Canola Nutrition for the HRZ - 2021

Jeremy Curry (Research Scientist) and Mark Seymour (Senior Research Scientist)
Department of Primary Industries and Regional Development, Esperance

Key Messages

- Increasing the nitrogen rate from 100N to 150N increased canola grain yield from 1.8t/ha to 2.5t/ha, with yield plateauing at the 200N and 250N rates (2.6-2.7t/ha).
- There was an obvious response to sulfur applications at this site, with applied sulfur increasing yield by 300kg/ha with 100N applied, and by over 800kg/ha with 250N applied. There was no significant response to applied phosphorus or potassium at this site.
- With the large yield responses to nitrogen at this site, even at a theoretical 3:1 urea to canola price, applying 150N resulted in the largest gross margin.

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

With farming system and agronomic improvements increasing realised canola yields in the HRZ, there has been increasing interest in the nutritional requirements of these larger crops. While growers are increasing their rates of nitrogen (N) application in line with this increased potential, there is uncertainty as to whether other macro or micronutrients may become limiting and whether current critical soil or tissue values hold true at these higher yield potentials (3+ t/ha). In the 2020 HRZ nutrition trial, despite yields of over 3.5t/ha when 200+ units of N was applied, there was little yield response to applying more than 15 units of phosphorous, and to any applications of sulfur (S), potassium (K) or trace elements (copper, zinc and manganese) (Curry and Seymour, 2021). The 2021 trial has been located on an ameliorated (deep ripped prior to the 2019 season) sandplain soil with some minor changes to the treatments applied.

Trial Details

Property	Shepwok Downs, Gibson WA 6448. GPS 33.632563 °S, 121.901997 ° E
Plot size & replication	2.0 m centres x 10 m sown x 6 reps
Soil type	Grey deep sandy duplex
Sowing date	16 April 2021
Seeding rate	3.9kg/ha (to target 40 plants/m^2 at 5.55mg seed weight/180000 seeds per kg)
Variety	HyTTec Trifecta
Fertiliser	As per treatment list
Herbicides and insecticides	IBS – 2 L/ha SpraySeed (135g/L paraquat + 115g/L diquat) + 2 LHa TriflurX (480g/L trifluralin) + 1.1kg/ha Farmozine 900WG (900g/kg atrazine) PSPE – 1L/ha Pyrinex Super (400g/L chlorpyrifos + 20g/L bifentrhin) Post-em – 27-May – 80g/ha Factor (250g/kg butroxydim) + 1% Hasten + 190ml/ha Elantra Xtreme (200g/L quizalofop-p-ethyl) + 2% Ammend. 10-June – 1.1L/ha Farmozine 900WG (900g/kg atrazine) + 80g/ha Lontrel (750g/kg clopyralid) + 1% Hasten. 1-October – 30mL/ha Trojan (150g/L gamma-cyhalothrin) 21 October – 2.5L/ha Roundup UltraMAX (570g/L glyphosate)
Fungicides	6-July – 650ml/ha Aviator Xpro (150g/L prothioconazole + 75g/L bixafen)
Harvested	11th November 2021
Growing season rainfall (April-October)	513 mm (DPIRD weather station at Esperance Downs Research Station)

Treatments

The trial consisted of two designs, made up of a total of 39 treatments with six replicates. The main trial was comprised of nine nutrition treatments consisting of varying levels of phosphorous (P), potassium (K) and sulphur (S) that were applied across four nitrogen (N) rates (100N, 150N, 200N and 250N) in a split plot design with N rate as main plots and nutrition treatments as sub-plots. An additional three treatments that did not fit within the factorial design were nested within the trial to test the impact of nil fertiliser or higher N rates (300N and 350N).

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 15 kg N/ha. The exception to the above applications were for treatment 8 (N only) at the 0N rate which received no fertiliser, and for treatment 9 (Double All) which received 30 kg/ha of N banded (as a consequence of the high rate of MAP required to supply 62P) and hence, received no top-dressed urea at seeding.

At five weeks after seeding (21 May), 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 ten weeks after seeding (24 June), the remainder of the N requirement for each treatment was applied as urea top-dressed by hand.

Table 1: Rates of nutrients (kg/ha) applied for each of the nine nutrition treatments and the N rates to which they were applied.

Nutrition Treatment	Macronutrient rate (kg/ha)			Nitrogen rate						
	P	K	S	0N	100N	150N	200N	250N	300N	350N
1. All	31	50	30		✓	✓	✓	✓	✓	✓
2. Med P	23	50	30		✓	✓	✓	✓		
3. Low P	15	50	30		✓	✓	✓	✓		
4. Minus P	0	50	30		✓	✓	✓	✓		
5. Minus K	31	0	30		✓	✓	✓	✓		
6. Minus S	31	50	2		✓	✓	✓	✓		
7. Base	15	0	2		✓	✓	✓	✓		
8. N only	0	0	0	✓	✓	✓	✓	✓		
9. Double All	62	100	60		✓	✓	✓	✓		

Results

Seasonal conditions

After minimal December and January rainfall, 30-40mm fell each month from February to April, with 16mm on 12 April ensuring soil moisture was adequate for germination at seeding. Above average rainfall in May and June resulted in significant waterlogging at the site, with average July and August rainfall prolonging these waterlogged conditions. Over the last 20 years, only the 2005 season has received more rainfall in the April to June period and no season has recorded more April to August rainfall (Figure 1).

Site characterisation

Soil testing was conducted near seeding in 10cm increments to 60cm depth. While Colwell P levels in the top 10cm were below critical limits (Brennan and Boland, 2007), PBI was low, there was evidence of higher levels of phosphorous below 20cm and DGT-P levels were adequate (Table 2). Potassium levels of above 50mg/kg indicated responses to applied K were unlikely (Brennan and Bolland, 2006). Sulfur levels in the top 30cm indicated a response to sulfur could be expected (Brennan and Bolland, 2006).

The crop decision tool, *Select your Nitrogen*, was used to predict the response of the site to nitrogen. With the low levels (0.72%) of organic carbon present at the site, the site was expected to be very responsive to N. Based on a 3.5t/ha yield potential, from a predicted yield of 1.23 t/ha with no N applied, yield was expected to plateau at around 300 kg N/ha, with predicted yields of 2.56t/ha at 100N, 3.17t/ha at 200N and 3.40t/ha at 300N.

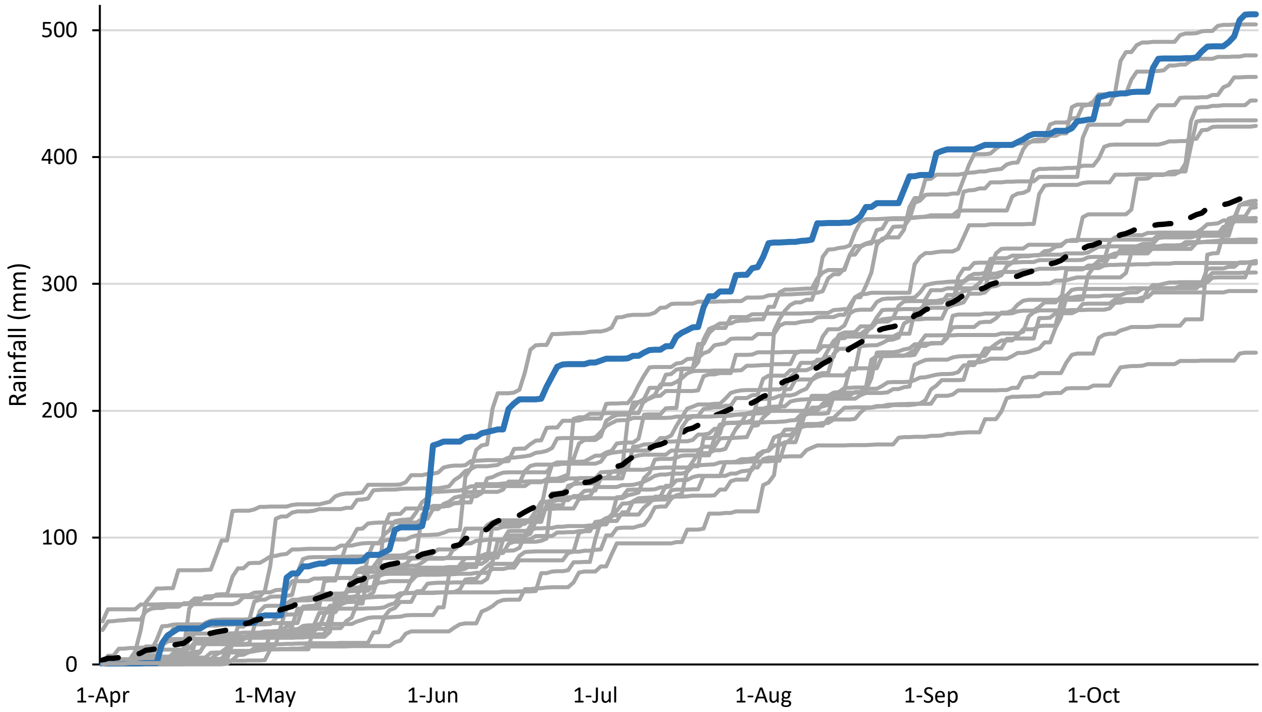

Figure 1: Cumulative growing season (Apr-Oct) rainfall from 2001-2021 at Esperance Downs Research Station (DPIRD weather station). Blue line = 2021, dotted line = average, grey lines = all other years. NB// The 2021 trial site was located 10km ESE of Esperance Downs Research Station.

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).

Soil group: Grey deep sandy duplex

Depth	0-10cm	10-20cm	20-30cm	30-40cm	40-50cm	50-60cm
pH (CaCl2)	5.1	5.2	5.0	4.9	5.3	5.6
pH (water)	6.0	6.1	5.9	5.7	6.2	6.6
P (HCO3) (µg/g)	12	9	23	19	6	2
K (HCO3) (µg/g)	59	42	31	39	36	68
N (NH4) (µg/g)	8	4	2	2	2	2
N (NO3) (µg/g)	16	9	7	6	5	3
S (µg/g)	4.1	4.8	6.9	10.5	7.5	14.5
Organic carbon (%)	0.72	0.59	0.25	0.18	0.14	0.14
PBI	10.3	10.7	17.5	23.4	28.4	61.3
Conductivity (dS/m)	0.071	0.057	0.060	0.067	0.061	0.060
Soil colour	GRWH	LTGR	LTGR	YWGR	YW	BR
Hand texture	1.5	1.5	1.5	1.5	1.5	2.5
Gravel (% by weight)	0%	0%	0%	0%	9%	52%
Aluminium CaCl2	1.25	1.24	1.87	2.56	0.66	< 0.20
DGT-P	111.72	88.28	60.94	21.09	< 5.00	< 5.00

Establishment and in-season growth

The trial was seeded into moist soil on 16 April and the first plants emerged within five days of seeding. Plant establishment counts were conducted at the 2-leaf stage with plant density averaging 47 plants/m^2, exceeding the target establishment of 40 plants/m^2. Unlike in 2020, fertiliser treatments had no impact on plant establishment, potentially as a result of increased separation between banded fertiliser and seed and a reduction in top-dressed fertiliser applied at seeding.

While the nil fertiliser treatment showed visual N deficiency symptoms from six weeks after sowing, it was not until the final post-seeding nitrogen application at ten weeks after sowing (late June) that the plots with 100N to 250N could be distinguished visually or with NDVI. The nil fertiliser plots showed delayed development (approx. 7 days delayed flowering) relative to the other plots, while flowering timing differences between 100N to 250N plots were generally insignificant.

In terms of PKS nutrition treatments, differences between treatments were not obvious prior to flowering although the 'N only' and 'Nil P' treatments were noted as potentially having reduced biomass from around eight weeks after sowing. NDVI was lower for the 'N only' plots than other treatments from six weeks after sowing, while the 'Nil P' plots had lower NDVI that was not statistically different to other treatments at six and eight weeks after sowing. Both the 'Nil P' and 'N only' plots had slightly delayed development. Following prolonged waterlogging and the onset of flowering, visual sulphur deficiency became evident (pale, discoloured flowers) around the start of August and remained evident through to harvest (re-flowering, shrivelled and aborted pods, stem reddening) (Figure 2).

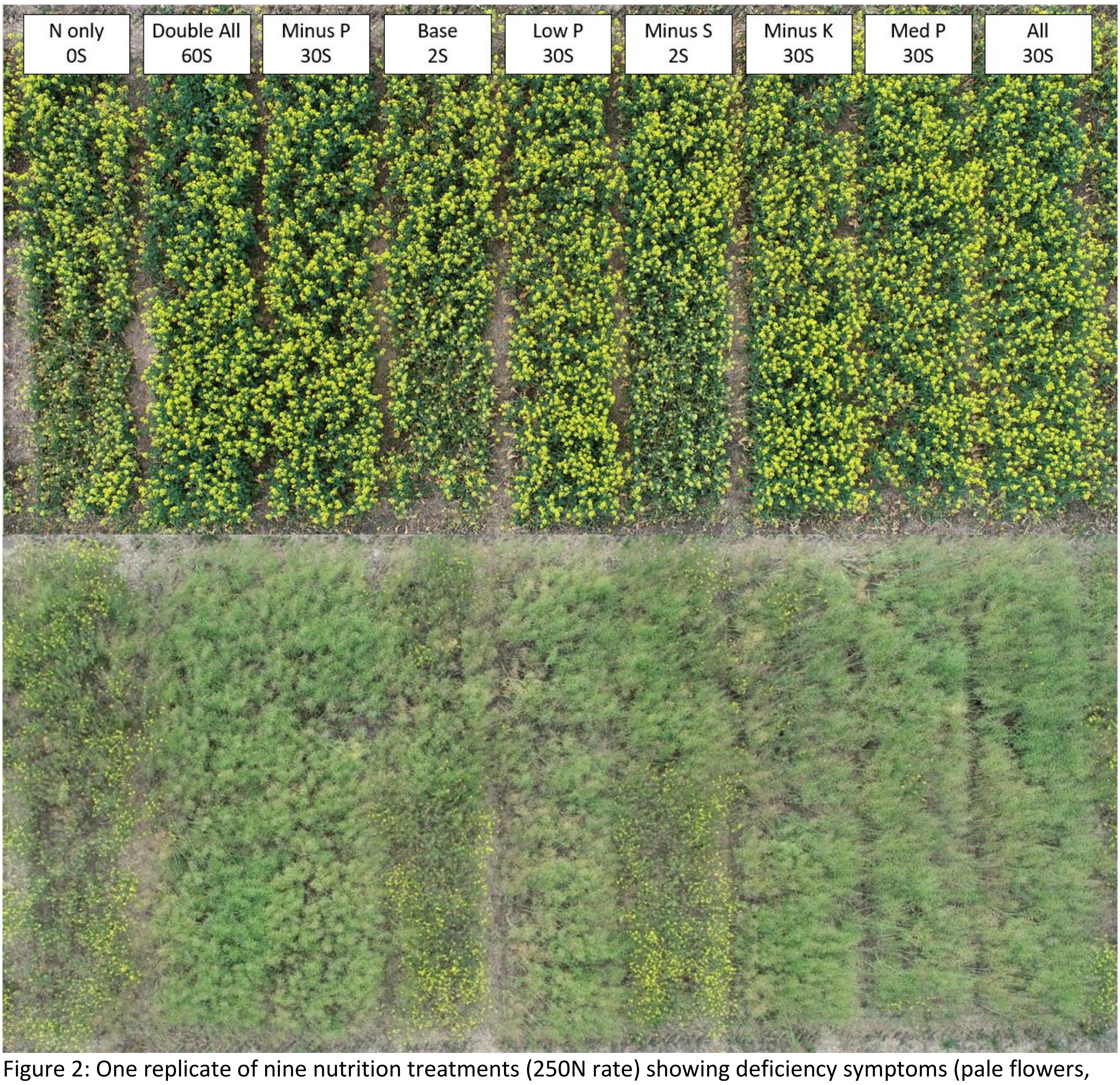

Figure 2: One replicate of nine nutrition treatments (250N rate) showing deficiency symptoms (pale flowers, reduced podding, re-flowering) in the low sulphur plots on 4 August 2021 (top) and 29 September 2021 (bottom).

Tissue testing

Tissue testing was conducted on whole top samples taken from three replicates from a subset of treatments at nine weeks after sowing (approximately eight leaves fully emerged). Plots that had received no fertiliser were deemed to be deficient in total nitrogen (3.45%), adequate for phosphorus (0.49%) and potassium (0.41%), but deficient in sulfur (0.45%). In terms of total applied nitrogen at the time of sampling, 65N increased total nitrogen to 4.50%, while applications over 100N had total nitrogen of approximately 5.50%. Interestingly, potassium levels increased with increased N application, as well as with the addition of MOP. Applications of 15 or 31P at seeding increased phosphorus to over 0.50%, while SoA applications increased sulfur to over 0.60%.

End of season canopy

There was a trend for increased height with increased N rate. From no fertiliser applied (101cm), applications of only N increased height to 112cm with 100N, up to 123cm at 250N. Lodging/leaning also increased with increasing N applications, although no plots had lodged excessively in this trial. Plots with no sulphur applied appeared to have slightly reduced lodging/leaning, potentially as a result of reduced canopy size.

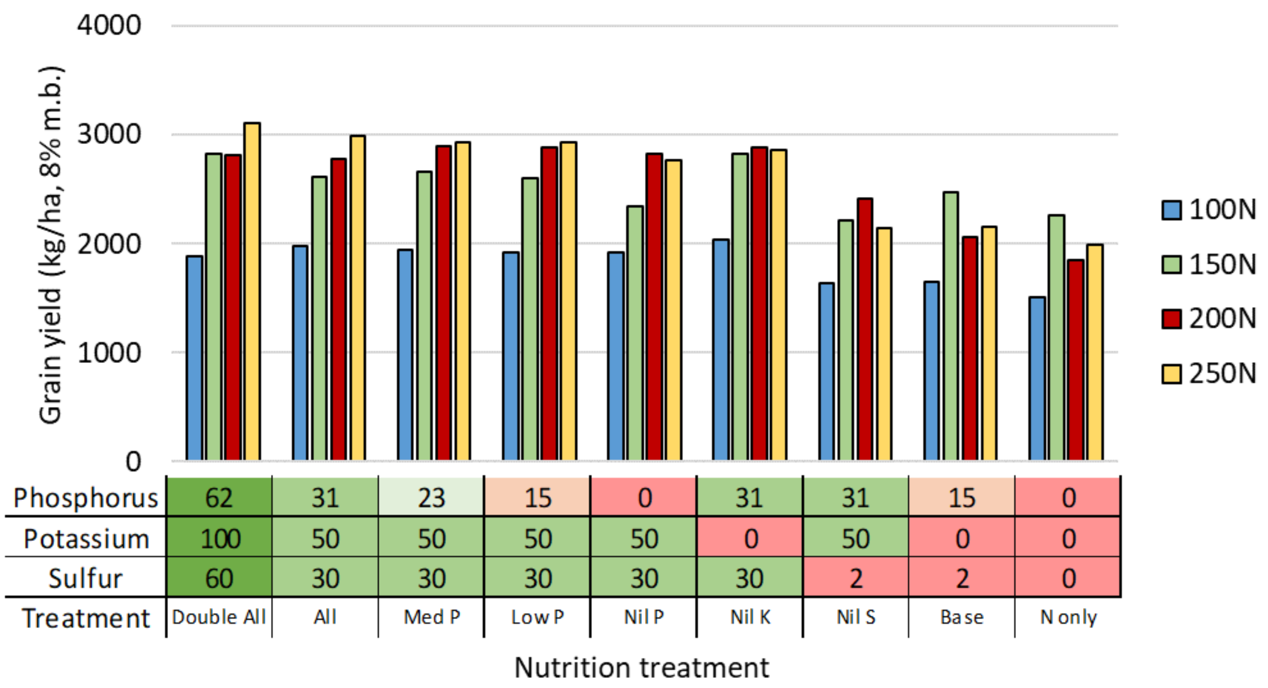

Figure 4: Canola grain yield (kg/ha, corrected to 8% moisture) of nine nutrition (variable phosphorus, potassium, sulfur) treatments across four nitrogen (N) rates at Gibson in 2021. F pr. (Nrate*Nutrition) = 0.011. LSD (0.05) = 690kg/ha (345kg/ha within same N rate).

Grain yield

Within the nutrition by N rate trial, increasing applied N from 100N to 150N increased grain yield from 1.8t/ha to 2.5t/ha, with yield plateauing at the 200N and 250N rates (2.6-2.7t/ha). Additional nitrogen rate plots at the site indicated further yield could be gained with higher N applications, peaking at 3.5t/ha at 350N, although further statistical analysis is required to assess the impact of spatial variability at the site.

It was evident that plots that received no top-up sulphur applications were significantly lower yielding than the other nutrition treatments. Applying 30S increased yield by approximately 0.3t/ha over plots that received no top-up sulfur. As N rate increased, this discrepancy also increased, with an approximate 0.8t/ha yield benefit to applied sulfur at the 250N rate (Figure 4).

Applying no P or K did not reduce yield relative to plots that received full rates of these macronutrients, while applying N only did not reduce yield relative to plots that received no sulphur top-up but did receive higher P and K rates. Applying no fertiliser at all resulted in a yield of 1.2t/ha.

Crop biomass indicated a trend towards increased biomass with increased N rate (particularly up to 150N), although variability meant this was not statistically significant (data not shown). Differences in biomass between nutrition (P, K, S) treatments appear to be less significant than differences in yield, with the 'N only' treatment standing out for reduced biomass, suggesting the yield response to sulfur was due more to conversion of biomass into yield (harvest index) rather than insufficient biomass production.

Grain quality
Increasing N applications above 150N increased grain protein and reduced oil, with 250N plots having 1.6% lower oil than 150N plots (data not shown). There was a significant effect of PKS nutrition on protein and oil, with the plots receiving no sulfur (Base, Minus S, N only) having 0.4% higher protein and 1.0% lower oil than the plots that received sulfur. Impacts of nutrition on grain weight were negligible.

Fertiliser ROI
Applications of sulphate of ammonia provided a significant return of investment in this trial, with the 120kg/ha application costing $50-80/ha (based on $400-700/t pricing) and returning 300-800kg/ha increased yield (dependent on N rate). Under long term pricing of an approximate one to one canola to urea price, there is a significant return on investment with increasing nitrogen applications up to 150N with a plateau above 150N. At a price of $550/t for both urea and canola, increasing N application from 100N to 150N increases gross income by $418 from a urea cost of $60 (7:1 return). Applications above 150N drop below a 2:1 return at this pricing. Even at a 3:1 urea to canola price (e.g. $1500/t urea, $500/t canola), increasing N application from 100N to 150N provided a $380/ha return on $163/ha urea cost (2.3:1 return).

Post-experimental modelling
Once again, *Select your Nitrogen* was used to retrospectively assess the response to N at this site. The predicted yield of no applied nitrogen (1.23t/ha) was similar to the 1.16t/ha observed in the trial (albeit sulfur may have limited yield in this treatment). With higher nitrogen applications, the modelled yields were consistently higher than the observed yields within the trial, with roughly 50kg N/ha extra N required to match the modelled yields. This may be the result of poor N uptake and efficiency in this waterlogged season.

Table 3: Modelled and actual yield (t/ha) response to increasing nitrogen rate. SYN – Select Your Nitrogen decision tool based on 3.5t/ha yield potential and 0.8% organic carbon. Actual – Yields from treatments with adequate sulfur applied.

	Nitrogen rate (kg/ha)					
	0N	50N	100N	150N	200N	250N
SYN (0.8% OC)	1.23	2.01	2.56	2.94	3.17	3.31
Actual	1.16*		1.95	2.64	2.84	2.93

*No sulfur applied.

Conclusion
With low soil organic carbon and a low frequency of legume crops, the Esperance sandplain has historically shown high responsiveness to nitrogen and based on paddock history and soil tests, this site was expected to be no exception. There was a significant 700kg/ha increase in yield as nitrogen rate was increased from 100N to 150N, with relatively minor increases from applications above 150N within the main trial. Supplemental plots at the site that received up to 350N averaged 3.5t/ha, well above the highest yielding treatment within the main trial, and further analysis is required to determine whether this truly indicated nitrogen deficiency in even the 250N plots (perhaps due to poor nitrogen uptake in waterlogged conditions) or whether it was the result of the spatially sporadic nature of waterlogging across the site.

Soil test results at seeding indicated that responses to sulfur and phosphorus were more likely than for potassium. There was a clear response to sulfur applications in this trial; compared to treatments with 30kg sulfur per hectare, treatments that received no sulfur yielded 300kg/ha lower at the 100N rate and over 800kg/ha lower at the 250N rate. There were minimal responses to phosphorus applications within this trial, despite the plots that received N only or nil P appearing to have reduced biomass (visually and with NDVI) during vegetative stages. Despite low Colwell-P in the top 10cm, DGT-P levels were reasonable, and Colwell-P levels increased at depth (20-40cm) suggesting the crop could accessed P during growth. There was no response to variable potassium rates within the trial, nor to doubling rates of phosphorus and sulphur (Double All treatment). Given the large yield responses, these nitrogen (up to 150N) and sulfur applications provided a significant return on investment even under increased prospective fertiliser prices leading into the 2022 season.

Overall, despite the challenging wet conditions, high yields were still achievable through applying adequate nitrogen (at least 150N) and ensuring that other macronutrient (particularly sulfur) deficiencies were not present. At this site, sulfur became severely limiting, particularly when nitrogen rates increased. Where soil sulfur levels are low, levels within compound or seeding fertiliser are unlikely to be adequate, particularly in a wet season, and products with higher rates of sulfur (such as with sulphate of ammonia that was used in this trial) will be required. However, such is the nature of waterlogging that in some cases it is not possible to 'feed' a crop to high yields in waterlogged conditions. This was evident in a co-located trial with HyTTec Trophy that despite having 200N and 27S applied, had top yields of 1.7t/ha, approximately 1t/ha less than reported in this trial.

For other reports related to this trial visit GRDC's on-farm trial web site at https://www.farmtrials.com.au

Acknowledgements
This experiment has been conducted through the *Optimising high rainfall zone cropping for profit in the Western and Southern Regions* project, funded by GRDC and run in collaboration by DPIRD, CSIRO and FAR Australia. DPIRD gratefully acknowledge the Whiting family and their staff for generously providing the trial site and their assistance during the season. Thanks to Chris Matthews and the Esperance RSU for trial management and Helen Cooper for her technical assistance.

References

Brennan R. F. & Bolland M. D. A. (2006) Soil and tissue tests to predict the potassium requirements of canola in south-western Australia. Australian Journal of Experimental Agriculture 46, 675-679.

Brennan R. F. & Bolland M. D. A. (2006) Soil and tissue tests to predict the sulfur requirements of canola in south-western Australia. Australian Journal of Experimental Agriculture 46, 1061-1068.

Brennan R. F. & Bolland M. D. A. (2007) Soil and Tissue Tests to Predict the Phosphorus Requirements of Canola in Southwestern Australia. Journal of Plant Nutrition, 30:11, 1767-1777.

Curry J. K. & Seymour M. (2021) Canola Nutrition for the HRZ, *Online Farm Trials*. Available at: https://www.farmtrials.com.au/trial/32517?sn=3

Contact

Jeremy Curry
Research Scientist
Department of Primary Industries and Regional Development
Jeremy.curry@dpird.wa.gov.au

Disclaimer: Please indicate any products that are registered trademarks to the first author of this article.