ranging from 3.5% in the UTC to 4.2% when 160kg N/ha was added. The lack of difference in grain nitrogen percentage between the 120kg N/ha and 160kg N/ha treatments suggest grain nitrogen content may have reached its agronomic maximum.

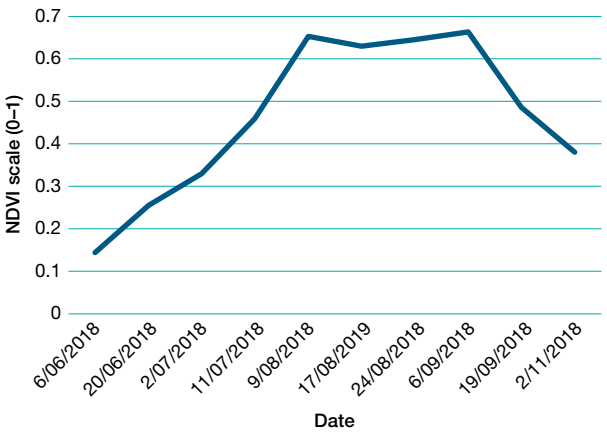

FIGURE 2 Average NDVI values across all treatments, measured from when cotyledons were unfolded (GS1.0) through to when most seeds were green-brown mottled (GS6.4), at Howlong, NSW

TABLE 5 Harvest yield and quality at Howlong, NSW

No.	Treatment	Yield* (t/ha)	Oil (%)	Protein (%)
1	UTC	0.89	44.3^{a}	20^{l}
2	40N:0S	1.14	43.3^{ab}	21.2^{jk}
3	40N:10S	1.15	43.8^{a}	20.8^{jkl}
4	40N:20S	1.21	43.6^{a}	21.4^{ijk}
5	40N:30S	1.20	43.1^{ab}	21.7^{hij}
6	0N:0S	0.93	43.5^{a}	20.6^{kl}
7	80N:0S	1.36	42.2^{bc}	22.2^{ghi}
8	80N:10S	1.25	41.4^{cd}	22.7^{gh}
9	80N:20S	1.36	39.8^{ef}	23.7^{ef}
10	80N:30S	1.31	40.5^{de}	22.8^{fg}
11	0N:0S	1.05	43.9^{a}	20.4^{kl}
12	120N:0S	1.41	40.7^{de}	24de
13	120N:10S	1.51	41.3^{cd}	23.9^{de}
14	120N:20S	1.44	40.6^{de}	24.1^{de}
15	120N:30S	1.26	40.5^{de}	24.6^{cde}
16	0N:0S	0.94	43.6^{a}	20.5^{kl}
17	160N:0S	1.26	38.3^{g}	25.8^{a}
18	160N:10S	1.29	39.1^{fg}	24.8^{bcd}
19	160N:20S	1.22	38.7^{fg}	25.7^{ab}
20	160N:30S	1.33	38.6^{g}	25.2^{abc}
Mean		**1.23**	**41.5**	**22.8**
LSD P=.05		0.22	1.24	1.0
P value		n.s.	<0.001	<0.001
CV		12.83	2.11	3.07
SD		0.157	0.87	0.70

*Trial harvested 28 November 2018

Increasing the rate of sulphur or nitrogen application did not significantly change the sulphur content of the grain.

vii) Post-season soil sampling

Soil sampling across the whole site was carried out during February 2019. There were no significant differences in either nitrogen or sulphur content in the soil post treatment.

viii) Gross margin

Gross margin (GM) analyses were undertaken to ascertain the optimum application rate of sulphur and nitrogen in canola. There was an error in the GM analysis of the 2017 data, which was reported to the GRDC during April 2018. This error is detailed in Appendix A and has been corrected in this report.

Costs were based on growers' input costs and included contract rates for machinery operations. Fertiliser rates were converted to combinations of urea and sulphate of ammonia, using values of $400/t for urea (2017 and 2018) and $350/t and $400/t (2017 and 2018 respectively) for sulphate of ammonia.

TABLE 6 Grain nitrogen and sulphur at Howlong, NSW at harvest (GS6.9), 28 November 2018

No.	Treatment	Grain nitrogen (%)	Grain sulphur (%)
1	0N:0S	3.5	0.3
2	40N:0S	3.3	0.3
3	40N:10S	3.5	0.3
4	40N:20S	3.2	0.3
5	40N:30S	3.3	0.3
6	0N:0S	3.3	0.3
7	80N:0S	3.4	0.3
8	80N:10S	3.7	0.3
9	80N:20S	3.8	0.3
10	80N:30S	3.9	0.3
11	0N:0S	3.4	0.4
12	120N:0S	3.3	0.3
13	120N:10S	3.9	0.4
14	120N:20S	3.5	0.3
15	120N:30S	3.4	0.3
16	0N:0S	3.6	0.3
17	160N:0S	4.2	0.3
18	160N:10S	4	0.3
19	160N:20S	4.4	0.3
20	160N:30S	4.2	0.4
Mean		**3.64**	**0.32**
LSD P=.05		0.52	0.08
P value		n.s.	n.s.
CV		10.03	17.66
SD		0.36	0.06

Grain value for the 2017–18 harvest was calculated using prices of $515/t for canola delivered Howlong and $470/t for Roundup Ready® canola delivered Yarrawonga. For the 2018–19 harvest the price was $570/t for Roundup Ready® canola delivered Howlong.

There was no statistical analysis of the GM results.

2017 results Yarrawonga

During 2017 (a decile 3 rainfall year), there was a significant canola yield response to the addition of 20kg of sulphur in combination with 160kg N/ha at the Yarrawonga site. The highest returning GM treatment was 160kg N/ha and 20kg S/ha, which was $319/ha more profitable than applying 160kgN/ha with no sulphur (Table 7; for full results see Appendix B, Yarrawonga results 2017).

The benefit:cost ratio of the application of 20kg S/ha (when nitrogen was applied at 160kg/ha) was $23.70:1, which means every additional dollar spent on sulphur up to 20kg/ha generated an additional $23.70 in gross income. When the amount of sulphur increased to 30kg/ha, there was no significant increase in yield from the nil sulphur treatment and minimal increase in GM.

TABLE 7 Gross margin analysis of applying nitrogen and sulphur fertiliser at Yarrawonga, 2017

Treatment	Yield (t/ha)	Fertiliser cost ($/ha)	Gross margin ($/ha)	Gross margin compared with 160N:0S ($/ha)
160N:0S	2.42^{e}	139	690	-
160N:10S	2.63^{cde}	146	783	93
160N:20S	3.11^{a}	153	1009	319
160N:30S	2.54^{de}	160	700	10

Figures followed by different letters are regarded as statistically different

2017 results Howlong

During 2017 (a decile 4 rainfall year) there were no significant canola yield responses to applying sulphur at the Howlong site (Table 8; for full results see Appendix B). Note that this site was shown to have high starting nitrogen levels compared with the Yarrawonga site. The highest returning GM treatment was 80kg N/ha and 20kg S/ha, which was $53/ha more profitable than applying 80kgN/ha with no sulphur.

The benefit:cost ratio of applying 20kg S/ha (when nitrogen was applied at 80kg/ha) was $4.78:1, which means every additional dollar spent on sulphur up to 20kg/ha generated an additional $4.78 in gross income. When the amount of sulphur increased to 30kg/ha, there was no significant increase in yield from the nil sulphur treatment and the GM decreased.

Sensitivity analysis 2017 data

A sensitivity analysis tested the impact of a change in key variables (canola price and fertiliser cost) on the economic optimum of nitrogen and sulphur at the Yarrawonga site during 2017. When the price of canola was reduced by 10% (from $470/t to $423/t), the most profitable option remained 160kg N/ha and 20kg S/ha (Table 9). Similarly, a 10% increase in the cost of fertiliser (urea from $400/t to $440/t and sulphate of ammonia from $350/t to $385/t) did not change the order of the most profitable application rate (Table 10).

A sensitivity analysis tested the impact of a change in key variables (canola price and fertiliser cost) on the economic optimum of nitrogen and sulphur at the Howlong site during 2017. When the price of canola was reduced by 10% (from $515 to $463.50), or the price of fertiliser increased by 10% (urea from $400/t to $440/t and sulphate of ammonia from $350/t to $385/t), the most profitable option remained 80kg N/ha and 20kg S/ha (Tables 11 and 12).

TABLE 8 Gross margin analysis of applying nitrogen and sulphur fertiliser at Howlong, 2017

Treatment	Yield (t/ha)	Fertiliser cost ($/ha)	Gross margin ($/ha)	Gross margin compared with 80N:0S
80N:0S	2.91[abc]	70	1237	-
80N:10S	2.84[abc]	76	1182	-55
80N:20S	3.04[a]	83	1290	53
80N:30S	2.84[abc]	90	1162	-75

Figures followed by different letters are regarded as statistically different

TABLE 9 Impact of a 10% reduction in the price of canola on the profitability of applying nitrogen and sulphur at Yarrawonga, 2017

Treatment	Gross margin (canola price reduced by 10%) ($/ha)	Gross margin (compared with 160N:0S) ($/ha)
160N:0S	575	-
160N:10S	658	83
160N:20S	860	285
160N:30S	582	7

TABLE 10 Impact of a 10% increase in the price of fertiliser on the profitability of applying nitrogen and sulphur at Yarrawonga, 2017

Treatment	Gross margin (fertiliser price increased by 10%) ($/ha)	Gross margin (compared with 160N:0S) ($/ha)
160N:0S	676	-
160N:10S	768	92
160N:20S	994	318
160N:30S	684	8

TABLE 11 Impact of a 10% reduction in the price of canola on the profitability of applying nitrogen and sulphur at Howlong, 2017

Treatment	Gross margin (canola price reduced by 10%) ($/ha)	Gross margin compared with 80N:0S ($/ha)
80N:0S	1073	-
80N:10S	1024	-49
80N:20S	1120	47
80N:30S	1004	-69

TABLE 12 Impact of a 10% increase in the price of fertiliser on the profitability of applying nitrogen and sulphur at the Howlong site, 2017

Treatment	Gross margin (fertiliser price increased by 10%) ($/ha)	Gross margin compared with 80N:0S ($/ha)
80N:0S	1230	-
80N:10S	1175	-55
80N:20S	1281	51
80N:30S	1153	-77

2018 results

There were two sites during 2018: Coreen and Howlong. A decision was made during October 2018 not to harvest the Coreen site, which was extremely drought affected. Therefore, no economic analysis was undertaken for this site. Even though the Howlong site was also drought affected (decile 1 GSR), the site had enough yield potential to be harvested.

The most economic treatment at Howlong was the application of 120kg N/ha, 10kg S/ha, which yielded 1.5t/ha with a gross margin of $353/ha (Table 13; for full list of treatment results, see Appendix C).

The second most profitable treatment (80kg N/ha and 0kg S/ha) had a GM of $329/ha. The third most profitable treatment was 120kg N/ha, 0kg S/ha. The three highest gross margin treatments were at least $100/ha more profitable than the average of the untreated control, suggesting it was economic to apply nitrogen and sulphur fertiliser in the low yielding conditions. However, as the yield of these treatments were not statistically different from the untreated controls, these gross margin results are not definitive.

Decreasing the canola price by 10% (from $570/t to $513/t) or increasing the fertiliser cost by 10% (urea and sulphate of ammonia from $400/t to $440/t) did not change the order of the most profitable options (Appendix C).

Discussion

The 2017 results from this trial were confounded due to the dry finish. Likewise, the 2018 results were confounded due to dry conditions throughout the season, with the Howlong site only recording decile 1 GSR. While the Coreen site had to be abandoned due to plant death, the Howlong site achieved a measurable yield.

While the yield results from Howlong do not show clear treatment influences due to the dry conditions, the early-season results suggest there was an effect from the nutrient treatments applied. A nitrogen response was seen with DM production at 20% flower, while plant tissue nitrogen also increased with additional nitrogen.

Interestingly, additional sulphur appeared to facilitate nitrogen uptake, with a strong relationship between tissue nitrogen and sulphur levels, which continued through to harvest. The increase in tissue sulphur content with increasing nitrogen was likely due to the increased DM production associated with nitrogen addition, with more roots and biomass resulting in greater uptake of sulphur from soil. If the seasonal conditions had been more favourable, it could be speculated this interaction could have followed through to an effect on yield.

TABLE 13 Gross margin analysis of applying nitrogen and sulphur fertiliser at Howlong, 2018

Treatment	Yield (t/ha)	Gross margin ($/ha)	Gross margin# ($/ha)	Gross margin^ ($/ha)
Average of untreated control	0.95n.s.	187	131	187
120N:0S	1.41n.s.	304	226	294
80N:0S	1.36n.s.	329	251	322
120N:10S	1.51n.s.	353	268	341

Canola price reduced by 10%
^ Fertiliser price increased by 10%)

This project was undertaken over two years, one of which (2017) experienced a dry finish, and the other (2018) experiencing drought conditions. This means the general knowledge to be derived from this project is limited.

Although recommendations on application rates and soil sulphur thresholds cannot be determined, this work does reinforce that basic sulphur nutrition is needed to ensure nitrogen supply is not limited. Rather than relying on standard application rates of sulphur with every canola crop, a focus on understanding fluctuations in soil sulphur levels at a paddock level needs to be valued in the same way as deep soil nitrogen (DSN) levels provide a measure of confidence in urea application rates.

The most economic combination of sulphur and nitrogen was specific to site and year and given both years were dry, no definitive conclusions can be drawn. There was a strong statistical and economic response to sulphur and nitrogen at Yarrawonga during 2017 (decile 3 year), while at Howlong in 2017 (decile 4 year), there was an economic response to sulphur but not a statistical yield response, suggesting the economic response was marginal. The 2018 results from the Howlong site were constrained by extremely low rainfall (decile 1) and therefore the economic optimum treatment was not representative of a typical year.

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Appendix A

Error in the 2018 GRDC report for *Optimising sulphur and nitrogen nutrition in canola*

The error was a result of an incorrect price for sulphate of ammonia and an incorrect calculation for the rates of urea, which resulted in lower amounts of urea used for gross margin (GM) calculations (Table A1). The original and corrected rates of urea for both the Howlong and Yarrawonga sites are the shaded treatments listed in Table A1. The original price used for sulphate of ammonia was $750/t and the corrected price was $350/t. There was no change to the sulphate of ammonia rate (Table A1).

To correct this error and to obtain some key economic take-home messages, a summary of the 2017 results was rewritten for this report and the amended GM of all treatments for 2017 have been included in Appendix B. The error did not change the most economic option for both sites, however the corrected GM was $11/ha lower for the Yarrawonga site and $19/ha higher for the Howlong site than reported during 2018.

TABLE A1 Urea rates used in gross margin analyses of 2017 data for Howlong and Yarrawonga

No.	Treatment	Incorrect urea rate (kg/ha)	Corrected urea rate (kg/ha)	Sulphate of ammonia rate (unchanged) (kg/ha)
1	UTC	0	0	0
2	UTC	0	0	0
3	UTC	0	0	0
4	UTC	0	0	0
5	40N:0S	87	87	0
6	40N:10S	67	67	42
7	40N:20S	50	50	83
8	40N:30S	30	30	125
9	80N:0S	174	174	0
10	80N:10S	134	154	42
11	80N:20S	100	136	83
12	80N:30S	60	116	125
13	160N:0S	348	348	0
14	160N:10S	268	328	42
15	160N:20S	200	309	83
16	160N:30S	120	290	125
17	240N:0S	521	521	0
18	240N:10S	402	502	42
19	240N:20S	300	483	83
20	240N:30S	180	465	125

Appendix B

Revised gross margin analysis for 2017 Yarrawonga (Table A2) and Howlong (Table A3).

TABLE A2 Yarrawonga 2017: Fertiliser application rate, gross margin and sensitivity analysis for treatments

Treatment	Urea application rate (kg/ha)	SOA application rate (kg/ha)	Gross margin ($/ha)	Gross margin# (canola price less 10%) ($/ha)	Gross margin# (fertiliser price plus 10%) ($/ha)
UTC	0	0	462*	386*	462*
40N:0S	87	0	647	548	644
40N:10S	67	42	635	536	631
40N:20S	50	83	713	605	708
40N:30S	30	125	706	598	701
80N:0S	174	0	818	697	811
80N:10S	154	42	964	827	956
80N:20S	136	83	875	746	866
80N:30S	116	125	874	745	865
160N:0S	348	0	690	575	676
160N:10S	328	42	783	658	768
160N:20S	309	83	1009	860	994
160N:30S	290	125	700	582	684
240N:0S	521	0	852	713	831
240N:10S	502	42	804	669	782
240N:20S	483	83	838	699	816
240N:30S	465	125	728	600	705

* Average of gross margin results from four untreated control treatments; # Gross margins not statistically analysed
Highlighted treatment has the highest gross margin

TABLE A3 Howlong 2017: Fertiliser application rate, gross margin and sensitivity analysis for treatments

Treatment	Urea application rate (kg/ha)	SOA application rate (kg/ha)	Gross margin ($/ha)	Gross margin# (canola price less 10%) ($/ha)	Gross margin# (fertiliser price plus 10%) ($/ha)
UTC	0	0	1110*	968*	1110*
40N:0S	87	0	1147	997	1143
40N:10S	67	42	1253	1091	1249
40N:20S	50	83	1210	1052	1205
40N:30S	30	125	1111	963	1106
80N:0S	174	0	1237	1073	1230
80N:10S	154	42	1182	1024	1175
80N:20S	136	83	1290	1120	1281
80N:30S	116	125	1162	1004	1153
160N:0S	348	0	1112	954	1098
160N:10S	328	42	1201	1034	1187
160N:20S	309	83	1097	940	1082
160N:30S	290	125	1059	904	1043
240N:0S	521	0	1006	852	985
240N:10S	502	42	1072	910	1050
240N:20S	483	83	1107	941	1085
240N:30S	465	125	973	821	950

* Average of gross margin results from four untreated control treatments; # Gross margins not statistically analysed. The difference between the gross margins of 80N:20S and 80N:0S is therefore likely to be minimal as the yields of these treatments were not statistically different.
Highlighted treatment has the highest gross margin

Appendix C

Full gross margin analysis Howlong 2018 (Table A4).

Table A4 Full gross margin analysis Howlong 2018

Treatment	Yield (t/ha)	Urea application (kg/ha)	SOA application (kg/ha)	Gross margin ($/ha)	Gross margin# (canola price less 10%) $/ha	Gross margin# (fertiliser price plus 10%) $/ha
0N:0S	0.89	0	0	155	103	155
40N:0S	1.14	87	0	251	184	247
40N:10S	1.15	67	42	248	180	243
40N:20S	1.21	50	83	270	200	265
40N:30S	1.20	30	125	251	181	245
0N:0S	0.93	0	0	172	118	172
80N:0S	1.36	174	0	329	251	322
80N:10S	1.25	154	42	245	174	237
80N:20S	1.36	136	83	278	203	269
80N:30S	1.31	116	125	250	177	240
0N:0S	1.05	0	0	245	183	245
120N:0S	1.41	260	0	304	226	294
120N:10S	1.51	241	42	353	268	341
120N:20S	1.44	222	83	297	216	284
120N:30S	1.26	203	125	188	117	175
0N:0S	0.94	0	0	179	124	179
160N:0S	1.26	348	0	161	93	147
160N:10S	1.29	328	42	172	102	157
160N:20S	1.22	309	83	121	55	106
160N:30S	1.33	290	125	170	98	153

Gross margins not statistically analysed

Highlighted treatment has the highest gross margin- note gross margins of four untreated controls averaged $187.