

# COMPANION CROPPING LEGUMES FOR LOWER-COST NITROGEN SUPPLY: RESULTS FROM THE SANGER REPLICATED TRIALS

## KEY MESSAGES

- **Growing wheat with vetch increased soil nitrogen in 2025, particularly under low nitrogen input conditions. However, lack of moisture in 2025 limited crop growth, so the extra nitrogen fixed by the vetch did not translate into higher wheat yields compared to wheat on its own.**
- **Termination timing of vetch is critical: an early September termination minimised competition for water and nutrients and maintained wheat yield, while a mid-October termination increased competition and reduced wheat yield.**
- **Higher yield did not necessarily result in higher grain protein, highlighting that both nitrogen availability and seasonal moisture determine grain quality.**
- **Companion cropping vetch and wheat can improve soil nitrogen status, but cereal performance depends on seasonal rainfall and careful management of legume termination timing.**
- **Despite a late June sowing and decile 1 growing season rainfall in 2025, vetch yielded 0.26 and 0.36 t/ha under low and high nitrogen conditions respectively, reflecting well on its performance in challenging years.**

## BACKGROUND

Nitrogen fertiliser is one of the biggest and most variable costs in grain farming systems. High prices and uncertain seasonal conditions increase the financial risk of applying large amounts of nitrogen early in the season. As a result, grain growers are increasingly looking for new ways to supply nitrogen more efficiently and at lower cost, while maintaining crop yield and profitability.

Legume intercropping is where two or more species are grown and harvested together. This practice has increased in popularity due to the ability of legumes to fix atmospheric nitrogen into plant available forms, offering opportunities to enhance soil nitrogen and reduce reliance on synthetic nitrogen fertilisers.

Companion cropping differs from intercropping in that the legume species (i.e. vetch) is terminated before it competes with the main crop for resources or reduces yield. In this system, the companion legume supports the main crop by fixing nitrogen, before being removed from the system. This practice, also referred to as temporary intercropping, has the potential to provide nitrogen benefits while maintaining the productivity of the main non-leguminous crop.

## AIM

This project is testing the effects of different desiccation timings of companion legumes (vetch) on the non-leguminous crop, as well as the nitrogen fixation contribution to the farming system and the costs associated with sowing and desiccation.

## METHOD

A replicated trial was originally established at Sanger, in southern NSW, in 2024, with the trial repeated in 2025. Treatments sown in 2025 were the same as 2024 (Table 1), except for the timing of nitrogen fertiliser application and vetch termination, which were adjusted due to late sowing caused by dry seasonal conditions. Vetch termination occurred at the same wheat growth stage as in 2024.

### *Soil sampling*

Incremental deep soil nitrogen (DSN) sampling was conducted at depths of 0–10, 10–30, 30–60 and 60–90 cm in June 2025. This aimed to determine the impact of different vetch termination timings from 2024 on soil nitrogen levels and moisture, before the 2025 treatments were sown. Soil sampling was repeated at anthesis on 20 October.

### Site preparation

The site was sown to Matador wheat at a rate of 60 kg/ha and Morava vetch at a rate of 40 kg/ha on 28 June 2025, using a plot seeder with a row spacing of 23 cm. Matador was chosen as it is slightly better suited to late sowing than Scepter (sown in 2024) and offers stronger resistance to crown rot and yellow leaf spot, reducing risk in stubble-retained paddocks. Seed was placed at a depth of 3 cm under approximately 60 percent stubble cover. Granular MAP was applied at 80 kg/ha as a starter fertiliser across all treatments. As in 2024, spreading in-crop granular urea proved challenging due to the dry conditions; therefore, liquid UAN was applied in September at a rate of 60 L/ha to the low-nitrogen treatments and 120 L/ha to the high-nitrogen treatments (Table 1).

For comparison, two additional buffer strips were added in 2025 to see how changing the wheat seeding rate to 40 kg/ha and 80 kg/ha affected vetch performance due to competition.

Vetch grown as a companion crop with wheat was terminated at different timings during August, September or October, depending on the treatment. Termination was achieved using Amicide Advance 700 (700 g/L 2,4-D present as the dimethylamine and monomethylamine salts), applied at a rate of 1.5 L/ha.

Wheat, as the main crop, was harvested on 6 December using a plot harvester, with wheat quality analysis also conducted. The vetch only (monoculture) treatments (high nitrogen and low nitrogen) were harvested on the same day as the wheat, to provide a baseline vetch yield.

**Table 1** Treatment details for the Riverine Plains and GRDC wheat and vetch companion cropping trial at Sanger, 2025

TREATMENT	CROP	NITROGEN APPLIED EARLY SEPTEMBER	VETCH TERMINATION DATE
Wheat + low nitrogen	Wheat	UAN 60 L/ha	Nil
Wheat + high nitrogen	Wheat	UAN 120 L/ha	Nil
Vetch + low nitrogen	Vetch	UAN 60 L/ha	Nil – vetch taken to harvest
Vetch + high nitrogen	Vetch	UAN 120 L/ha	Nil – vetch taken to harvest
Companion crop terminated august	Wheat/vetch	UAN 60 L/ha	End August
Companion crop terminated september	Wheat/vetch	UAN 60 L/ha	Early September
Companion crop terminated early October	Wheat/vetch	UAN 60 L/ha	Early October
Companion crop terminated mid October	Wheat/vetch	UAN 60 L/ha	Mid- October
Companion crop terminated early October + high nitrogen	Wheat/vetch	UAN 120 L/ha	Early October

### **Field measurements**

Crop establishment counts were conducted on 30 July 2025. Wheat and vetch biomass samples were collected before each vetch termination, then oven-dried for 48 hours at 70°C to determine final dry matter. Nodulation scoring was conducted on 22 September at flowering, when nodules were fully formed and actively fixing nitrogen. Nodulation scoring was done only in the vetch terminated in early October + high nitrogen and vetch terminated in early October treatments, as the remaining companion cropping treatments had already been terminated. Harvest index was measured on 5 December to assess how efficiently the treatments converted total biomass into grain (data not presented).

## **RESULTS & DISCUSSION**

### **Emergence**

Although total summer rainfall (January–April) at the site was 79 mm in 2025, conditions remained dry from mid March to late May, which had the effect of delaying sowing to late June.

Wheat emergence ranged from 80 plants/m<sup>2</sup> in the straight wheat + high nitrogen treatment to 122 plants/m<sup>2</sup> in the companion crop terminated in mid-October treatment, with emergence in other treatments falling between the two (Table 2). However, emergence between these treatments was not statistically significant, with the higher establishment in the mid-October termination treatment likely due to paddock variability at sowing. For vetch, the highest emergence (79 plants/m<sup>2</sup>) was observed in the straight vetch + high nitrogen treatment, while the lowest was in the straight vetch + low nitrogen treatment and companion treatment terminated early October (58 plants/m<sup>2</sup>). Emergence in the companion treatments was similar, ranging between the two, with no significant difference in vetch emergence between treatments.

Vetch emergence is often lower when it is sown alongside wheat in companion cropping systems. This is because wheat has a strong early growth advantage, while vetch emergence is often lower due to hard seed coat dormancy, slower germination, and greater sensitivity to sowing depth.

### **Biomass**

Biomass was measured for wheat and vetch in the companion cropping treatments only. There was an increase in mean biomass between July and October, reflecting the normal pattern of plant dry matter accumulation over the growing season (Table 2). Biomass for both wheat and vetch was low (0.30 t/ha and 0.02 t/ha respectively) in the companion crop terminated July treatment, which was in-line with its early termination and shortened growing season. Both wheat and vetch biomass was highest in the companion crop terminated mid October treatment (wheat: 4.35 t/ha and vetch: 0.57 t/ha), highlighting the rapid biomass accumulation that occurs during spring.

Despite higher crop emergence in 2025, wheat produced 34% less dry matter than in 2024 (average 1.73 t/ha in 2025 vs 2.63 t/ha in 2024). This decline aligns with lower in-crop rainfall in 2025 (172 mm), compared to 2024 (228 mm), indicating that moisture stress likely limited crop growth.

### **Nodulation**

Nodulation was assessed on 22 September and was low overall in vetch, likely due to delayed sowing and dry spring conditions. Root examination showed moderate nodulation (5–20 nodules per plant; nodulation score 3) in the vetch + low N treatment and in both the low and high nitrogen companion cropping terminated in early October treatments.

In contrast, the vetch + high nitrogen treatment had low nodulation, averaging about 5 nodules per plant with a nodulation score of 2. In this treatment, some plants had no nodules or only a few small, ineffective nodules, indicating poor symbiotic performance (Table 2). This response is consistent with the well-established effect of high soil nitrogen suppressing biological nitrogen fixation—whereby legumes preferentially use readily available mineral nitrogen rather than investing energy in making their own—while low nitrogen conditions are more likely to encourage nitrogen fixation in properly inoculated legumes.

In the companion cropping treatments, wheat probably competed strongly for soil nitrogen, with its faster root growth and wider root distribution acting to reduce nitrogen concentration in the rhizosphere (the area surrounding the nodules). This in turn may have stimulated the vetch nodules to fix more nitrogen.

Interestingly, relatively higher nodulation scores and moderate nodule numbers were observed in the companion cropping + high nitrogen

treatment, which appears contradictory to the general expectation that higher soil nitrogen suppresses nodulation. This may have been caused by relatively low initial (pre-sowing) soil nitrogen levels, which may have stimulated early nodulation before fertiliser nitrogen became available to the crop. Further, the nodulation assessment on 22 September corresponded to GS30–GS32 (stem elongation) when wheat is rapidly accumulating biomass and nitrogen demand is high. During this period, wheat likely competed strongly for available soil nitrogen, potentially reducing nitrogen availability to vetch in the rhizosphere. As a result, vetch may have increased nodulation to compensate for limited nitrogen access.

Based on the rule of thumb that legumes can fix 20 kg N/ha per tonne of dry matter produced, the amount of nitrogen fixed in the companion cropped vetch was estimated to be between 1.4 kg N/ha and 11.2 kg N/ha, depending on the timing of termination (Table 2).



Example of nodulation (pink large nodules) in the companion crop + high nitrogen, terminated early October treatment

**Table 2** Emergence, biomass, estimated nitrogen fixation and nodulation score for the different companion cropping termination timings, Sanger, 2025.

TREATMENT	EMERGENCE		BIOMASS		ESTIMATE OF NITROGEN FIXED BY VETCH (kg N/ha)	VETCH NODULATION Score (0-5)
	Wheat	Vetch	Wheat	Vetch		
Unit	(plants/m <sup>2</sup> )		(t/ha)*			
Wheat + low nitrogen	95	-	-	-	-	
Wheat + high nitrogen	81	-	-	-	-	-
Vetch + low nitrogen	-	59	-	-	-	3
Vetch + high nitrogen	-	76	-	-	-	2
Companion crop terminated August	90	67	0.2	0.1	1.4	-
Companion crop terminated September	98	66	0.4	0.2	3.8	-
Companion crop terminated early October	93	59	1.7	0.3	6.4	3
Companion crop terminated mid October	122	67	4.4	0.6	11.2	-
Companion crop terminated early October + high nitrogen	98	64	1.9	0.4	7.4	3

\*Biomass cuts taken on 19 August, 2 September, 27 September and 13 October, depending on termination treatment

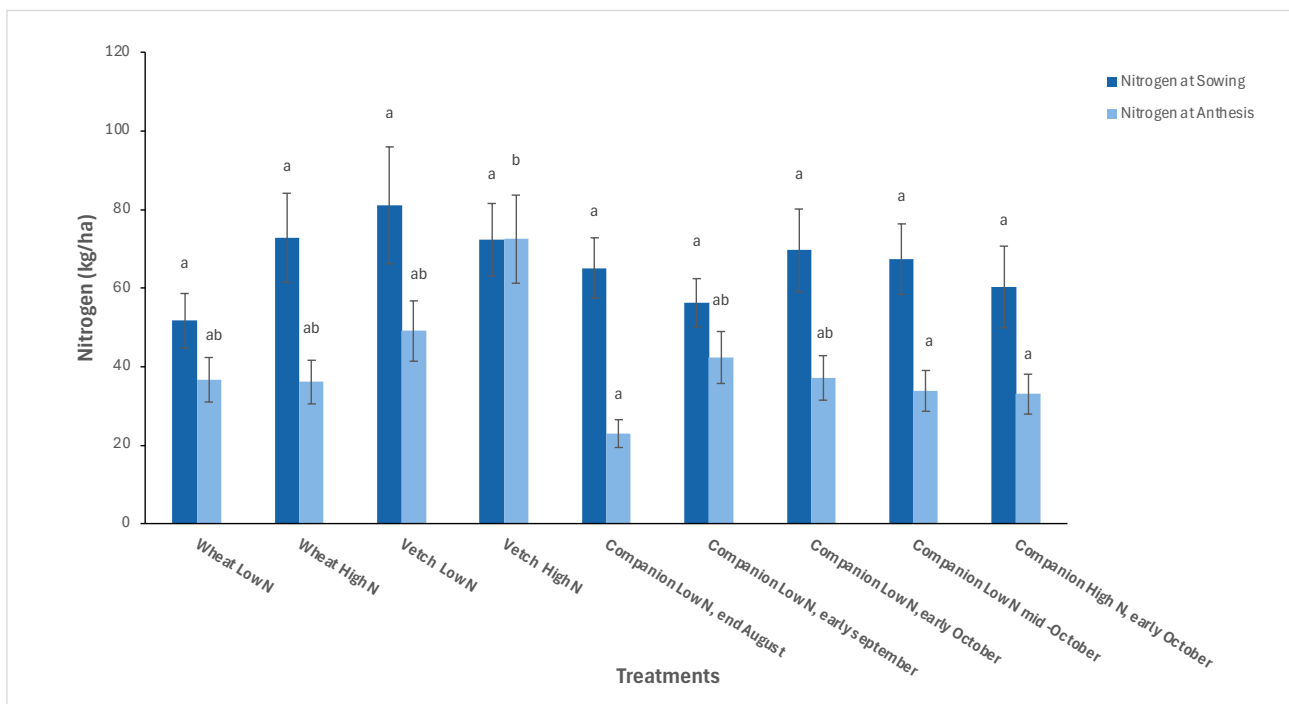
### Total soil moisture, nitrogen at sowing and anthesis

After the 2024 harvest, there were no significant differences in soil moisture between the companion treatments with different vetch termination timings at either sowing or anthesis in 2025. However, early termination of vetch in 2024 resulted in lower soil water at the following year's (2025) sowing, compared with later termination timings (data not shown). This likely happened because earlier termination leaves less time for vetch to grow and accumulate biomass, meaning that there was less residue to protect the soil from evaporation or trap water runoff.

At anthesis, soil moisture was lower for all treatments than at sowing, which was expected given wheat water use peaks during flowering and grain filling. During these stages, the crop has a large canopy and high transpiration, so it extracts more water from the soil. Poor late winter and spring rainfall also contributed to lower soil moisture at anthesis compared to sowing, because soil moisture reserves were not replenished during this time.

Results from 2025 show that straight wheat + low nitrogen had the lowest nitrogen at sowing, although this was not significantly different to the other treatments in the trial. This was as expected given this treatment also had low fertiliser inputs (60 L/ha UAN) in 2024, which was not enough to increase soil mineral nitrogen. Unlike vetch, wheat does not add nitrogen to the system, instead removing soil nitrogen for biomass and grain production.

Treatments involving vetch, either sown on its own in a monoculture or in a companion crop, increased soil nitrogen through biological nitrogen fixation and residue mineralisation. There was a trend for the vetch monoculture to have higher nitrogen than the companion crops, because it fixed a higher amount of total nitrogen due to its greater biomass (Figure 1). From sowing to anthesis, total soil nitrogen decreased across all treatments as nitrogen was taken up by the crop during growth. The greatest reduction occurred in the wheat + high nitrogen treatment, where abundant soil nitrogen likely stimulated greater biomass production and nitrogen demand. Wheat has a dense and competitive root system and relies heavily on soil mineral nitrogen, resulting in a larger decline in soil nitrogen. In the companion treatments, there was a lower reduction in nitrogen to anthesis compared to the wheat + low nitrogen treatment.



**Figure 1** Nitrogen comparison at sowing and anthesis for treatments sown as part of the Riverine Plains companion cropping trial, Sanger, 2025

**Notes:** Numbers followed by the same letter are not significantly different from each other ( $P < 0.05$ )

**Wheat competition on vetch (low seeding rate vs high seeding rate buffer strip demonstration)**

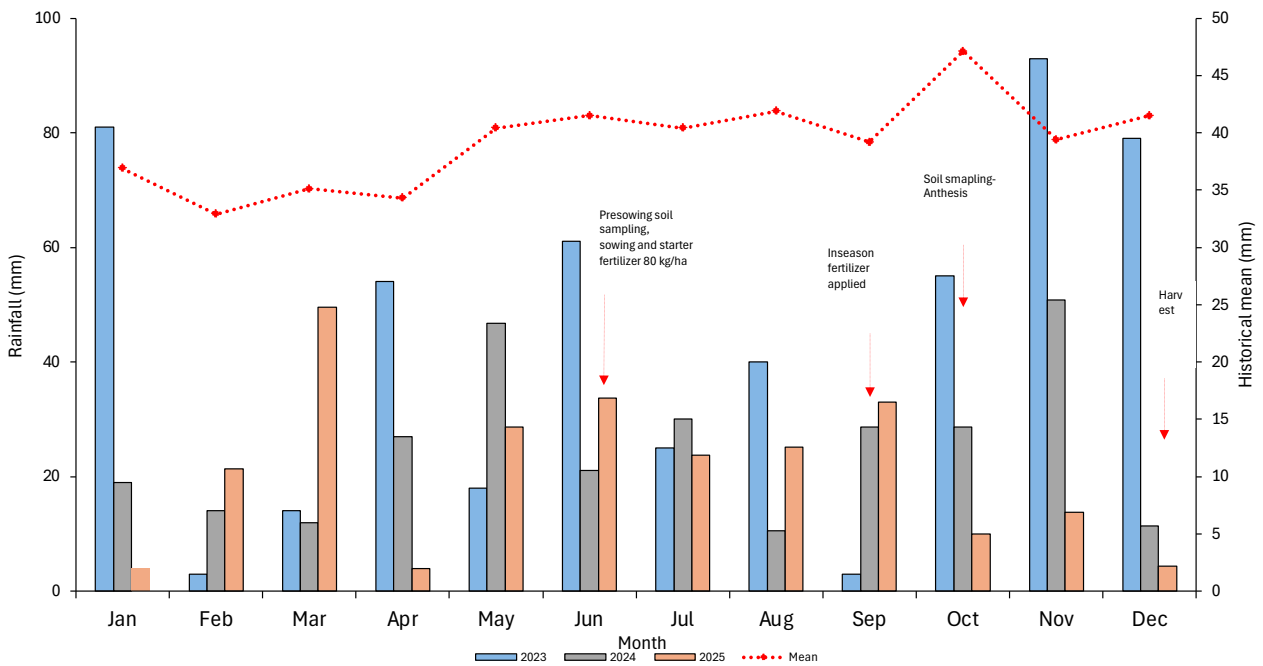
Two additional buffer strips were sown to compare how changing the wheat seeding rate to 40 kg/ha and 80 kg/ha affected vetch performance due to competition. These buffer strips were sown as a demonstration alongside the main replicated trial, which had a wheat sowing rate of 60 kg/ha.

Lower wheat seeding rates in the companion cropping treatments visually reduced competition and allowed vetch to grow more vigorously. While the statistical analysis showed no differences in terms of yield, protein and screening in these two buffer strips, there was a trend to higher yield and protein with higher seeding rate.

**Yield and grain quality results**

In dryland cropping systems, grain yield is primarily determined by water availability and nitrogen supply. In Australia’s southern cropping zone, rainfall after July is critical for achieving high wheat yields, while stored soil moisture plays a key role during grain filling and in helping the crop avoid terminal drought, which can lead to shrivelled grains and yield loss.

Rainfall from July-October 2025 was 92 mm, which was much lower than the long-term average (Figure 2). As a result, both total dry matter and grain yield were lower across all treatments compared with 2024. This was driven by dry spring conditions that limited water availability during critical growth stages, which reduced biomass accumulation and yield for wheat growing under moisture stress.



**Figure 2** Monthly total rainfall (2024 and 2025) and long-term mean rainfall at the Riverine Plains companion cropping trial site, Sanger, 2025. (ARM Online, Agricultural Risk Management Tools), Oaklands General Store, Australia.

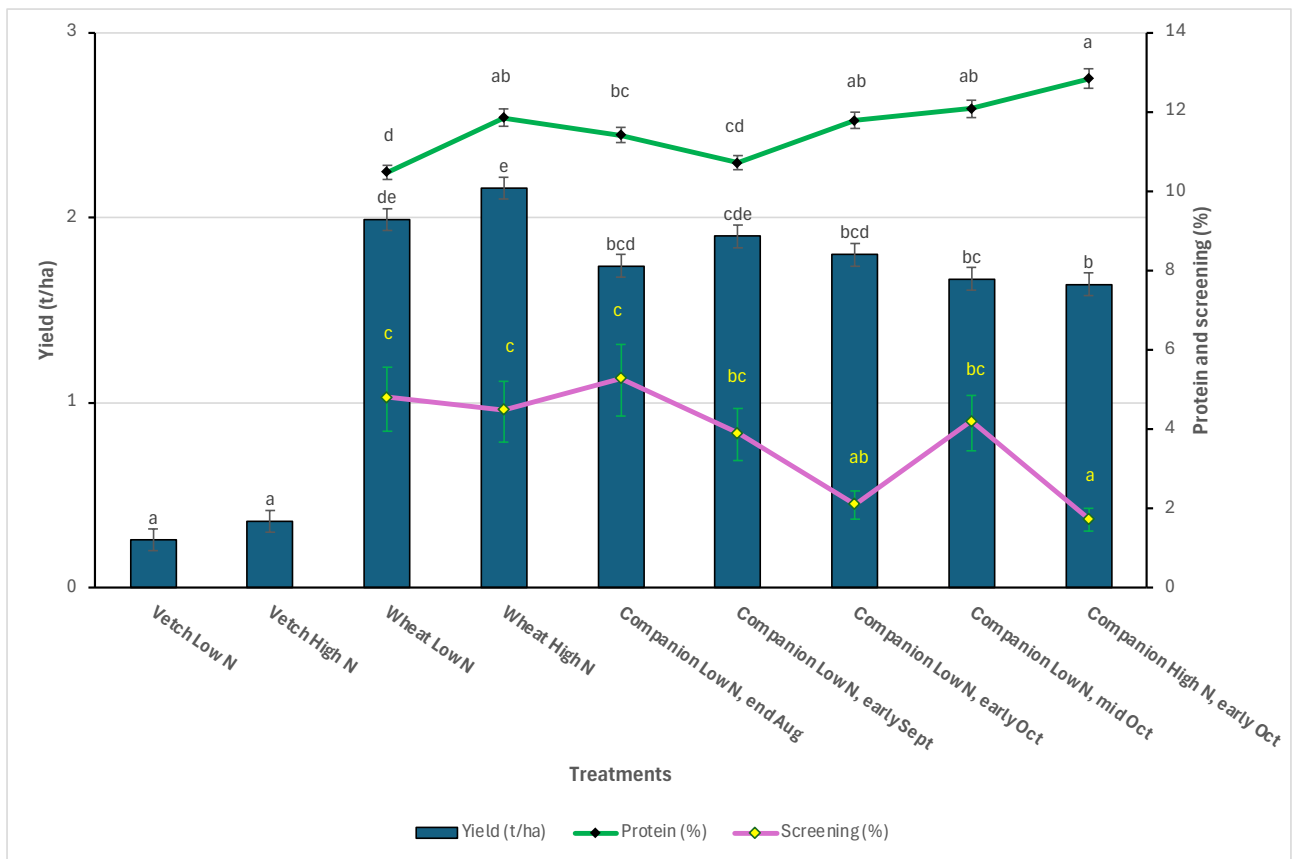




The highest wheat yield (1.9 t/ha) in the companion cropping treatments was observed in the companion crop terminated early September treatment, which was significantly greater than the high nitrogen companion treatment terminated in early October treatment (Figure 3) by nearly 14 percent. The increased wheat yield observed in the September termination treatment is attributed to improved resource use, due to less competition with vetch. Conversely, the reduced wheat yield in the October terminated high nitrogen treatment was likely due to greater soil water depletion caused by longer vetch growth. Leaving the vetch in the system for too long relative to the season at hand probably used up soil water that the wheat could have used later, contributing to water stress at important growth stages and reducing yield.

In 2025, the wheat-only treatments produced the highest yields overall, with little difference between the low and high nitrogen rates (1.99 and 2.16 t/ha respectively).

The vetch-only treatments were harvested to produce a baseline yield, with the high nitrogen treatment yielding 0.36 t/ha and the low nitrogen treatment yielding 0.26 t/ha, which were not significantly different from each other. The vetch-only yield was considerably higher in 2025 than in 2024 for both the high and low nitrogen treatments, despite being sown almost four weeks later. This might be because the establishment of vetch was better in 2025 compared to 2024. Further the cooler and drier filling conditions in 2025 might have favoured vetch growth compared to the wetter spring and harvest experienced in 2024.



**Figure 3** Wheat yield, protein and screenings across different treatment at the Riverine Plains Companion Cropping trial site, Sanger, 2025

**Notes:** Numbers followed by the same letter are not significantly different from each other ( $P < 0.05$ )

Post-anthesis nitrogen supply is very important for grain protein. The highest protein was observed in the high-nitrogen companion, terminated early October treatment, however, this did not differ significantly from the high-nitrogen wheat monoculture or other companion treatments. In contrast, the early September termination had significantly lower grain protein (Figure 3), which may be related to the comparatively low level of nitrogen fixed by vetch in this treatment (3.9 kg N/ha). The limited biomass produced by this treatment at the early termination timing was much lower than in the later termination treatments and, as a result, the nitrogen contribution from vetch residues was insufficient to increase grain protein concentration in this treatment.

In contrast, later termination allowed greater vetch biomass production, leading to higher nitrogen fixation. However, this also increased competition between vetch and wheat for water and nutrients in later-terminated treatments, which acted to reduce wheat yield. Despite the lower yield, grain protein concentration increased in these treatments, likely due to the greater nitrogen contribution from vetch residues and a concentration effect associated with reduced yield.

Overall, screenings were high across the treatments due to the dry finish during grain filling, ranging from 1.7–5.3 percent. The companion crop + high nitrogen terminated early October treatment had significantly lower screenings than the other treatments, possibly due to its slightly lower yield, which may have improved its ability to fill grain. Also, the termination of vetch in early October may have freed up water and nutrients for the wheat during the critical grain filling period, reducing competition for soil moisture at the time when the crop needed it most. There were no differences observed in grain weight among the companion cropping treatment (data not shown).



## OBSERVATIONS AND COMMENTS

All companion cropping treatments sown in 2025 resulted in higher soil nitrogen than straight wheat with low nitrogen, reflecting the ability of vetch to fix atmospheric nitrogen.

Mineralisation of vetch residues gradually contributes to the soil nitrogen pool, which can benefit the following crop. However, 2025 was an extremely dry year, and the nitrogen contribution of the vetch was relatively low, ranging from 1.4–11.2 kg N/ha. As such, there was no measurable increase in wheat yield across the companion cropping treatments. Overall, wheat yield was approximately half of the 2024 harvest, highlighting the strong dependence of cereal yield on moisture availability during the critical spring growth period.

Amongst the companion crop treatments, the vetch terminated early September treatment achieved a yield most like the wheat-only + low nitrogen treatment. This is likely because early termination reduced competition for water and nutrients between wheat and vetch, allowing the cereal to develop effectively. These results indicate that vetch termination timing is critical in companion cropping systems: early termination can minimise competition and support wheat performance, whereas while late termination can boost nitrogen fixation through biomass production, it may come at the cost of reduced cereal yield. Wheat sown on its own with high nitrogen yielded significantly higher than the companion cropping treatments, highlighting the trade-off for farmers for achieving higher yields and the extra cost of synthetic nitrogen fertiliser.

Grain protein was influenced by nitrogen availability during the season. Higher yield did not necessarily result in higher protein, highlighting the complexities of nitrogen management, especially in dry years.

Legumes regulate nodulation depending on soil mineral nitrogen levels. Under high nitrogen conditions plants suppress nodule formation, while under low soil nitrogen conditions nodulation and nitrogen fixation is often stimulated (assuming good inoculation and the absence of major soil constraints). This is because fixing nitrogen is energy expensive, so if mineral soil is available, the plant prefers taking nitrogen up from the soil rather than investing energy in symbiosis.

## SUMMARY

This trial is highlighting how vetch can be used to supply nitrogen to wheat in temporary companion cropping systems. While the nitrogen contribution of vetch to the soil has been relatively low over the past two years due to dry conditions restricting biomass production, different results may be seen where moisture is not limiting. This trial is also highlighting how termination timing can impact yield by affecting access to water, nutrients and light, and how the “sweet spot” for termination likely changes in response to the season at hand.

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