Effect of rainfall, rotations and residue on wheat performance

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Key messages

- There were no significant yield differences between Monoculture wheat and wheat in the more diverse rotations for the first five years.
- After this period, lower yields in some years with Monoculture wheat compared with the more diverse rotations was thought to be due to one or more factors, including disease associated with lack of rotation and heavy residues from the previous year affecting crop establishment.
- Heavy canola residues had no effect on wheat yield, whereas heavy cereal residues reduced yields in some years.
- Over the nine years of the trial Continuous cereal had the highest mean gross margin, followed by Monoculture wheat, then the Max diversity and Max profit treatments, which had similar gross margins.

Aims

To understand the long term effects of crop rotation and residue retention on wheat crop performance

Method

Experimental design and treatments

This 9 year experiment was started in 2007 at the College of Agriculture Cunderdin. The soil was an alkaline red, sandy clay-loam. All plots were 36m x 80m, with a 2m wide buffer along each side of the plots, providing a 4m guard between plots. The treatments were based on four different cropping philosophies "P1 –Maximum carbon input (Continuous cereal)", "P2 – Maximum diversity (cereal/legume/brassica rotation)", "P3 – control (Monoculture wheat)" and "P4 – Maximum profit (cereal/cereal/legume or fallow)" (Table 1). The treatments were not rigidly set because the experiment was relatively long term and we wanted the management to remain relevant. The P1, P2 and P4 philosophies had a three-year rotations with each phase presented every year and each replicated three times in a randomised complete block design. The intention was to retain maximum crop residues in P1-P3, so these treatments were seeded with a low soil disturbance 'disc opener'. It was expected that lower levels of residue would occur in P4, which was seeded with a higher soil disturbance 'tine and knifepoint' no-tillage seeder.

Table 1. Crop sequences for the different philosophies† at Cunderdin from 2007 to 2015, with every crop presented every year

	P1† **Max carbon input**	**P2** **Max diversity**	**P3** **Monoculture wheat**	**P4** **Max profit**
07-09‡	*Retain residue*	*Retain residue*	*Retain residue*	*Retain residue*
2007	Oat CC*	Wheat	Wheat	Wheat
2008	Barley	Vetch/oat CC	Wheat	Barley
2009	Barley	Canola	Wheat	Lupin
10-12‡	*+/- Windrow burn*	*+/- Windrow burn*	*Retain residue*	*Windrow burn whole plot*
2010	Wheat	Wheat	Wheat	Wheat
2011	Wheat	Field pea	Wheat	Barley
2012	Wheat	Canola	Wheat	Field pea
13-15‡	*+/- Windrow burn*	*+/- Windrow burn*	*Retain residue*	*Windrow burn whole plot +/- tillage*
2013	Wheat	Wheat	Wheat	Wheat
2014	Wheat	Chickpea	Wheat	Barley
2015	Barley	Canola	Wheat	Fallow

†Philosophy (P) 1 = Continuous cereal, P2 = cereal/legume/brassica, P3 = Monoculture wheat and P4 wheat/barley/legume or fallow. Every crop presented every year and any changes to crop only made after 3 years.

‡Residue management for the next three years. Note: plots split from 2010 onwards for retain residue (spread behind harvester) or windrow burn, unless indicated.
*CC = cover crop

From 2007 to 2009, the cover crops (CC) were black (Saia) oat (*Avena strigosa* Schreb.) and vetch/oat CC, which was a mix of Popany vetch (*Vicia benghalensis* - 40 kg ha-1) and Swan oats (Avena sativa - 30 kg ha-1). The other crops were Bonnie Rock wheat (*Triticum aestivum* L.), Baudin barley (malt-type, *Hordeum vulgare* L.), Mandelup lupin (*Lupinus angustifolius* L.) and Stubby canola (*Brassica napus* L.) in 2007/2008 and Tanami canola in 2009. In 2010 to 2012, the varieties were Magenta wheat, Buloke barley (malt-type), Eclipse (Roundup Ready - RR) canola and Kaspa field pea (*Pisum sativum* L.) in 2010 and Twilight field pea in 2011/2012. From 2013 to 2015 the varieties were Mace wheat, Striker chickpea (*Cicer arietinum* L.), Scope barley in 2013/2014 and Buloke in 2015, with Sturt TT canola in 2013 and IH30RR canola in 2014/2015 (Table 1). In 2013 wheat in P1, P2 and P3 was re-sown due to pre-emergent herbicide damage, whereas P4 was not re-sown as the damage was less with the tine and knifepoint.

Measurements for crop yield, residue and economics

Crop yields were measured by taking a total of 18 hand cuts of 1m of crop row for each split plot. This was done by walking down the tramlines (where the harvester travels) and selecting 3 locations at random on the harvester tracks, then taking three samples of 2m crop rows at each location that were kept separate (directly behind the harvester, middle and outer edge of the cutting front). Pre-seeding crop residue was measured in March/April, in a similar manner.

Results

Rainfall

Since its inception in 2007, the trial has had relatively low rainfall, with only 2011 (420mm) exceeding the 20 year annual average for Cunderdin Airport of 300mm (Table 2). Four of the years (2007, 2010, 2012 and 2015) had <250mm annual rainfall, with the driest in 2010 (168mm). Overall, there was a strong relationship between growing season rainfall and wheat yield, with rainfall explaining about 80% of the variation in wheat yield (Fig. 1).

Table 2. Pre-seeding, growing season and annual rainfall at Cunderdin from 2007-2015

	Preseed (Jan-Mar)	Apr-June	GSR (Apr-Oct)	Annual
2007	21	64	186	235
2008	27	120	284	338
2009	43	77	213	280
2010	39	37	101	168
2011	67	85	268	420
2012	35	77	137	228
2013	71	50	229	303
2014	8	148	321	360
2015	29	64	188	242

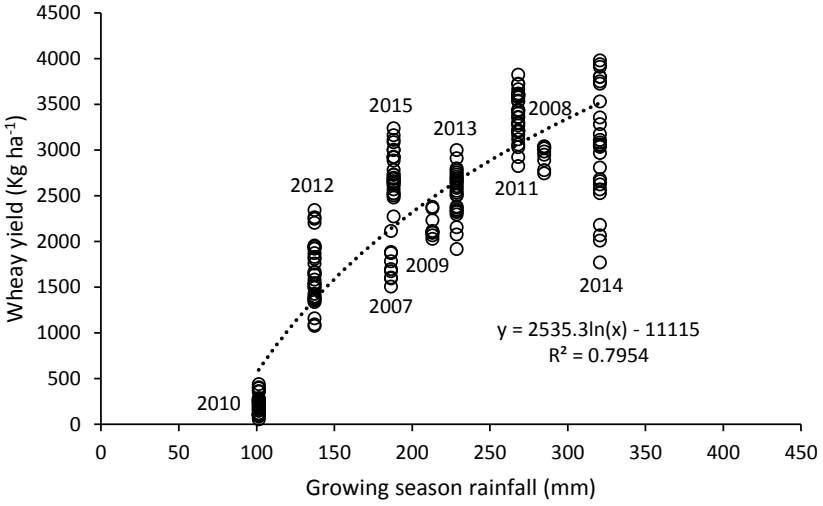

Fig. 1. Relationship between wheat yield and growing season rainfall from 2007 to 2015

Rotation

There are many factors influencing yield responses in crop rotation trials. For instance, there may be a well-documented 'rotation effect' with lower level of disease and/or improved soil fertility or water storage. In addition, there are also a number of possible residue effects. A large amount of residue may impede the seeding operation or establishment of the following crop. The effect of residue amount over time is also unlikely to be consistent if changes to the seeding machinery are made that may improve residue handling or a different harvester is used that spreads the residue better. An additional factor affecting the residue response is that the establishment of the crop may depend on the type of residue interacting with the crop type.

There was a wide range of rotations in this trial including Monoculture wheat, cereal/cereal/legume (or fallow) (called Max profit) and cereal/legume/brassica (called Max diversity). All treatments had residue retention for the first three years, following which some plots were split for windrow burn (although still retaining some residue) and full residue retention (spread behind harvester).

There were no significant differences in wheat yield between Monoculture wheat (which only had fully retained residue) and wheat grown with Continuous cereal and fully retained residue. Therefore, only the Monoculture wheat was shown for the comparison of the rotations, as this treatment was present for all years (and for clarity) (Fig. 2).

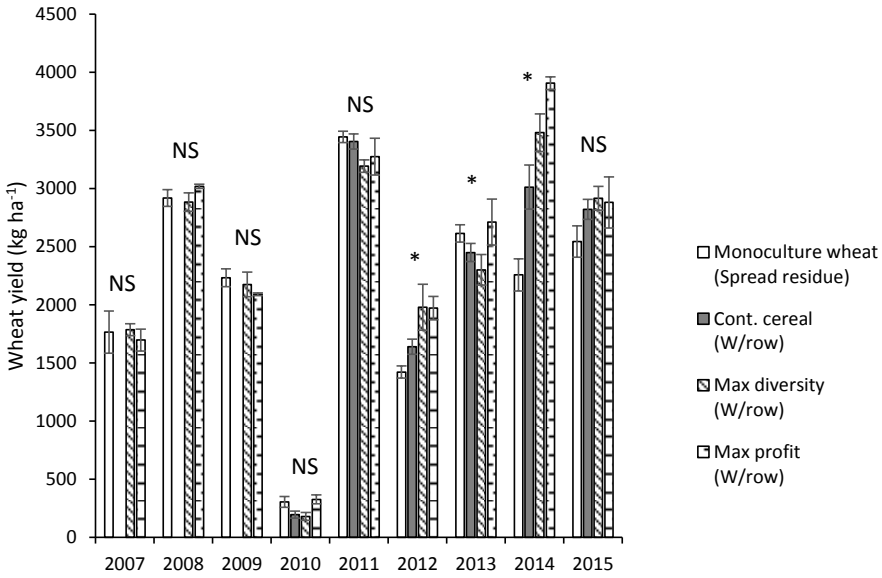

Fig. 2. Wheat yield for Monoculture wheat (residue retained by spreading), Continuous cereal (windrow burn), Maximum diversity (wheat/legume/brassica with windrow burn) and Maximum profit (wheat/barley/legume or fallow with windrow burn). Note 2007-2009 was all barley for Continuous cereal, so no yields shown. NS = not significant and asterisk (*) indicates significance at P≤ 0.05 (2012 and 2014 Monoculture < Max diversity and Max profit; 2013 Max diversity < Max profit). Error bars are ±SE (n=3, except for Continuous cereal where n=9 from 2010 to 2012 and n=6 from 2013 to 2015).

There were no significant differences between Monoculture wheat and the more diverse rotations for the first five years (2007 to 2011). There was a significantly lower yield with Monoculture wheat compared with the more diverse rotations (Max diversity and Max profit) in 2012 and 2014 and no significant differences in 2013 and 2015, although the Monoculture wheat was still the lowest in 2015 (Fig. 2).

The lower yield with the Monoculture wheat in 2012 and 2014 may have been due to the 'rotation effect' as we measured higher disease in the Monoculture wheat (data not shown). Also this treatment had higher levels of crop residue present at seeding (approx. 5500 kg/ha in 2012 and approx. 3400 kg/ha in 2014) which reduced establishment and/or number of tillers/wheat heads (data not shown); whereas the other windrow burn treatments had between 400 kg/ha and 2000 kg/ha of residue at seeding. Residue management was improved in 2015 with the addition of residue managers on the seeder, therefore the effect of residue on yield was less evident.

Wheat yield differences between the Max diversity and Max profit treatments were only significant in 2013 ($P \leq 0.05$) (Fig. 2). It is possible that the higher yield with the Max profit treatment in 2013 was due to the fertility effect from the previous field peas, as the fallow had not been implemented at the start of 2013; whereas the Max diversity wheat was following canola (with field peas before that). Also, the Max diversity treatment had very little residue left after the crop was re-sown (following legume and canola) and the soil dried out and formed a crust which affected establishment/growth. The slightly higher wheat yield in 2014 was likely to be due to a 'fallow effect', with a relatively dry summer, although this was not significant at $P \leq 0.05$ (Table 2). There was no 'fallow effect' in 2015.

Residue comparisons (spread vs windrow burn) for the Continuous cereal and Max diversity

The different residue treatments (spread (fully retained) and windrow burn) were implemented after the end of the 2010 growing season, to provide different levels and composition of crop residue. The Continuous cereal and Max diversity rotations had similar amounts of crop residue. Both had an average of 3600 kg/ha of pre-seeding residue (from 2011 to 2015) in the spread treatment, while the Continuous cereal averaged 2200 kg/ha and the Max diversity 1900 kg/ha in the windrow burn treatments, although this varied considerably and was relatively low following dry seasons. Residue levels exceeded 5000 kg/ha in Continuous cereal with residue spread in 2012, following the relatively high rainfall in 2011. The effect of residue management (spreading the residue compared with windrow burning) on wheat yields was only significant for the Continuous cereal treatment, despite there being similar dry-mass of residue in both rotations (Fig 3). The differences were due to type of residue, with wheat being grown in wheat residue for the Continuous cereal treatment, whereas wheat was grown in canola residue in the Max diversity treatment.

For the Continuous cereal rotation, spreading all the residue had a slight positive effect on yield in 2013, but a negative effect in 2012, 2014 and 2015. The negative effect was due to reduced establishment and/or tillers, and this was mainly due to poor spreading of the residue by the harvester. The negative effect was minimised in 2015 due to the use of residue managers, however, improving the spread by the harvester would be a better solution.

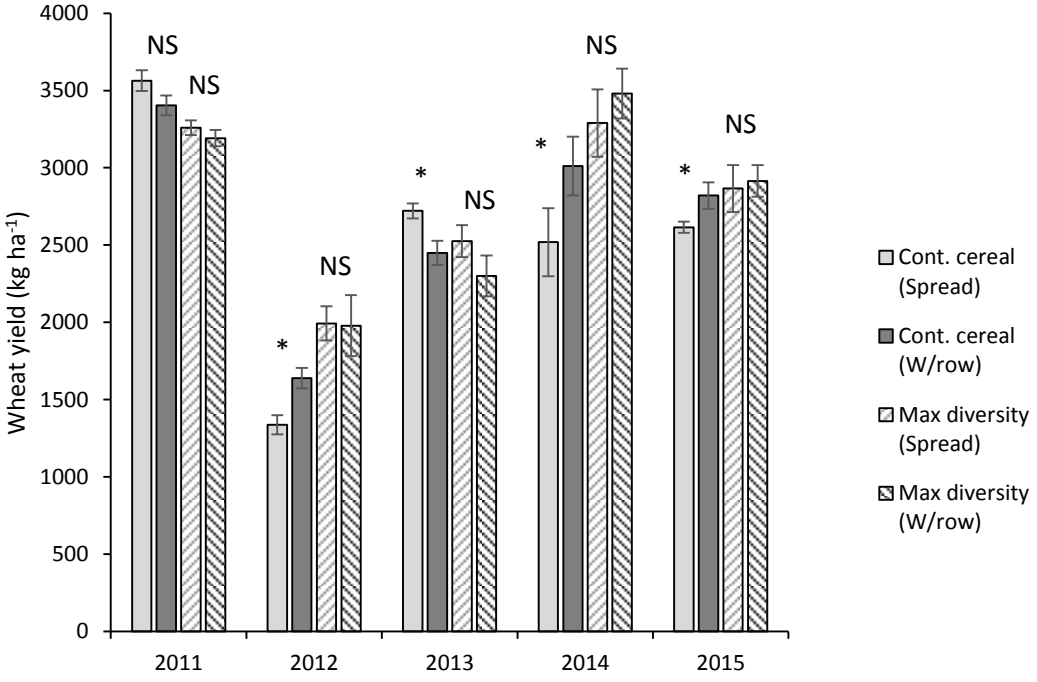

Fig. 3. Wheat yield for Continuous cereal and Max diversity from 2011 to 2015, comparing residue retained by spreading with windrow burn. Note residue treatments only implemented for the 2011 season. NS = not

significant and asterisk (*) indicates significance at P≤ 0.05 for residue spread vs windrow burn for the Continuous cereal treatment only. Error bars are ±SE (n=3, except for Continuous cereal where n=9 from 2010 to 2012 and n=6 from 2013 to 2015).

Economics

Over the nine years of the trial Continuous cereals had the highest mean gross margin, followed by Monoculture wheat then the Max diversity and Max profit treatments, which had similar gross margins (Fig. 4). The low gross margin for the Continuous cereal and Max diversity in the first three years, from 2007-2009, was due to the inclusion of the cover crops and for the latter due to poor canola yield in 2007 and 2009, which were relatively dry. Similarly, this treatment also had poor canola yields in 2010 and 2012, which were also low rainfall years, and this reduced the mean gross margin for the next three year period from 2010-2012. The profitability of the Max profit treatment was reduced by the inclusion of the legume, as was the Max diversity treatment, and the fallow from 2013-2015, despite higher wheat yields in some years. The high gross margin in the Continuous cereal in the 2013-2015 period was largely driven by exceptional barley yield in this treatment in 2013 (data not presented), which was nearly 1 tonne more than the barley in the Max profit treatment in that year.

These rotation gross margins assume equal land area for each component of the rotation, so in the future they will need to be modelled to determine the optimum area of land allocated to the different crops to maximise gross margins.

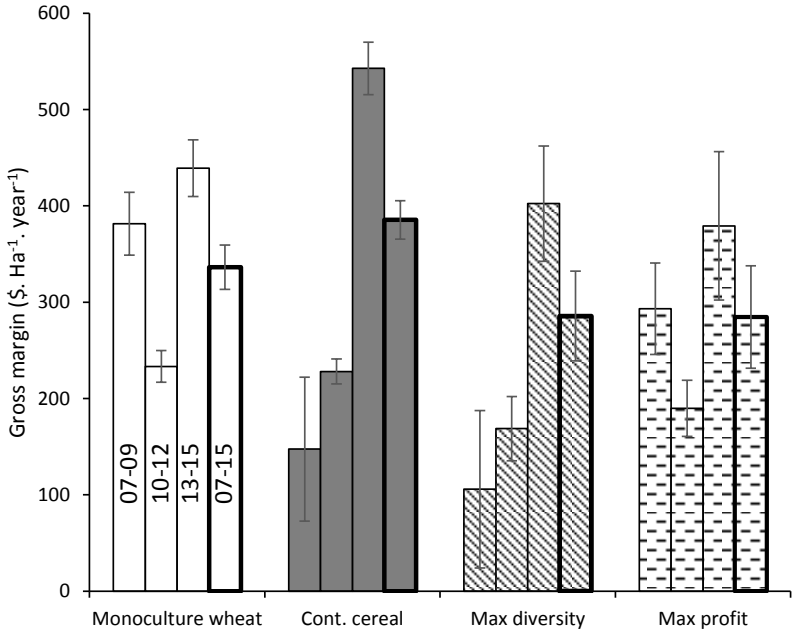

Fig. 4. Mean rotation gross margins ($ ha^{-1} year^{-1} including all crops/fallow in the rotation) over each three year period (in order) from 2007-2009, 2010-2012, 2013-2015 and over nine years from 2007-2015. The gross margin calculations were based on nine year mean input and grain prices. Error bars are ±SE (three year gross margins n=9 for Monoculture wheat and 27 for other treatments, nine year gross margins n = 27 for Monoculture wheat and 81 for the other treatments).

Conclusion

There were no significant differences between Monoculture wheat and the more diverse rotations for the first five years (2007 to 2011). There was a significantly lower yield with Monoculture wheat compared with the more diverse rotations (Max diversity and Max profit) in 2012 and 2014 and no significant differences in 2013 and 2015, although the Monoculture wheat was still the lowest in 2015.

The type of crop residue had a significant impact on wheat yield, with heavy canola residues having no effect on wheat yield, whereas heavy cereal residue (such as in Continuous cereal) reduced yield in some years compared with the equivalent windrow burn plots. For Continuous cereal, spreading all the residue had a slight positive effect on yield in 2013 compared with windrow burning, but a negative effect in 2012, 2014 and 2015. The negative effect was due to reduced establishment and/or tillers, and this was mainly due to poor spreading of the residue by the harvester. The negative effect was minimised in 2015 due to the use of residue managers.

Overall, Continuous cereal had the highest gross margin followed by Monoculture wheat and the Max Diversity and Max profit were similar. The lower gross margin in the Max diversity was because of the cover crop grown in the first

three years, along with poor canola yields in the relatively dry years of 2007, 2010 and 2012. The profitability of the Max diversity and Max profit treatments was reduced by the inclusion of the less profitable legumes, despite higher wheat yields. The fallow also reduced the profitability of the Max profit treatment from 2013-2015.

Key words

No-tillage, conservation agriculture, rainfall rotation, crop residue, stubble

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