

Long-term rotation diversity, but not residue handling, affects wheat yield and protein content.

Phil Ward¹, Ken Flower^{2,3}, David Minkey³, Shayne Micin¹, Neil Cordingley³, ¹CSIRO, ²University of Western Australia, ³WANTFA

Key messages

- Wheat in the most diverse rotation is now consistently producing more grain (by about 0.2t/ha), with consistently higher grain protein (by about 1.6%), compared with the continuous wheat treatment.
- Residue windrowing and burning has reduced residue levels by about 50%, which has had an inconsistent impact on crop yield and has decreased wheat protein in the cereal rotation, but not in the diverse rotation.

Aims

The long-term rotation trial at Cunderdin was originally established in 2007 to develop and test enhanced conservation farming practices, built around minimum soil disturbance, maximum residue retention, and diverse rotations. In this report we show the impacts of rotation diversity and residue handling on wheat yield and protein content.

Method

Trial design and location

The trial was set up in a randomised block split-plot design with three replicates, in a paddock on the Cunderdin Agricultural College on a red loamy soil. Each main plot (based on rotation – see next sub-section) is 36m by 80m.

Rotations and N application





Four rotations are being compared in the main plots of the trial: continuous wheat (one plot); continuous cereal (three plots, e.g. wheat/wheat/barley); 'district practice' (three plots e.g. wheat/wheat/chemical fallow); and diverse (three plots, e.g. wheat/legume/canola) (Table 1). Therefore there are 10 main plots per replicate. The trial commenced in 2007, and has just completed its 4th full three-year rotation (2007-09; 2010-12; 2013-15; 2016-18). The wheat variety was Bonnie Rock  (2007-09), Magenta  (2010-12), Mace  (2013-15) and Impress  (2016-18).

Table 1. Crop rotations at the long-term trial, and average quantity of N applied (kg N/ha/yr) for each rotation.

Sequence	1	2	3	4	5	6	7	9	10	11
Year	Continuous cereal			Diverse			Wheat	District practice		
2007	Saia	Barley	Barley	Wheat	Vetch	Canola	Wheat	Wheat	Barley	Lupin
2008	Barley	Barley	Saia	Vetch	Canola	Wheat	Wheat	Barley	Lupin	Wheat
2009	Barley	Saia	Barley	Canola	Wheat	Vetch	Wheat	Lupin	Wheat	Barley
2010	Wheat	Wheat	Wheat	Wheat	Pea	Canola	Wheat	Wheat	Barley	Pea
2011	Wheat	Wheat	Wheat	Pea	Canola	Wheat	Wheat	Barley	Pea	Wheat
2012	Wheat	Wheat	Wheat	Canola	Wheat	Pea	Wheat	Pea	Wheat	Barley
2013	Wheat	Wheat	Barley	Wheat	Ch.pea	Canola	Wheat	Wheat	Barley	Fallow
2014	Wheat	Barley	Wheat	Ch.pea	Canola	Wheat	Wheat	Barley	Fallow	Wheat
2015	Barley	Wheat	Wheat	Canola	Wheat	Ch.pea	Wheat	Fallow	Wheat	Barley
2016	Wheat	Wheat	Barley	Wheat	Albus	Canola	Wheat	Wheat	Barley	Fallow
2017	Wheat	Barley	Wheat	Albus	Canola	Wheat	Wheat	Barley	Fallow	Wheat
2018	Barley	Wheat	Wheat	Canola	Wheat	Albus	Wheat	Fallow	Wheat	Barley
N applied	50.1	51.3	50.1	32.1	33.4	32.7	53.7	31.2	30.5	31.8

Nitrogen was applied to each crop based on anticipated N requirement and yield depending on seasonal conditions. No extra N was applied to legumes or fallows.

Residue handling

In the continuous cereal and diverse rotations, the main plots were split into sub-plots (18 m by 80 m) commencing with the 2010 harvest. Sub-plot treatments were residue retained and spread behind the header; or residue windrowed and burned before sowing the next crop.

Results and Discussion

Wheat yield

Wheat yield has varied considerably from year to year, and differences between the rotations were small and non-significant for 2007-2009 (average 2.3 t/ha) (Figure 1). For the period 2010-2017, average wheat yield in the higher residue treatments was greatest in the district practice treatment (2.49 t/ha), where wheat has been grown after a fallow since 2013. In the diverse treatment, average wheat yield (2.25 t/ha) was significantly (LSD = 0.12) greater than from the continuous cereal treatment and the continuous wheat treatment (both 2.07 t/ha).

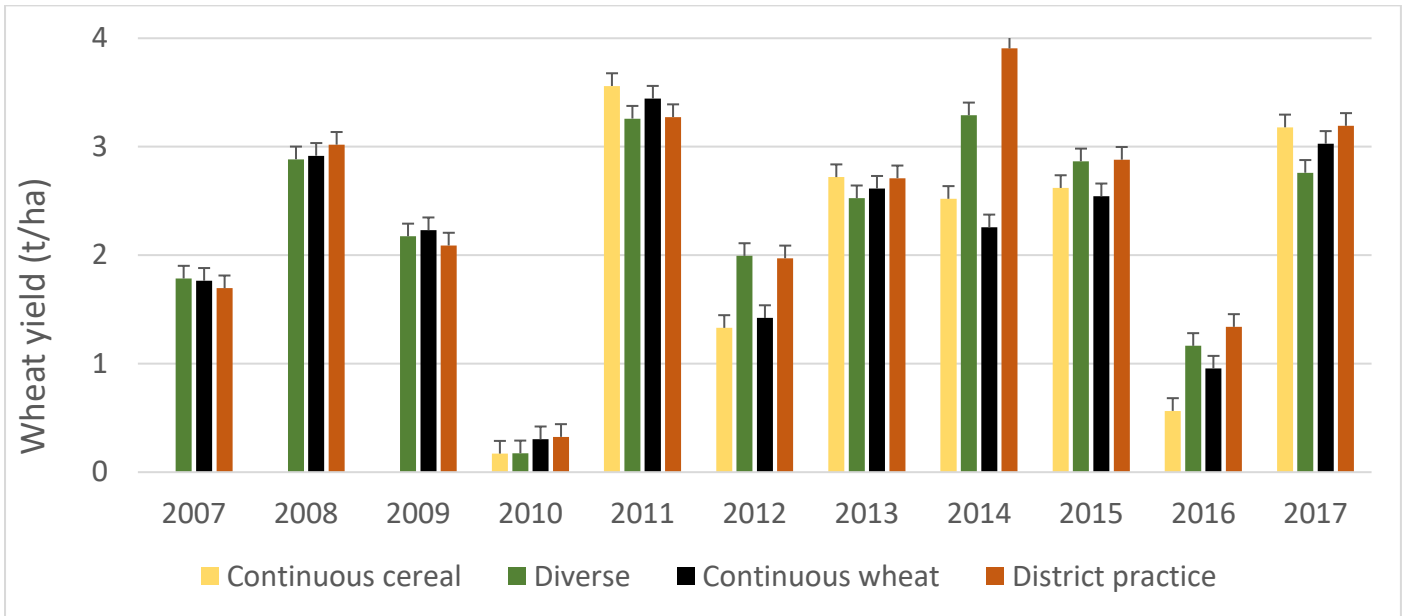


Figure 1. Wheat yield in various higher residue rotations since 2007. Error bars represent the least significant difference (LSD) for comparing treatments.

There was no consistent effect of residue management on crop yield. In some years (e.g. 2011 and 2013), residue retention was associated with increased crop yield, but in other years (e.g. 2014), residue burning gave higher yields (Figure 2).



Figure 2. Wheat yield as affected by residue retention and rotation. Error bars represent the least significant difference (LSD) for comparing treatments.

Grain protein

Wheat grain protein content varied considerably from year to year (Figure 3). It was generally highest in the district practice treatment (grown after the fallow since 2013), and was nearly always higher in the diverse treatment than in the continuous wheat treatment (Figure 3). For the period 2011 -2017, average grain protein was 12.9% in the district practice, 12.6% in the diverse, 11.7% in the continuous cereal, and 11.0% in the continuous wheat treatments (LSD = 0.3). The higher grain protein in the diverse rotation is associated with the inclusion of the legume in the rotation, and the assumed N fixation in the legume crop. There may also be benefits from enhanced N cycling associated with the diverse rotation, but further research will be necessary to determine the magnitude of any effect. The higher grain protein in the district practice treatment in earlier years of the trial is presumably due to legumes in the rotation, and in later years is related to mineralised nitrogen accumulated in the fallows.

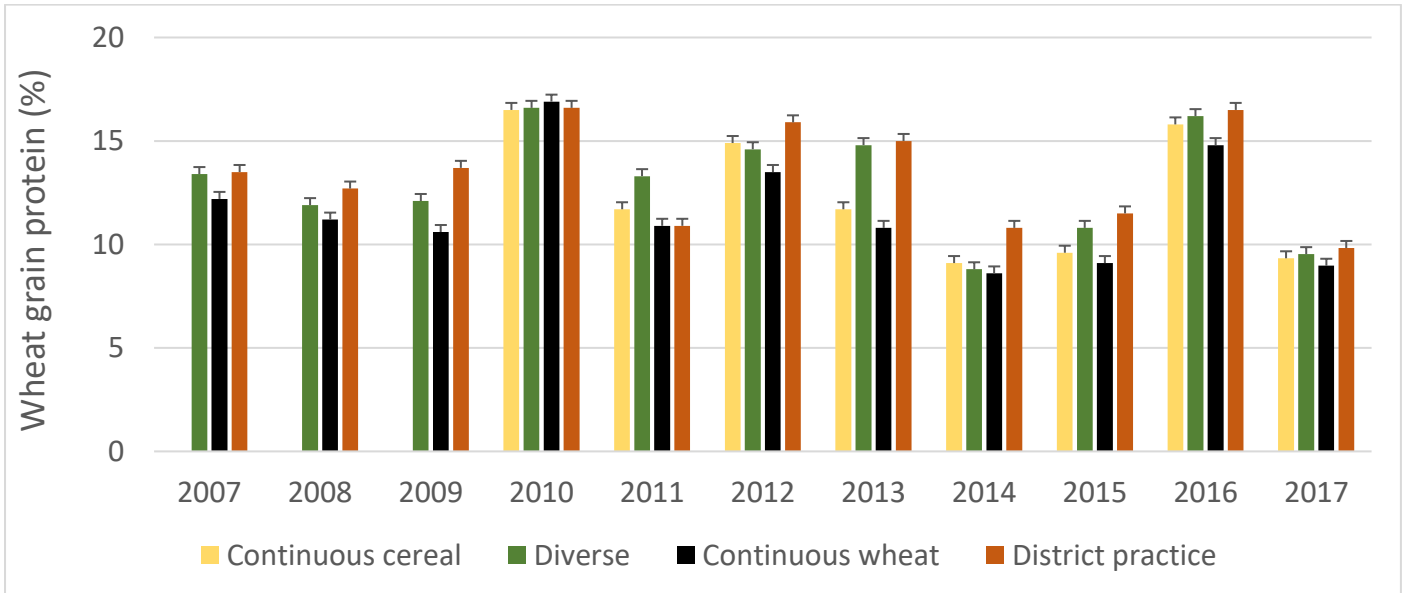


Figure 3. Wheat grain protein content in various rotations since 2007. Error bars represent the least significant difference (LSD) for comparing treatments.

Overall, residue retention significantly increased grain protein in the continuous cereal treatment, with average grain protein (2011 – 2017) increasing from 11.2% to 11.8% with residue retention. There was no significant effect of residue retention on average wheat grain protein in the diverse rotation (12.6% for high residue, 12.5% for low residue) (Figure 4). The retention of cereal stubble, with a generally low N content, was previously thought to tie up soil N, and was expected to lead to a decline in wheat grain protein. Therefore, the increase in grain protein with residue retention in the continuous cereal rotation was a surprising result. The greater input of fresh organic matter may have stimulated microbial activity leading to greater N mineralisation, but again, further research will be necessary to confirm this, and to determine the value of any positive impact.

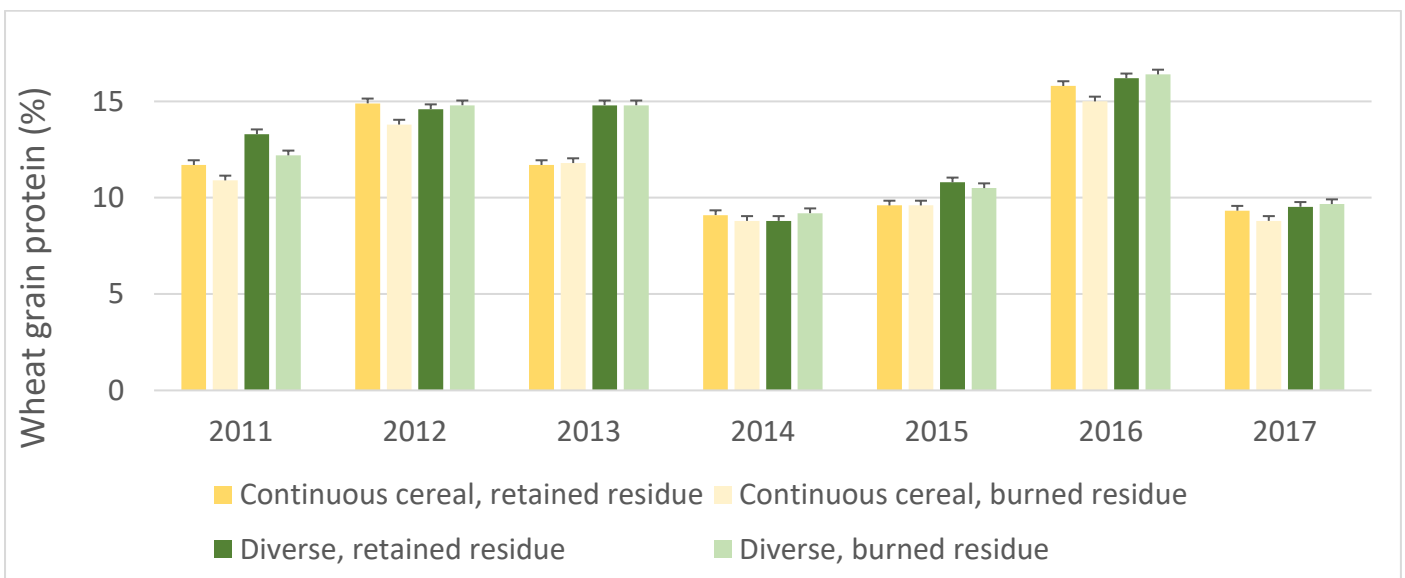


Figure 4. Wheat grain protein as affected by residue retention and rotation. Error bars represent the least significant difference (LSD) for comparing treatments.

Nitrogen balance

Over the last 12 years, the frequency of cereal crops was 100% in the continuous cereal and continuous wheat rotations, 67% in the district practice rotation, and 33% in the diverse rotation. The frequency of legume crops was 0%, 0%, 17% and 33% for the respective rotations. Looking at all phases of each rotation, up to the 2018 season, N application as fertiliser to the continuous cereal, and continuous wheat rotations (50 - 54kg N/ha/yr; Table 1), was around 8kg/ha/year greater than the N exported in grain. With assumptions for rhizobial N fixation taken from Unkovich et al. (2010) for the legume crops, N input was around 10 kg/ha/year greater than exported in the diverse rotation, but the balance was very close to neutral for the district practice rotation. Given that there is no allowance in this calculation for N leaching or other losses, it seems likely that higher yields and grain protein levels in the district practice treatment are due to mineralisation and accumulation of soil N reserves during the fallow. Without adequate replacement of these reserves, the high yields and protein contents observed in the district practice treatment may not last for much longer. However, results in the diverse rotation showing higher wheat yields with higher grain protein contents appear sustainable in the long term.

Conclusion

A diverse rotation of wheat/legume/canola, over the long term, leads to increased wheat yield (by about 0.2 t/ha), and also to increased wheat grain protein content (by 0.9% to 1.6%), when compared with a continuous cereal, or a continuous wheat rotation. Preliminary estimates of the N balance of the rotations suggests that these benefits are sustainable. While the causes of the yield and protein benefit are associated with the inclusion of grain legumes in the rotation, there may also be other benefits in the associated soil N cycling that have not been quantified yet.

The district practice rotation (with legume initially and then fallow) also resulted in higher yields (by about 0.4 t/ha) and grain protein (by 1.2% and 1.9%) compared with continuous cereal and continuous wheat; however the sustainability of this is yet to be determined.

Key words

Conservation agriculture, nitrogen fixation, grain quality

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