# Investigating Double Break Options

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**Summary**

The use of break crops in rotation are well known to reduce soil disease levels and weed burdens in cropping paddocks to increase the grain yield of cereal crops. However, high disease and weed burdens are not always reduced to a low level following one break crop, and this project aimed to evaluate a range of double break crop scenarios to effectively reduce the impact of disease and weeds on grain yield. Four demonstration sites and one replicated field site were established across the Kwinana West and Kwinana East port zones in 2017 following a range of break crops in 2016. A range of legume crops were sown at each site, including lupin, chickpea, and lentil, and were compared to either wheat or canola that was sown in the same paddock adjacent to the demonstration site. Pratylenchus neglectus was found to be the most prevalent disease constraint across all sites in this study. The use of lupin and lentil was found to be most effective at reducing these nematodes, while canola and chickpea were not effective and led to an increase in P.neglectus levels in general. Volunteer pasture as the first break crop that likely contained grasses and cereals still had a large amount of root disease constraints in the following year. Chemical fallow was not effective at controlling Crown rot as crop stubble was retained during the fallow period. Double breaks were considered effective at controlling constraints to root growth when the crop type and resistance status was matched to the root constraint to give a reduction in root constraint in the following year. The use of the PredictaB root disease testing service is highly recommended to identify root diseases prior to planning an effective break crop rotation.

**BACKGROUND**

Why do the work? Why the trial was done. The issue that led to the project, impetus for the work, or previous work that has led to this project

Including break crops into rotations with cereals can influence the nitrogen (N) dynamics of cropping systems (Peoples et al. 2001) and assist in the management of weeds and reduce disease incidence in crop rotations (Kirkegaard et al. 2008). However, the adoption of break crop rotations in WA by grain growers is low due to the low perceived profitability of these crops. This is influenced by high input costs for canola, and fluctuating grain prices of pulses (Seymour et al. 2012).

A review in 2009 was conducted using forty years of crop sequencing trials by the Department of Agriculture and Food WA to give Western Australian grain growers an insight into the rotational benefits of break crops. Approximately 160 crop sequence experiments were analysed, and the data clearly demonstrated that continuous wheat was rarely as productive or economically viable as rotations that included either a pasture or break crop, regardless of how much nitrogen fertiliser was applied. It also points to the difficulty of achieving yields higher than 2.5t/ha when wheat is sown after wheat. Overall, wheat sown after lupins out yielded wheat sown after wheat.

The use of a single break crop in rotation has been shown to be an effective tool in managing both weed and diseases that affect wheat production. Two GRDC funded trials in paddocks with herbicide-resistant annual ryegrass at Eurongilly, NSW (near Junee) in 2012 and 2013 found weeds had a significant impact on wheat production. Both trials demonstrated that clean fallow or break crop can deliver cheaper, more effective ryegrass control compared with in-crop grass management options in wheat. However, despite the effectiveness of break crops in reducing ryegrass seedbanks (from 5500 to between 114 and 500 seeds per square metre), a single year of weed control was insufficient to prevent yield reductions in the following wheat crop, even with additional in-crop control measures. It was concluded that a break of at least two years was needed to prevent grass seed set and substantially reduce grass seedbank numbers (Peoples 2013)

The use of two successive break crops has led to large increases in cereal yields in the low rainfall zone of South Australia. Intensive field trials of 40 different break sequences have been investigated, including pastures and break crops - such as pulses, canola, brown manure vetch and oaten hay, and have been grown for up to two seasons. Despite very strong wheat yields in the first two years of the trial, disease and grassy weeds are now starting to reduce performance of continuous wheat. However, wheat following two-year breaks are now producing gross margins several hundreds of dollars per hectare higher than continuous wheat that has no major yield constraints present. One-year breaks have improved the following wheat performance, but weeds and diseases are still present.

There has been little work conducted in Western Australia to evaluate the use of successive break crops on the grain yield of wheat. Through the use of economic simulations using the model 'LUSO', the following scenarios have been investigated. Under high wheat prices, in 3 years, continuous wheat was the most profitable. When the rotation was extended to 5 years, including 1 canola break crop gave the highest economic return. When the rotation length was extended to 10 years, 2 green manure pasture breaks increased the economic return. At low wheat prices: adding 1 canola crop in a 3 year rotation, 2 canola crops in a 5 year rotation, and 2 canola crops and 2 green manure pastures in a 10 year rotation, all led to the highest economic return. The size of the weed seedbank required to justify growing a break crop declined as the planning horizon increased and the commodity price of wheat decreased (Lawes, Zee 2015)

This project will investigate the use of double break crops to increase the yield of subsequent wheat crops in the Kwinana East and West port zones of the WA grain growing region through the use of field experimentation.

**OBJECTIVES**

What are the objectives of the trial? What is intended to be achieved in carry out the trial?

The main objective of this project is to quantify the rotational benefits of broadleaf crops or pastures for cereals – looking at 1 or 2-year break, and to:

- identify whether profitable broadleaf cropping sequence are available as alternatives to continuous cereals for low, medium and high rainfall zones
- provide guidelines for grain-growers and their advisers when and where to include a double break crop to achieve the best outcome.

**METHODS**

*How the trials was done. Avoid overly technical language; yet describe the way the project has approached the task.*

*NOTE: Please include trial location details :Latitude and Longitude, or nearest town, using the table below*:

**Main Replicated Trial Site**

| **Trial: Phil Gray, Nokaning WA** | **Latitude (decimal degrees)** | **Longitude (decimal degrees)** |
|---|---|---|
| **Trial location** | -31.373891° | 118.285035° |
| **Nearest Town** | Merredin, WA | |

This trial is managed by Kalyx and is situated north of Merredin. The trial will be going into its 3rd year in 2018 and all trial plots will be sown into wheat. The aim is to determine the difference in grain yield for wheat following a range of single or double break crop rotations, compared to continuous wheat. The site was established in 2016 on a paddock that had very high level of ryegrass that was affecting crop production. This area around this trial has been in pasture for 2017 as the comparison farmer solution for the issue.

Table 1. The 3-year treatment rotation plan for the Merredin trial site to evaluate a range of break crop rotations. This site was implemented in 2016 and will finish at the end of 2018.

| Treatment number | Year 1 | Year 2 | Year 3 |
|---|---|---|---|
| 1 | Vetch | Canola TT | Wheat |
| 2 | Narrow-leaf Lupin | Canola TT | Wheat |
| 3 | Balansa clover | Canola TT | Wheat |
| 4 | Fallow | Fallow | Wheat |
| 5 | Fallow | Chickpea | Wheat |
| 6 | Fallow | Lentil | Wheat |
| 7 | Fallow | Canola TT | Wheat |
| 8 | Subclover | Canola TT | Wheat |
| 9 | Fallow | Subclover | Wheat |
| 10 | Fallow | Field Pea | Wheat |
| 11 | Fallow | Oats | Wheat |
| 12 | Wheat | Wheat | Wheat |

This site is a randomised block design experiment with 4 replicates and has a range of double-break crop rotations using combinations of Bonito canola, chemical fallow, PBA Striker chickpeas, Hurricane lentils, Balansa clover, Field pea, Williams oats and Mace wheat. The plot size was 12 m long by 3.6 m wide.

The site was sown dry on the 5$^{th}$ of June, with the details of seeding rate, fertiliser, and chemical applied during the season being listed in Appendix A. The site was harvested on the 25$^{th}$ of November, with the wheat, field pea, and oats being harvested by mechanical harvester. The lentil and chickpea plots were too short to mechanically harvest, and yield was determined by hand harvest using a 1 $m^2$ quadrat. There was no data recorded for the TT canola as the grain had shed before it was able to be harvested.

**Demonstration Site 1**

| Demonstration 1: Barry Large | Latitude (decimal degrees) | Longitude (decimal degrees) |
|---|---|---|
| **Trial location** | -30.488858° | 166.243044° |
| **Nearest Town** | Miling, WA | |

Table 2. Description of cropping inputs used at the Miling site in 2017

| Item | Quantity | Date Used |
|---|---|---|
| **Fertiliser (type and rate)** | MAP 50 kg/ha<br>ALOSCA inoculant 10 kg/ha | 30 May 2017 |
| **Herbicide** | Glyphosate 450 - 1.5 L/ha<br>Trifluralin - 2.0 L/ha<br>Chlorpyrifos – 200 mL/ha | 30 May 2017 (before seeding) |

| | | |
|---|---|---|
| | Quizalafop 200 – 50 mL/ha<br>Clethodim – 400 mL/ha<br>Uptake – 0.5% | 25 July 2017 |

In 2017 demonstration site 1 was cropped into blocks of Jurien lupins, PBA striker desi chickpeas and Hurricane lentils. The 2017 crops were the second break crop for the demonstration area. In 2016 this site was volunteer pasture.

The trial area was seeded by the farmer, using an air seeder in single strips that were a seeder width wide and 100m long. Throughout the season chemicals were applied by a ute mounted sprayer specific to each plot. Further information regarding the chemicals and fertilisers are presented in Table 2. All 2017 crops were hand harvested in 1 square meter sections as they were too low for machine harvesting due to the dry seasonal conditions that were experienced in this region. There was wheat grown as a comparison in the remaining area of the paddock at this site.

In 2018 the paddock will be sown to wheat by the farmer. The demonstration site will be monitored throughout the year by WMG.

**Demonstration site 2**

| Demonstration 2: Nick Gillet | Latitude (decimal degrees) | Longitude (decimal degrees) |
|---|---|---|
| **Trial location** | -30.674600° | 117.894633° |
| **Nearest Town** | Bencubbin, WA | |

Table 3. Description of fertiliser and herbicide inputs for the Bencubbin site in 2017.

| Item | Quantity | Date Used |
|---|---|---|
| **Fertiliser (type and rate)** | MAP – 50 kg/ha<br>ALOSCA inoculant -10 kg/ha | 28 April 2017 |
| **Herbicide** | Propyzamide – 1kg/ha<br>Clethodim – 500 mL/ha<br>Uptake – 0.5% | 28 April 2017<br>July 2017 |

Demonstration site 2 was located near Bencubbin. In 2016 the paddock was a chemical fallow. In 2017 Jurien lupins, Desi chickpeas, Hurricane lentils and Kabuli Chickpeas were planted in 250 metre by 18 metre strips. The trial was seeded using farmer equipment on the 28th April 2017, and post emergent spraying completed using a ute mounted sprayer. All herbicide and chemicals used at the site are presented in Table 3. The crops were too short for machine harvesting, and were hand harvested using a 1 $m^2$ quadrat at maturity.

This year the paddock will be sown to wheat by the farmer and the trial areas will be monitored by WMG.

**Demonstration site 3**

| Demonstration 3: John Even | Latitude (decimal degrees) | Longitude (decimal degrees) |
|---|---|---|
| **Trial location** | -31.106779° | 116.597726° |
| **Nearest Town** | Calingiri, WA | |

Table 4. Description of fertiliser and herbicide inputs at the Calingiri site in 2017.

| Item | Quantity | Date Used |
|---|---|---|
| **Fertiliser (type and rate)** | MAP – 50 kg/ha<br>ALOSCA inoculant – 10 kg/ha | 3 June 2017 |
| **Herbicide** | Propyzamide – 1 kg/ha<br>Clethodim – 500mL/ha<br>Uptake – 0.5% | 3 June 2017<br>4 August 2017 |

Demonstration site 3 is now located near Calingiri. This demonstration site was moved from the original demonstration site (Goomalling) due to the farmer seeding across the trial area with oats in 2017.

In 2017, strips of 250 metres by 12 metres were seeded on the 3rd June to Jurien lupins and Hurricane lentils using farmer equipment. The previous year in 2016 the paddock was sown to RR canola. Throughout the year, chemical was applied using a ute mounted sprayer. Details of the fertiliser and herbicides used for the demonstration site are presented in Table 4. The demonstration area was hand harvested using a 1 $m^2$ quadrat due to being too short for mechanical harvesting. It was also noted that this site had areas of waterlogging across it due to heavy rainfall in July 2017.

This year the paddock will be sown to wheat by the farmer and the demonstration area will be monitored by WMG.

**Demonstration** site 4

| Demonstration 4: Corrigin | Latitude (decimal degrees) | Longitude (decimal degrees) |
|---|---|---|
| **Trial location** | -32.322497° | 118.084961° |
| **Nearest Town** | Corrigin, WA | |

Table 5. Description of fertiliser and herbicide inputs at the Corrigin site in 2017.

| Item | Quantity | Date Used |
|---|---|---|
| **Fertiliser (type and rate)** | Triple Super (Summit Fertiliser) – 30 kg/ha<br>ALOSCA granular inoculant – 10 kg/ha | 28th April 2017 |
| **Herbicide** | Trifluralin – 2.5 L/ha<br>Paraquat – 2 L/ha<br>Terbyne – 1.4 kg/ha | 28th April 2017 |

Demonstration site 4 is located near Corrigin and is managed by the Corrigin Farm Improvement Group. In 2016 the paddock was a chemical fallow. In 2017 plots of 18.9m x 300m trial were sown to Wharton field peas, Amira albus lupins, Hurricane lentils and Neelam chickpeas. The plots were sown on the 28th April 2017 with the use of the local grower's seeder. Throughout the season the site was maintained through the use of the local grower's sprayer and harvester. Table 5 above outlines the fertiliser and herbicides used on the crops throughout the period. It was noted that there was a dry start to the season and several frosts occurred towards the end of august and throughout September affecting the crop yield.

In 2018 the paddock will be sown to wheat and the site will continue to be managed by the Corrigin Farm Improvement Group.

## RESULTS and DISCUSSION

*What happened? Description of the results from the work so far, can include graphs / photos; some interpretation of what these mean in terms of farm practice or modified approaches to the underlying issue when interpreted for on-farm use.*

Table 6. Comparison of the yearly rainfall data amount for the 2017 season for the demonstration and trial sites (bom,2018).

| | Miling | Calingiri | Bencubbin | Corrigin | Merredin |
|---|---|---|---|---|---|
| **Jan** | 93 | 72 | 52 | 47.8 | 32 |
| **Feb** | 36 | 61 | 49 | 122.2 | 53 |
| **Mar** | 31 | 27 | 22 | 39.6 | 21 |
| **Apr** | 0 | 1 | 3.8 | 6.4 | 4.8 |
| **May** | 8.5 | 16 | 7.3 | 13.6 | 28 |
| **Jun** | 6.7 | 29 | 2.5 | 27.4 | 5 |
| **Jul** | 44.4 | 78 | 31.2 | 47 | 35.9 |
| **Aug** | 58.5 | 74.4 | 53.2 | 59.8 | 47.6 |
| **Sep** | 28 | 40.8 | 30.4 | 36.2 | 48.2 |
| **Oct** | 10.5 | 12.7 | 17.4 | 38.6 | 25.6 |
| **Nov** | 9.5 | 13.6 | 9.8 | 13.4 | 10.8 |
| **Dec** | 7 | 11.4 | 4.9 | 16.2 | 4.4 |
| **Total (mm)** | 333 | 437 | 283 | 468 | 316 |
| **GSR (mm** | 157 | 252 | 146 | 229 | 195 |

The annual and growing season rainfall for the 2017 season for the Miling, Calingiri, Bencubbin, Corrigin and the Merredin sites is presented in Table 6. The large amount of summer rainfall at most sites would have led to an increase in stored soil water available for crops during the growing season. Growing season rainfall, particularly for April and May, was very low at all sites and was considered a restriction for the growth and early establishment of the break crops. Most sites received adequate rainfall during spring, along with cooler temperatures, to allow the legume crops to adequately flower and fill grain. Plant height was restricted by the low growing season rainfall, resulting in the Miling, Calingiri and the Bencubbin sites being hand harvested to estimate grain yield. The Merredin site also experienced this problem, with the chickpeas and lentils being too short for mechanical harvest.

### *Grain Yield*

Table 7. Comparison of legume grain yield of break crops at the demonstration and trial sites compared to wheat and canola for the 2017 season (where grown at the site). na = data not available.

| | Jurien Lupins (t/ha) | Albus Lupins (t/ha) | Desi Chickpeas (t/ha) | Hurricane Lentils (t/ha) | Genesis Kabuli Chickpea (t/ha) | Field Peas (t/ha) | Oats (t/ha) | Wheat (t/ha) | RR Canola (t/ha) |
|---|---|---|---|---|---|---|---|---|---|
| **Trial Site - Merredin** | | | | na | na | 0.78 | 2.76 | 2.72 | |
| **Demo Site 1 - Miling** | 0.97 | | 0.67 | 0.82 | | | | 1.6 | |
| **Demo Site 2 - Bencubbin** | 1.42 | | 1.07 | 0.59 | 0.6 | | | | 0.6 |
| **Demo Site 3 - Calingiri** | 0.97 | | | 0.36 | | | | | |
| **Demo Site 4 - Corrigin** | | 0.80 | 0.9 | 0.29 | | 1.16 | | | |

The grain yield of the break crops at each demonstration site and the main trial site are summarised in Table 7. This project has evaluated a range of alternate grain legumes that can be used in combination with Canola and oats as a break crop in crop rotation. In terms of grain legumes, Lupins are a common legume break crop in Western Australia, and this report will compare lupin yield with the yield of the newer high value legumes. At all sites, Jurien lupins had a higher grain yield compared to all other legumes, and varied in a range of 0.97 t/ha to 1.42 t/ha. Striker Chickpeas yielded closest to lupins at the Bencubbin site, achieving 75% of lupin yield, while at the Miling site, Hurricane lentils achieved 85% of lupin yield. However, Hurricane lentils only achieved 42% of lupin yield at Bencubbin, and 37% of lupin yield at Calingiri, while Kabuli chickpea only achieved 42% of lupin yield at Bencubbin. At the Corrigin site, Desi chickpeas and field peas were the best performing legumes, although lupins were not included as a comparison at this site. Hurricane lentils at the Corrigin site yielded only 0.29 t/ha due to not being able to be mechanically harvested at the site.

The data indicates that high value grain legumes can be grown across the Kwinana West and East port zone, but there may be limitations in the areas that each particular legume species can be grown. For example, the mid-sized Desi Chickpea may be better adapted to the mid to low rainfall environment, while lentils may be a better option for mid to high rainfall environments. More work is required to validate and understand the reasons behind this conclusion, and it is important to note that it is based on one year of demonstration site data in a season with low growing season rainfall.

The inclusion of high value grain legumes in the crop rotation may increase the profitability of crop rotations across the Kwinana West and East port zones. Even though lupins had a higher yield compared to chickpea and lentil the value of chickpea and lentil is normally significantly higher (at least double) compared to lupins. This means that the 15-25% yield penalty evident at these sites from growing chickpeas and lentils can be easily offset by the increase in value of the grain. Further analysis of the economics of growing high value legumes in crop rotation is warranted, based on this data, although is outside the scope of this project.

From a practical farmers perspective, the results presented from the 2017 season may not increase their desire to try break crops other than lupins. Lupins are easily harvested in most circumstances with a machine harvester that has minimal modifications required to harvest lupins. The lentils and chickpeas at each site were hand harvested due to the low plant height of these crops, and the inability to harvest with a mechanical plot harvester. This practical harvesting issue does have some possible solutions to allow these crops to be integrated into future farming systems. Harvesting technology is available that uses a flexing harvest front to allow for short crops to be easily harvested, assuming that there is an absence of large rocks and other obstructions in the paddock. Inter-row seeding into standing stubble has also been shown to increase legume grain yield in Victoria by 18% on average, due to a combination of higher plant height and higher distance to first pod on the plant.

### *Effect of double break crops on root disease levels*

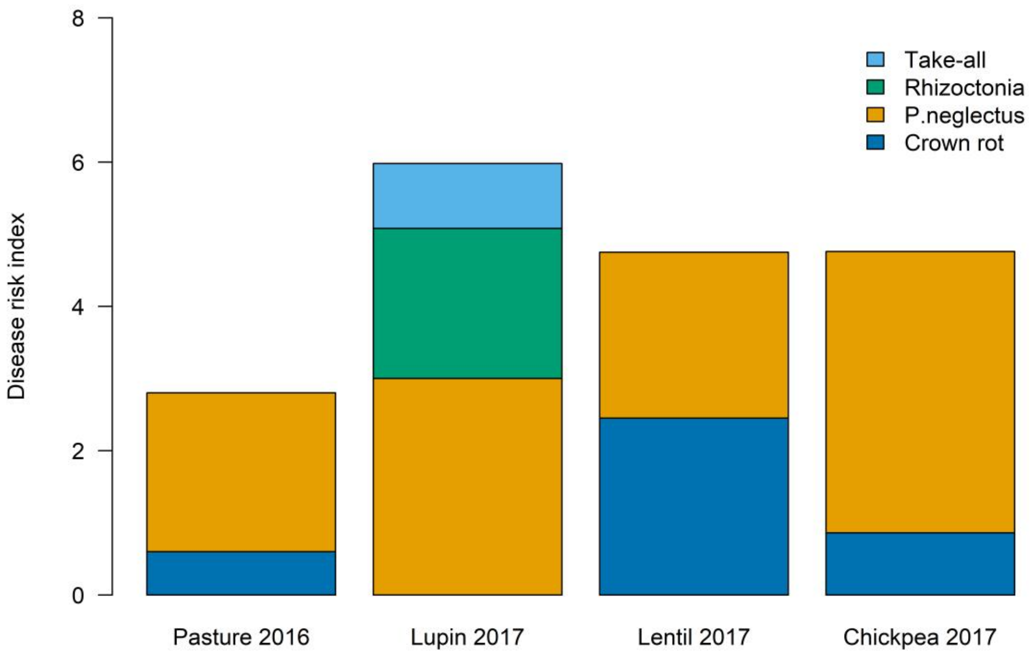


Figure 1. Root disease risk increased following a range of legume crops grown at the Miling site in 2017. PredictaB sampling was conducted at the start of the 2017 and 2018 seasons following volunteer pasture in 2016 and legume crops in 2017.

The dominant root disease constraint at the Miling site was **Pratylenchus neglectus** (P.neglectus, Figure 1), with a low amount of Crown rot present following a volunteer pasture in 2016. The levels of these diseases increased following growing lupin, lentil, and chickpea in 2017. Lupin was effective at reducing Crown rot compared to lentil and chickpea, however, there was a large increase in Rhizoctonia and Take-all. While an increase in Rhizoctonia under lupin is a common occurrence, this site appears to not have been an effective double break due to the volunteer pasture in 2016 potentially containing grasses and cereals that are susceptible to Crown rot and P.neglectus. It is also important to note that chickpea is susceptible and lentil are moderate hosts to P.neglectus, and this would be a large reason why the increase in P.neglectus was highest under chickpea, and lower under lentil. It is not clear why P.neglectus increased under lupin, which is considered a resistant crop, but may be due to a presence of increased inoculum from the volunteer pasture. P.neglectus continues to be a yield constraint at this site for the 2018 season.

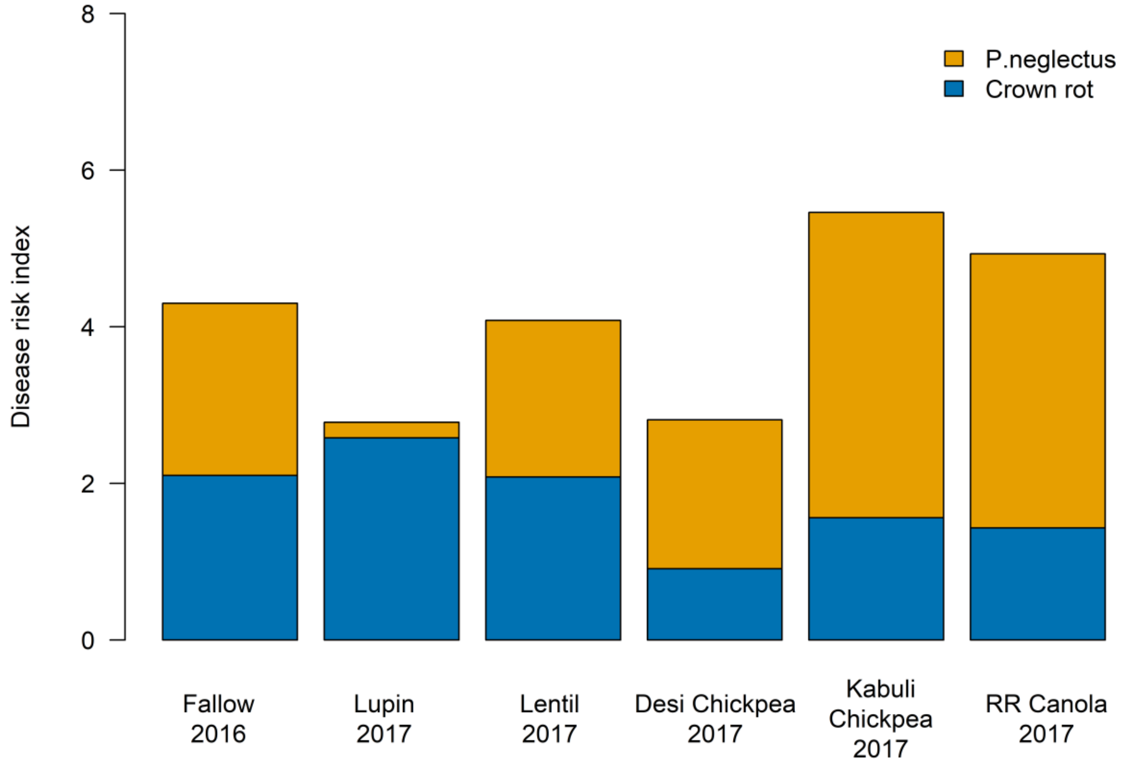


Figure 2. The change in disease risk following a range of legume crops grown at the Bencubbin site in 2017. PredictaB sampling was conducted at the start of the 2017 and 2018 seasons following each respective crop. Roundup Ready canola (RR Canola) was grown in the paddock around the demo sites, and is included as a comparison.

The demonstration site at Bencubbin was a chemical fallow in 2016 prior to being sown to a wide range of legumes in 2017 (Figure 2). The dominant root disease constraint at this site were P.neglectus and Crown rot. Inoculum levels of these diseases were high following the fallow in 2016, as Crown rot was most likely harboured in the retained crop stubble on the soil surface. The dry season in 2017 would allow for carryover of this inoculum into 2017 as there would have been little stubble breakdown during the season. This site highlights that lentil, chickpea, and canola are all classified as susceptible to moderate hosts of P.neglectus that maintained or increased the levels of this nematode in the soil. At this site, the resistance of lupin to P.neglectus can be clearly seen to reduce the numbers of nematodes in the soil compared to the other legume and canola crops. There maybe a trend in this data that Canola and chickpea were better at reducing the levels of Crown rot at this site.

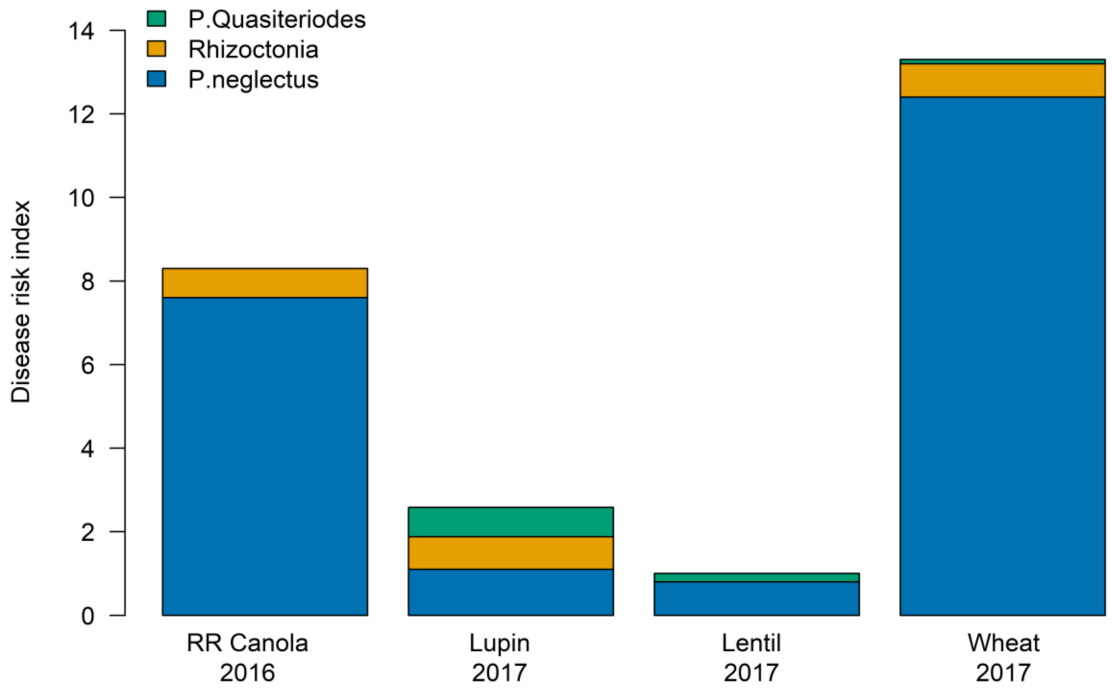


Figure 3. The change in disease risk following a range of legume crops following at the Calingiri site in 2017 following canola in 2016. PredictaB sampling was conducted at the start of the 2017 and 2018 seasons following each respective crop. Wheat was grown in the paddock around the demo site in 2017, and is included as a comparison.

The site at Calingiri was sown to Roundup Ready Canola (RR Canola) in 2016 prior to demonstration sites being established in 2017 (Figure 3), while the remaining portion of the paddock was sown to Wheat. The dominant root disease constraint at this site was P. neglectus following Canola in 2016. This was greatly decreased by growing lupin and lentil, and greatly increased by growing wheat in 2017. This large increase under the wheat would have had a significant impact on grain yield, with an estimated potential yield loss of 30-50%. Lupins slightly increased the level of Rhizoctonia and Pratylenchus Quasiteriodes at this site, which is consistent for Rhizoctonia under lupin for other demonstration sites in this project. The use of a double break rotation at the Calingiri site was an effective method of reducing the nematode constraint to grain yield.

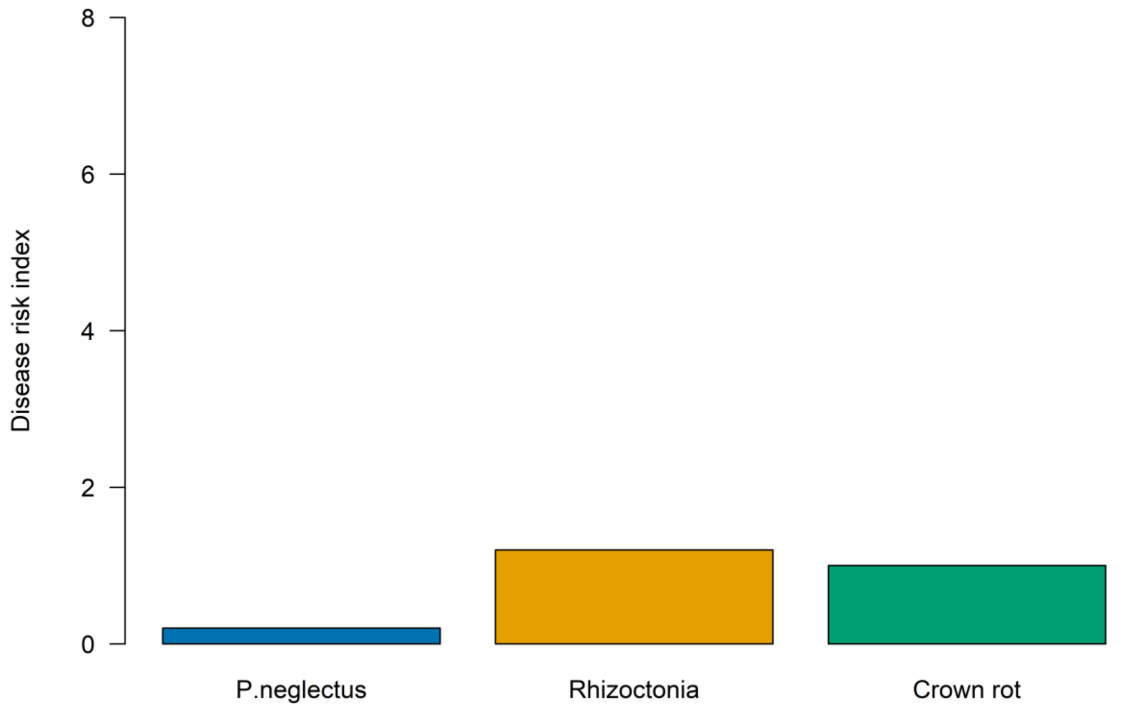


Figure 4. Root disease levels at the Corrigin site in 2017 following chemical fallow and before legume breaks crops were planted.

The amount of root disease present at the Corrigin site at the start of the 2017 season following a chemical fallow was low compared to other sites in this study (Figure 4). Sampling for root disease using PredictaB following the break crops in 2017 will be conducted prior to the season in 2018, and will be available in the next report.

**CONCLUSIONS**

*Summary of findings, implications and future activities.*

This project aims to evaluate the use of double break crop rotations as a method to effectively control root diseases that act as constraints to achieving grain yield potential. It has been shown that a double break can be effective at removing yield constraints where the break crop has been matched to the yield constraint. For example, lupin and lentil appear to be effective in reducing P.neglectus levels. However, where the break crop type has been mis-matched with the yield constraint, then they have not been effective in reducing disease risk. This is most evident with canola and chickpea, where levels of P.neglectus generally increased following these crops. It becomes essential that paddocks that have a suspected yield constraint are sampled using the PredictaB service to identify the disease or nematode factors that are operating. From this, the correct crop type can be selected to remove this yield constraint. Where multiple constraints are present, it may be necessary to implement a series of crops, rather than focus on one or two break crops to reduce the majority of disease and nematode constraints over time.

This project has also highlighted that a double break crop is only effective when both break crops are managed to be an effective disease break. For example, the presence of volunteer grasses or cereals in a pasture or legume crop will lower the effectiveness of these crop types in reducing disease constraints. This was most evident in the pasture phases in this project. Similarly, the maintenance of a clean chemical fallow was not effective at reducing Crown rot due to the retained stubble on the soil surface carrying over inoculum during the fallow period. This was accentuated by a dry season in 2017 that reduced the breakdown of stubble during the growing season, and it is important to acknowledge the impact of dry and wet seasons on the build-up and reduction in root diseases in conjunction with an effective crop rotation.

2018 will be the final year for the double break crop options trial, with all sites to be sown to wheat to assess the effectiveness of single and double break crops on the management of root disease yield constraints. All demonstration sites will continue to be overseen and monitored by the WMG, with Kalyx continuing to monitor the trial site at Merredin, and Corrigin Farm Improvement Group monitoring Demonstration Site 4.

## Appendix 1

Description of herbicide and fertilisers used at the Merredin replicated trial site in 2017.

| Trt No. | Treatment Name | Rate | Rate Unit | Growth Stage |
|---|---|---|---|---|
| 1 | Atrazine | 1.1 | kg/ha | IBS |
| Canola | Propyzamide 500 g/L | 1 | l/ha | IBS |
| ATR Bonito | Maxam | 100 | kg/ha | TD IBS |
| | Gusto | 80 | kg/ha | banded |
| | Canola: ATR Bonito | 4 | kg/ha | seeding |
| | Atrazine | 1.1 | kg/ha | PSPE |
| | Chlorpyrifos | 300 | ml/ha | PSPE |
| | Bifenthrin | 200 | ml/ha | PSPE |
| | Urea | 50 | kg/ha | post em |
| | Clethodim | 500 | ml/ha | post em |
| | Uptake | 0.5 | % v/v | post em |
| | Ammonium Sulphate | 1 | % v/v | post em |
| 2 | Atrazine | 1.1 | kg/ha | IBS |
| Canola | Propyzamide 500 g/L | 1 | l/ha | IBS |
| ATR Bonito | Maxam | 100 | kg/ha | TD IBS |
| | Gusto | 80 | kg/ha | banded |
| | Canola: ATR Bonito | 4 | kg/ha | seeding |
| | Atrazine | 1.1 | kg/ha | PSPE |
| | Chlorpyrifos | 300 | ml/ha | PSPE |
| | Bifenthrin | 200 | ml/ha | PSPE |
| | Urea | 50 | kg/ha | post em |
| | Clethodim | 500 | ml/ha | post em |
| | Uptake | 0.5 | % v/v | post em |
| | Ammonium Sulphate | 1 | % v/v | post em |
| 3 | Atrazine | 1.1 | kg/ha | IBS |
| Canola | Propyzamide 500 g/L | 1 | l/ha | IBS |
| ATR Bonito | Maxam | 100 | kg/ha | TD IBS |
| | Gusto | 80 | kg/ha | banded |
| | Canola: ATR Bonito | 4 | kg/ha | seeding |
| | Atrazine | 1.1 | kg/ha | PSPE |
| | Chlorpyrifos | 300 | ml/ha | PSPE |
| | Bifenthrin | 200 | ml/ha | PSPE |
| | Urea | 50 | kg/ha | post em |
| | Clethodim | 500 | ml/ha | post em |
| | Uptake | 0.5 | % v/v | post em |
| | Ammonium Sulphate | 1 | % v/v | post em |
| 4 | Fallow | | | |
| 5 | Trifluralin | 1.5 | l/ha | IBS |
| Chickpea | Balance | 100 | g/ha | IBS |

| | | | | |
|---|---|---|---|---|
| PBA Striker | Gusto | 80 | kg/ha | banded |
| | Chickpea Inoculant | 90 | kg/ha | seeding |
| | P-Pickle T | 200 | ml/100 kg | seeding |
| | Chlorpyrifos | 300 | ml/ha | PSPE |
| | Bifenthrin | 200 | ml/ha | PSPE |
| | Broadstrike | 25 | g/ha | 4-6 WAS |
| | chlorothalonil | 1.5 | l/ha | 4-6 WAS |
| | Clethodim | 500 | ml/ha | 8-12 WAS |
| | Uptake | 0.5 | % v/v | 8-12 WAS |
| | Ammonium Sulphate | 1 | % v/v | 8-12 WAS |
| | chlorothalonil | 1.5 | l/ha | flowering |
| | chlorothalonil | 1.5 | l/ha | mid-podding |
| 6 | Trifluralin | 1.5 | l/ha | IBS |
| Lentil | Diuron | 550 | g/ha | IBS |
| Hurricane | Gusto | 80 | kg/ha | banded |
| | Lentil: Hurricane XT inoculant | 75 | kg/ha | seeding |
| | P-Pickle T | 200 | ml/100 kg | seeding |
| | Chlorpyrifos | 300 | ml/ha | PSPE |
| | Bifenthrin | 200 | ml/ha | PSPE |
| | Imazethapyr | 35 | g/ha | PSPE |
| | Clethodim | 500 | ml/ha | 8-12 WAS |
| | Uptake | 0.5 | % v/v | 8-12 WAS |
| | Ammonium Sulphate | 1 | % v/v | 8-12 WAS |
| | Pirimicarb | 300 | g/ha | flowering |
| | Carbendazim | 500 | ml/ha | mid-podding |
| 7 | Atrazine | 1.1 | kg/ha | IBS |
| Canola | Propyzamide 500 g/L | 1 | l/ha | IBS |
| ATR Bonito | Maxam | 100 | kg/ha | TD IBS |
| | Gusto | 80 | kg/ha | banded |
| | Canola: ATR Bonito | 4 | kg/ha | seeding |
| | Atrazine | 1.1 | kg/ha | PSPE |
| | Chlorpyrifos | 300 | ml/ha | PSPE |
| | Bifenthrin | 200 | ml/ha | PSPE |
| | Urea | 50 | kg/ha | post em |
| | Clethodim | 500 | ml/ha | post em |
| | Uptake | 0.5 | % v/v | post em |
| | Ammonium Sulphate | 1 | % v/v | post em |
| 8 | Atrazine | 1.1 | kg/ha | IBS |
| Canola | Propyzamide 500 g/L | 1 | l/ha | IBS |
| ATR Bonito | Maxam | 100 | kg/ha | TD IBS |
| | Gusto | 80 | kg/ha | banded |
| | Canola: ATR Bonito | 4 | kg/ha | seeding |
| | Atrazine | 1.1 | kg/ha | PSPE |
| | Chlorpyrifos | 300 | ml/ha | PSPE |

| | | | | |
|---|---|---|---|---|
| | Bifenthrin | 200 | ml/ha | PSPE |
| | Urea | 50 | kg/ha | post em |
| | Clethodim | 500 | ml/ha | post em |
| | Uptake | 0.5 | % v/v | post em |
| | Ammonium Sulphate | 1 | % v/v | post em |
| 9 | Trifluralin | 2 | l/ha | IBS |
| Sub Clover | Gusto | 80 | kg/ha | banded |
| Balansa Clover | Sub clover: | 10 | kg/ha | seeding |
| | Chlorpyrifos | 300 | ml/ha | PSPE |
| | Bifenthrin | 200 | ml/ha | PSPE |
| | Clethodim | 500 | ml/ha | post em |
| | Uptake | 0.5 | % v/v | post em |
| | Ammonium Sulphate | 1 | % v/v | post em |
| 10 | Trifluralin | 1.5 | l/ha | IBS |
| Field Pea | Diuron | 550 | g/ha | IBS |
| | Gusto | 80 | kg/ha | banded |
| | Field Pea Inoculant | 120 | kg/ha | seeding |
| | P-Pickle T | 200 | ml/100 kg | seeding |
| | Chlorpyrifos | 300 | ml/ha | PSPE |
| | Bifenthrin | 200 | ml/ha | PSPE |
| | Imazethapyr | 35 | g/ha | PSPE |
| | Diflufenican | 100 | ml/ha | 4-6 WAS |
| | Metribuzin | 100 | g/ha | 4-6 WAS |
| | Clethodim | 500 | ml/ha | 8-12 WAS |
| | Uptake | 0.5 | % v/v | 8-12 WAS |
| | Ammonium Sulphate | 1 | % v/v | 8-12 WAS |
| | Karate Zeon | 24 | ml/ha | flowering + 10 days |
| | Karate Zeon | 24 | ml/ha | mid-podding |
| 11 | Dual Gold | 500 | ml/ha | IBS |
| Oats | Diuron | 400 | g/ha | IBS |
| Williams | Chlorpyrifos | 200 | ml/ha | IBS |
| | Maxam | 100 | kg/ha | TD IBS |
| | Gusto | 80 | kg/ha | banded |
| | Oats: Durack | 80 | kg/ha | seeding |
| | Precept | 1.5 | l/ha | post em |
| | Hasten | 1 | % v/v | post em |
| | Urea | 50 | kg/ha | post em |
| 12 | Boxer Gold | 2.5 | l/ha | IBS |
| Wheat | Chlorpyrifos | 200 | ml/ha | IBS |
| Mace | Maxam | 100 | kg/ha | TD IBS |
| | Gusto | 80 | kg/ha | banded |
| | Wheat: Mace | 70 | kg/ha | seeding |
| | Velocity | 670 | ml/ha | post em |

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|---|---|---|---|---|
| | MCPA LVE | 400 | ml/ha | post em |
| | Hasten | 1 | % v/v | post em |
| | Urea | 50 | kg/ha | post em |