Canola Nutrition for the HRZ – Gibson 2022

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Key messages

- Despite similar soil P levels to the nearby 2021 trial that saw no P response, there was significant response to fertiliser P applications evident from early growth to harvest.
- While treatments with banded P increased from 3.0 to 3.5 t/ha as N increased from 100N to 250N, treatments with no applied P showed a more modest N response (from 2.5 to 2.7 t/ha).
- Applying 150N and 15P was profitable under a range of fertiliser prices, while the profitability of higher N and P rates were more dependent on fertiliser and grain prices.
- Post-emergent P applications alleviated significant deficiency in-season, while benefits to incorporation of manure or to high rates of synthetic fertiliser applied over multiple applications suggest that there may be merit to alternative nutrition strategies to address transient nutrient deficiency.

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 at Gibson), and another at Condingup, 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 (19 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 (21 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 21 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 thirteen weeks after seeding (11 May to 21 July). The total nutrients applied to 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

Following below average summer rainfall, consistent rainfall in April enabled seeding into moist topsoil albeit with minimal moisture at depth. Rainfall was slightly below average throughout the rest of autumn and the first half of winter, followed by slightly above average rainfall in July and August. These patterns resulted in infrequent periods of moisture stress but of particular importance was the lack of waterlogging at the site (a common constraint to production in this area particularly in June to August). September was slightly drier than average, followed by well above average rainfall in October and November which combined with unseasonably cool conditions provided ideal grain filling conditions.

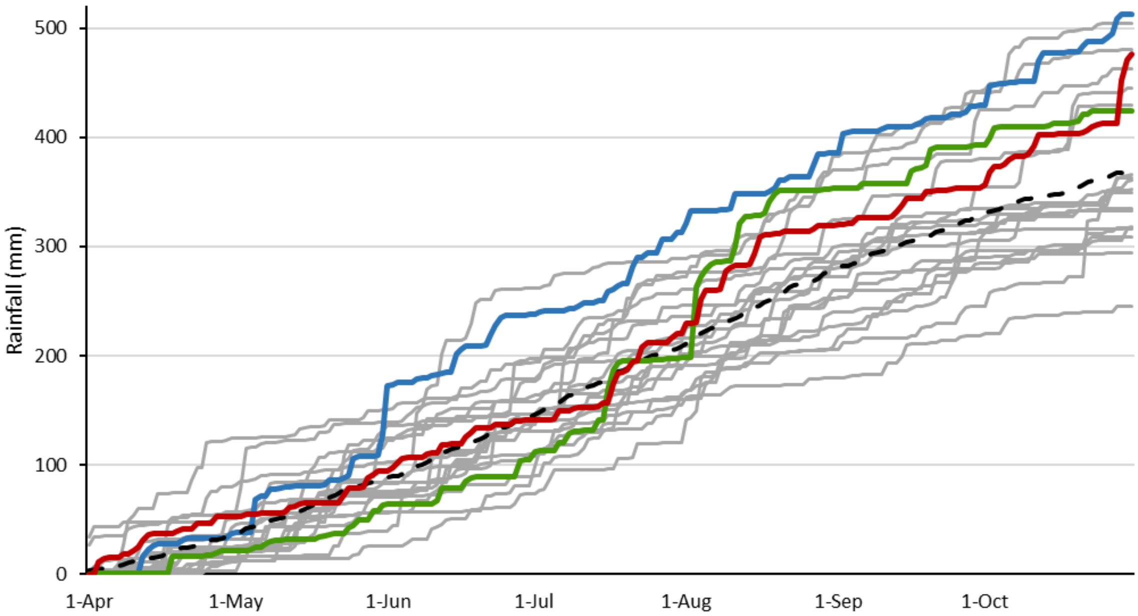

Figure 1: Cumulative growing season (Apr-Oct) rainfall from 2001-2022 at Esperance Downs Research Station (DPIRD weather station). The 2022 (red), 2021 (blue), 2020 (green) and average (black, dashed) are highlighted. NB// The 2021 and 2022 trials were located 10km ESE of Esperance Downs Research Station.

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).

Depth	**0-10cm**	**10-20cm**	**20-30cm**	**30-40cm**	**40-50cm**	**50-60cm**
pH (CaCl2)	5.3	4.9	4.9	5.3	5.5	5.9
pH (water)	6.3	5.7	5.8	6.1	6.2	6.8
P (HCO3) (µg/g)	11	18	18	7	4	3
K (HCO3) (µg/g)	46	65	46	82	131	112
N (NH4) (µg/g)	10	3	2	2	2	2
N (NO3) (µg/g)	20	9	5	4	3	2
S (µg/g)	8.6	6.1	5.6	8.9	11.1	14
Organic carbon (%)	1.35	0.66	0.51	0.46	0.34	0.35
PBI	18	17	27.4	39.9	73.1	117
Conductivity (dS/m)	0.099	0.063	0.046	0.045	0.04	0.043
Soil colour	GR	LTGR	LTGR	BRGR	BRGR	BROR
Hand texture	2.0	2.0	2.0	2.0	2.0	2.0
Gravel (% by weight)	1%	7%	40%	52%	50%	54%
Aluminium CaCl2	1.56	2.3	2.61	0.73	0.27	< 0.20
DGT-P	52.37	47.06	18.98	< 5.00	< 5.00	< 5.00

Site characterisation

The site was located on a deep sandy duplex with sand above gravel (commencing at 30-50cm). Soil testing was conducted immediately after seeding at 10cm increments to 60cm depth. Colwell P was low in the top 10cm, slightly increasing to 30cm and PBI, while generally very low, gradually increased with depth (Table 2). DGT-P was moderate near the surface. While Colwell-P in the top 10cm is low and would indicate a likely P response (Brennan and Bolland, 2007), the increasing level in the shallow subsoil creates uncertainty around soil supply. Potassium levels were moderate to high (low response expected), while sulfur levels were generally low, indicating a likely response to sulfur (Brennan and Bolland, 2006).

Establishment and in-season growth

The crop was seeded into moist soil on 22 April, with the first plants emerging within six days. Plant establishment (as measured at the one- to two-leaf stage) averaged 44 plants m^{-2}, slightly exceeding the target of 40 plants m^{-2}. There were no significant treatment effects, although the manure plots appeared to have slightly larger plants at this early stage.

The nil fertiliser treatment (B1) showed visual N deficiency from six weeks after sowing (four- to five-leaf stage, early June), while the manure only treatment (B2) also showed some N deficiency (albeit to a lesser extent) at this stage. There were minimal visual effects of N rate (100N to 250N) during vegetative growth stages. NDVI recordings taken every two weeks during vegetative growth picked up only very small differences across these N rates and only on 30 June and 13 July.

Figure 2: Treatment B6 (left) 231N-102P-80K-24S to date. Treatment B5 (right) 165N-31P-50K-30S + 10t/ha chicken manure (IBS) to date. Photos taken 01 June 2022.

The effects of variable phosphorus applications were evident within four weeks of sowing, with the treatments that received no P at seeding looking less vigorous; this was also detected with NDVI (data not shown). By early June, nil phosphorus plots were delayed in leaf emergence by one leaf and this delayed growth persisted through the vegetative stage. In contrast, plots that received manure IBS at seeding (B2 and B5) appeared to have slightly advanced early plant growth (up to early June, six weeks after seeding), even compared to higher fertiliser treatments (Figure 2). The Late P treatment received phosphorus (top-dressed as MAP) on 21 June, eight weeks after seeding; by the start of flowering (four weeks later), this treatment showed enhanced biomass (as detectable by NDVI) compared to the plots that had received no phosphorus. There were no visible S or K deficiencies identified during growth.

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 (%) was lowest in the N only and Minus P treatemnts (0.41-0.44%) and highest in the Constant Feed treatment (0.73%). Plots that received manure only (treatment B2) had an equivalent phosphorus concentration to plots that received 31P (as MAP) banded at seeding (treatment A2). Plant size responses to phosphorus likely interacted with sulfur intake, with sulfur concentration (%) being lowest (0.50%) in plots that received P at seeding but no supplemental sulfur (treatment A4) and highest (0.83%) in plots that received supplemental sulfur but with no P applied at seeding (treatment A5). Potassium was above 4% for all treatments and was highest (5.76-5.97%) in the plots that received manure (B2 and B5) and lowest (4.56%) in the plots with no applied fertiliser. Total nitrogen was lowest (5.9%) in the plots that received no supplemental urea (B1 and B2). Overall, macronutrient concentrations exceeded critical values in all treatments, despite differences between treatments.

End of season canopy

As expected, plant height increased with increasing N rates, while plots that received no phosphorus had reduced height relative to the other treatments (data not shown). The Late P treatment was equivalent in height to plots that received P at seeding. Lodging was generally not an issue in the trial but did increase at higher N rates (with applied P). Treatments B5 and B6 had the greatest level of lodging and were the only treatments to have a level of lodging that would be of concern (in terms of yield effects or reducing harvest efficiency).

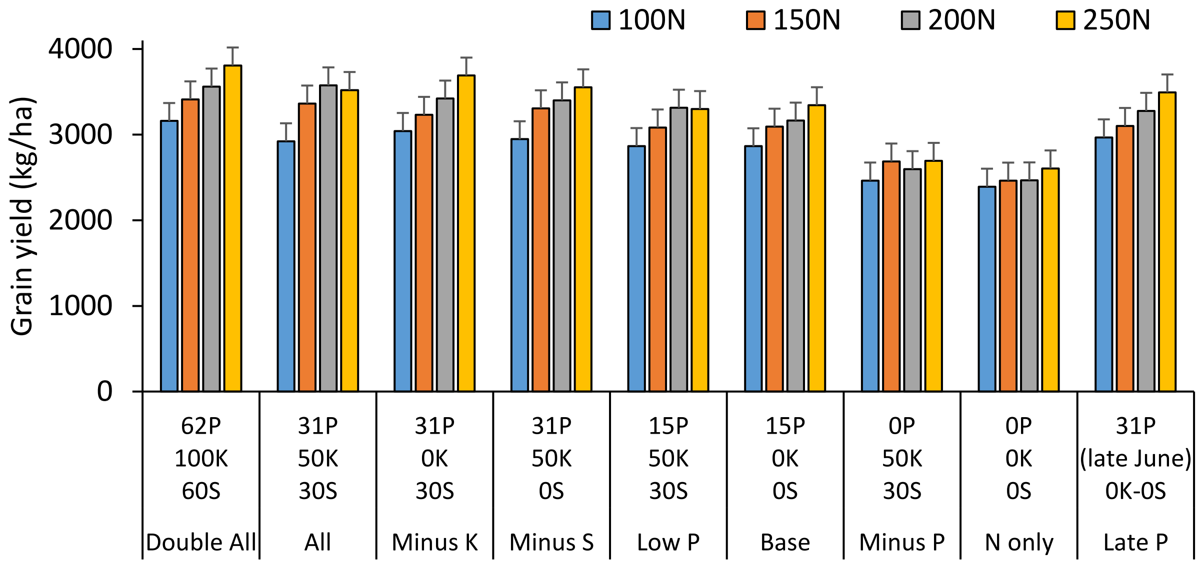

Figure 3: Grain yield (kg/ha, corrected to 8% moisture) for nine nutrition treatments at four nitrogen rates applied to canola at Gibson in 2022. Errors bars indicate LSD (Nrate*Nutrition).

Grain yield

There were significant yield responses to both N and P applications in this trial but no significant responses to sulfur or potassium applications (Figure 3). In treatments with at least 15 kg P/ha applied at seeding, increasing applied N from 100N to 150N increased yield from 3.0t/ha to 3.2t/ha, increasing to 3.4t/ha at 200N and 3.5t/ha at 250N.

The treatments with no P applied (treatments A5 and A9) were the lowest yielding at all N rates. With 100N applied, nil P treatments yielded 2.4t/ha, compared to 2.8-3.2t/ha across all the other treatments. As N rate increased, so did the difference between P treatments. At the 250N rate, nil P treatments yielded 2.6-2.7t/ha, compared to 3.3-3.8t/ha across the other treatments.

Compared to applying 15P (A3 and A4), applying 62 kg P/ha (A1) resulted in higher yields across all N rates, while applying 31 P at seeding (A2, A6, A7) generally increased yield when N rates exceeded 100N. Applying 62 kg P/ha generally yielded similarly to treatments that received 31 P at seeding (A2, A6, A7). The application of P top-dressed eight weeks after seeding (A8) alleviated P deficiency and resulted in yields equivalent to where the same rate of P was applied banded at seeding (A2, A6, A7).

Incorporation of 10t/ha chicken manure at seeding increased grain yield from 2.0t/ha with no fertiliser, up to 2.8t/ha (Figure 4). The addition of 10t/ha chicken manure IBS to high rates of synthetic fertiliser (B5) also resulted in an increase in grain yields (by 0.3t/ha compared to B3) but yielded the same as the treatment containing equivalent nutrition applied as synthetic fertiliser (B6).

Crop biomass increased with nitrogen rate and phosphorus rate and nutrition responses were generally similar to that which occurred for yield (data not shown). The exception was that treatments with no P application showed reduced in biomass to a greater extent than for yield, suggesting that they slightly compensated for this reduced biomass with improved conversion of biomass into yield (harvest index).

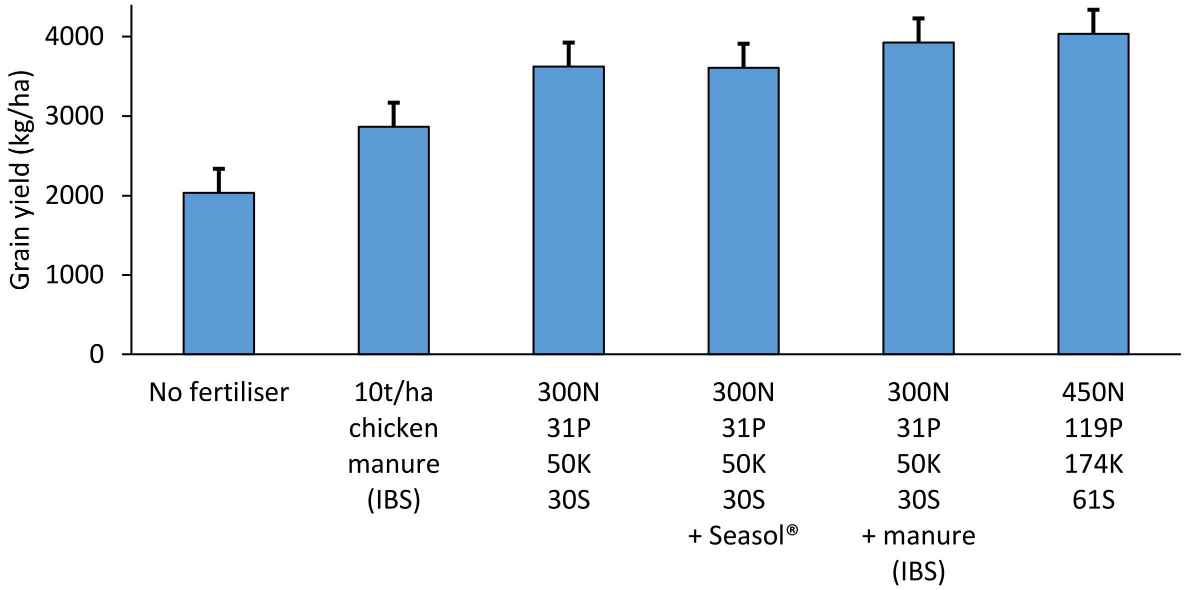

Figure 4: Grain yield (kg/ha, corrected to 8% moisture) for six supplementary treatments applied to canola at Gibson in 2022. IBS – Incorporated by sowing. Error bars indicate LSD (Treatment).

Grain quality

As expected, grain protein increased with nitrogen applications (by an average of about 0.5% protein per 50N applied) and was highest (20.2%) in the Constant Feed treatment (B6). Plots that received no phosphorus had an elevated level of protein relative to plots that received phosphorus, highlighted by the plots that received manure only (B2) having 1.2% lower grain protein than the plots that received no fertiliser at all (B1).

Oil concentration was inversely related to protein, reducing with increased N applications by an average 0.5% oil per extra 50N applied (from 47.9% at 100N to 46.3% at 250N). Plots with no P applied generally had lower oil than plots that received P, although this was inconsistent across N rates.

Grain weight was influenced by nutrition, with plots that received nil (A5) or low (A3) P rates with otherwise adequate nutrition slightly reduced grain weight, and the higher P rates (A1) having higher grain weight. When other nutrition was not adequate (A4 and A9), grain weight was less impacted by low or nil applied phosphorus. This was highlighted in the supplementary treatments by the nil fertiliser and manure only treatments (B1 and B2) having higher grain weight than those with adequate all-round nutrition (B3 and B4), while excessive nutrient supply (B5 and B6) significantly increased grain weight.

Fertiliser ROI

Treatments that received no phosphorus showed a small yield response to increases in N rate, therefore, gross income was also relatively flat and gross margins reduced as N rates increased (due to the cost of the nitrogen).

Where P was applied, however, there was a positive yield response to increasing N rates and this resulted in an increase in gross income. Under equivalent urea to canola prices (e.g. $550/t for urea and canola), increasing N application from 100N to 150N increased gross income by $152/ha from $60/ha expenditure ($2.50 return for each $1 invested). Increasing applications above 150N (to 200N or 250N) resulted in yield increases that would cover the cost of the nitrogen but with only small profit. Under a 2:1 ratio of urea to canola price (e.g. $1100/t for urea and $550/t for canola), increasing N application from 100N to 150N cost $120/ha for a $152/ha return ($32/ha profit), while applications above 150N did not provide adequate yield improvements to cover the cost of nitrogen.

Returns from phosphorus (MAP) applications were evident in this trial. At a canola price of $550/t, applying 66 kg/ha MAP (15 kg P/ha) at seeding increased gross income by $267-$422/ha relative to treatments that received no MAP. This easily covers the $40-$80/ha input cost (based on an MAP price of $600-$1200/t). Increasing MAP applications up to 136 kg/ha (at an additional $40-$80/ha) increased gross income by $66-$157/ha (increasing at higher N rates), indicating that higher P rates become more profitable when applied in tandem with higher N rates.

Conclusion

Colwell-P in the top 10cm indicated a likely phosphorus response at this site, although there was an increase in Colwell P in the shallow subsoil which produced some uncertainty as to the phosphorus supply of the soil. Responses to banded P applications were evident within four weeks of seeding and these P responses persisted throughout the season. While treatments with banded P increased from 3.0 to 3.5 t/ha as N increased from 100N to 250N, treatments with no applied P showed reduced yield potential and a more modest N response (from 2.5 to 2.7 t/ha).

While the P responses in this 2022 trial were not unexpected based on soil test results, they were in stark contrast to the responses of the 2021 trial that was located just 3km away in a paddock with similar soil test results and cropping history. While PBI was slightly lower in 2021, the other large contrast was the extremely wet conditions during vegetative growth in 2021 compared to 2022. Growth during May and June 2021 was constrained by constantly wet topsoil, which along with reducing yield potential may also have enabled greater root exploration and P uptake than in 2022. While 2022 still had reasonable early rainfall, it is possible that sporadic periods of dry topsoil conditions could have constrained soil P uptake, resulting in a greater reliance on fertiliser P supply.

Despite soil sulfur levels being low (less than 10mg/kg S in the top 30cm), there were no visual symptoms or yield responses to sulfur applications. Tissue testing confirmed sulfur applications had been taken up by the plant and increased tissue concentration. Potassium was expected to be sufficient and there was no response to K despite changes in tissue concentration of K with fertiliser applications.

Assuming no other macronutrient deficiencies, increasing N rates from 100 kg N/ha to 150 kg N/ha was profitable under high or neutral urea to canola prices. Going above 150 kg N/ha provided yield increases that covered urea costs under neutral urea to canola prices but reduced gross margin under higher fertiliser prices. Applying 15 kg P/ha (66 kg MAP/ha) was highly profitable, while applying 31 kg P/ha (136 kg MAP/ha) increased gross income when coupled with high N rates. This suggests that growers should apply at least 150 kg N/ha with 15 kg P/ha banded to maximise profitability, while higher rates (e.g. 250N or 31P) were most profitable when both macronutrients were increased in tandem.

An attempt to correct phosphorus deficiency in-season was made by substituting some urea for MAP (total of 31 kg P/ha) during top-dressing on 21 June. Within one month of this application, the Late P treatment had increased biomass compared to treatments with no P. Despite the late application, the Late P treatment had the same yield as treatments with 31P applied banded at seeding. While sandy soils with low PBI and consistent rainfall likely assisted P release and uptake, this result was largely unexpected given that banding P is recommended practice.

Incorporation of chicken manure at sowing increased the early vigour of these treatments compared to all other fertiliser treatments. Phosphorus and potassium tissue concentration, in particular, were increased when measured at the six-leaf stage. This manure increased yield by 304 kg/ha relative to a high rate of synthetic fertiliser (300N-31P-50K-30S), although this yield response was matched when equivalent nutrition was applied as synthetic fertiliser throughout vegetative growth. The improved early vigour of the manure plots, as well as the prolonged grain filling of the Constant Feed plots, even in some very high fertiliser scenarios (e.g. '300N All' treatment), nutrient deficiency is still limiting yield. These deficiencies might be able to be alleviated with alternative nutrition sources and application strategies. The early response to manure may be the result of improved distribution of P, in this case through incorporating a high rate of a dilute source throughout the topsoil. Additionally, the post-emergent P applications (such as in treatments A8 and B6) might provide benefits in improve plant P concentration and avoiding deficiency during growth.

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. The profitability of higher rates of P and N were reliant on fertiliser pricing but were most profitable when increased in tandem. There was no response to S or K fertiliser applications, but low soil sulfur levels and large responses in the 2021 trial suggest that sulfur applications should not be neglected, even as insurance. Interesting responses to manure, post-emergent P applications and multiple applications of high rates of fertiliser rates indicate nutritional deficiencies that might be able to be profitably addressed, and these may be the target of future work.

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 through 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

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Appendix A: Trial details and management

Property	Shepwok Downs, Gibson WA 6448. GPS -33.633626°S, 121.869946° E
Plot size & replication	1.9 m centres x 10 m sown x 6 reps
Soil type	Grey deep sandy duplex (gravel at 30-50 cm)
Sowing date	22 April 2022
Seeding rate	3.9kg/ha (to target 40 plants/m^2 at 5.49mg seed weight/180000 seeds per kg)
Variety	HyTTec Trifecta
Fertiliser	As per treatment list plus 23-June - 1kg/ha CuSO4 + 1kg/ha ZnSO4 + 4kg/ha MnSO4.
Herbicides and insecticides	IBS – 2 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 – 27-May – 75mL/ha Verdict 520 (520g/L haloxyfop) + 330mL/ha Select Xtra (360g/L clethodim) + 1.1kg/ha Atragranz (900g/kg atrazine) + 0.5% Uptake (582g/L paraffinic oil + 240g/L alkoxylated alcohol non-ionic surfactants) + 1% ammonium sulphate. Desiccation - 18-November – 3L/ha Reglone (200g/L diquat) + 0.16% BS1000
Fungicides	22-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	29th November 2022
Growing season rainfall (April-October)	471 mm (DPIRD weather station at Esperance Downs Research Station, 10km WNW of trial site).