COMPANION CROPPING LEGUMES FOR LOWER-COST NITROGEN SUPPLY – RESULTS FROM THE REPLICATED TRIALS AT SANGER

KEY MESSAGES

- **At a replicated trial site established at Sanger during 2024, there were no significant differences in nitrogen levels at anthesis between wheat sown on its own in a monoculture and wheat sown with vetch in a companion crop.**
- **There were no significant differences in wheat yield or quality when grown in a monoculture compared to being grown as a companion crop with vetch, except when the companion crop with 50 percent nitrogen was terminated in September, which yielded significantly less.**
- **Vetch and wheat biomass increased as the season progressed, however vetch biomass was highest at the September termination, while wheat was highest at the October termination, suggesting wheat was better able to compete for resources.**
- **Vetch biomass production was relatively low when sown as part of a companion cropping mix with wheat, likely due to factors relating to the dry season, as well as competition by the wheat.**
- **The estimated nitrogen benefit of the vetch varied between 0.4 kg–6 kg N/ha, with the highest nitrogen benefit occurring at the end of September.**
- **Vetch sown in a monoculture yielded poorly in this trial (approximately 0.1 t/ha), likely due to seasonal conditions.**

BACKGROUND

Australian grain growers are increasingly reliant on inorganic (synthetic) nitrogen (N) fertilisers to meet the nitrogen demands of crop production.

Australian wheat production currently sits at around 30 million tonnes annually, which requires an estimated 1.2 million tonnes of nitrogen to be supplied from the soil. Currently a bit less than half (45 percent) of this nitrogen is supplied by synthetic nitrogen fertilisers and grain growers are increasingly looking for new, affordable and more environmentally friendly ways to manage their nitrogen supply.

One established approach is to incorporate legumes in the farming systems—this adds nitrogen to the soil in organic form that is later mineralised and taken up by subsequent non-leguminous crops. However, this approach requires the dedication of a full-year of winter crop production to the pulse crop, which can be challenging given many growers grow pulses one-in-six years, while others remain reluctant to grow pulses at all.

A different approach involves sowing a companion legume (e.g. vetch), every year together with a non-leguminous crop, with the companion legume terminated by desiccation before it impacts on the yield of the main crop. This is also known as temporary intercropping.

By integrating companion legumes annually, grain growers can enhance nitrogen fixation without sacrificing the productivity of their non-leguminous crops.

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 demonstration trial has been established at Sanger, in southern NSW, to investigate the amount of nitrogen fixed by leguminous companion crops (vetch) and the optimal timing of their desiccation (termination).

SOIL SAMPLING

On 2 June 2024, soil samples were collected for soil mineral nitrogen analysis in 0–10, 10–30, 30–60, 60–90 cm increments. Soil characterisation was also conducted to establish the baseline conditions of the paddock. A second round of soil testing occurred prior to anthesis on 16 October 2024. Follow-up soil testing will be repeated prior to sowing the 2025 wheat crop, to assess the treatment effects on soil mineral nitrogen.

SITE PREPARATION

The trial site was burnt prior to sowing in 2024, ensuring the removal of crop residue. It was sown to wheat (cv Scepter) at approximately 80 kg/ha, vetch (cv Morava) at approximately 40 kg/ha, or a combination of wheat and vetch in a companion cropping mix on 6 June, via direct drill.

The trial was sown in a complete randomised block design that included nine treatments, each with either high nitrogen (120 L UAN/ha), or 50 percent of high nitrogen (60 L UAN/ha) applied in late August (Table 1). Each plot measured 1.4 x 12 m, and treatments were randomised across four replicates. Buffer strips planted with Catapult wheat were also established around the trial.

Granular mono-ammonium phosphate (MAP) was applied at sowing as a source of nitrogen at a rate of 80 kg/ha. While soil tests indicated sufficient soil nitrogen reserves to meet target crop yields at the start of the season, a lack of rainfall during the growing season meant that expected mineralisation did not occur. This meant a top up of nitrogen was required. Given the risk of urea losses were high as a result of dry conditions, liquid urea ammonium nitrate (UAN) was chosen as the nitrogen source, applied as foliar spray at varying rates across all treatments in late August (Table 2). Each treatment had different level of nitrogen inputs.

Vetch grown as a companion crop together with wheat was terminated at different timings during July, August, September or October using Amicide Advance 700 (700 g/L 2,4-D present as the dimethylamine and monomethylamine salts) (Table 2).

Wheat, as the main crop, was harvested on 14 December, using a plot harvester, with wheat quality analysis also conducted. The vetch monoculture treatments (high nitrogen and 50 percent high nitrogen) were also harvested on the same day as the wheat, to provide a baseline vetch yield.

Crop establishment counts were conducted on 24 July 2024. Wheat and vetch biomass cuts were taken before each termination timing, with samples oven-dried for 48 hours at 70˚C to calculate the final dry weight biomass.

Table 1 Treatment details for the Riverine Plains wheat and vetch companion cropping trial at Sanger, 2024

TREATMENT	CROP	NITROGEN APPLIED LATE AUGUST	VETCH TERMINATION DATE
Wheat monoculture, 50% of high nitrogen	Wheat	UAN 60L/ha late August	Nil
Wheat monoculture, high nitrogen	Wheat	UAN 120 L/ha, late August	Nil
Vetch monoculture, 50% of high nitrogen	Vetch	UAN 60L/ha late August	Nil – vetch taken to harvest
Vetch monoculture, high nitrogen	Vetch	UAN 120 L/ha,	Nil – vetch taken to harvest
Companion crop, terminated July	Wheat/Vetch	UAN 60L/ha late August	End July
Companion crop, terminated August	Wheat/Vetch	UAN 60L/ha late August	End August
Companion crop, terminated September	Wheat/Vetch	UAN 60L/ha late August	End September
Companion crop, terminated October	Wheat/Vetch	UAN 60L/ha late August	End October
Companion crop, high nitrogen, terminated September	Wheat/Vetch	UAN 120 L/ha	End September

RESULTS AND DISCUSSION

EMERGENCE

The highest establishment for wheat was observed in the wheat monoculture treatment (82 plants/m²) and the lowest in the companion crop, terminated August treatment (66 plants/m²). For vetch, the highest establishment was observed in the vetch monoculture, high nitrogen treatment (41 plants/m²) and the lowest in the companion crop, terminated October treatment (27 plants/m²). The higher emergence seen in the wheat treatments is due to its faster germination, greater seed uniformity, and ability to establish well at standard sowing depths. In contrast, vetch emergence is often lower due to hard seed coat dormancy, slower germination, and greater sensitivity to sowing depth, factors that can especially affect performance in mixed cropping systems.

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 3). 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 the early termination and measurement for this treatment. Wheat biomass was highest in the companion crop, terminated October treatment (4.95 t/ha), which was a marked increase from September (3.6 t/ha), highlighting the rapid biomass accumulation that occurs during spring. Vetch biomass was highest in the companion crop, terminated September treatment (0.30 t/ha); vetch biomass did not increase beyond September, with the October vetch termination biomass yielding 0.23 t/ha. This suggests that the wheat outcompeted the vetch for resources in the companion crop system. Adding 120L/ha UAN at the end of August did not increase wheat or vetch biomass compared to the nil nitrogen treatment when measured at the end of September, likely because the dry spring conditions limited further biomass accumulation.

Given the relatively low amount of biomass produced by the vetch at the time of termination in September and October, it's estimated that only a modest amount of nitrogen was fixed by the vetch crop, in the range of 4.6–6t kg N/ha.

Table 2 Emergence and biomass accumulation for the different companion cropping termination timings, Sanger, 2024.

TREATMENT	EMERGENCE (PLANTS/M²)		BIOMASS (T DM/HA) *		ESTIMATE OF NITROGEN FIXED BY VETCH (KG N/HA) **
	Wheat	Vetch	Wheat	Vetch	
Wheat monoculture, 50% of high nitrogen	82	-	-	-	-
Wheat monoculture, high nitrogen	74	-	-	-	-
Vetch monoculture, 50% of high nitrogen	-	33	-	-	N/A
Vetch monoculture, high nitrogen	-	41	-	-	N/A
Companion crop, terminated July	76	33	0.2	0.02	0.4
Companion crop, terminated August	66	37	1.0	0.12	2.4
Companion crop, terminated September	73	34	3.6	0.30	6.0
Companion crop, terminated October	70	27	5.0	0.23	4.6
Companion crop, high nitrogen, terminated September	78	36	3.3	0.29	5.8

*Biomass cuts taken either 24 July, 26 August, 26 September 24 October, depending on termination treatment

** Based on the rule of thumb that legumes fix 20 kg N/ha per tonne of dry matter produced

TOTAL NITROGEN ANALYSIS AT SOWING AND ANTHESIS

Soil nitrogen content (0-90 cm) at sowing was variable across treatments, highlighting paddock variability in the first year of the trial. The highest nitrogen was recorded in the companion crop, terminated July treatment (93.9 kg/ha), which was significantly higher than the nitrogen in the companion crop terminated in August treatment (59.8 kg./ha) and October treatment (54 kg/ha). All other treatments, including wheat monoculture at both nitrogen rates, vetch monoculture at both nitrogen rates, and other companion crop termination dates had average soil nitrogen of between 60–78 kg/ha, with no significant differences across treatments.

From sowing to anthesis, the total soil nitrogen levels across all companion crop treatments decreased in line with crop use, with anthesis averages ranging between 31.5kg N/ha and 50.1 kg N/ha and no statistical difference between treatments (Table 3). This could be due to a combination of factors, including poor nodulation and nitrogen fixation by the vetch, combined with dry conditions (Note: nodulation was not scored in this trial). Pulse residues can take time to break down, so it's also likely the nitrogen provided by the vetch had not had a chance to break down and add nitrogen back into the soil. 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 0.4 kg N/ha and 6.0 kg N/ha, depending on the timing of termination (Table 3).

The impact of the companion cropped vetch will be clearer after soil sampling is completed ahead of sowing in 2025.

Table 3 Nitrogen at sowing, anthesis and grain yield across different wheat and vetch treatments at Sanger, 2024

TREATMENT	SOIL NITROGEN AT SOWING (KG N/HA)	SOIL NITROGEN AT ANTHESIS (KG N/HA)	GRAIN YIELD (WHEAT OR VETCH) (T/HA)
Wheat monoculture, 50% of high nitrogen	71.5 ab	49.4 a	4.65 c
Wheat monoculture, high nitrogen	78.0 ab	23.7 a	4.65 c
Vetch monoculture, 50% of high nitrogen	65.0 ab	47.1 a	0.14 a
Vetch monoculture, high nitrogen	65.7 ab	50.1 a	0.07 a
Companion crop, terminated July	93.9 a	31.5 a	4.15 bc
Companion crop, terminated August	59.8 bc	38.0 a	4.14 bc
Companion crop, terminated September	61.4 abc	36.1 a	3.88 b
Companion crop, terminated October	54.0 c	44.2 a	4.10 bc
Companion crop, high nitrogen, terminated September	61.8 abc	50.1 a	3.92 b

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

YIELD AND GRAIN RESULTS

The wheat monoculture treatments yielded the highest, with both nitrogen treatments performing similarly to each other (4.65 t/ha). While the wheat monoculture yields at either nitrogen rate were significantly higher than the companion crop vetch terminated in September treatment (3.88 t/ha) and the high nitrogen terminated in September treatment (3.92 t/ha), there were otherwise no significant differences in wheat yield across the treatments.

Although not statistically significant, both the wheat monoculture treatments (high nitrogen and 50 percent of high nitrogen) showed a trend to higher yields (4.65 t/ha), compared to wheat sown in the companion crop mix (range 3.88–4.15 t/ha).

There was no difference in grain quality, including protein, moisture and screenings, between treatments (data not presented).

The vetch in the monoculture treatments was also harvested, with the high nitrogen rate yielding 0.07 t/ha and the 50 percent nitrogen rate yielding 0.14 t/ha (not significantly different). The low vetch yield was likely due to a combination of later-than-ideal sowing and dry seasonal conditions.

OBSERVATIONS AND COMMENTS

At sowing, all treatments had similar nitrogen levels, except for the companion cropping terminated July treatment, which had significantly higher nitrogen than the treatment terminated in October, likely indicating paddock variability. There was no difference in total soil nitrogen levels difference between wheat as a monoculture and wheat and vetch grown in a companion cropping system at anthesis, regardless of whether nitrogen was applied at a high rate, or 50 percent of the high rate. Several factors likely contributed to this outcome, including reduced mineralisation of soil nitrogen due to low in-season rainfall and poor nodulation and activity as a result of dry seasonal conditions. The long interval between vetch termination, vetch residue breakdown and the release of nitrogen back into the soil is also likely to have contributed to the lack of difference between treatments.

While there was a trend towards lower wheat yield the longer the vetch remained as a companion crop, these differences were not statistically significant.

Additional data will be needed to determine the optimal timing for termination of the companion crop. In the coming year, nitrogen applied at both high and low rates will be paired with a nitrogen budget, informed by seasonal outlooks, to gain a clearer understanding of the nitrogen contribution from vetch as a companion crop.

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