

3.1 THE DEVELOPMENT OF NITROGEN YIELD CURVES IN SOUTH-WEST VICTORIA



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KEY MESSAGES

- The Willaura wheat trial showed the most typical nitrogen response curve, with yield peaking with nitrogen (N) rates of 200 kg N/ha before declining and plateauing.
- In the Streatham wheat trial, nitrogen significantly influenced grain protein but not yield, likely due to high starting soil nitrogen and environmental stressors.
- Drought, frost, and seasonal cut-offs influenced trial outcomes, limiting the ability of crops to utilise additional nitrogen.
- Nitrogen applications had no significant yield effect at Willaura in the canola but showed clear yield and oil responses at Streatham, with 80 kg N/ha being optimal.
- High starting soil nitrogen levels reduced the impact on in-season nitrogen applications, especially evident in both canola & wheat trials at Streatham.

Keywords: nitrogen, wheat, canola, yield curve, urea

BACKGROUND

Nitrogen (N) is a key driver of crop growth and yield, but applying the right amount at the right time is critical for maximising efficiency and profitability. Nitrogen yield curve trials help determine the relationship between nitrogen application rates and crop yield, identifying the optimal level where yield is maximised without excessive input costs or environmental risks.

A fundamental principle behind nitrogen yield curve trials is the law of diminishing returns. Initially, increasing nitrogen rates results in significant yield gains as the crop responds to improved nutrition. However, beyond a certain point, additional nitrogen leads to progressively smaller yield increases. Eventually, excessive nitrogen can reduce yields due to lodging or haying off. Excessive nitrogen use may contribute to environmental issues such as leaching and greenhouse gas emissions.

Understanding nitrogen yield curves is essential for optimising both economic and environmental outcomes in crop production. By identifying the most cost-effective nitrogen rate, growers can maximise their return on investment while avoiding unnecessary fertiliser expenses. Efficient nitrogen use is also critical for environmental sustainability, as excessive applications can lead to nitrate leaching, runoff, and nitrous oxide emissions. Nitrogen management plays a key role in crop health and quality, as excessive nitrogen can encourage unnecessary vegetative growth at the expense of grain production, impacting both harvestability and grain protein content. A clear understanding of nitrogen response curves allows growers to adjust nitrogen strategies based on seasonal conditions, soil moisture levels, and overall nitrogen availability, helping to mitigate risks associated with variable growing conditions.

METHOD

Two trial sites were established in South-West Victoria, one at Willaura and another at Southern Farming Systems (SFS) Streatham trial site. Trials were established in two crop types at each site, one in canola and another in wheat (Table 1). The sites were chosen due to variable starting soil nitrogen, with Willaura having much lower soil available nitrogen than Streatham.

Table 1. Trial details for yield curve trials

Site	Crop	Variety	Sowing Date
Willaura	Wheat	BigRed	15-April
	Canola	45Y28 RR	03-May
Streatham	Wheat	BigRed	13-April
	Canola	45Y28 RR	16-April

Both trial sites had pre-sowing soil tests taken in April. Table 2 shows the starting nitrogen at three depths and the organic carbon.

All four trials were set up with the same treatments (Table 3 and 4) which ranged from 0 kg N/ha to 320 kg N/ha in 40 kg N/ha increments. These 40 kg N/ha increments were chosen with the general rule of thumb that 40 kg N/ha equates to 1 t/ha of grain yield in cereals and 0.5 t/ha in canola. These increments were chosen with the intention to build a standard yield curve for each trial.

The total nitrogen for each treatment was split evenly into thirds and applied until the treatment total was reached. Tables 3 and 4 show the application amounts,

timings and growth stages. For some treatments total nitrogen applied was very high and others quite low per application when split evenly into thirds.

The reason an even split was used was to remove the timing factor from the trials to focus on rate of product applied only.

Table 2. Pre-sowing soil test results from trials at Willaura and Streatham.

Variety	Streatham		Willaura	
	Wheat (kg N/ha)	Canola (kg N/ha)	Wheat (kg N/ha)	Canola (kg N/ha)
0 - 30 cm	62.2	97.1	39.9	47.2
30 - 60 cm	27.7	24.4	14.3	19.3
60 - 90 cm	27.3	20.6	16.8	12.6
Organic Carbon (%)	1.9	2.5	1.7	2.2

Table 3. Wheat nitrogen yield curve treatments, application date, growth stage and splits of urea applied.

Treatment	Streatham			Willaura		
	Tiller	GS30	GS32	Tiller	GS30	GS39
	10-Jul	9-Aug	30-Aug	10-Jul	9-Aug	10-Sep
	Urea (kg/ha)			Urea (kg/ha)		
1	0	0	0	0	0	0
2	29	29	29	29	29	29
3	58	58	58	58	58	58
4	87	87	87	87	87	87
5	116	116	116	116	116	116
6	145	145	145	145	145	145
7	174	174	174	174	174	174
8	203	203	203	203	203	203
9	232	232	232	232	232	232

Table 4. Canola nitrogen yield curve treatments, application date, growth stage and splits of urea applied.

Treatment	Streatham			Willaura		
	Cabbage/Early Green Bud	Green to Yellow Bud	5% Flowering	Cabbage to Yellow Bud	5% Flowering	30% Flowering
	10-Jul	24-Jul	9-Aug	2-Aug	15-Aug	30-Aug
	Urea (kg/ha)			Urea (kg/ha)		
1	0	0	0	0	0	0
2	29	29	29	29	29	29
3	58	58	58	58	58	58
4	87	87	87	87	87	87
5	116	116	116	116	116	116
6	145	145	145	145	145	145
7	174	174	174	174	174	174
8	203	203	203	203	203	203
9	232	232	232	232	232	232

The trial received standard management for herbicide, fungicide and all other inputs. An application of MAP at 130 kg/ha at sowing was applied, providing approximately 13 kg N/ha from the nitrogen content in MAP. Since MAP was applied uniformly across all treatments, it did not introduce variability that could influence one treatment more than another. The nitrogen supplied by the MAP has not been included in subsequent calculations; however, it is important to highlight this for the readers understanding.

Post-harvest soil tests were completed in January. All plots were sampled and then composited by treatment and sent to the lab for analysis.

These trials have been calculated using kg N/ha to represent the amount of nitrogen applied. Table 5 provides the conversions from kg N/ha to urea (kg/ha) for easier comparison.

Table 5. N (kg/ha) to urea (kg/ha) conversions for each treatment

Treatment	Total N Applied (kg/ha)	Total Urea Applied (kg/ha)
1	0	0
2	40	87
3	80	174
4	120	261
5	160	348
6	200	435
7	240	522
8	280	609
9	320	696

RESULTS & DISCUSSION

Willaura Wheat Site

Of the four trials undertaken, the wheat yield curve at Willaura displayed the most conventional and anticipated curve (Figure 1). The highest yield achieved was 5.83 t/ha with 200 kg N/ha. This represents the peak of the nitrogen response curve, indicating this rate of nitrogen was the most efficient for maximising yield. After 200 kg N/ha, yield declined to 5.32 t/ha and then plateaued at around 5–5.2 t/ha in the 280 and 320 kg N/ha treatments. The yield curve starts at 4.27 t/ha with 0 kg N/ha (keeping in mind that soil mineralisation also provides some nitrogen) and steadily increases by approximately 0.5 t/ha per treatment until 200 kg N/ha.

Grain protein content follows a similar trend to grain yield. In general, protein levels above about 10.8% suggest that nitrogen is not limiting yield. 0 to 120 kg N/ha resulted in lower protein levels, with 40 kg N/ha as low as 8.1%, suggesting that nitrogen was limiting yield. In contrast, 160 to 320 kg N/ha had protein levels above 11%, indicating that nitrogen was no longer a limiting factor. The 280 kg N/ha and 320 kg N/ha treatments had the highest grain protein levels at 13.1%, with yields of 5.02 t/ha and 5.24 t/ha

respectively. This high grain protein suggests that any excess nitrogen may have been incorporated into grain protein rather than contributing to additional yield. It is also possible that extra nitrogen went into biomass, but since biomass was not measured, this cannot be confirmed.

It is also important to consider seasonal conditions. The dry season, especially the dry finish, may have limited the plant's ability to convert extra nitrogen into biomass or grain yield, leading instead to increased grain protein levels.

Pre-sowing soil tests showed approximately 40 kg N/ha in the 0-30 cm depth (Table 2). Post-harvest soil tests indicate an increase in available nitrogen where nitrogen was applied in-season. Even the 0 kg N/ha treatment, maintained a similar starting soil nitrogen post-harvest compared with the pre-sowing test. There is a clear trend of increasing nitrogen availability in the 0-30 cm depth across all treatments.

A trendline has been fitted to the post-harvest soil test results (Figure 2). It is important to note that these tests have not been statistically analysed but were conducted to help understand where the applied nitrogen may have gone during the season. While not conclusive, these soil tests provide useful insights, particularly in practical, on-farm applications.

The total soil nitrogen calculated from pre-sowing soil tests was 71 kg N/ha in the 0-90 cm range (Table 2). In a dry season such as 2024 it would be expected that roots would have easily reached 90 cm and potentially even deeper. The general rule of thumb of 40 kg N per tonne of grain yield indicates that there was enough nitrogen available for a 1.78 t/ha grain yield. The 0 kg N/ha treatment obtained a grain yield of 4.27 t/ha, indicating a large amount of nitrogen was available most likely through mineralisation, but also at depths greater than 90 cm.

Willaura Canola Site

There were no significant effects of nitrogen application on either yield or oil content in the canola yield curve trial at Willaura (Table 6). Because the results were not statistically significant, they should be interpreted with caution, regardless of the nitrogen rate applied.

The lack of significant results may be due to the timing of nitrogen applications and the split germination observed in the trial. Despite the trial being sown on the 3rd of May, some plants were still germinating through to the end of June, with a range of growth stages at the start of July from cotyledon to 4-5 true leaf. This resulted in varying growth stages throughout the season up to flowering and made decisions on the timing of nitrogen applications more challenging. The first application on the 2nd of August may have been slightly too late for some plants, given the plant's growth stage, and may have missed the window when the crop had the highest nitrogen demand.

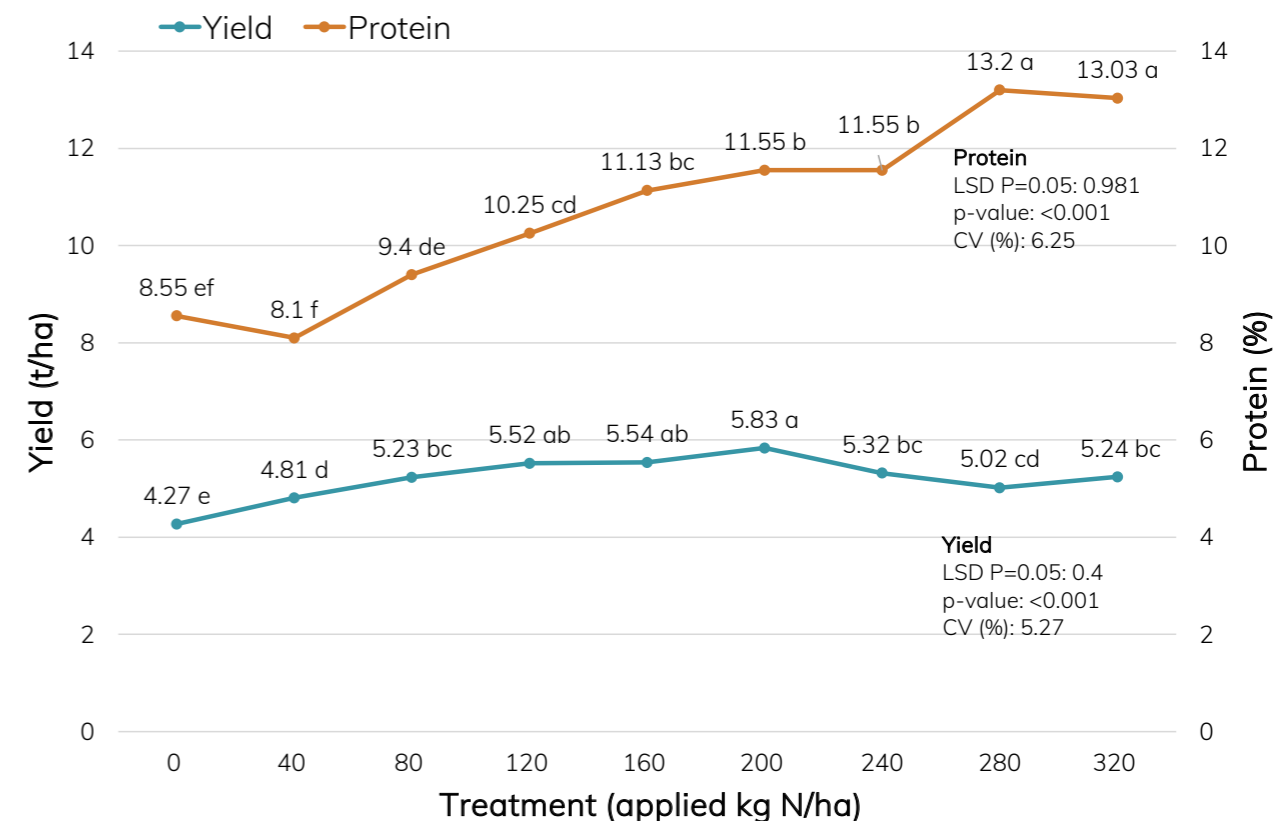


Figure 1. Grain yield and protein from the wheat yield curve trial at Willaura. Means followed by the same letter do not significantly differ ($p > 0.05$).

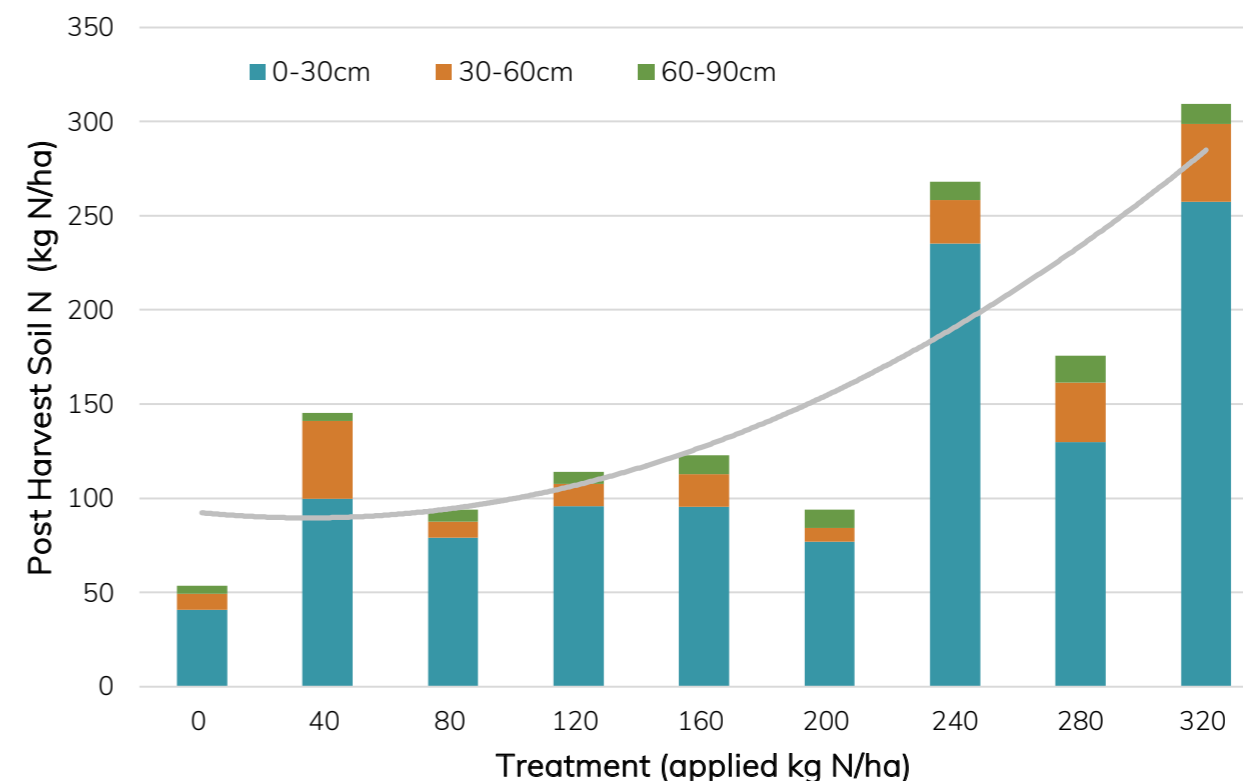


Figure 2. Post harvest soil test results from the wheat yield curve trial at Willaura. A trendline has been fitted to the post-harvest soil test results.

Applying nitrogen two weeks earlier might have better aligned with the canola plant's nutrient requirements, even those plants that were somewhat smaller. Repeating this trial with the knowledge gained from this season could help determine whether a clear yield curve for canola can be established.

Table 6. Yield and oil content results for the canola yield curve trial

Treatment (kg N/ha)	Yield	Oil
0	3.54 -	45.75 -
40	3.90 -	46.13 -
80	3.71 -	44.21 -
120	3.62 -	45.65 -
160	3.81 -	44.50 -
200	3.60 -	45.10 -
240	3.78 -	45.15 -
280	3.65 -	45.08 -
320	3.86 -	45.73 -
LSD P = 0.05	0.4629	2.741
p-value	0.7518	0.8805
CV (%)	8.53	4.13

Post-harvest soil tests have been completed for the Willaura canola site. Unlike other post-harvest tests, a trendline could not be fitted due to the variability in available nitrogen. No clear pattern emerged, but an interesting observation was that the 0 kg N/ha treatment had nearly 150 kg N/ha available comparable to the 80 kg N/ha treatment, which had 175 kg N/ha available. However, a consistent trend with other post-harvest tests was observed, which was a high concentration of nitrogen in the 0-30 cm depth.

Streatham Wheat Site

The wheat yield curve trial at Streatham showed significant results only in grain protein levels (Figure 4). All grain protein results were above 10.8%, indicating nitrogen was not limiting. The 320 kg N/ha treatment had the highest grain protein at 16.03%, which is extremely high and likely a result of the high nitrogen application rates and the season. The 0 kg N/ha, which received no applied nitrogen, had a grain protein level of 12.53%.

The significant protein results, along with the trend of increasing then plateauing yield, are likely influenced by several factors. Pre-sowing soil tests (Table 2) showed 117.2 kg N/ha available in the 0 – 90 cm zone. Based on calculations, this alone provided a yield potential of nearly 3 t/ha. With additional in-season soil mineralisation and potentially accessing nutrients below 90cm, an extra 1.72 t/ha yield potential was available, allowing 0 kg N/ha treatments to achieve

a yield of 4.65 t/ha. This explains why applying additional nitrogen in-season did not increase yield but instead contributed to higher grain protein levels.

The trial was conducted in a very dry season, particularly through winter and spring, with 260 mm of GSR rainfall recorded (see Soil & Climate Data). A sharp seasonal cut-off occurred in spring due to low rainfall and high temperatures, likely causing drought stress in the trial. The lack of moisture may have limited yields, regardless of nitrogen application. Severe frosts also occurred during late August, which may have further impacted yield potential, independent of nitrogen treatments.

Overall, while additional nitrogen influenced grain protein, it did not significantly impact yield due to already sufficient nitrogen levels, dry seasonal conditions, and possible frost damage.

Pre-sowing soil tests showed approximately 62 kg N/ha in the 0–30 cm depth (Table 2). Interestingly, post-harvest soil tests indicated a slight increase in available nitrogen, even with 0 kg N/ha. There is a clear trend of increasing nitrogen availability in the 0–30 cm depth across all treatments. A trendline has been fitted to the post-harvest soil test results. It is important to note that these tests have not been statistically analysed, but were conducted to help understand where the applied nitrogen may have gone during the season.

While there is a trend of increasing soil nitrogen with greater applied nitrogen, this does not necessarily mean there will be the same amount of soil nitrogen available for the following season. It is hard to guarantee how much nitrogen is going to be available as summer rainfall will have an impact on how much remains through loss pathways such as leaching. However, these trials have given an insight into what has happened to the applied nitrogen, especially since it was not translated into significant yield results.

Streatham Canola Site

The canola yield curve trial at Streatham showed significant differences between treatments for both yield and oil content (Figure 6). The yield response displays a noticeable curve, especially when excluding the 200 kg N/ha treatment, which appears to be an outlier. This trial had a starting nitrogen level of 97.1 kg N/ha in the 0-30cm, as indicated by pre-sowing soil tests (Table 2). Interestingly, unlike the Willaura canola yield curve, applying nitrogen in this trial clearly influenced yield outcomes.

Treatments with 80 to 160 kg N/ha and 280 to 320 kg N/ha achieved the highest yields, averaging 4.13 t/ha. Since these treatments are all grouped under the same statistical category (denoted by the letter "a"), their yields are not significantly different from one another. Although 320 kg N/ha had the highest numerical yield at 4.29 t/ha, it is statistically no different from 80 kg N/ha, which yielded 4.08 t/ha.

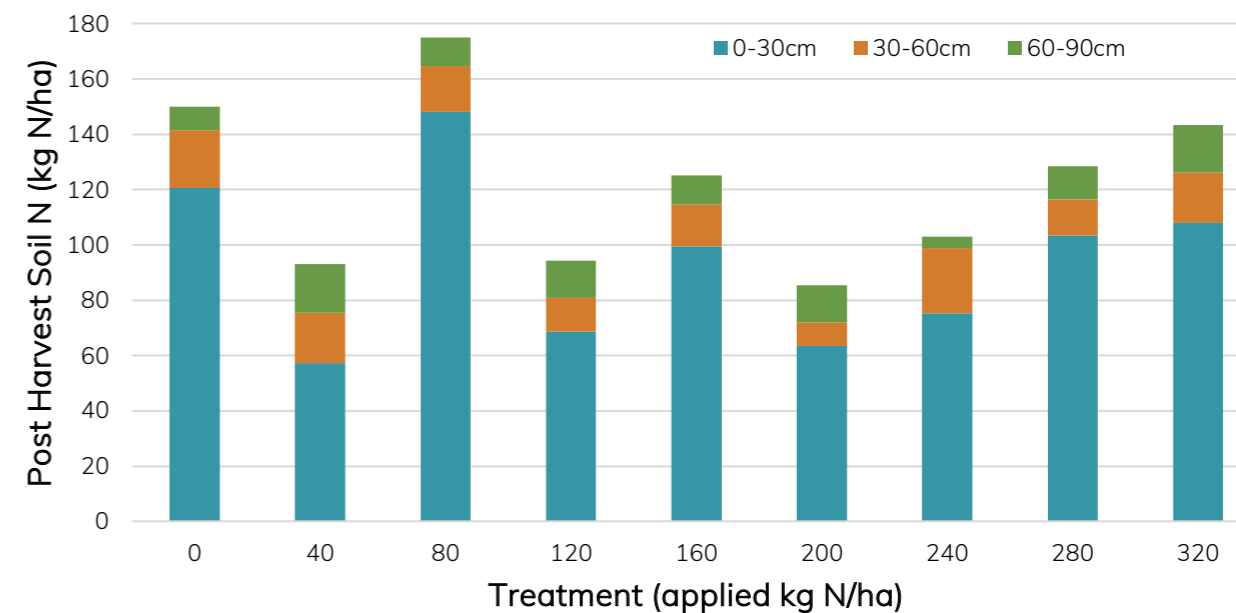


Figure 3. Post harvest soil test results from the canola yield curve trial at Willaura.

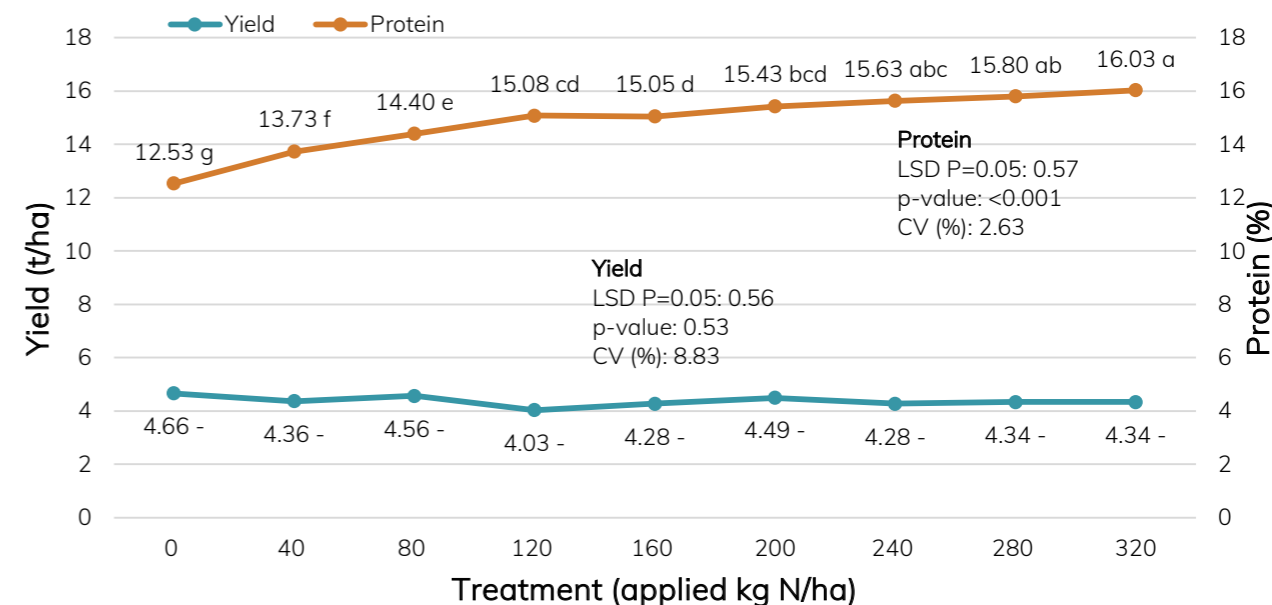


Figure 4. Grain yield and protein from the wheat yield curve trial at Streatham. Means followed by the same letter do not significantly differ (p>0.05).

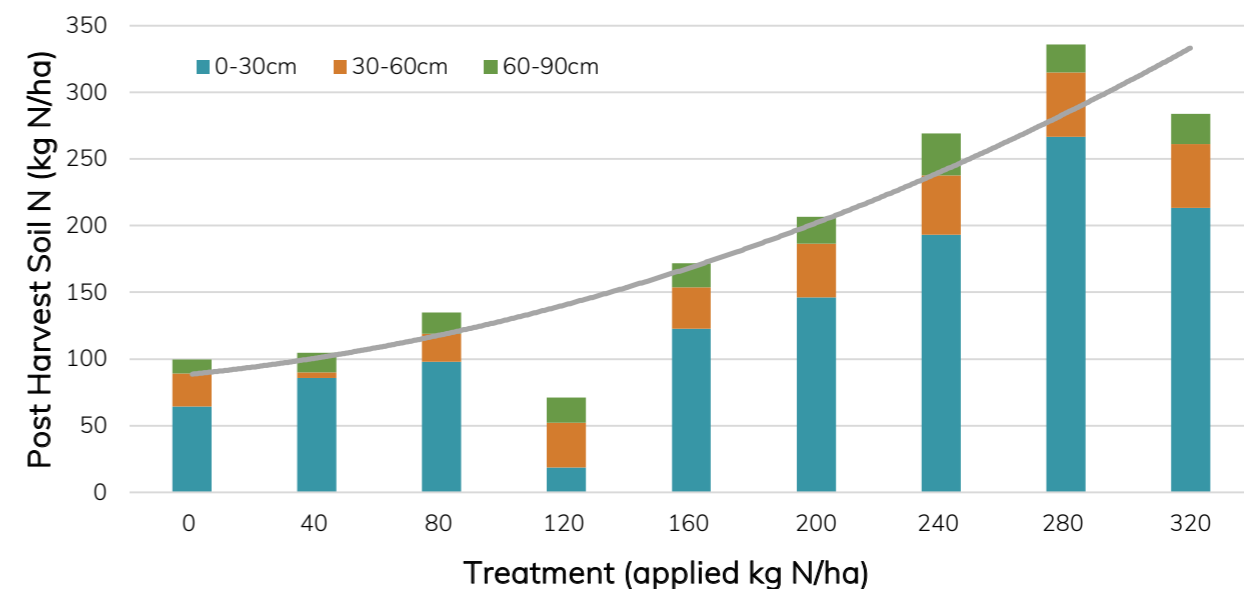


Figure 5. Post harvest soil test results from the wheat yield curve trial at Streatham. A trendline has been fitted to the post-harvest soil test results.

This trial suggests that applying 80 kg N/ha, combined with the existing soil nitrogen and in-season mineralisation, was sufficient to achieve the maximum significant yield response. Even when 320 kg N/ha was applied, it did not produce a statistically higher yield.

Several factors may explain why this trial produced a more defined yield curve and significant results compared to the Willaura site. The higher starting soil nitrogen, nearly 100 kg N/ha, enabled the canola to yield 3.7 t/ha without any in-season nitrogen applications. Additionally, it was sown two weeks earlier than at Willaura, and this meant the timing of the nitrogen applications were also two weeks earlier. This earlier timing may have better aligned with the crop's nitrogen demand, contributing to the observed yield response.

Pre-sowing soil tests showed approximately 100 kg N/ha in the 0–30 cm depth (Table 2). There is a clear trend of increasing nitrogen availability in the 0–30 cm depth across all treatments (Figure 7). A trendline has been fitted to the post-harvest soil test results. It is important to note that these tests have not been statistically analysed, but were conducted to help understand where the applied nitrogen may have gone during the season.

CONCLUSION

The nitrogen yield curve trials conducted across Willaura and Streatham provided valuable insights into crop responses to varying nitrogen application rates with two different crop types under different environmental conditions. The wheat yield curve at

Willaura displayed the most conventional response, with yield peaking at 5.83 t/ha with 200 kg N/ha before plateauing, indicating the point of nitrogen use efficiency. In contrast, the Streatham wheat trial showed significant results only in grain protein, suggesting that nitrogen availability was not a limiting factor for yield due to high starting soil nitrogen and seasonal constraints such as dry conditions and frost.

The canola trials presented contrasting outcomes: while nitrogen applications had no significant impact on yield or oil content at Willaura, the Streatham site demonstrated clear yield and oil content responses to nitrogen, with 80 kg N/ha being sufficient to achieve maximum yield.

Environmental factors, including starting soil nitrogen, seasonal rainfall variability, and nitrogen application timing, played critical roles in influencing trial outcomes. These findings highlight the importance of tailoring nitrogen management strategies to specific site conditions, seasonal variability, and crop requirements to optimise both yield and nitrogen use efficiency.

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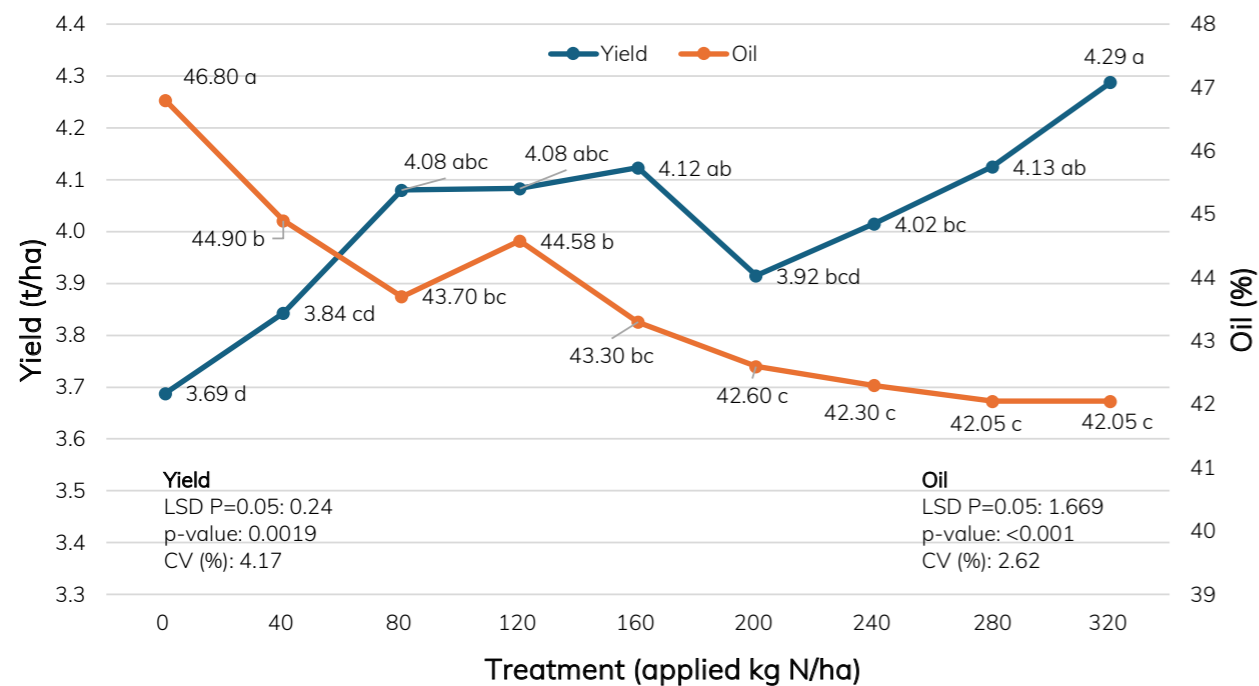


Figure 6. Grain yield and oil from the canola yield curve trial at Streatham. Means followed by the same letter do not significantly differ (p>0.05).

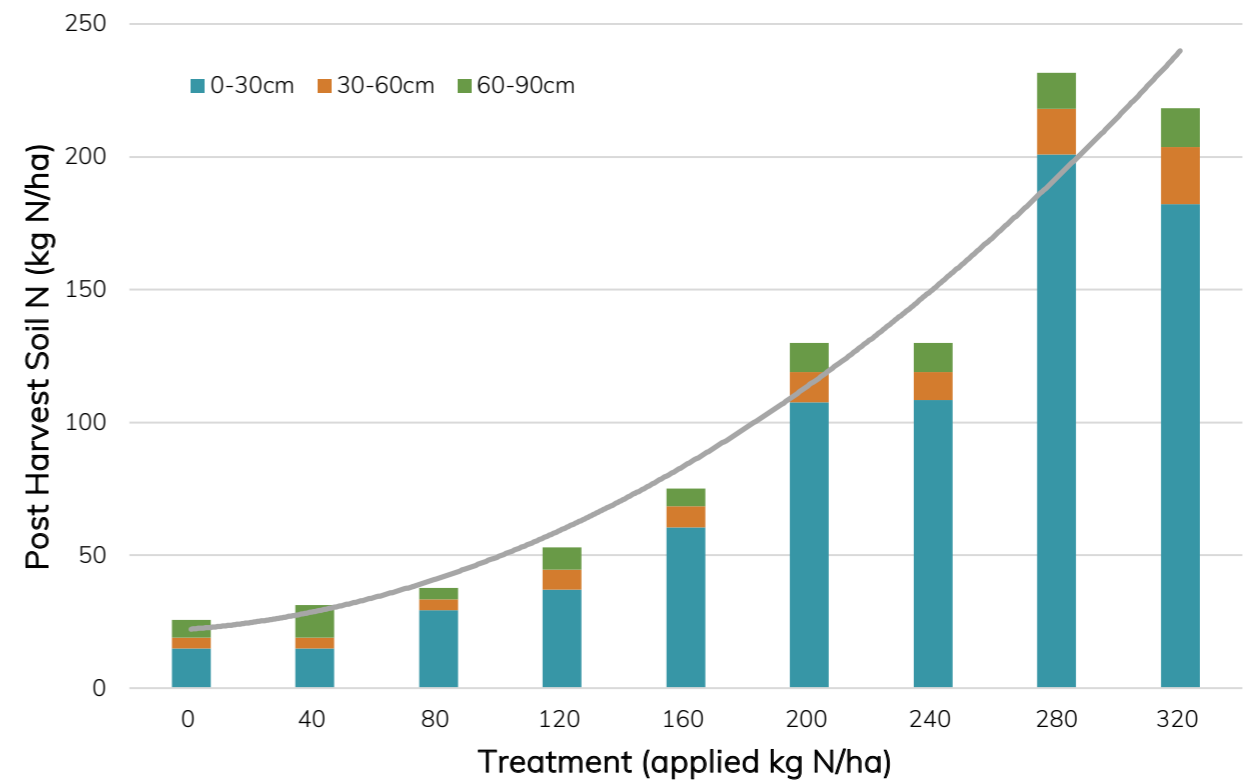


Figure 7. Post harvest soil test results from the canola yield curve trial at Streatham. A trendline has been fitted to the post-harvest soil test results.

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