Canola Nutrition for the HRZ – Condingup 2022

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Key messages

- Increasing applied nitrogen from 100N to 150N increased yield from 2.8 to 3.2 t/ha and was profitable under both standard and high fertiliser prices. Yield responses up to 200N at least covered fertiliser costs, while increasing to 250N reduced gross margin under high fertiliser pricing scenarios.
- Despite reasonable Colwell P levels in the top 10cm (22 mg/kg), responses to banded phosphorus were evident early in the season. Applying 15 kg P/ha provided yield responses that broke even under high fertiliser prices or were profitable under average prices, while yield responses generally did not justify the significant costs of applying more than 15P.
- Despite yields of 3.8 t/ha with 300N-31P-50K-31S applied, incorporation of manure at seeding or applying high rates of synthetic fertiliser over multiple application timings increased yield by up to 0.5 t/ha, indicating that nutritional deficiencies may still be present even with these high fertiliser rates.

Aim

To determine whether macronutrient supply (phosphorus, potassium, sulfur) becomes limiting as canola growers target high yields with high nitrogen rates in the high rainfall zone of WA.

Background

Advances in farming system and agronomic management have resulted in significant improvements to canola yields in the high rainfall zone (HRZ). With yields of over 3+ t/ha becoming more common, there has been increased interest as to the nutritional demands of these higher production crops. While growers can and do increase their nitrogen (N) rates in response to the potential of the season, there remains uncertainty as to how high their nitrogen rates should be in their higher potential seasons. While N rates are often matched to seasonal potential, applications of other macronutrients (phosphorus [P], potassium [K] and sulfur [S]) tend to be more fixed, and there is uncertainty as to whether previously standard rates are still adequate for these higher yielding crops.

Both the 2020 and 2021 nutrition trials saw significant yield responses to nitrogen up to around 150kg/ha, with little evidence that applications above 200kg N/ha are required to optimise yields. There were minimal responses to macronutrients in 2020, while the 2021 trial saw a significant (800+ kg/ha) response to sulfur applications. This trial (located in Condingup), and another at Gibson, have been established in 2022 to further test the nutritional demands of high yielding crops, as well as whether the addition of animal manure can provide benefits above those available from synthetic fertilisers.

Treatments

As in 2021, the main trial comprised nine nutrition treatments consisting of varying levels of phosphorus, potassium and sulfur applied across four nitrogen rates (100N, 150N, 200N and 250N) in a split-plot design with N rate as main plots and nutrition treatments (A1-A9) as sub-plots (Table 1). An additional six treatments (B1-B6) that did not fit within this factorial design were nested within the trial to test the impact of very low and high rates of synthetic fertiliser, with or without animal manure or seaweed concentrate (Seasol®).

At seeding, each treatment received different quantities of mono-ammonium phosphate (MAP, 11N-23P-0K-1S) and urea (46-0-0-0) banded below the seed to supply a total of 15 kg/ha of nitrogen (N) and the applicable rate of phosphorus (P) as per Table 1. A total of 33 kg/ha of urea was top-dressed by hand soon after seeding to supply an additional 15kg N/ha to all treatments except A1 and B6 (which had received 30kg N/ha banded within the high rate of MAP required to supply 62 kg P/ha) and treatments B1 and B2 which received no synthetic fertiliser. Composted chicken manure (containing 1.5% N, 0.9% P, 1.2% K and 0.3% S on a fresh weight basis) was top-dressed before seeding and incorporated by sowing at a rate of 10 t/ha (fresh weight) to treatments B2 and B5.

At four weeks after seeding (25 May), variable quantities of sulphate of ammonia (SOA, 21-0-0-24), muriate of potash (MOP, 0-0-50-0) and urea were top-dressed by hand to supply the total K and S requirement for each treatment (as per Table 1), as well as half of the remaining N requirement. At eight weeks after seeding (24 June), the remainder of the N requirement for each treatment was applied as urea top-dressed by hand. The Late P treatment also received MAP on 24 June to provide 31P with the equivalent rate of N.

Table 1: Treatment list for nine nutrition (P-K-S) treatments (A1-A9) applied across four nitrogen rates in the main trial, plus six supplementary treatments (B1-B6) nested within the trial site.

Nutrition treatment	Macronutrient rate (kg/ha)			
	N	P	K	S
A1. Double All	100, 150, 200, 250	62	100	60
A2. All	100, 150, 200, 250	31	50	30
A3. Low P	100, 150, 200, 250	15	50	30
A4. Base	100, 150, 200, 250	15	0	2
A5. Minus P	100, 150, 200, 250	0	50	30
A6. Minus K	100, 150, 200, 250	31	0	30
A7. Minus S	100, 150, 200, 250	31	50	2
A8. Late P	100, 150, 200, 250	31	0	0
A9. N only	100, 150, 200, 250	0	0	0

Supplementary Treatment	Details
B1. Nil fertiliser	No fertiliser.
B2. Manure only	10t/ha chicken manure incorporated-by-seeding (IBS) only.
B3. 300N All	300N, 31P, 50K, 30S.
B4. 300N All + Seasol	As per B3 + 5L/ha Seasol at three applications.
B5. 300N All + manure	As per B3 + 10t/ha chicken manure IBS.
B6. Constant Feed	Fertiliser applied across six applications to match nutrition in B5.

The Constant Feed treatment (B6) received fertiliser regularly throughout the season to match the nutrients present in the manure and synthetic fertiliser applied in the 300N All + manure treatment (B5). This consisted of banded MAP at seeding and combinations of MAP, urea, SOA and MOP top-dressed post seeding across five applications from three to twelve weeks after seeding (17 May to 20 July). The total nutrients applied in this treatment was 450N-119P-174K-61S. The 300N All + Seasol® treatment included 5L/ha of Seasol® seaweed concentrate streamed onto the crop at an equivalent water rate of 5000 L/ha at four, eight and twelve weeks after seeding.

Results

Seasonal conditions

After a very dry summer, significant rainfall fell in April (most notably 57mm from 12-14 April), resulting in wet seeding conditions (Figure 1). Following average rainfall in May (50mm) and slightly below average rainfall in June (30mm), the back half of July (66mm) and August (87mm) were wetter than average. September had average (41mm) rainfall but was generally cool, while 132mm fell in October, ensuring grain filling conditions through spring were optimal.

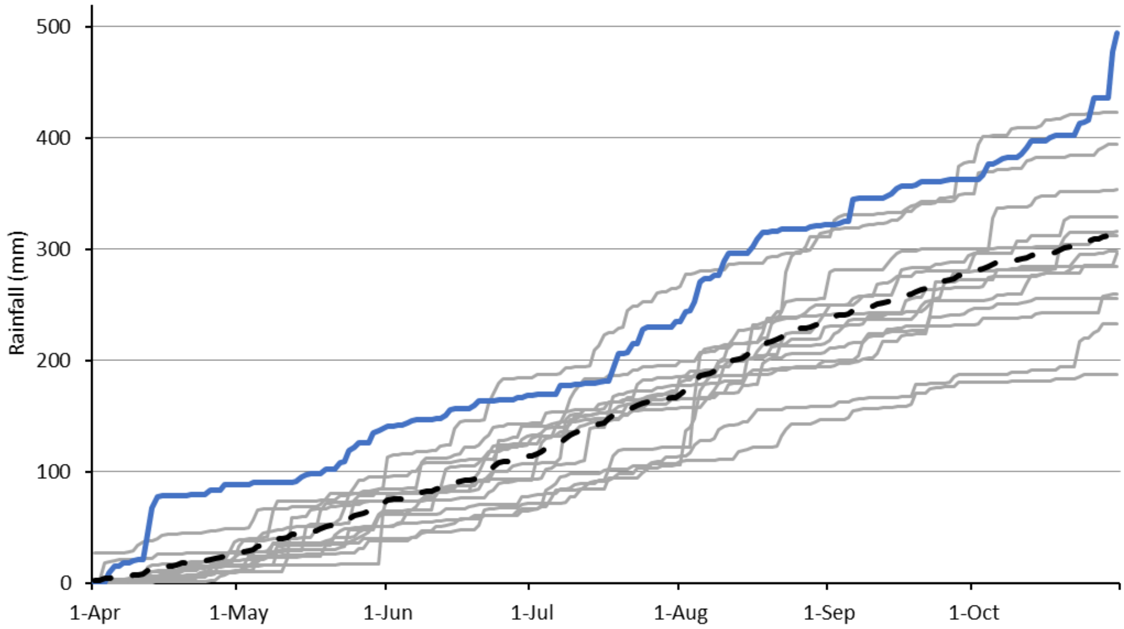

Figure 1: Cumulative growing season (Apr-Oct) rainfall from 2009-2022 at Mt Howick (DPIRD weather station). The 2022 (blue) and average (black, dashed) are highlighted. NB// The 2022 Condingup trial was located 10km ESE of the DPIRD weather station.

Table 2: Soil test results taken at seeding at 10cm incremental depths (0-10cm – composite of 40 samples, 10-60cm – composite of six samples per 10cm).

Depth	**0-10cm**	**10-20cm**	**20-30cm**	**30-40cm**	**40-50cm**	**50-60cm**
pH (CaCl2)	6.0	5.0	5.2	6.4	5.6	6.4
pH (water)	6.6	5.9	6.5	7.0	7.5	8.2
P (HCO3) (µg/g)	22	22	14	6	3	3
K (HCO3) (µg/g)	48	80	118	180	236	336
N (NH4) (µg/g)	8	10	6	2	1	1
N (NO3) (µg/g)	8	9	5	2	2	1
S (µg/g)	6	20.1	13.8	17.3	14.8	16.1
Organic carbon (%)	0.82	0.59	0.48	0.37	0.35	0.31
PBI	17.6	41.1	53.3	62.8	55.3	65.7
Conductivity (dS/m)	0.084	0.115	0.106	0.128	0.156	0.164
Soil colour	GR	LTGR	BRGR	BROR	YWGR	GRYW
Hand texture	2.0	2.0	2.0	2.0	2.0	2.0
Gravel (% by weight)	0%	0%	0%	0%	0%	0%
Aluminium CaCl2	0.53	1.18	0.63	0.31	< 0.20	< 0.20
DGT-P	26.57	20.49	< 5.00	< 5.00	< 5.00	< 5.00

Site characterisation

The site was located on a deep sandy duplex with sand above clay (starting at 35 cm depth). Soil testing was conducted immediately after seeding at 10cm increments to 60cm depth (Table 2). Colwell P in the top 10cm was just above levels that would indicate P deficiency is likely (<20 mg/kg, Brennan and Bolland, 2007), although Colwell P decreased and PBI increased in the shallow subsoil and DGT-P was low throughout the profile. Potassium levels were moderate but increased below 10cm, while sulfur levels were generally low but above critical levels for which a sulfur response would be expected (<10 mg/kg in top 30cm).

Establishment and in-season growth

The crop was seeded into moist soil on 26 April, with the first plants emerging within one week. Plant establishment (as measured at the two-leaf stage) averaged 42 plants m^{-2}, slightly exceeding the target of 40 plants m^{-2}. Within the main trial, there were no significant treatment effects, although the plots that received urea only at seeding (no phosphorus) appeared slightly delayed in growth.

Within the supplementary treatments, there was a significant ($p=0.015$) effect of treatment on plant density, with the 'Nil fertiliser' and 'Manure only' treatments having 5-10 plants m^{-2} more than the other treatments (except 'All + Seasol'). The plots with manure IBS were also noted to have slightly larger plants at this early stage.

Differences in nitrogen rate were imposed by fertiliser applications at 25 May (three-leaf stage) and 24 June (eight-leaf stage, early stem elongation). Subtle differences were detected visually and with NDVI by just before the second nitrogen top-up. Nitrogen rate differences continued to be subtle throughout the rest of the season, until lodging became more prevalent in higher N rate plots.

Phosphorus deficiency was evident within four weeks of sowing. The treatments with no P applied at seeding appeared to be less vigorous and/or developmentally delayed and this was reflected in NDVI values throughout the rest of the vegetative period, with differences becoming difficult to detect past July (commencement of flowering). Given the Late P applications were made on 24 June as P deficiency started to become less obvious, improvements to growth following this application were difficult to detect.

Some sulfur deficiency symptoms were noted at the one- to two-leaf stage (late May), especially in compacted wheel tracks. Once plants reached a larger size, these symptoms dissipated (despite being present in late emerging plants), and sulfur deficiency was not noted in the trial for the rest of the season. There was no evidence of potassium deficiency at any stage.

Compared to the Nil fertiliser treatment, the Manure only treatment had significantly more vigour within four weeks of sowing. Compared to plots with N top-ups in late May, the Manure only treatment began to show N deficiency symptoms in June. The All + manure treatment had the highest NDVI values in early June but was not always significantly higher than All or All + Seasol.

Tissue testing

Tissue testing was conducted on whole plant samples taken from three replicates on a subset of treatments at the six-leaf stage (seven weeks after sowing). Phosphorus ranged from 0.40% (nil fertiliser) to 0.63% (Constant Feed). Plots that received manure only (treatment B2) had an equivalent phosphorus concentration to plots that received 31P (as MAP) banded at seeding (treatment A2). Sulfur was lowest (0.54-0.60%) in treatments that received no supplemental S and were highest (0.77-0.79%) in the plots that received supplemental sulfur but no P at seeding (likely due to reduced plant size). Potassium was low (3.86-5.02%) in treatments that received no top-dressed potassium but was generally above 5% when potassium was applied.

End of season canopy

As expected, plant height increased with increasing N rates (up to 141 cm at 250N), and although there was a significant effect of nutrition, treatments differed by only up to 6cm (data not shown). The Constant Feed treatment (153cm) was significantly taller than the other supplementary treatments.

Lodging became evident from early August, especially in the higher nitrogen treatments. When lodging was assessed at maturity, there was a clear increase at higher N rates, while the plots that received no phosphorus had slightly reduced lodging (especially at higher N rates) (data not shown). The Constant Feed and 'All + manure' treatments had the highest levels of lodging at the site, with some areas of collapsed canopy.

Grain yield

There were significant responses to both N and P applications in this trial (Figure 2). There were no significant responses to sulfur or potassium applications.

Averaged across nutrition treatments, applying 100N resulted in a yield of 2.8 t/ha, which increased to 3.2 t/ha at 150N, 3.4 t/ha at 200N and 3.6 t/ha at 250N. Averaged across N rates, the N only treatment (3.06t/ha) was the lowest yielding, followed by the Minus P treatment (3.14 t/ha), while the Double All treatment (3.55 t/ha) was significantly higher yielding than all other treatments. The other six treatments ranged from 3.24 to 3.36 t/ha.

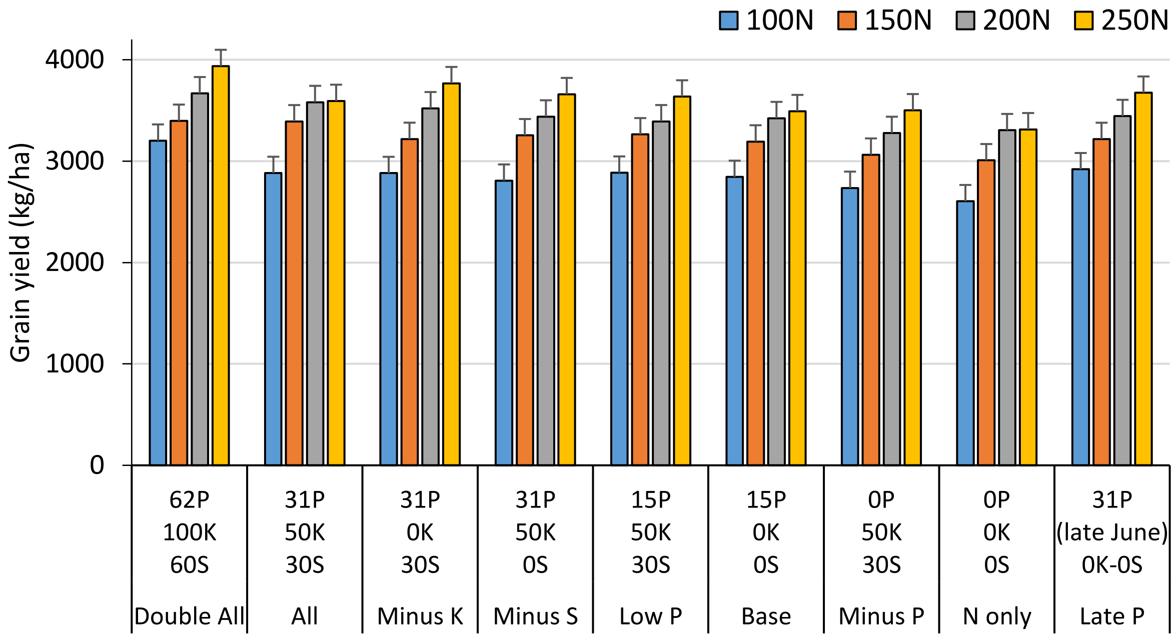

Figure 2: Grain yield (kg/ha, corrected to 8% moisture) for nine nutrition treatments at four nitrogen rates applied to canola at Condingup in 2022. Errors bars indicate LSD (Nrate*Nutrition).

Despite there being a statistically significant N rate by nutrition effect, differences were subtle and are not easily explainable. All nutrition treatments increased by between 649 and 886 kg/ha when N rate was increased from 100N to 250N. The Double All treatment was the highest yielding at all N rates, and the N only and Minus P were among the lowest three treatments at each N rate, but the other treatments switched ranking across the N rates tested.

The Nil fertiliser treatment yielded 1.8 t/ha, while the Manure only treatment yielded 2.6 t/ha (Figure 3). The All and All + Seasol treatments yielded 3.8t/ha, significantly lower than the All +

manure treatment (4.0t/ha). The Constant Feed treatment outyielded all other treatments, averaging 4.3t/ha, and had a noticeably longer grain filling duration than the other treatments (Figure 4).

Dry matter at maturity increased with nitrogen rate, indicating that differences in yield were the result of increased biomass rather than changes in harvest index (data not shown). The N only treatment had lower dry matter than the Double All, Late P and Minus S treatments, indicating biomass likely drove nutrition yield responses as well.

Grain weight was influenced by nutrition treatments, with the nil or late P treatments having slightly lower average grain weight than the other treatments (data not shown). Interestingly, there was no statistical difference between N rates or the supplemental treatments.

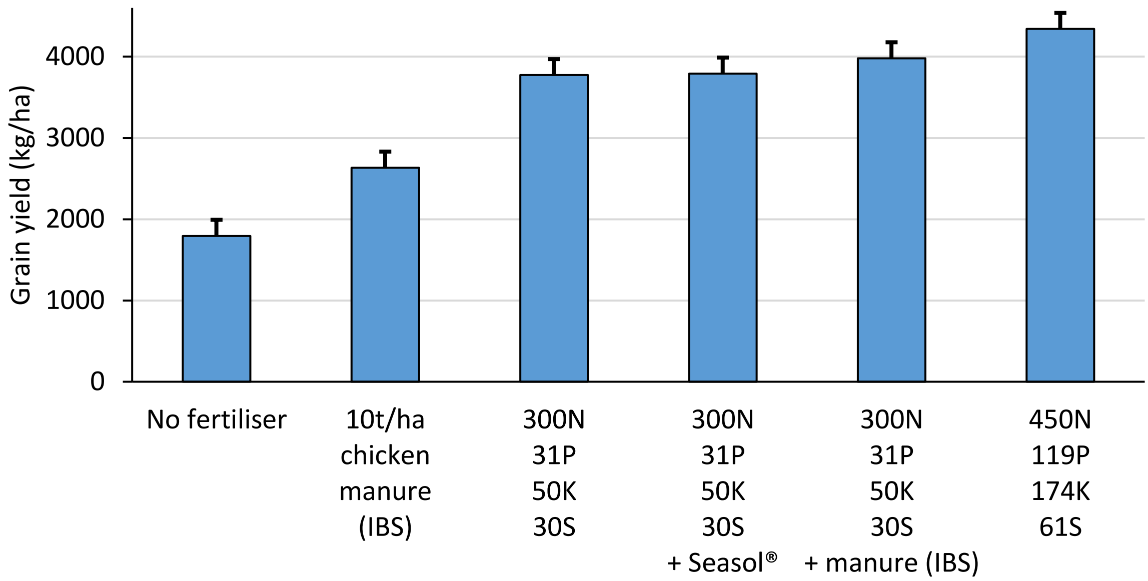

Figure 3: Grain yield (kg/ha, corrected to 8% moisture) for six supplementary treatments applied to canola at Condingup in 2022. IBS – Incorporated by sowing. Error bars indicate LSD (Treatment).

Grain quality

As expected, grain protein increased with nitrogen applications (by an average of about 0.4% protein per 50N applied), peaking at 17.7% at 250N. There was no difference in the grain protein based on P, K or S applications. The Constant Feed treatment had higher protein (18.8%) than the other supplementary treatments.

Oil concentration was inversely related to protein, reducing with increased N applications by an average 0.4% oil per extra 50N applied (from 49.0% at 100N to 47.8% at 250N). There was a general trend that higher P treatments (e.g. Double All, All) had lower oil than plots with no P applied, although treatments differed by only 0.6%.

Fertiliser ROI

Assuming an equivalent urea to canola price (e.g. $550/t for urea and canola), increasing N application from 100N to 150N increased gross income by $210/ha from $60/ha expenditure (3.5:1 return). Incrementally increasing to 200N resulted in a 2:1 return, while further increasing to 250N provided adequate yield response to pay for the fertiliser investment. Under a more pessimistic pricing scenario of urea being double the price of canola (e.g. $1100/t for urea and $550/t for canola), increasing N rate from 100N to 150N was still profitable (1.75:1), with applications over 150N either just breaking even (to 200N) or losing money (above 200N).

Applying 66 kg MAP/ha (15 kg P/ha) at seeding costs approximately $40-80 in fertiliser (based on an MAP price of $600-$1200/t). The treatments with 15P banded at seeding yielded around 150 kg/ha more than the treatments with no P applied, ensuring that costs would be covered under high fertiliser pricing and a small profit of around $40/ha with a lower MAP cost. Yield responses to applications above 15P were too inconsistent to be sure of a return in going above 15P, and although the 'Double All' treatment yielded the highest, yield responses would at best cover the expensive MAP costs for this treatment.

Figure 4: Prolonged grain filling in the Constant Feed treatment (foreground) as compared to the rest of the site (background) on 26 October 2022.

Conclusion

Based on Colwell P, the soil was not expected to be particularly responsive to phosphorus applications, although DGT-P levels were low. Treatments with no P applied at seeding were visually deficient within four weeks of seeding, and although these treatment differences diminished through the season, these plots were significantly lower yielding. The treatment with 62 P banded at seeding (Double All) had the highest average yield, indicating phosphorus was limiting growth in some treatments. Overall, yield responses to P at least covered costs or were profitable up to 15 kg P/ha while yield responses to P did not justify applications above 15 P (66 kg MAP/ha). Top-dressed MAP in late June was able to alleviate P deficiency in-season.

Soil sulfur levels were particularly low in the top 10cm, although increased below 10cm depth. Some sulfur deficiency symptoms were identified only up to the two-leaf stage, suggesting that transient sulfur deficiency was alleviated as plants took up sulfur from deeper in the profile. There was no evidence of potassium deficiency at this site.

Averaged across nutrition treatments, applying 100N resulted in a yield of 2.8 t/ha, which increased to 3.2 t/ha at 150N, 3.4 t/ha at 200N and 3.6 t/ha at 250N. Increasing N rate from 100N to 150N was profitable under both standard (similar urea and canola price) or high fertiliser pricing (urea price double that of canola), while increasing to 200N was either profitable or broke even under standard or high fertiliser pricing. Applications above 200N were not justified based on the yield responses at this site. This indicates that growers should apply at least 150 kg N/ha with 15 kg P/ha banded to maximise profitability. Although higher rates did provide some yield responses, these responses did not always justify the cost and represented increased risk especially under high fertiliser pricing.

Incorporation of chicken manure at sowing appeared to increase the vigour of plants during early growth. Compared to treatments with 300N, 31P, 50K and 30S (All and All + Seasol) that yielded 3.8t/ha, the incorporation of manure increased yield to 4.0 t/ha. When the equivalent nutrition to this treatment was applied with synthetic fertiliser across six applications from seeding to 20 July, yields were further increased to 4.3 t/ha. These responses indicate that alternative nutrition application strategies, such as applying a large quantity of a dilute phosphorus source through the topsoil at seeding (as with the manure), or applying constant top-ups of nutrition (including P) during the season, may help alleviate small deficiencies in-season and result in higher yields.

Overall, canola growers in the high rainfall zone of Esperance should consider applying at least 150kg N/ha with 15 kg P/ha to maximise profitability. Higher nitrogen and phosphorus rates (such as up to 200N and 31P) resulted in yield responses that generally covered fertiliser costs but were not always profitable. Despite the lack of sulfur response, there were some early symptoms of sulfur deficiency at this site, and generally low soil sulfur levels on the Esperance sandplain would suggest that sulfur applications should not be neglected.

The application of manure and applying high rates of synthetic fertiliser top-dressed throughout the first three months of growth improved grain yields by up to 0.5 t/ha from a very high base of nutrition (300N-31P-50K-30S), indicating that nutritional deficiencies may still be limiting yield at these high rates. These, along with unexpectedly good responses to post-emergent P applications would warrant further exploration as to whether transient nutritional deficiencies can be addressed with alternative nutrient application strategies.

Acknowledgements
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References

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Appendix A: Trial details and management

Property	Willyama, Howick WA 6450. GPS -33.681450 °S, 122.817292 ° E
Plot size & replication	2.0 m centres x 12 m sown x 6 reps
Soil type	Grey deep sandy duplex (sand over clay at ~35cm)
Sowing date	26 April 2022
Seeding rate	3.7kg/ha (to target 40 plants/m^2 at 5.24mg seed weight/190000 seeds per kg)
Variety	Nuseed Condor
Fertiliser	As per treatment list plus 27-June - 1kg/ha $CuSO_4$ + 1kg/ha $ZnSO_4$ + 4kg/ha $MnSO_4$.
Herbicides and insecticides	IBS – 1.5 L/ha SpraySeed (135g/L paraquat + 115g/L diquat) + 2 L/ha Treflan (480g/L trifluralin) PSPE – 1L/ha Pyrinex Super (400g/L chlorpyrifos + 20g/L bifentrhin) Post-em – 3-Jun 0.9kg/L Roundup Ready Herbicide with PLANTSHIELD (690g/kg glyphosate) 16-Jun – 0.9kg/L Roundup Ready Herbicide with PLANTSHIELD (690g/kg glyphosate) 12-Aug - 48 Desiccation - 03-Nov – 3L/ha Reglone (200g/L diquat) + 0.16% BS1000
Fungicides	26-April – 400ml/ha Impact (250g/L flutriafol) in-furrow 22-July – 450mL/ha Prosaro (210g/L prothioconazole + 210g/L tebuconazole) 12-August – 500mL/ha Aviator Xpro (150g/L prothioconazole + 75g/L bixafen)
Harvested	15th November 2022
Growing season rainfall (April-October)	495mm (DPIRD weather station at Mt. Howick, 10km WNW of trial site).