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Northern farming systems – Narrabri site report, 2015–2020

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Key findings

- The three systems (higher nutrient, higher legume and higher intensity) had similar productivity and gross margins (GM) compared with the baseline system, which represents the typical grower's cropping rotation for the local area.
- The systems with lower cropping frequency (lower intensity) and those aimed at growing more diverse crops (higher diversity) had lower grain production compared with the baseline system.
- In 2016, nematode numbers (*Pratylenchus thornei* (Pt)) numbers were higher after chickpea compared with faba bean and field pea, while canola and cotton reduced Pt numbers that year. The higher Pt numbers after chickpea in 2016 continued through to December 2017, after that year's wheat crop.
- High yielding legumes exported more nitrogen (N) and potassium (K) from the farming systems (baseline, higher nutrient, and higher legume) compared with the systems that contained no legumes or lower yielding legumes (higher diversity, high intensity, and lower intensity).
- The high cropping diversity (higher diversity) system reduced soil pathogen levels over the five years compared with the baseline system.

Introduction

Growers face challenges from declining soil fertility, increasing herbicide resistance, and increasing soil-borne pathogens in their farming systems (FS), hence change is needed to maintain FS productivity and profitability. The Queensland Department of Agriculture and Fisheries (DAF), New South Wales Department of Primary Industries (NSW DPI) and CSIRO are collaborating to conduct an extensive field-based FS research program, focused on developing FS to better use available rainfall and to increase productivity and profitability.

The project started in 2014, and will continue through to 2025 with sites in NSW and Qld.

The experimental site at Narrabri examined multiple aspects of a northern FS, including the effects modified systems have on water use, nutrient use, weed ecology and soil/root pathogens.

What was done

In 2014, research began after consultation with local growers and agronomists to identify the key FS limitations, consequences and economic drivers in the northern region.

Experiments were established at seven locations including a large factorial experiment at Pampas, and local sites at six regional centres (Emerald, Billa Billa, Mungindi, Spring Ridge, Narrabri and Trangie (red and grey soils)).

Site details

Location

Llara, University of Sydney research farm, Narrabri, NSW (Latitude 30°11’37.99”S, Longitude 149°37’6.24”E).

Farming system treatments at Narrabri

- **Baseline**: designed to represent a standard cropping system for the local north-western grains region. The planting trigger will be 50% of a full soil moisture profile.
- **Higher nutrients**: This system duplicates the crop sequence for the baseline system, but fertilising will be targeting a higher yield (90% of seasonal yield potential for N and 100% replacement for phosphorus (P).
- **Higher crop intensity**: the trigger for planting will be 30% of a full soil moisture profile.
- **Higher crop diversity**: This system is investigating alternative crop options to help manage and reduce nematode populations, disease and herbicide resistance.
- **Higher legume**: The high legume system is focused on soil fertility and reducing the amount of N input required through fertiliser. One in every two crops must be a legume.
- **Lower crop intensity**: This lower intensity system is designed to plant at a lower frequency when the moisture profile is greater than 80% full. High value crops are targeted.

Site characteristics

Llara: chocolate vertosol with plant available water content (PAWC) of 210 mm to a depth of120 cm. The soil is slightly alkaline at the top-soil and increases in pH at depth, as does the calculated sodicity (ESP) (Table 1). These characteristics are common for Northern NSW grain soils.

Table 1 Site soil chemical characteristics for 0–120 cm depth at Llara.

	Soil depth (cm)				
	0–15	15–30	30–60	60–90	90–120
pH_{Ca}	7.44	7.93	8.21	8.43	8.55
Organic carbon (%)	0.79	0.63	0.54	0.39	0.25
Exchangeable sodium percentage (ESP)	3.3	5.8	11.0	16.0	23.0
Colwell-P (mg/kg)	24.0	8.0	10.0	16.0	20.0
Conductivity (dS/m)	0.12	0.15	0.22	0.29	0.34

Weather report

- Climatic conditions during the experiment were generally hotter and drier than average, receiving lower than average rainfall for Narrabri (Table 2).
- The project experienced more days over 35°C than the 17-year average of Narrabri.
- Within the project four out of six years had a 200 mm deficit of rainfall compared to cumulative annual average (Figure 1).
- The conditions did influence system performance as the 2016/17 cotton crop was impacted by severe heat and the low rainfall in 2018-2019, resulting in several crop failures (2018 sorghum, 2018 mungbean, 2019 chickpea and 2019 durum).

Table 2 The number of days recorded at the site greater than 35 °C and below 0 °C (1 June 2015 to 30 November 2020).

	2015	2016	2017	2018	2019	2020	Site mean
Days <0 °C	10	1	21	24	9	3	13
Days >35 °C	21	62	66	64	86	41	53

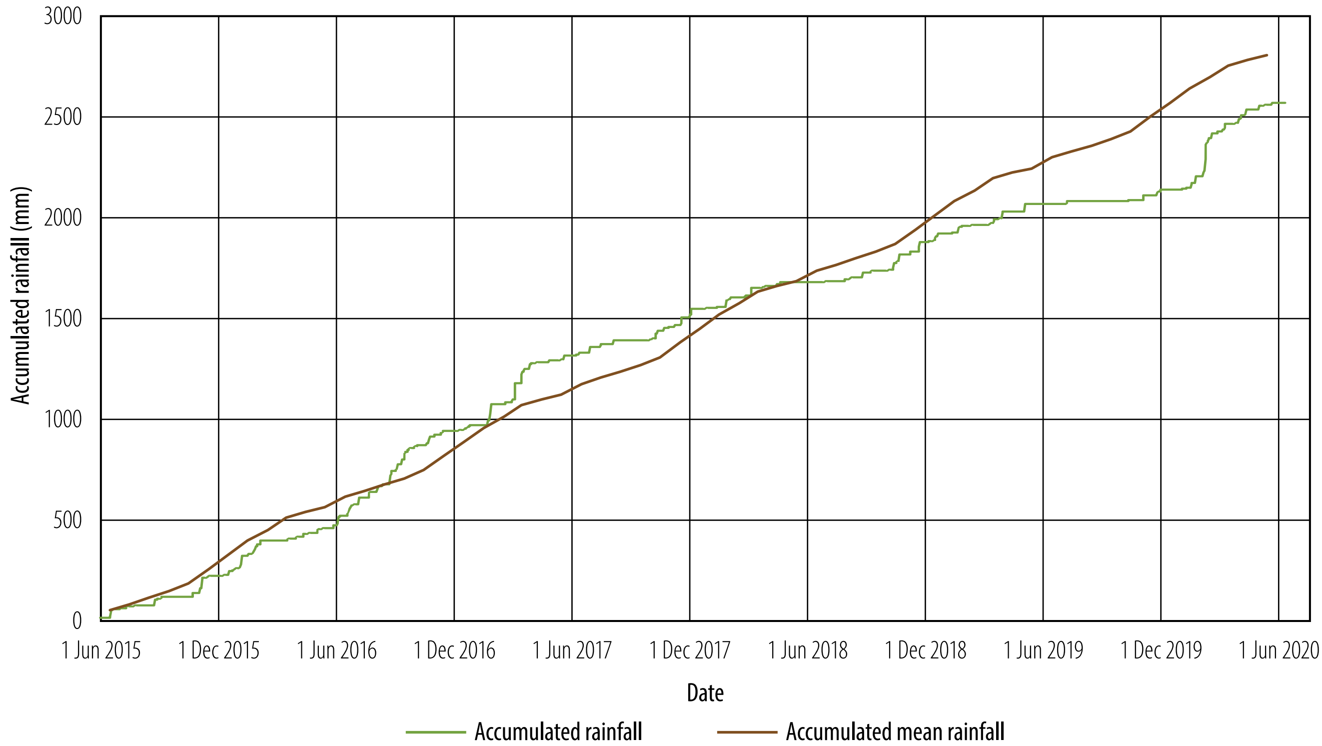

Figure 1 Accumulated rainfall at Narrabri between 2015 and 2020.

System cropping sequence at Narrabri

The six FS treatments at Narrabri had varying cropping sequences over the last five years with:

- The baseline planted to five crops (three wheat, one chickpea and one sorghum) (Figure 2).
- The higher intensity system had the greatest crop number (six or 1.2 crop/year), due to a double cropped chickpea, following sorghum (2018/19).
- The lower intensity systems had the lowest harvested crop number with three (two wheat and one cotton crop), with a cover crop planted following the cotton crop to maintain stubble cover across the treatments.

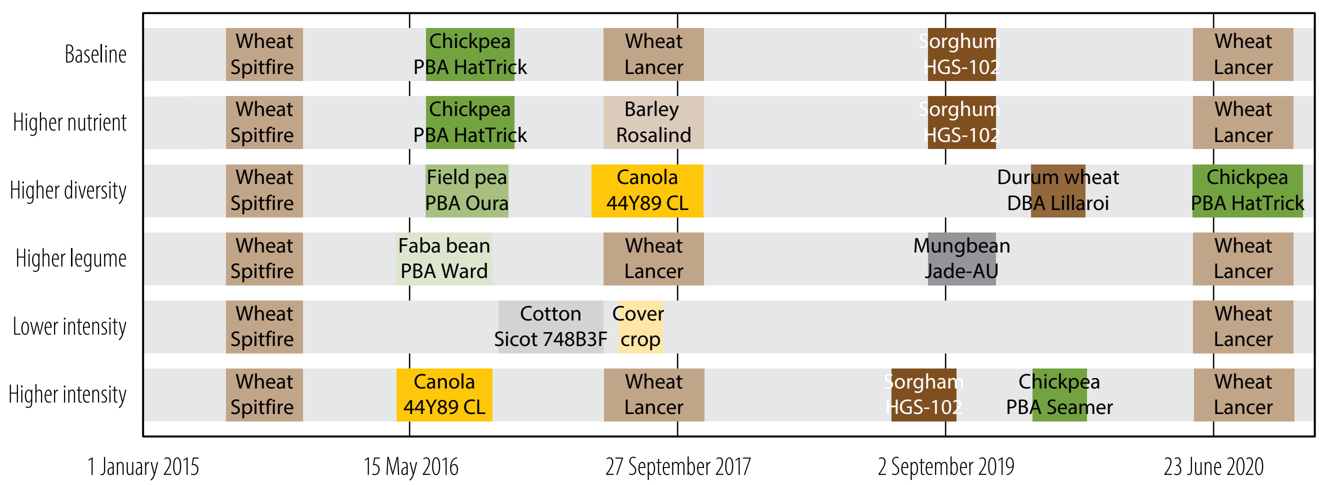

Figure 2 Cropping sequence and fallow length of the six farming systems at Narrabri.

It is noted that between 2018 and 2019 there was minimal grain production during the prolonged dry at Narrabri. The 2020 winter crops were the first profitable grain crops since the winter of 2017 (Figure 3). In 2018/19, sorghum yields ranged between 0.4 t/ha and 0.6 t/ha (baseline, higher nutrients and higher intensity). The mungbean (higher legume), chickpea (higher intensity) and durum (higher diversity) crops failed to produce grain.

Results

System grain yield

After five years of the experiment, the baseline, higher nutrient, higher legume and higher intensity systems resulted in similar cumulated grain yields of 11.1, 10.6, 10.8 and 10.4 tonnes/ha respectively (Figure 3).

The four systems (baseline, higher nutrients, higher legume and higher intensity) produced significantly more total grain (or grain and lint) than both the higher diversity and lower intensity systems (7.6 and 7 tonnes/ha). This is attributed to two failed crops in the higher diversity systems (2017 canola from frost damage, and 2019 durum from moisture stress), and the fewer grain producing crops in the lower intensity system (3) compared with the baseline system (5).

Cumulated yields indicate there was no advantage in applying additional N and P fertiliser between 2015 and 2020, as no crop within the higher nutrient system outperformed a baseline crop. The system performance results suggest that nutrition was never limited during the project and that other factors (most likely plant available moisture) limited crop response to the applied nutrients.

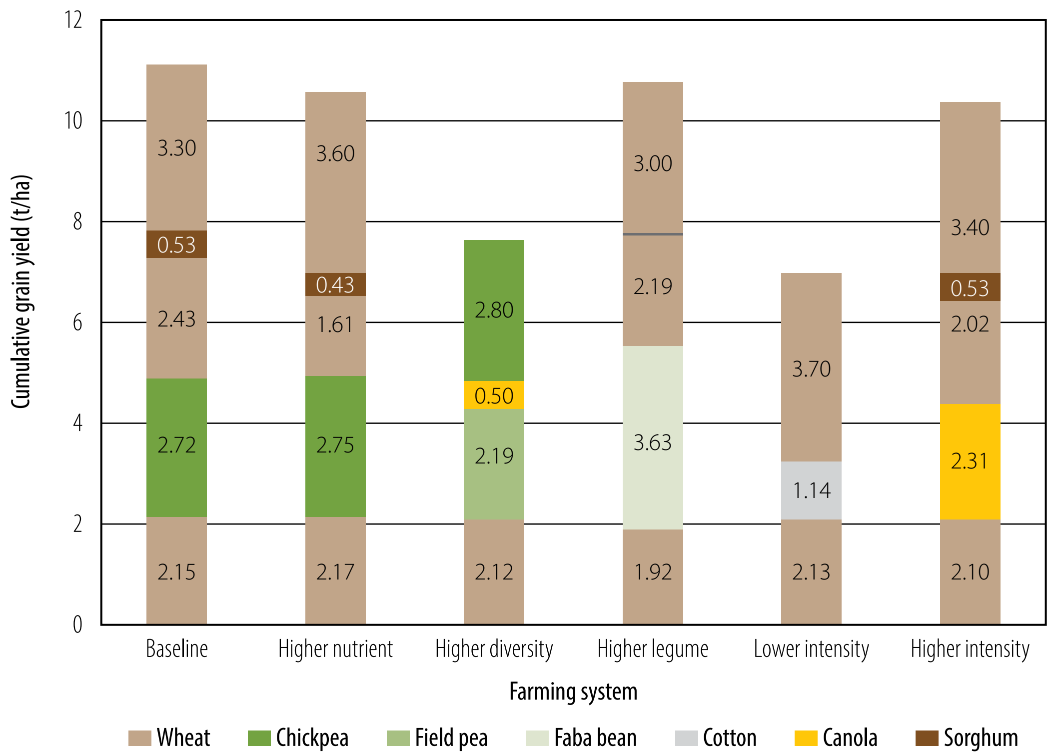

Figure 3 Cumulative system grain yield of the six farming systems treatments at Narrabri (2015–2020).

System gross margin

- The baseline and the higher legume systems had the greatest accumulated system GM with $1313/ha and $1324/ha respectively (Figure 4).
- The baseline system had higher crop income (+$132/ha) and higher crop associated costs (+$143) than the higher legume system. When evaluating the return on variable costs (ROVC) for the systems, the higher legume system had the highest return with 2.11 compared with 1.99 for the baseline system.

- The higher nutrient system had a lower GM compared with the baseline system ($701). This was due to the additional fertiliser costs (+$311/ha), which did not result in greater grain productivity (Figure 4). The added expense of additional fertiliser reduced the ROVC for the higher nutrient system to 1.37, which is 0.42 below the baseline system.
- Varying the cropping intensity to either more frequent cropping rotations or decreasing the cropping frequency had similar GM at Narrabri, $808/ha for the higher intensity and $858/ha for the lower intensity. But both systems achieved their respective GM in a contrasting way. For example, the higher intensity had higher system income (>$500/ha) and costs (>$550/ha) compared with the lower intensity system. Consequently, the lower intensity system is seen to be more efficient at converting income to profit as it had a ROVC of 1.9, which is 0.36 higher than the higher intensity system.

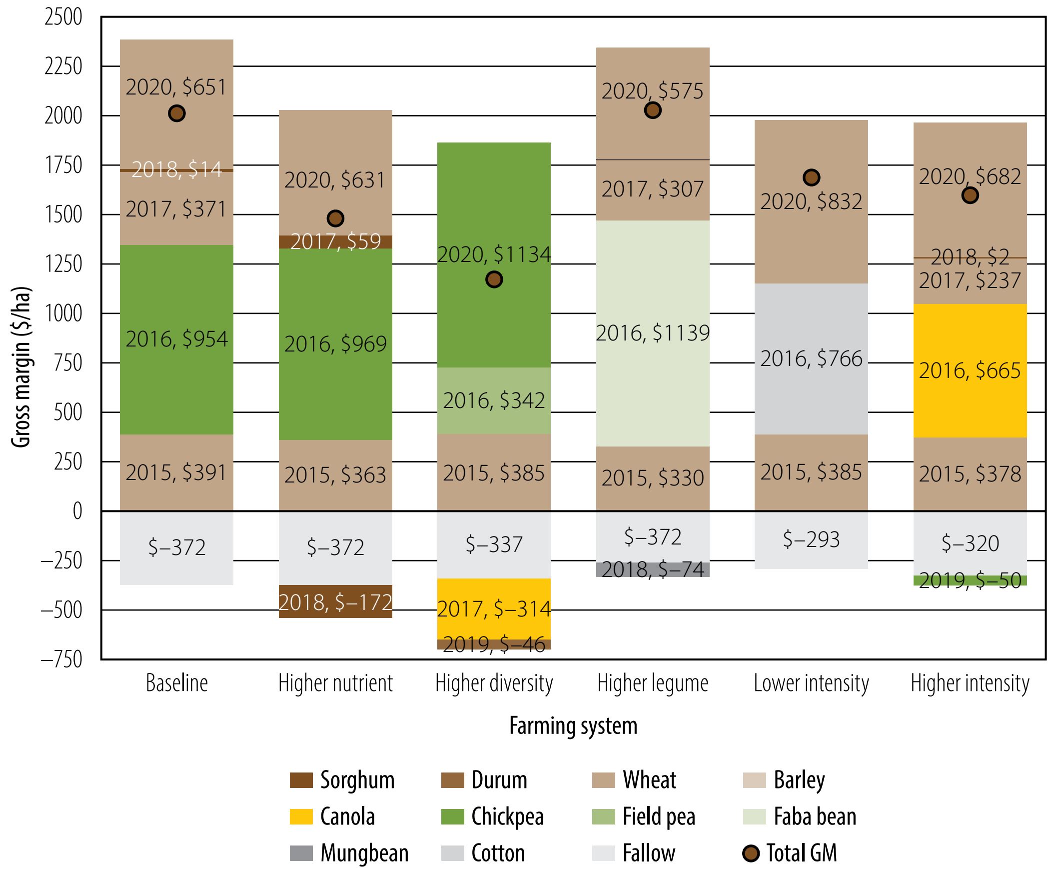

Figure 4 Cumulative system gross margins for each farming system and crop at Narrabri (2015–2020).

System water and nutrient use

The FS cropping intensity system had the greatest influence on the fallow efficiency at Narrabri between 2015 and 2020 (Table 3). The FS treatments that were in-crop the highest crop frequencies that led to consistent levels of cereal stubble, had the highest fallow efficiency (FE) The higher intensity system had an FE of 32%, the baseline was 30% and the higher nutrient system 26% FE. The fourth system that had the same time in-crop, the higher legume system, had a lower FE of 25%. This indicates the lower amount of ground cover from legume residue resulted in poor FE compared with higher coverage with the carbon rich, cereal stubble. The high N:C ratio of legume stubble promoted greater dry matter degradation, resulting in less stubble cover and poor moisture retention during the fallow periods.

The higher legume system resulted in the greatest water use efficiency (WUE) of 4.9 kg/mm/ha. This was 0.5 kg/mm/ha greater than the baseline system at 4.4 kg/mm/ha. Interestingly, the higher intensity system resulted in identical WUE to the lower intensity system (3.7 kg/mm/ha). Therefore, a similar productivity was achieved per millimetre of moisture from decreasing the cropping intensity compared with systems with greater cropping frequency. Additionally, the income per millimetre of used moisture was similar between the lower intensity, higher intensity and the baseline systems. These results show that Narrabri grain producers can be versatile with their cropping frequency and maintain system profitability.

The lower intensity treatment has:

- different/bigger planting triggers than the baseline and higher intensity treatments, i.e., sown into a conservative soil moisture profile
- a similar $/mm compared with the baseline treatment
- a higher GM/mm than the higher intensity treatment

The above highlight that the low intensity treatment has a the greater rainfall:grain production conversion than the other systems.

Implementing a greater frequency of legume crops into the FS did increase key nutrient export: N, P and K, from the cropping system, compared with the baseline system. This is due to legume seeds having a higher nutrient concentration than cereal grain. Moving forward, growers need to be aware of the exported nutrients from their system, in particular P and K, as they will need to be replaced and some constrained soils could possibly need increased application to ensure a full yield potential.

Table 3 Narrabri cropping systems water and nutrient use efficiency (NUE), 2015–2020.

System	Water use			Nutrient use			
	Average FE (%)	Average grain WUE (kg/mm/ha)	System ($/mm)	Exported N (kg N/ha)	System NUE (kg grain/kg N)	Exported P (kg P/ha)	Exported K (kg K/ha)
Baseline	30	4.4	0.62	176	1.65	26	42.1
Higher nutrient	26	3.7	0.29	159	0.79	24	41.5
Higher legume	25	4.9	0.63	230	2.54	34	54.3
Higher diversity	26	3.1	0.0	139	-1.87	21	31.6
Higher intensity	32	3.7	0.39	160	0.71	31	29.5
Lower intensity	11	3.7	0.59	99	-1.46	17	19.6

FE = ∑Soil water ÷ ∑fallow rain
Grain WUE = ∑grain yield ÷ crop water use
System WUE = system GM ÷ crop water use
Exported N, P and K = grain yield × grain content (N, P or K)
System NUE = exported N ÷ ∑crop N use.

During the FS project, Predicta B ® testing for disease, including *Pratylenchus thornei* (Pt) occurred biannually, pre and post every crop. At Narrabri, Pt nematode numbers indicated a strong correlation with FS treatments (Figure 5). In 2016 the crop choice had a large effect on Pt numbers. Chickpea planted in the baseline and higher nutrient systems increased Pt numbers by up to five times over the 2016 pre-sowing numbers. The other legumes planted in 2016, field pea in the higher diversity plots and faba bean in the higher legume system, also increased Pt numbers, but not to the extent in chickpea. Although Pt numbers did increase to moderate levels in 2016 within the baseline and higher nutrient systems, there was no yield effect – chickpea yields for both systems was 2.7 t/ha.

P. thornei numbers reduced across all six systems during the 2016–17 summer fallow. Numbers in both the baseline and higher nutrient systems increased slightly during the 2017 wheat crop (LongReach Lancer⁽ᶦ⁾). As a result, both these systems had more than three times the Pt numbers than the other four farming systems by the end of 2017. Conversely, in the other four farming systems treatments, Pt numbers reduced during 2017 with levels less than 1.3 nematodes/g soil (Figure 5) by the end of 2017. With drought-like conditions starting in the winter of 2018, Pt DNA numbers dropped across all treatments and remained in the low population category until the end of the project (May 2020).

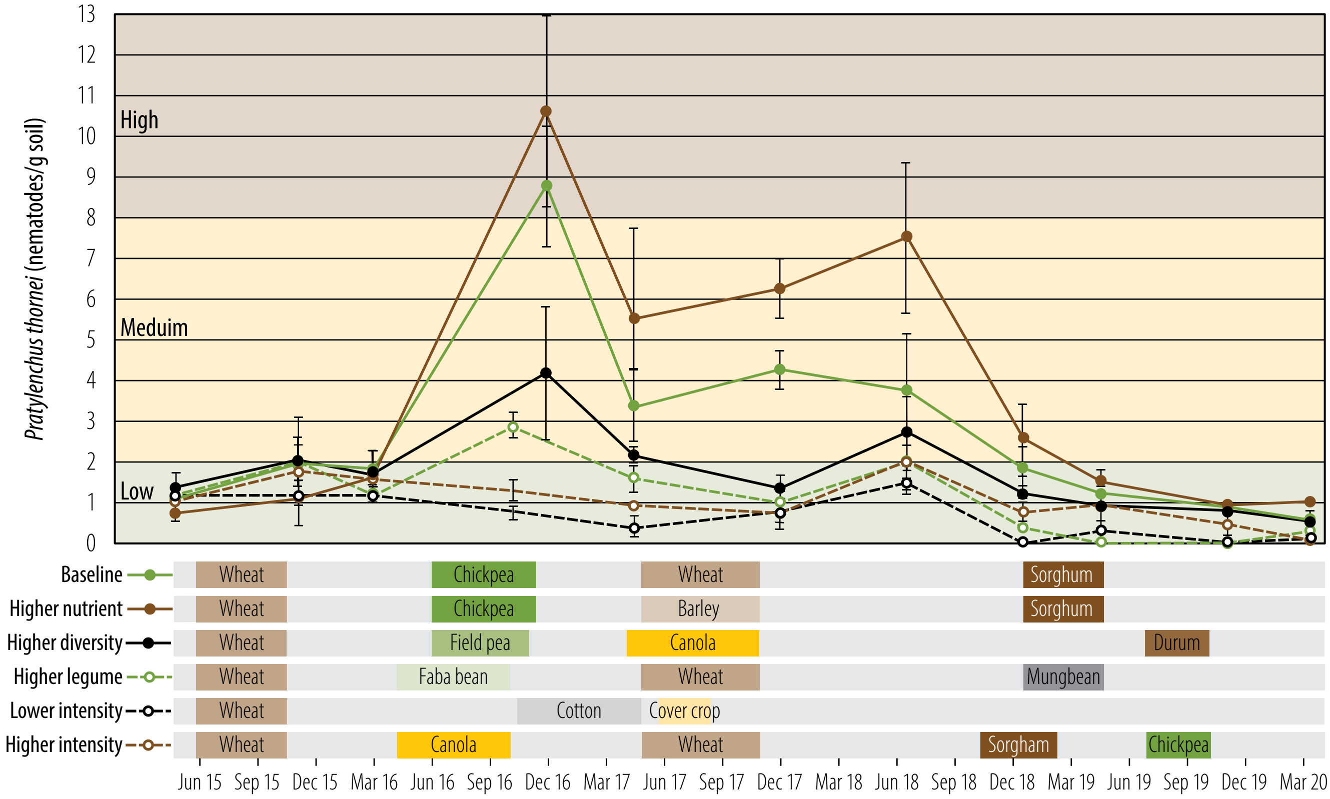

Figure 5 Root lesion (*P. thornei*) nematode numbers at Narrabri between 2015 and 2020.

Conclusions

In terms of grain productivity and systems gross margin, both the baseline and the higher legume systems performed above the other four systems during the five-year experiment. Both systems (baseline and higher legume) had high grain yields during the favourable seasons, in addition the selected crops had high grain value which improved the gross margins.

There was no increase in grain production for the higher legume system over the baseline treatment. These results show that there was not a nutrient deficiency in the years of this experiment for the Narrabri crops, but that water limited yield potential. As this research continues, it will be interesting to analysis if the additional fertiliser added to the higher nutrient system will generate more yield in favourable conditions.

The crop sequence for the baseline system (wheat–chickpea–wheat) had implications for soil-borne disease and nematode numbers. Of particular concern were the long-term effects on nematode numbers (especially *P. thornei*). Future crop selections for the baseline and higher nutrient systems will need to consider the varieties' nematode susceptibility. The system required a species to decrease nematode numbers, with sorghum chosen for this experiment.

The increased frequency of legume crops within the cropping system at Narrabri has not improved soil fertility. Conversely, the modern, high yielding legume cultivars can create a nutrient deficiency within the cropping system. Both faba bean and chickpea crops decreased soil mineral N and K levels in the immediate fallow period post harvest, mainly due to the high nutrient exportation in the seed. Future systems will need to apply more fertiliser to take into account this high nutrient exportation.

Although grain productivity and system income were lower in the lower intensity system, it did have a high conversion of rainfall to income and ROVC. This was evident during the low rainfall seasons at Narrabri, proving that a conservative approach to cropping intensity is beneficial when growing conditions are not ideal. Similar to northern NSW, Narrabri received low rainfall during the 2018-2019 seasons which compromised any benefits of aggressive cropping frequencies (such as the higher intensity systems)

Acknowledgements

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