Legacy effects of canola nutrition on a sandy duplex in the high rainfall zone of Western Australia

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Key Messages

- Residual effects of high rates of nitrogen, sulfur and phosphorus applied to canola could be detected in soil tests prior to seeding wheat in the following season.
- Nitrogen applied to the wheat crop had a much larger impact (1 t/ha grain yield increase) than carryover effects of nitrogen applied to the canola crop (up to 0.6% grain protein concentration increase).
- Phosphorus rates applied to canola influenced the yield of the following wheat crop only when no P was applied to the wheat, with no difference in yield when 27 kg P/ha was applied at seeding of the wheat.
- Growers in WA's high rainfall zone are unlikely to see meaningful carryover effects in the cereal phase from high rates of nutrition applied to canola the year prior. They should, therefore, continue to focus on expected responses in the current year only when determining the most profitable rates of fertiliser to apply to their crops.

Background

With amelioration of subsoil constraints having significantly increased yield potential and reduced seasonal variability (such as through waterlogging), canola growers in Western Australia are more willing to apply higher rates of fertiliser to maximise the yield potential of their canola crops (DPIRD, 2019). However, there is little understanding of the legacy effects of high or low fertiliser applications in a farming system context, and whether residual nutrition from fertiliser applications made to canola should impact nutrition strategies for the following cereal.

Recent work conducted in eastern Australia has demonstrated that N management strategies that maintain a neutral to positive nitrogen balance across seasons are most profitable based on nitrogen being carried over to future seasons (Hunt et al. 2021). High rates of fertiliser are often applied to crops in Western Australia's high rainfall zone, although seasonal variability (particularly waterlogging) can drastically influence the yield and nutrient removal. This, along with other risk factors of soils being typically sandy with low organic carbon with high leaching potential suggest nutrient carryover will be smaller than that observed in the east of Australia.

A canola nutrition trial established on the Esperance sandplain demonstrated significant responses to nitrogen, but minimal response to the application of other macronutrients (Curry and Seymour, 2021). There remains the question of how much of the excess nutrition applied in 2020 will be accessible in the soil in the following crop in 2021. Therefore, this trial aims to assess whether fertiliser applied nutrition can provide value to the following crop on sandy soils in the HRZ of WA.

Aim

To investigate whether residual soil nutrition from canola grown with high fertiliser inputs should influence nutrition strategies in the following wheat crop.

Trial details and management

A small plot field trial (20m by 6 seeding rows per plot) was established on the Esperance sandplain at Gibson in 2020. Rates of nitrogen, phosphorus, potassium and sulfur fertiliser were applied to canola and harvested by a small-plot harvester to determine the impact of nutrition on crop growth, yield and quality (Curry and Seymour, 2021).

In April 2021, soil testing was conducted within the plot area of six treatments from 2020 representing a range of P and N rates. Sampling was conducted in 10cm increments to 30cm depth (30 sample composite in top 10cm, 10 sample composite 10-20cm and 20-30cm).

On 25 May 2021, wheat (cv. Scepter) was sown directly into the same plot layout, with each plot split into sub-plots (10m by 6 seeding rows) and treated with two rates of nitrogen (50 kg N/ha or 110 kg N/ha) or phosphorus (0 kg P/ha or 27 kg P/ha) (Table 1).

For the nitrogen experiment and the high P treatment in the phosphorus experiment, 200 kg/ha Summit Vigour Rich (total of 21N, 27P, 20K and 10S) was banded below the seed. The low P treatment in the phosphorus experiment received 49 kg/ha of sulphate of potash, 7 kg/ha of sulphate of ammonia, and 42 kg/ha of urea banded (total of 21N, 0P, 20K and 10S). All plots also received 100 kg/ha sulphate of potash (total of 42K and 17S) top-dressed at seeding.

Plants emerged within 10 days of seeding and plant establishment was uniform across the site., Nitrogen treatment differences were applied six weeks after sowing (09 July), with 63 kg/ha or 194 kg/ha urea top-dressed to supply 29 kg N/ha or 89 kg N/ha respectively. The phosphorus experiment received 89 kg N/ha top-dressed as urea.

Table 1: The rates (kg/ha) of nitrogen (N), phosphorus (P), potassium (K), sulfur (S) and trace elements (TE) applied in 2020 (canola) and 2021 (wheat).

Phosphorus Experiment	2020 treatment details					2021 treatment details		
	Trt	P	K	S	TE[1]	Trt	P	Other nutrition
Treatments #1 to #4 (containing 15 kg P/ha to 93 kg P/ha) were applied across three N rates (100N, 200N, 300N) in 2020. Two P rates were applied in 2021 (0 kg P/ha and 27 kg P/ha).	#1	15	50	31	Y	High P	27	110N, 61K, 28S
						Low P	0	
	#2	31	50	31	Y	High P	27	
						Low P	0	
	#3	62	99	62	Y	High P	27	
						Low P	0	
	#4	93	149	93	Y	High P	27	
						Low P	0	

Nitrogen Experiment	2020 treatment details					2021 treatment details		
	Trt	P	K	S	TE[1]	Trt	N	Other nutrition
Treatments #5 to #8 were applied across four N rates (15N, 100N, 200N and 300N) in 2020. Two N rates were applied in 2021 (50 kg N/ha and 110 kg N/ha).	#5	31	0	31	Y	High N	110	27P, 61K, 28S
						Low N	50	
	#6	31	50	2	Y	High N	110	
						Low N	50	
	#7	31	50	31	N	High N	110	
						Low N	50	
	#8	15	0	2	N	High N	110	
						Low N	50	

[1]Trace elements – 200g/ha copper, 355g/ha zinc, 1270g/ha manganese.

Results

Table 2: Soil test results (sampled May 2021) from six of the 2020 nutrition treatments of varying nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) rates.

Depth	2020 Nutrition	pH (CaCl2)	Ammonium Nitrogen	Nitrate Nitrogen	Total Nitrogen	Organic Carbon	Conductivity
0-10cm	0N - 0P - 0K - 0S	5.3	14.3	18.3	0.11	1.24	0.09
	15N - 31P - 50K - 31S	5.4	14.0	17.3	0.12	1.24	0.10
	100N - 31P - 50K - 31S	5.3	16.3	17.3	0.12	1.39	0.10
	200N - 31P - 50K - 31S	5.3	13.0	22.0	0.11	1.13	0.11
	300N - 31P - 50K - 31S	5.3	14.7	23.3	0.13	1.24	0.11
	300N - 62P - 99K - 62S	5.2	16.7	25.3	0.12	1.33	0.12
10-20cm	0N - 0P - 0K - 0S	4.7	4.3	7.0	0.05	0.65	0.04
	15N - 31P - 50K - 31S	4.8	5.3	8.0	0.06	0.68	0.05
	100N - 31P - 50K - 31S	4.7	4.3	10.0	0.06	0.84	0.07
	200N - 31P - 50K - 31S	4.8	5.0	11.7	0.06	0.68	0.07
	300N - 31P - 50K - 31S	4.8	4.3	14.0	0.06	0.79	0.07
	300N - 62P - 99K - 62S	4.8	4.7	15.7	0.06	0.82	0.08
20-30cm	0N - 0P - 0K - 0S	4.8	3.3	5.7	0.04	0.61	0.04
	15N - 31P - 50K - 31S	4.8	3.0	4.3	0.04	0.53	0.04
	100N - 31P - 50K - 31S	4.8	2.3	4.3	0.04	0.52	0.04
	200N - 31P - 50K - 31S	4.7	2.0	5.7	0.04	0.42	0.04
	300N - 31P - 50K - 31S	4.8	2.7	6.0	0.03	0.53	0.04
	300N - 62P - 99K - 62S	4.9	3.3	5.7	0.05	0.57	0.05
Depth	**2020 Nutrition**	**Colwell P**	**Colwell K**	**Sulfur**	**PBI**	**DGTP**	
0-10cm	0N - 0P - 0K - 0S	13.0	49.3	8.9	13.7	107	
	15N - 31P - 50K - 31S	15.7	65.0	11.6	11.3	142	
	100N - 31P - 50K - 31S	15.7	81.0	11.9	9.0	140	
	200N - 31P - 50K - 31S	15.7	68.7	11.7	9.8	124	
	300N - 31P - 50K - 31S	17.7	68.7	12.8	14.0	123	
	300N - 62P - 99K - 62S	20.7	74.7	14.7	12.2	140	
10-20cm	0N - 0P - 0K - 0S	18.0	40.3	4.5	16.4	65	
	15N - 31P - 50K - 31S	18.0	40.7	5.1	14.5	78	
	100N - 31P - 50K - 31S	20.3	42.7	7.2	12.5	72	
	200N - 31P - 50K - 31S	19.3	43.0	7.9	13.1	67	
	300N - 31P - 50K - 31S	19.3	37.0	5.5	15.3	46	
	300N - 62P - 99K - 62S	22.0	41.0	8.4	15.7	83	
20-30cm	0N - 0P - 0K - 0S	18.3	55.0	5.5	20.6	31	
	15N - 31P - 50K - 31S	20.7	52.7	6.0	23.1	48	
	100N - 31P - 50K - 31S	22.7	69.0	8.3	29.1	17	
	200N - 31P - 50K - 31S	18.3	49.0	5.5	28.0	18	
	300N - 31P - 50K - 31S	16.0	63.3	6.9	30.6	13	
	300N - 62P - 99K - 62S	19.3	62.0	11.4	27.4	17	

Seasonal conditions and soil testing

The 2021 season was particularly wet, receiving 475mm of growing season (May to October) rainfall, compared to 334mm average over the previous 19 years (2002-2020).

Rates of nitrogen applied to the 2020 trial made minimal difference to ammonium or total nitrogen levels in the soil, although nitrate nitrogen levels in the top 20cm increased from high N treatments (Table 2). Conductivity was also increased by N rate.

While Colwell P in the top 10cm appeared to increase at high P application rates from the 2020 trial, the DGT-P levels were more variable between 2020 P rates and between replicate plots sampled. The mobility of sulfur was evident with the high and low sulfur plots in 2020 showing high and low levels respectively in the soil at all depths to 30cm. Although Colwell K had been reduced in the nil fertiliser plot in the top 10cm, there was minimal impact of applying more than 50K on Colwell K levels.

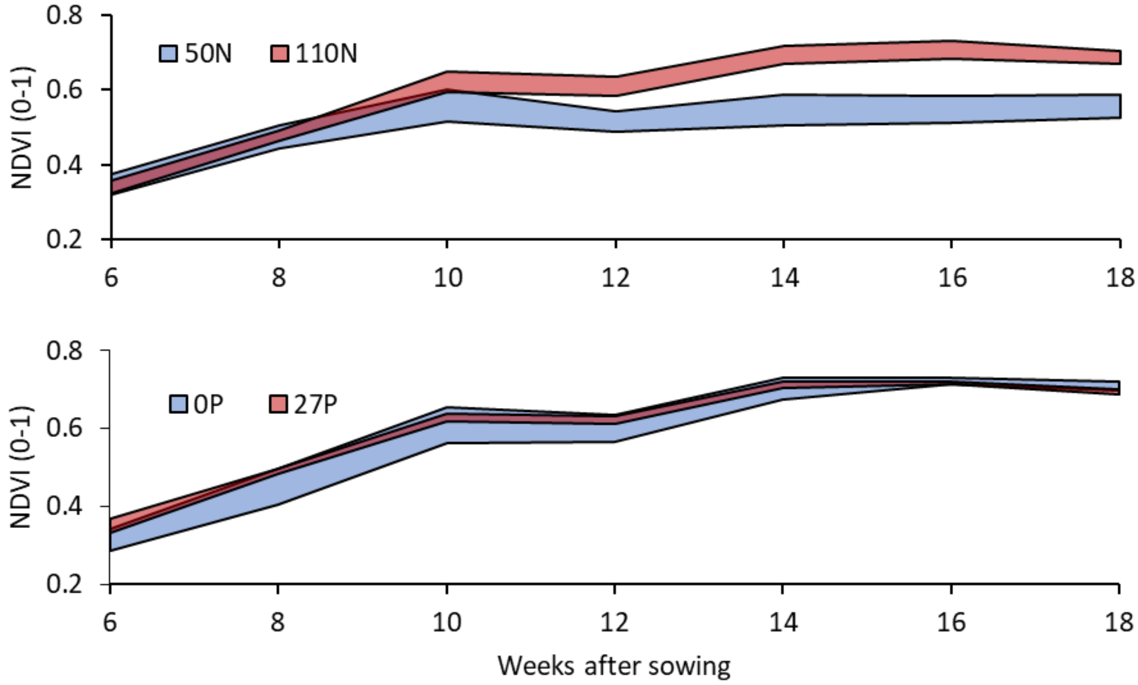

Figure 1: (Top) Range (shaded area) of normalised difference vegetative index (NDVI, 0-1) values of wheat across four nitrogen (N) treatments applied to canola the previous year (15 kg N/ha to 300 kg N/ha). 50 kg N/ha (blue) or 110 kg N/ha (red) was applied to the wheat crop at six weeks after sowing.
(Bottom) Range (shaded area) of NDVI (0-1) values of wheat across four phosphorus (P) treatments applied to canola the previous year (15 kg P/ha to 93 kg P/ha). 0 kg P/ha (blue) or 27 kg P/ha (red) was applied to the wheat crop at seeding.

Effect of carryover nitrogen
Plant growth was assessed visually and as NDVI (using handheld GreenSeeker) throughout the season. Effects of nitrogen rates applied in 2020 were observed from early July (as the 2021 N treatments were being applied), which was confirmed with NDVI. Within four weeks, 2021 N applications became extremely visually evident and NDVI differences were highly significant, while any effect of 2020 N application had dissipated (NDVI values were no longer statistically different). NDVI detected significant effects of 2021 N rates for the rest of the season.

Grain yield in this trial averaged 4.7 t/ha across all treatments, with a significant effect of N rate applied in 2021, with an increase in grain yield from 4.1 t/ha to 5.1 t/ha as N rate was increased from 50N to 110N. Interestingly, 2020 nutrition treatment 8 yielded 140-170 kg/ha less than treatments 5 and 6 ($p=0.045$), despite the high rates of P, K and S applied to cover any residual effects of these treatments.

Grain protein averaged 10.35%, with a significant linear trend of 2020 N rate treatments and significant effects of 2020 nutrition and 2021 N rate. Applying 110N in 2021 resulted in lower protein (10.19%) than where 50N was applied (10.51%). The high N treatment produced more protein produced on a ‘per area’ basis (grain protein yield) but was diluted by greater grain production.

Wheat plots sown where 300 kg N/ha was applied to canola in 2020 recorded a grain protein concentration of 10.68%, significantly higher than where 15 kg N/ha was applied (10.11%).

Physical grain quality was mainly influenced by nitrogen applied in 2021, with a statistically significant (albeit not biologically significant) reduction in hectolitre weight (-0.41 kg/hL), grain weight (-2.0mg) and an increase in screenings (+0.1%).

Effect of carryover phosphorus

Crop growth effects of phosphorus nutrition applied in 2020 and 2021 were detected visually from early July (six weeks after sowing) until August (ten weeks after sowing), with more obvious responses to P applied in 2021 where lower P was applied in 2020. These observations were confirmed with NDVI measurements, with interactions between 2020 and 2021 P rates until mid-August (Z32, second node), at which point the 2021 P treatments were no longer statistically different. NDVI did not detect any differences between treatments after August (booting onwards).

Grain yield averaged 5.1 t/ha. Compared to applying no P in 2021, applying 27 kg P/ha increased grain yield by just over 0.2 t/ha. Treatment 4 from 2020 (93 kg P/ha) yielded 0.3 t/ha more than treatment 1 (15 kg P/ha in 2020). The interaction between 2020 treatments and 2021 P rates (p=0.073) indicated that rates of P applied in 2020 significantly impacted yield only where no P was applied in 2021.

Grain protein (average of 10.24%), hectolitre weight (average of 85.4 kg/hL), grain weight (average of (54.6mg) and screenings (average of 0.9%) were not influenced by phosphorus nutrition applied in 2020 or 2021.

A separate treatment that received no fertiliser in 2020 yielded 3.1 t/ha (average of three replicates) when no fertiliser was applied again in 2021, increasing by 1.5 t/ha under full nutrition in 2021.

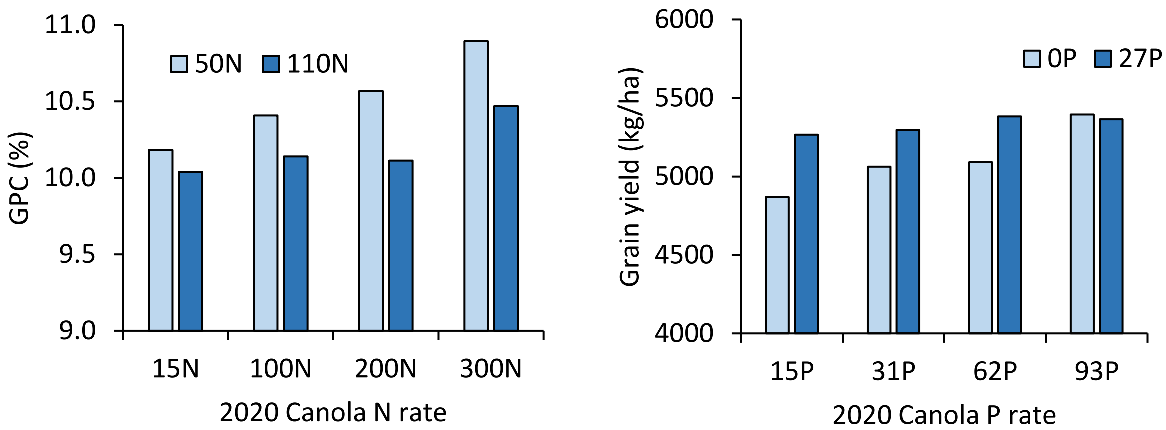

Figure 2: (Left) Grain protein concentration (GPC, %) of wheat grown with 50 kg N/ha (light blue) or 110 kg N/ha (dark blue) following four nitrogen (N, kg/ha) rates applied to canola in 2020. LSD = 0.49%.
(Right) Grain yield (kg/ha) of wheat grown with 0 kg P/ha (light blue) or 27 kg P/ha (dark blue) following four phosphorus (P, kg/ha) rates applied to canola in 2020. LSD = 283 kg/ha

Conclusions

Sandy soils and high rainfall present a high risk of leaching of many nutrients, suggesting that WA's high rainfall zone is unlikely to be conducive to nutrition applied during the canola phase remaining present in the soil and influencing nutrition strategies in the following cereal crop. Nutrition treatments applied to canola in 2020 (range 15 kg N/ha to 300 kg N/ha, 15 kg P/ha to 93 kg P/ha) contained rates that exceed that which WA HRZ growers would typically apply, providing a range of treatments in which to test for nutritional legacy effects in the following wheat crop.

Soil testing indicated that very high levels of applied nitrogen (300 kg N/ha) can increase nitrate nitrogen in the topsoil (by around 7mg/kg relative to no nitrogen). The nitrogen rates applied in 2020 did not influence the grain yield of wheat in 2021 under low (50 kg N/ha) or high (110 kg N/ha) rates, although they did increase grain protein concentration by up to 0.6%. With a 1 t/ha yield response to increasing N rates applied to wheat (from 50 kg N/ha to 110 kg N/ha), responses to nitrogen applied in the wheat phase dwarfed any quality responses from applications made in the canola phase. These data indicate that growers in the high rainfall zone should not expect high rates of nitrogen applied to canola crops to meaningfully impact their nitrogen management decisions in the following cereal crop.

Colwell P in the topsoil at seeding in 2021 appeared to increase following very high rates of P applied in the canola phase in 2020. There were statistically significant yield responses to P treatments in 2020 ($p<0.01$) and 2021 ($p<0.01$) and their interaction ($p=0.07$). The P rates applied in 2020 did influence wheat yield when no P was applied in 2021, but there was no difference between treatments when 27 kg P/ha was applied to the wheat in 2021. Therefore, while high P rates can influence soil P levels and be detected in the following crop (especially at very high rates), applying more moderate levels of P fertiliser in each season is a more cost-effective and lower risk strategy.

Overall, there is little evidence that high rates of nitrogen or phosphorus fertiliser applied to canola in the high rainfall zone should influence nutrition strategies in the following cereal crop. Responses to fertiliser applied to the wheat crop in 2021 greatly exceeded responses to carryover nitrogen, and completely alleviated any responses to carryover phosphorus. Scenarios of crop failure (such as severe frost) where nutrients are not removed in canola seed yield may alter this response, although these scenarios are rare in WA's high rainfall zone (generally low frost risk). Future research in this space should focus on highly productive but seasonally variable areas (such as high frost risk areas in the medium rainfall zone), particularly on heavier soil types. It is these areas where carryover nutrition is likely to have greater impact from an agronomic and farming system perspective.

References

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