Profitable Crop Rotation Choices

By Simon Wallwork, Agronomist.

Summary

Two significant weather events that had an important influence over the results in this project, in 2016, frost and 2017, summer rain. In 2016, there were multiple severe frost events during the critical, flowering stage of the growing season. Oats being a relatively frost tolerant species proved to be the best performing species for yield and gross returns in 2016. The broadleaf crops, both legumes and canola were severely impacted by frost.

For barley in 2016 the accumulated gross returns for two years was higher in rotation, fallow 2015; barley 2016 when compared with wheat 2015 barley 2016. This supports previous work by CFIG that including fallow in the rotation can increase gross returns over a two year period.

In season 2017 frost damage was minor when compared to 2016. Season 2017 was dominated by heavy summer rainfall and a very dry start to winter. The fallow plots were impacted by the summer rain due to lack of soil cover. The loamy, morrell soil set hard at the surface as a result of the heavy summer rain which severely impacted penetration of the seeding equipment and subsequently, crop establishment was poor. The very dry start to the season likely exacerbated the poor establishment on the fallow plots.

Oats performed well again in 2017 in terms of yield but barley produced higher gross returns. Chickpeas and lentils were the best performing of the broadleaf crops in 2017.

When the gross returns in 2017 were compared by rotation (2015-2017), it is interesting to note that 2017 cereals grown in rotation with legumes in 2016 generally performed well.

The gross returns for every rotation tested in the trial were compared on an accumulative return over 3 years (2015-2017) and the rotation with the highest accumulative return was year 1; wheat year 2; chickpeas and year 3; barley. This demonstrates the value of a legume in a rotation which contributed to the highest yielding plot, which was barley in 2017.

The top two highest total gross return rotations over three years had a legume crop in one year of the rotation. The third highest return rotation had a fallow phase which confirms fallow as a rotation option. In the top 10 highest returning rotations, 4 had fallow in one year of the rotation.

Introduction

The aim of this project is for the Corrigin Farm Improvement Group (CFIG) to compare the profitability of a range of crop rotations, including chemical fallowing, on a medium textured, loamy soil type east of Corrigin. Gross returns are assessed both on an annual basis and on an accumulative multi-year basis.

This project was funded through the COGGO Research Fund over two seasons, 2016 and 2017.

Background to the project.

Previous research by CFIG has shown that crops grown on chemical fallow can increase returns on medium and heavier textured soils in the Corrigin district. Chemical fallow is the process of non-crop, chemical control of weeds in year one with the aim to reduce the weed population, reduce disease risk and store soil moisture and nutrients and subsequently produce higher crop yields in year two and subsequent seasons. CFIG trials have shown that crops grown on chemical fallowed paddocks may produce a higher net return over two years compared with the total return from cropping continuously for two years. While chemical fallow is a rotational option, high value pulse species and canola are also alternatives. New varieties of lentils, chickpeas and Albus lupins need to be assessed and compared to find the highest returning rotation of a multi-year basis. This also means testing the double break as a rotation option, i.e. chemical fallow

followed by a break crop. Break crops may also benefit from fallow and prepare a cereal phase with low level of weeds and disease.

Objectives

This project was designed to test the relative benefit of chemical fallow with a range of different crop types. The trial compared different crop types on chemical fallow with the aim to identify which crop is likely to produce the highest return. The project also aims to investigate the profitability of different rotations over multiple years which include both chemical fallows and continuous crop.

2016 Trial

Methodology

In 2016 the replicated small plot trial was sown through an area of which grew wheat in 2015 and an adjacent area of which was maintained as a chemical fallow in 2015.

The plots were sown, sprayed and harvested by a contractor using small plot trial equipment. Soil moisture tests were conducted with a volumetric soil moisture probe both in June and September. Plant establishment counts were taken in June to coincide with crop establishment and plot yield and quality measurements were taken at harvest. Due to the significant number of frost events throughout the flowering period frost induced sterility assessments were taken on the wheat and barley plots to estimate the level of frost damage.

Trial Layout

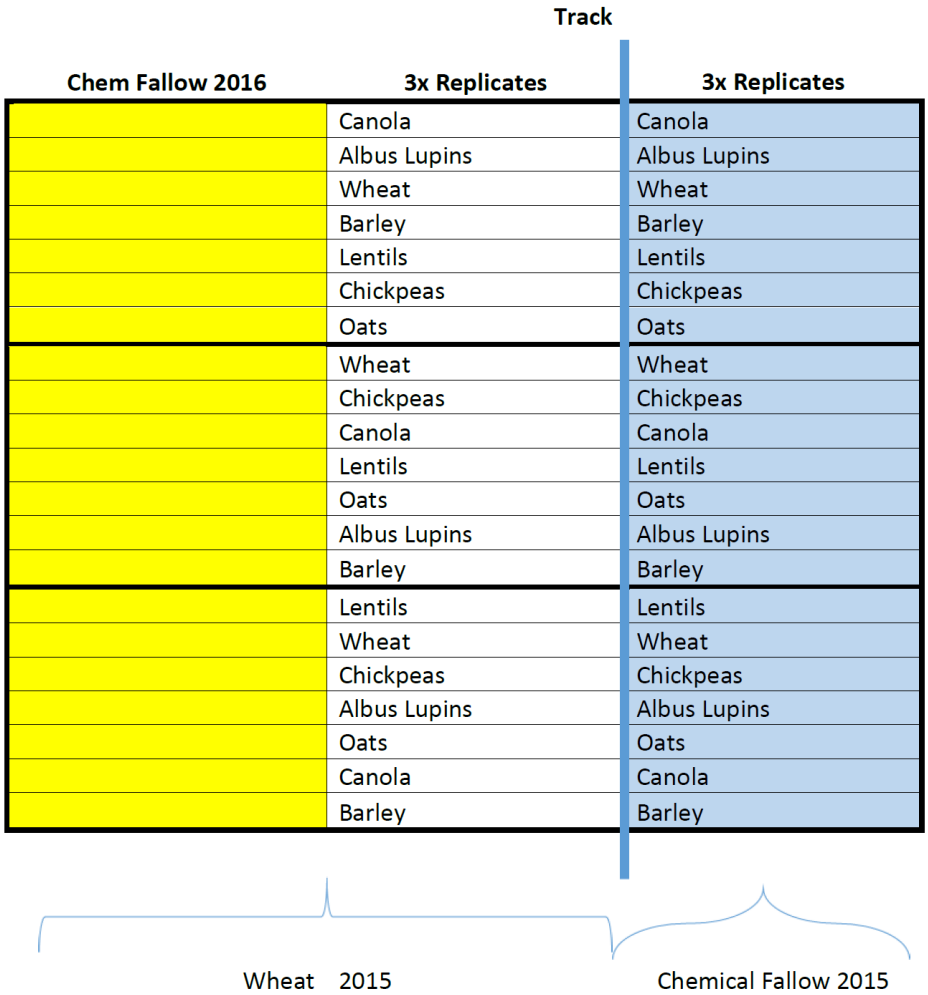


Figure 1. Trial layout with replicated plots of different crop types

Photo 1. Trial Site 12th September 2016.

Trial Details

Sown: 9th May, 2016
Machine: Living Farm small plot trial seeder with Ryan tine and split boot on 25.4 cm row spacing

Seeding rates

	Variety	Seed Rate (kg/ha)
IT Canola	44C79	3
Albus lupins	Amira	120
Wheat	Mace	100
Barley	Fatham	100
Lentils	Hurricane	60
Chickpeas	Neelam	80
Oats	Carrolup	100

Fertiliser

9th May	44C79 IT Canola	MAPSCZ / SOA Blend	132kg/ha
	Amira Albus Lupins	Triple Super	30kg
	Mace Wheat	MAPSCZ / SOA Blend	132kg/ha
	Fathom Barley	MAPSCZ / SOA Blend	132kg/ha
	Hurricane Lentils	Triple Super	30kg
	Chickpeas	Triple Super	30kg
	Carrolup Oats	MAPSCZ / SOA Blend	132kg/ha

8th July	44C79 IT Canola	UAN	100L/ha
	Mace Wheat	UAN	100L/ha
	Fathom Barley	UAN	100L/ha
	Carrolup Oats	UAN	100L/ha

Herbicides

9th May	44C79 IT Canola	1.5L/ha Paraquat + 2.5L/ha Trifluralin
	Amira Albus Lupins	1.5L/ha Paraquat + 2.5L/ha Trifluralin + 1.4kg/ha Terbyne
	Mace Wheat	1.5L/ha Paraquat + 1.5L/ha Trifluralin + 350g/ha Diuron
	Fathom Barley	1.5L/ha Paraquat + 1.5L/ha Trifluralin + 150g/ha Metribuzin
	Hurricane Lentils	1.5L/ha Paraquat +2.5L/ha Trifluralin + 1.4kg/ha Terbyne
	Neelam Chickpeas	1.5L/ha Paraquat + 2.5L/ha Trifluralin + 1.4kg/ha Terbyne
	Carrolup Oats	1.5L/ha Paraquat + 500g/ha Diuron + 1kg/ha Terbyne

13th June	44C79 IT Canola	500ml/ha Select + 0.5% Uptake
	Amira Albus Lupins	500ml/ha Select + 0.5% Uptake
	Mace Wheat	670ml/ha Velocity + 0.5% Hasten
	Fathom Barley	670ml/ha Velocity + 0.5% Hasten
	Hurricane Lentils	500ml/ha Select + 0.5% Uptake
	Neelam Chickpeas	500ml/ha Select + 0.5% Uptake
	Carrolup Oats	1L/ha Precept + 0.5% Hasten

Insecticides

9th May	44C79 IT Canola	1L/ha Chlorpyrifos + 200ml/ha Bifenthrin
	Amira Albus Lupins	1L/ha Chlorpyrifos + 200ml/ha Bifenthrin
	Mace Wheat	1L/ha Chlorpyrifos + 200ml/ha Bifenthrin
	Fathom Barley	1L/ha Chlorpyrifos + 200ml/ha Bifenthrin
	Hurricane Lentils	1L/ha Chlorpyrifos + 200ml/ha Bifenthrin
	Neelam Chickpeas	1L/ha Chlorpyrifos + 200ml/ha Bifenthrin
	Carrolup Oats	1L/ha Chlorpyrifos + 200ml/ha Bifenthrin

Observations

Rainfall

The total rainfall (Jan to Dec 2016) was 366.5mm and is above average when compared with the long term average of 309mm at Bendering weather station (25km east of trial location). The growing season rainfall (April to October 2016) of 209.5mm is below average when compared to the long term average of 235.2mm at Bendering. (Appendix 1)

Soil Test and Soil Root Disease Results

The full soil tests results are in Appendix 2. From these results there is a key difference in the soil nitrate levels between the wheat 2015 sites and the chemical fallow 2015 sites. The average soil nitrate levels of these sites is listed in Table 1.

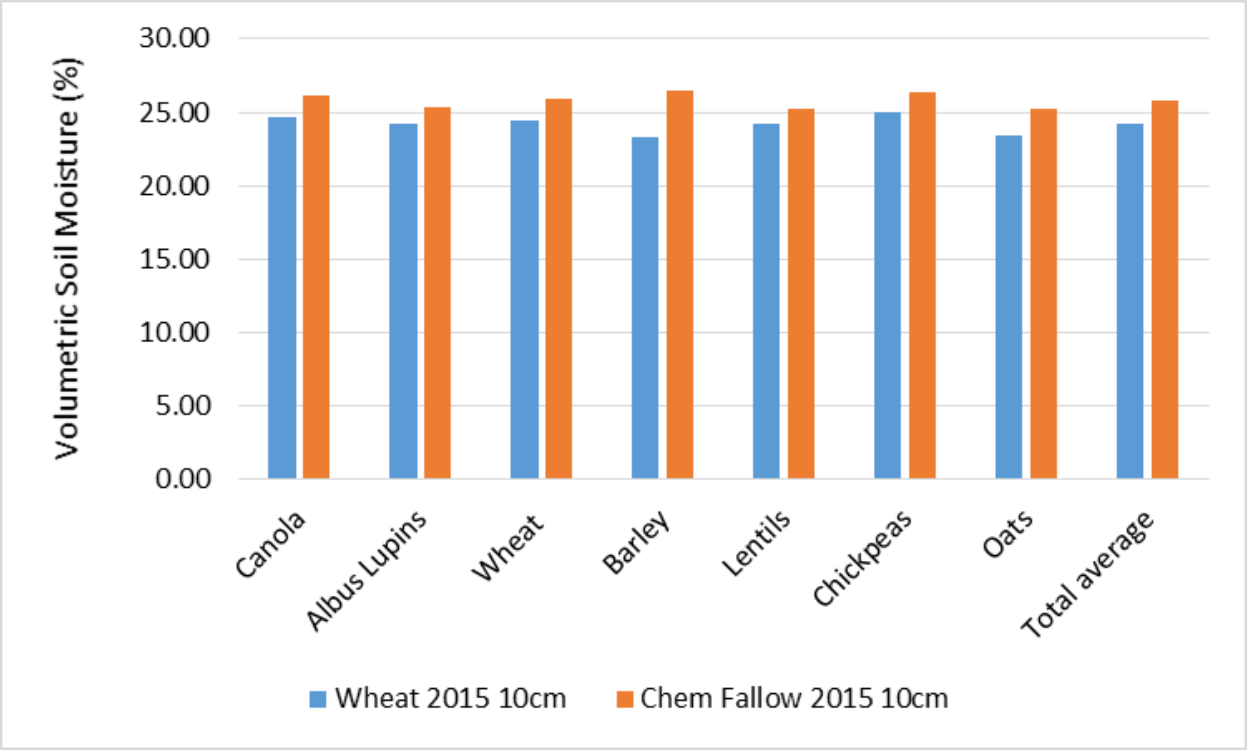
Table 1. Average Soil Test Results for Soil Nitrate (mg/kg)

Wheat 2015	Chemical Fallow 2015
21.5	40

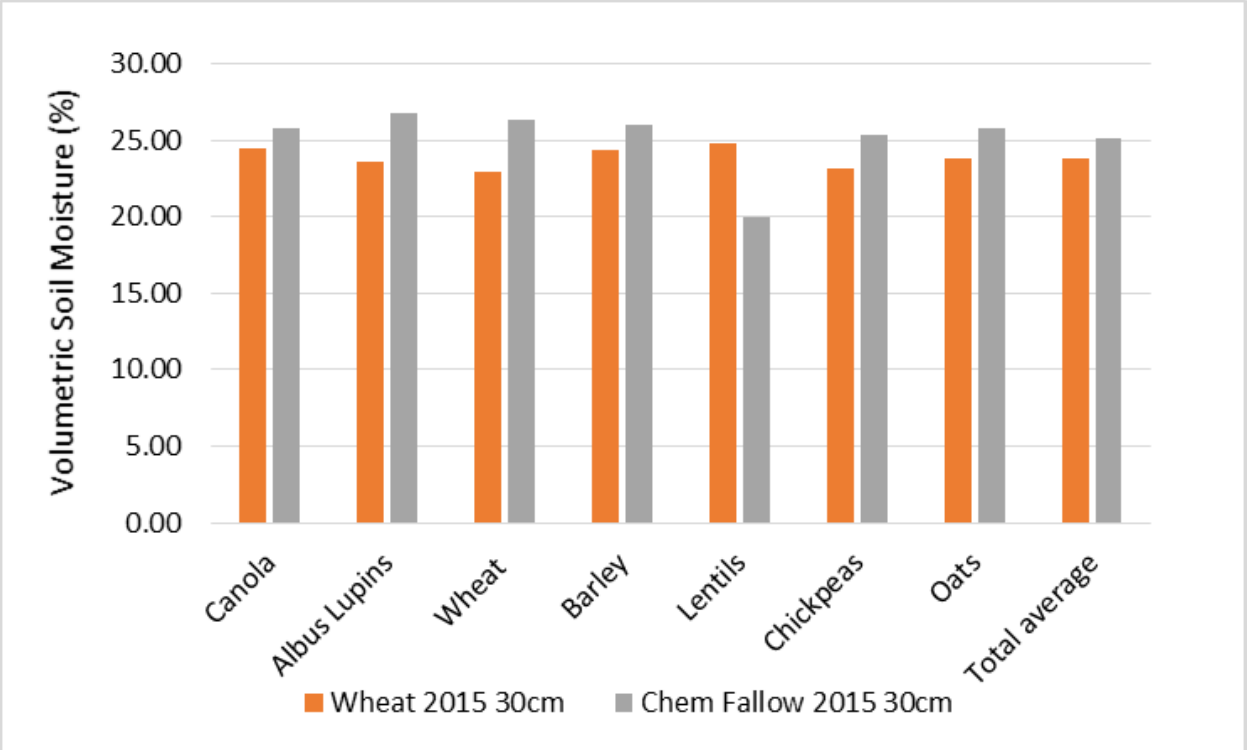
The soil root disease risk sampling results (Appendix 3) indicate higher levels of inoculum for the disease Rhizoctonia and Crown Rot for the wheat 2015 compared with the chemical fallow 2015 site.

Soil Moisture

Soil moisture measurements were taken with a volumetric soil moisture probe at two soil depths of 10cm and 30cm on the 2nd June 2016. These measurements were used to compare the soil moisture levels between the plots sown on wheat in 2015 versus the chemical fallow in 2015. At both depths of 10cm and 30cm there is an indication that volumetric soil moisture is at higher levels for the plots sown on chemical fallow versus wheat. There is only one exception to this for both soil depths which is the lentil plots at 30cm.

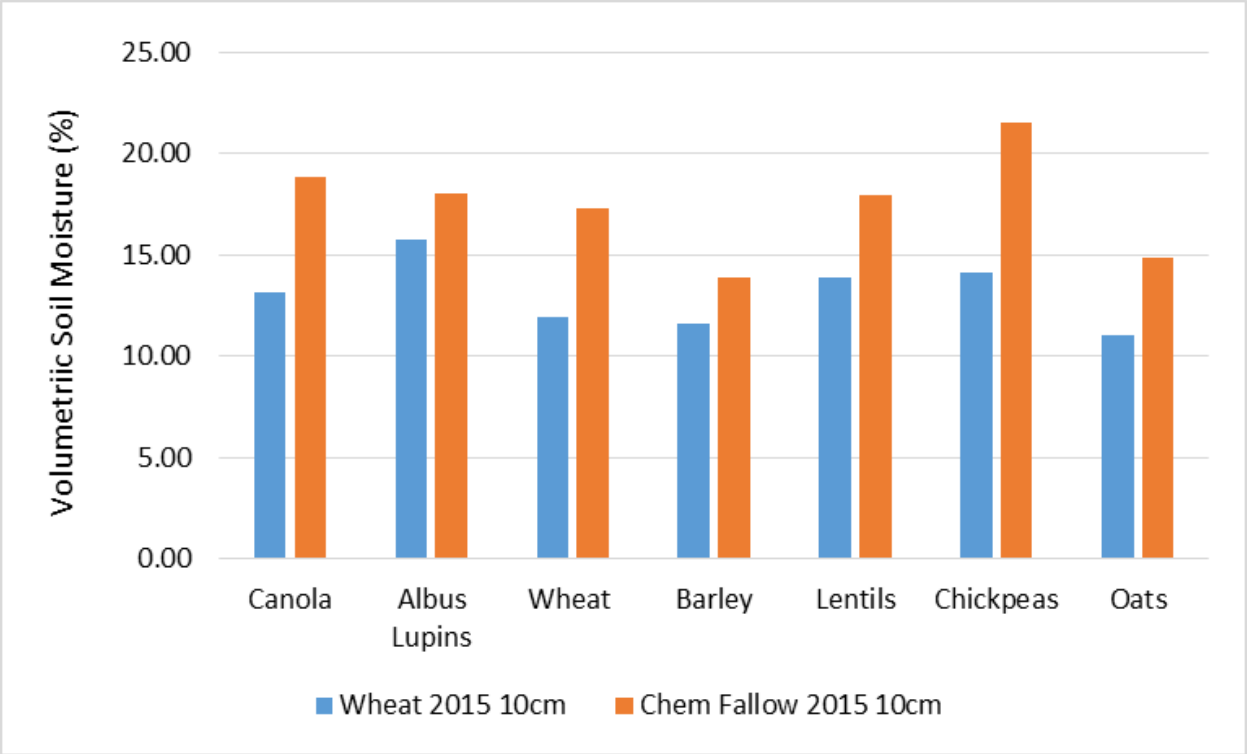


Graph 1. Volumetric Soil Moisture at 10cm on the 2nd June

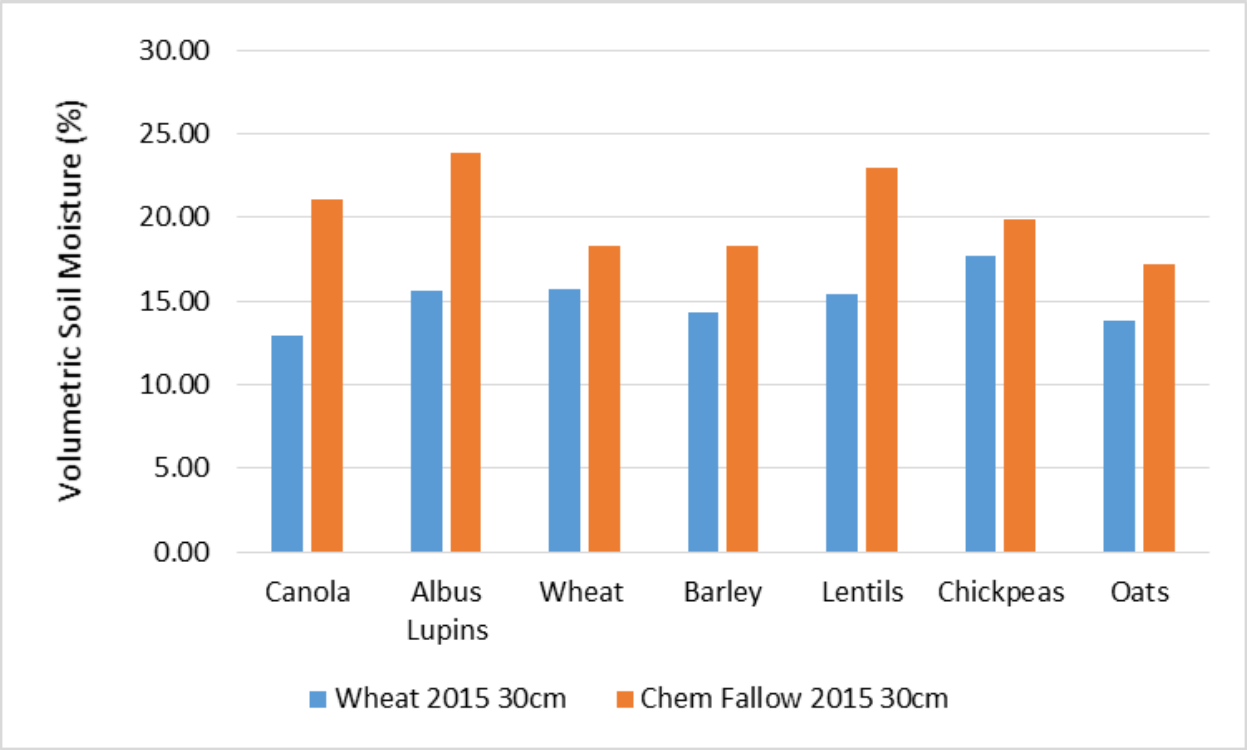


Graph 2. Volumetric Soil Moisture at 30cm on the 2nd June

Volumetric soil moisture measurements were also taken with a volumetric soil moisture probe at 10cm and 30cm on the 12th September 2016. At this timing, later in the season, these measurements still indicate that the plots sown on chemical fallow 2015 have higher levels of soil moisture when compared with the plots sown on the wheat 2015. The differences in soil moisture are more pronounced for canola, Albus lupins and lentils at 30cm when compared with wheat, barley, chickpeas and oats.



Graph 3. Volumetric Soil Moisture at 10cm on the 12th September



Graph 4. Volumetric Soil Moisture at 30cm on the 12th September

Plant Establishment

Plants establishment counts were taken on the 2nd of June 2016 (Table 2). Plant establishment was generally in an acceptable range of the target density although plant densities for each species did vary between sown on wheat in 2015

and chemical fallow in 2015. It is likely the establishment of the Albus lupins, particularly on the wheat stubble, has affected yield performance in the trial so this needs to be considered in the analysis. It may be possible that the bare surface of the chemical fallow plots for wheat, barley and oats reduced establishment success due to pre-emergent chemical damage when compared with the wheat stubble. However the plant density of these plots was still above the target density.

Table 2. Plant establishment 2nd June, 2016.

	Average plants/m2 on Wheat 2015	Average plants / m2 on chemical fallow 2015	Target Density plants/m2
Canola	38	34	40
Albus Lupins	23	33	40
Wheat	217	158	150
Barley	206	183	150
Lentils	161	159	150
Chickpeas	39	41	40
Oats	263	213	160

Photo 2. Chickpeas 12th September 2016.

Photo 3. Barley Frost Damage 2016.

Observations and Frost Damage

There was some bare areas that developed in some of plots particularly in the north – east corner of the trial site, including the Albus lupins and canola plots sown on chemical fallow. It is likely these bare patches were caused due to chemical damage from post emergent spraying, however the final yield was not affected by this.

There was a significant number of damaging frost events at the trial site during the vulnerable stages (crop flowering and grain fill). Between July and October the minimum temperature for a 24 hour period fell below zero on 29 occasions (Appendix 1). Assessments of frost damage to wheat and barley are included in the results section. The severity and number of frosts during the season is likely to have cause weakening of stems, particularly the canola, and subsequent lodging of plants. The frost also caused major flower abortion of all the broadleaf crops including canola, Albus lupins, lentils and chickpeas.

Results and Discussion

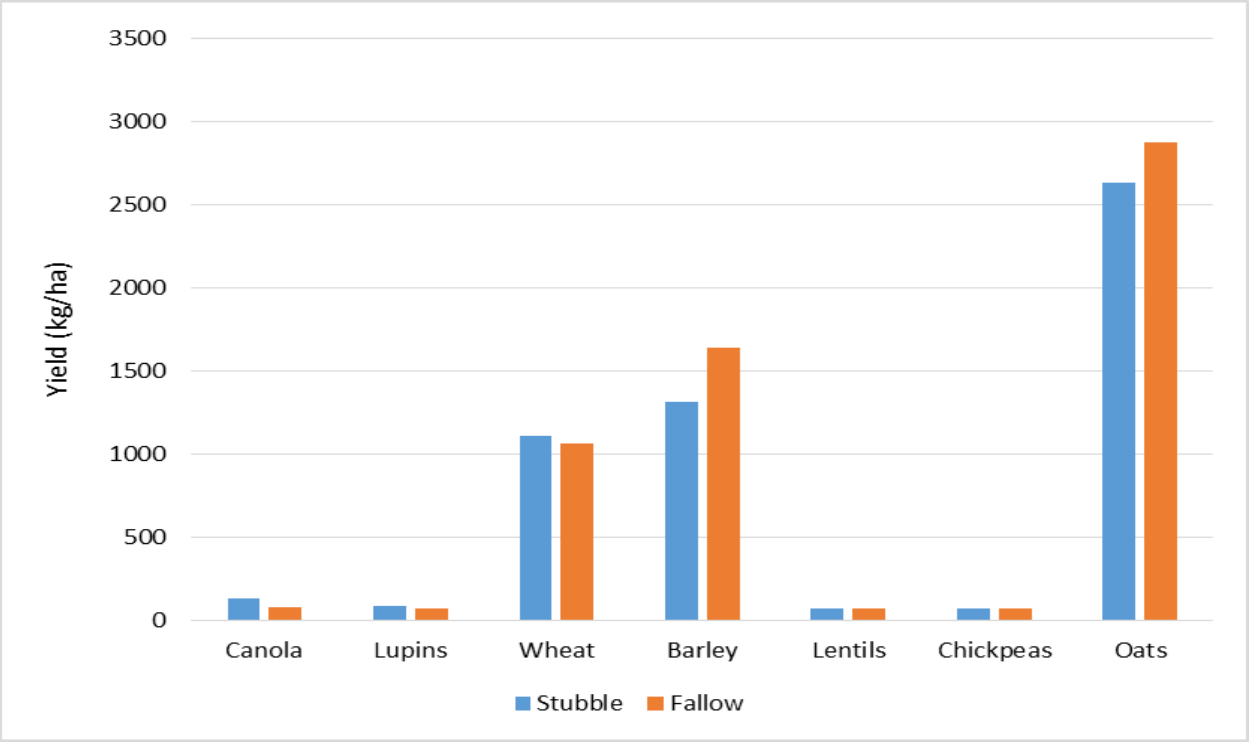
Oats was the highest yielding crop in this trial, with the Oats sown on chemical fallow producing the highest average yield of 2870 kg/ha (Graph 5). In comparison the oats sown on wheat in 2015 produced 2630kg/ha. The barley sown on chemical fallow (1640kg/ha) was also higher yielding than the barley sown on wheat (1310kg/ha). The barley yielded higher than the wheat in 2016 even though the assessment of frost induced sterility (Table 3) indicates that the barley, on average, had higher levels of frost damage. The wheat sown on chemical fallow did not produce a yield benefit for the wheat, in-fact there was a slight yield decrease. Frost damage for the wheat and barley was very similar for both the plots sown on chemical fallow versus wheat 2015.

All of the broadleaf crop performed poorly at the site. Frost is likely to be the most influential factor in the performance of the broadleaf crops. Poor crop establishment of the Albus lupins was also likely to be a limiting factor of crop yield for this crop type for plots sown on both wheat and chemical fallow.

The soil test results indicate that the chemical fallow site accumulated higher levels of soil nitrates compared with the wheat 2015 site prior to sowing. This may help explain the yield benefit to the barley and oats on chemical fallow versus wheat. Higher soil nitrate levels is a factor that normally contributes to yield gain of crops grown on chemical fallow however a high rate (100 litres per ha Urea Ammonium Nitrate) was applied to non-legume crops which would offset some of the benefits of accumulated soil nitrate with chemical fallow.

The volumetric soil moisture tests in June confirm that chemical fallow is a technique to accumulate and store soil moisture from one season to the next; both in the top soil (10cm) and subsoil (30cm). The soil moisture tests in September show that different crop types are using this stored soil moisture at different rates. It is likely all of the broadleaf crops in this trial did not accumulate sufficient early biomass to take advantage of the higher soil moisture conditions under chemical fallow. While relatively lower early biomass production is not generally an expected trait associated with legume crops this was not expected with canola which may indicate other limiting factors to canola at this site. Farmers experience on these soil types indicates that it is a difficult crop to successfully grow. It seems that both the barley and oats utilised the extra stored soil moisture of the chemical fallow and produced yield benefits with this.

It is interesting that the root disease risk tests indicate lower risk of rhizoctonia and crown rot disease on the chemical fallow site versus the wheat stubble site which is an observation needing further examination.



Graph 5. Average plot yield (kg/ha) for each crop species on wheat stubble versus chemical fallow.

Table 3. Yield gain or loss for chemical fallow treatments for each crop respectively.

	Yield (kg) loss/gain	% yield/loss gain
Canola	-55	-41
Lupins	-11	-12
Wheat	-45	-4
Barley	326	25
Lentils	4	6
Chickpeas	0	0
Oats	241	9

Table 4. Frost Induced Sterility Assessment (Average % Frosted)

	Rotation	
2016	**Wheat 2015**	**Fallow 2015**
Wheat	59	58
Barley	89	87

2016 Gross Returns

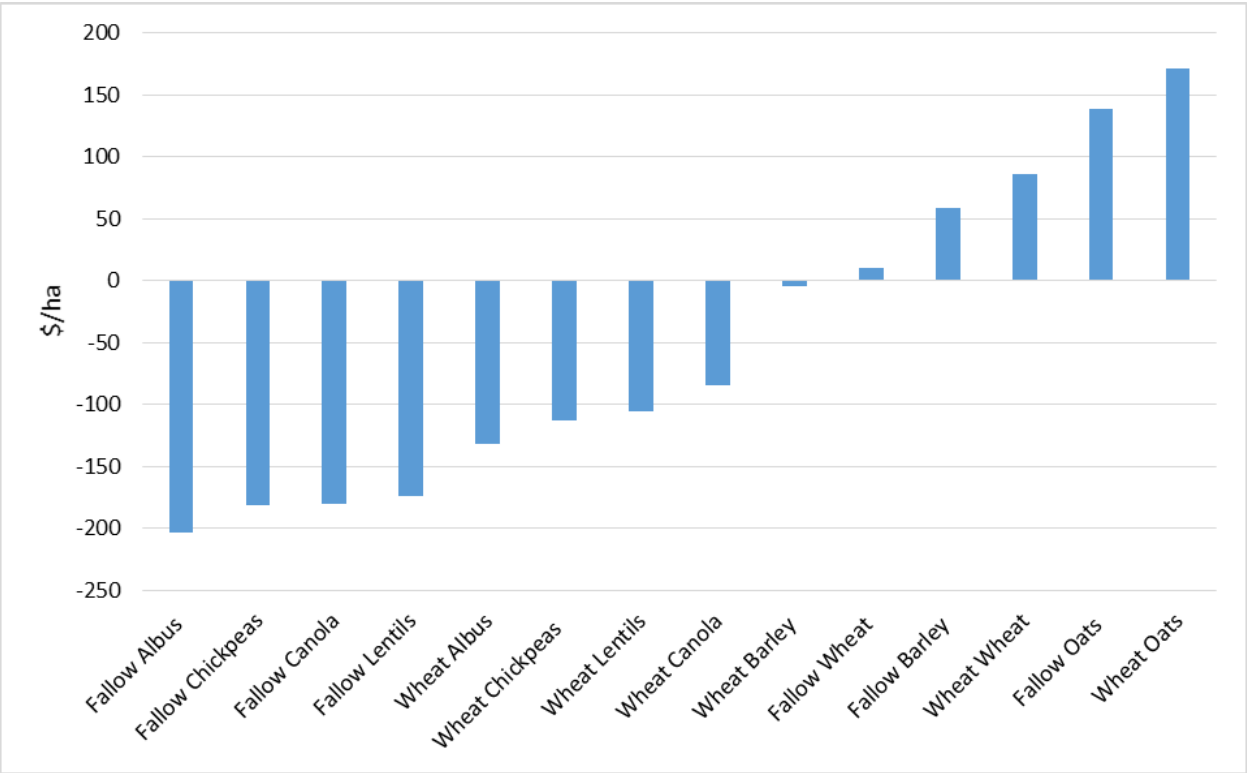
Oats produced the highest gross return (income less input costs) in this trial with oats 2016; wheat 2015, the highest and oats 2016; chemical fallow 2015, as the second highest return (Table 5, Graph 6). This is an indication of its tolerance to frost given the significant number (>20) frost events at this site in 2016. Even though the Oats on chemical fallow was higher yielding than the oats on wheat stubble, the higher costs associated with the chemical fallow reduced its relative gross return.

The only crop that had a higher gross grown on chemical fallow in 2015 compared with wheat in 2015 stubble was barley (Graph 6). The higher gross return of the barley on chemical fallow was a result of higher relative income due to quality (higher price) and higher yield.

All of the broadleaf crops grown produced lower gross returns than the cereal crops and growing them on chemical fallow also reduced gross returns further. In this case the cost of the damage of the frost to the broadleaf crops was accentuated by growing them on the more costly chemical fallow.

Table 5. Trial Yield and Gross Returns for 2016 for the Rotations (2015 2016)
**Only cost of seed, fertiliser and chemical. Machinery costs not included but are the same for each crop in this trial.*

Rotation (2015 2016)	Yield (t/ha)	Price $/t	Income ($/ha)	Fallow Herbicide Costs ($/ha)	Seed, Fert, Chem Costs ($/ha)	Total input costs* ($/ha)	Gross Return (Income - Input Costs) ($/ha)
Fallow Barley	1.64	200	328.00	68.54	200.62	269.16	58.84
Wheat Barley	1.31	150	196.50	0.00	200.62	200.62	-4.12
Fallow Wheat	1.06	264	279.84	68.54	201.17	269.71	10.13
Wheat	1.11	259	287.49	0.00	201.17	201.17	86.32
Fallow Canola	0.08	550	44.00	68.54	156.07	224.61	-180.61
Wheat Canola	0.13	550	71.50	0.00	156.07	156.07	-84.57
Fallow Albus	0.07	300	21.00	68.54	156.27	224.81	-203.81
Wheat Albus	0.08	300	24.00	0.00	156.27	156.27	-132.27
Fallow Lentils	0.07	720	50.40	68.54	156.27	224.81	-174.41
Wheat	0.07	720	50.40	0.00	156.27	156.27	-105.87
Fallow Chickpeas	0.07	900	63.00	68.54	176.27	244.81	-181.81
Wheat Chickpeas	0.07	900	63.00	0.00	176.27	176.27	-113.27
Fallow Oats	2.87	150	430.50	68.54	223.32	291.86	138.64
Wheat Oats	2.63	150	394.50	0.00	223.32	223.32	171.18



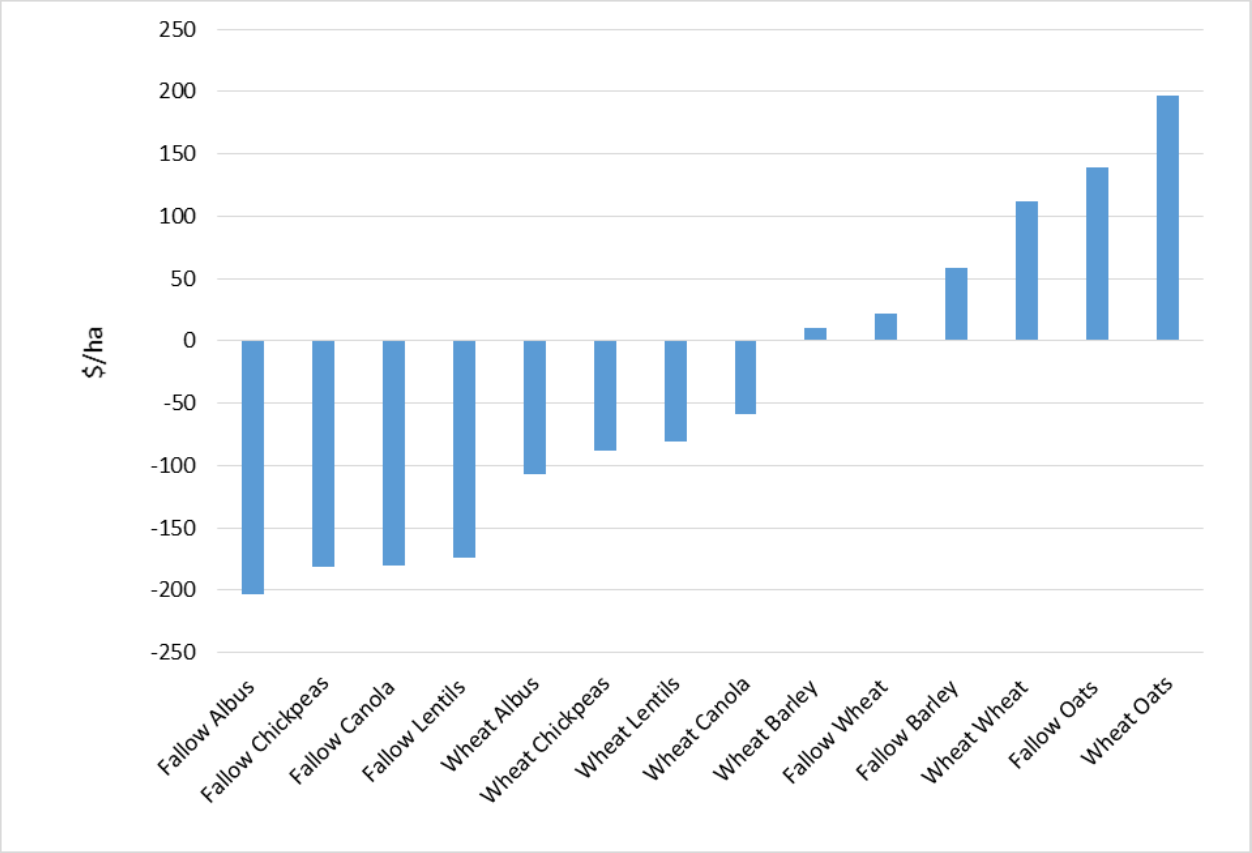
Graph 6. Ranking of Gross Return (2016) ($/ha) for each Crop type grown on Wheat Stubble or Chemical Fallow

Multiyear Gross Returns

The wheat grown in the paddock in 2015 produced a gross rmargin of $25.38 per hectare. The multi-year gross returns for plots sown on the wheat 2015 is calculated by combining the 2015 wheat gross margin with the gross returns from 2016. The multi-year gross return for those plots sown on chemical fallow of 2015 is the gross return from 2016 less the cost of fallow in 2015.

Oats sown on wheat 2015 remains the highest total gross return over the two years. The two year gross return for barley on chemical fallow 2015 remained higher than the barley grown on wheat 2015. This demonstrates that growing a crop for one year on chemical fallow can produce a higher total gross return than two consecutive crops even if frost damages these crops. These results indicate that barley has been the most suitable crop to grow on chemical fallow and it will be interesting to see whether this continue in the 2017 trial.

While the oats grown on chemical fallow in 2015 produced a lower two year gross return than the oats grown on wheat 2015 it does have a higher two year gross return than all the other crop types; either on wheat or chemical fallow. Given drier seasonal conditions it would be expected that crops sown on chemical fallow plots would produce relatively higher yields than plots sown on wheat.



Graph 7. Ranking of 2 year Gross Returns (2015-2016) including 2015 Wheat Gross Margin

2017 Trial

Methodology

In 2017 the small plot trial was sown in three blocks (Figure 2); 1. 2016 fallow, 2. Sown back on 2016 cropped plots (all species), and 3. Wheat sown on 2016 cropped plots (all species).This design allows the comparison of the range of rotations that could be possible over the three period, to compare yield and gross returns.

The plots were sown, sprayed and harvested by a contractor using small plot trial equipment. Soil moisture tests were conducted with a volumetric soil moisture probe at 10cm and 30cm in both June and September. Plant establishment counts were taken in June to coincide with crop establishment and plot yield and quality measurement were taken at harvest. NDVI readings were taken with both a hand held reader and with aerial imagery.

There was frost events at the site therefore frost induced sterility assessments were taken on the wheat and barley plots to estimate the level of frost damage.

Trial Layout

	Block 1 – Chemical Fallow, 2016	**Block 2 – Sown onto 2016 plots**	**Block 3- Wheat sown onto 2016 plots**
	Buffer	Buffer	Buffer
Rep 1	Barley	Barley	Wheat
	Oats	Oats	Wheat
	Chickpeas	Chickpeas	Wheat
	Lentils	Lentils	Wheat
	Wheat	Wheat	Wheat
	Canola	Canola	Wheat
	Albus Lupins	Albus Lupins	Wheat
Rep 2	Lentils	Lentils	Wheat
	Oats	Oats	Wheat
	Wheat	Wheat	Wheat
	Barley	Barley	Wheat
	Chickpeas	Chickpeas	Wheat
	Canola	Canola	Wheat
	Albus Lupins	Albus Lupins	Wheat
Rep 3	Oats	Oats	Wheat
	Albus Lupins	Albus Lupins	Wheat
	Barley	Barley	Wheat
	Wheat	Wheat	Wheat
	Lentils	Lentils	Wheat
	Chickpeas	Chickpeas	Wheat
	Canola	Canola	Wheat
	Buffer	Buffer	Buffer

track

2015 Wheat stubble — Chem Fallow 2015

Fallow 2016 **Randomise x 3 reps** — *Multi trial crops 2016* **Randomise x 3 reps** — *Multi trial crops 2016* **Bulk sow cereal**

Figure 2. Trial layout with replicated plots of different crop types

Photo 4. Trial Site 27th June 2017.

Trial Details

Sown; 28th April, 2017
Machine; Kalyx Australia small plot trial seeder with 6 tynes on 24cm spacings with 1.44m wide plots and 12 m long

Seeding rates

	Variety	Seed Rate (kg/ha)
IT Canola	44C79	3
Albus Lupins	Amira	120
Wheat	Mace	100
Barley	Fathom	80
Lentils	Hurricane	60
Chickpeas	Neelam	80
Oats	Banister	100
Buffer	Wheat	100

Fertiliser

IT Canola	44C79	Cereal Extra	70 kg/ha
Albus Lupins	Amira	Triple Super	30 kg/ha
Wheat	Mace	Cereal Extra	70 kg/ha
Barley	Fathom	Cereal Extra	70 kg/ha
Lentils	Hurricane	Triple Super	30 kg/ha
Chickpeas	Neelam	Triple Super	30 kg/ha
Oats	Banister	Cereal Extra	70 kg/ha

Herbicide Applications

IT Canola	2L/ha Paraquat + 2.5L/ha Trifluralin
Albus Lupins	2L/ha Paraquat +2.5L/ha Trifluralin + 1.4kg/ha Terbyne
Wheat	2L/ha Paraquat + 1.5L/ha Trifluralin + 350g/ha Diuron
Barley	2L/ha Paraquat + 1.5L/ha Trifluralin + 150g/ha Metribuzin
Lentils	2L/ha Paraquat + 2.5L/ha Trifluralin + 1.4kg/ha Terbyne
Chickpeas	2L/ha Paraquat + 2.5L/ha Trifluralin + 1.4kg/ha Terbyne
Oats	2L/ha Paraquat + 500g/ha Diuron + 1kg/ha Terbyne

Observations

Rainfall

The total rainfall (Jan to Dec 2017) of 384.5mm is above average when compared with the long term average of 309mm at Bendering weather station (25km east of trial location). While the growing season rainfall (April to October 2017 of 187mm is below average when compared to the long term average of 235.2mm at Bendering. (Appendix 1) 35mm and 30mm of rain fell in September and October respectively. This would be considered a desirable finish to the season by local growers. Summer rain prior to the season was plentiful, between January and March 2017 total rainfall amounted to 172.75mm.

Plant Establishment

Plants establishment counts were taken on the 27th of June 2017 (Table 6). The plant establishment of all crop types on sown on the 2016 fallow plots were poorer when compared with the plots sown back to 2016 cropped plots. For canola, Albus lupins, and chickpeas the plant density was well below an acceptable level when sown on the 2016 fallow. The lentil establishment was better than other break crops on the fallowed block.

The plots sown back to the 2016 cropped plots were generally in an acceptable range of the target density except for canola and Albus lupins.

It is likely that the heavy summer rain (172mm) caused compaction on the bare surface of the 2016 fallow block. These morrell loam soil types can be susceptible to slaking, due to low organic matter. During the soil moisture testing it was observed that the topsoil for the bare fallow blocks was hard set and difficult to penetrate with auger. Also the small plot seeder did not have capability to penetrate the hard topsoil and place seed into moisture – this was exacerbated by a very dry start to the growing season.

The wheat block sown back onto plots cropped in 2016 achieve acceptable plant density.

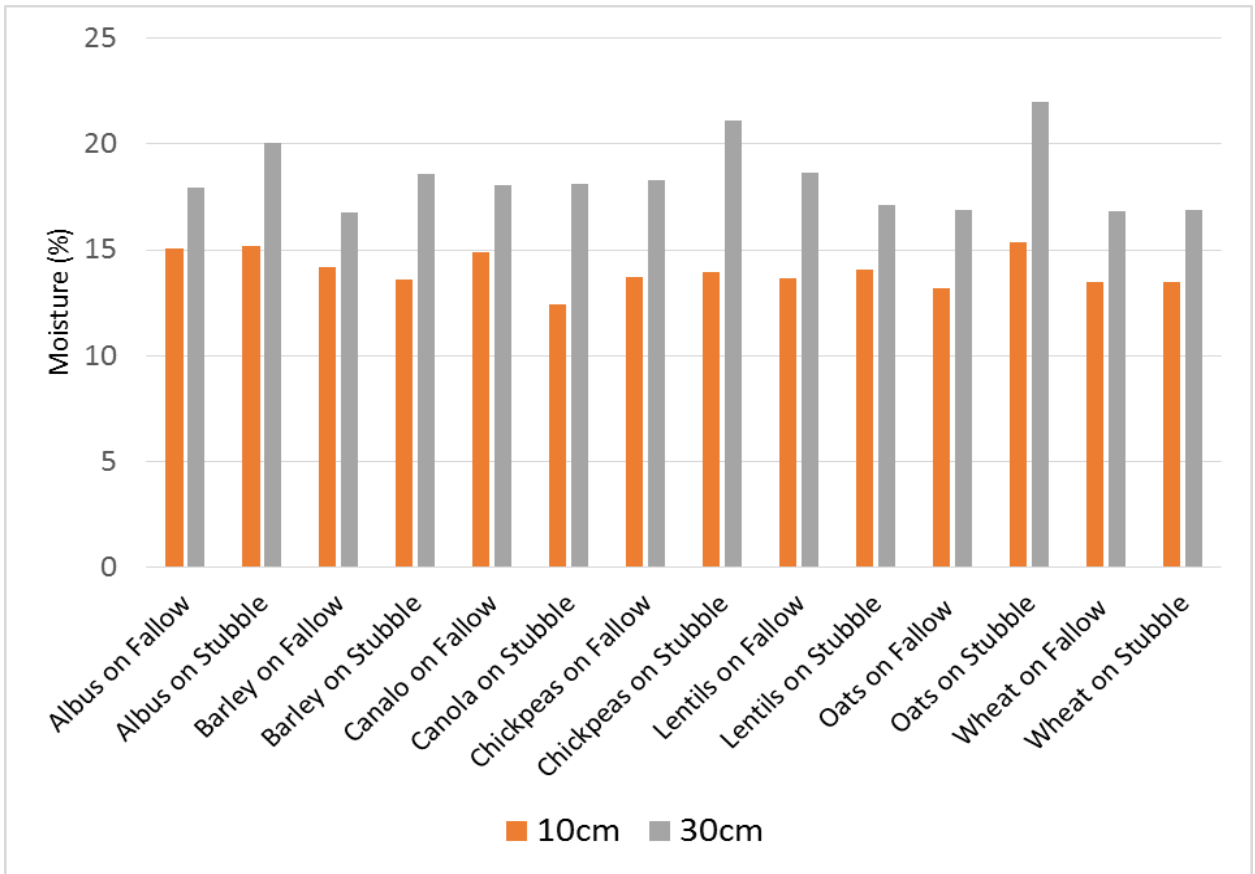
Table 6. Plant establishment 27nd June, 2017.

2017	Fallow 2016 Plants/m2	Cropped plots in 2016 plants/m2	Target Density plants/m2
Canola	6	18	40
Albus Lupins	11	26	40
Wheat	153	190	150
Barley	153	167	150
Lentils	122	190	150
Chickpeas	8	42	40
Oats	145	209	160
2017	**Cropped plots in 2016**	**Wheat Plants/m2**	**Target Density plants/m2**
Wheat	Canola	170	150
Wheat	Albus Lupins	197	150
Wheat	Wheat	148	150
Wheat	Barley	142	150
Wheat	Lentils	181	150
Wheat	Chickpeas	163	150
Wheat	Oats	166	150

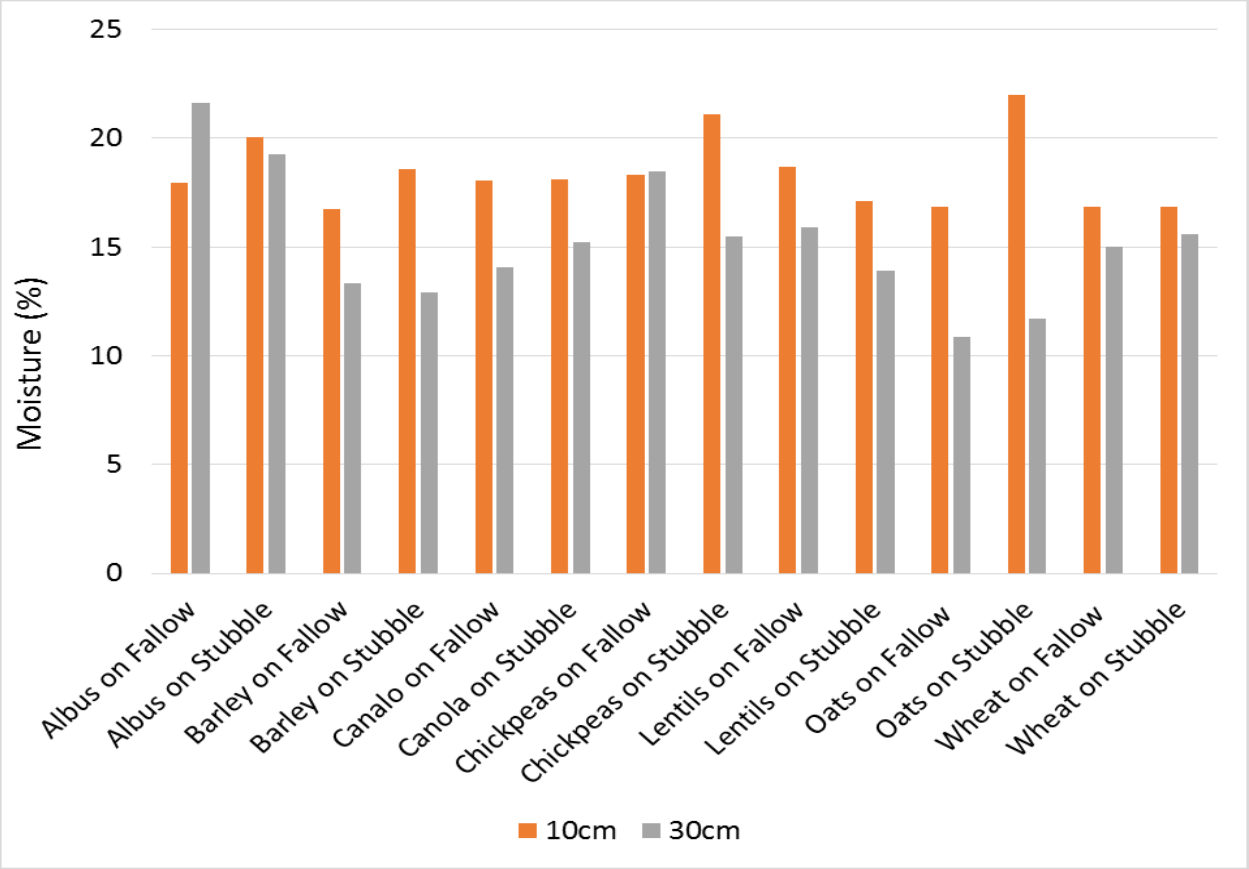
Photo 5. Poor establishment of fallow plots in the foreground compared with plots sown on 2016 cropped plots; 5th September 2017.

Soil Moisture

Volumetric soil moisture measurements were also taken with a volumetric soil moisture probe at 10cm and 30cm on the 20th June, 2017 (Graph 8). Unlike the 2016 results, the measurements indicate that generally the plots sown on stubble (2016 cropped plots) tend to have higher levels of soil moisture at 30cm when compared with plots sown on chemical fallow, for the same crop type. This perhaps demonstrates the large influence the summer rain has had on the soil moisture at the site. Also the chemical fallow blocks had little soil cover and most likely were subject to higher level of evaporation between the summer rainfall events and sowing.



Graph 8. Volumetric Soil Moisture at 10cm and 30cm on the 20nd June 2017.



Graph 9. Volumetric Soil Moisture at 10cm and 30cm on the 15th September 2017.

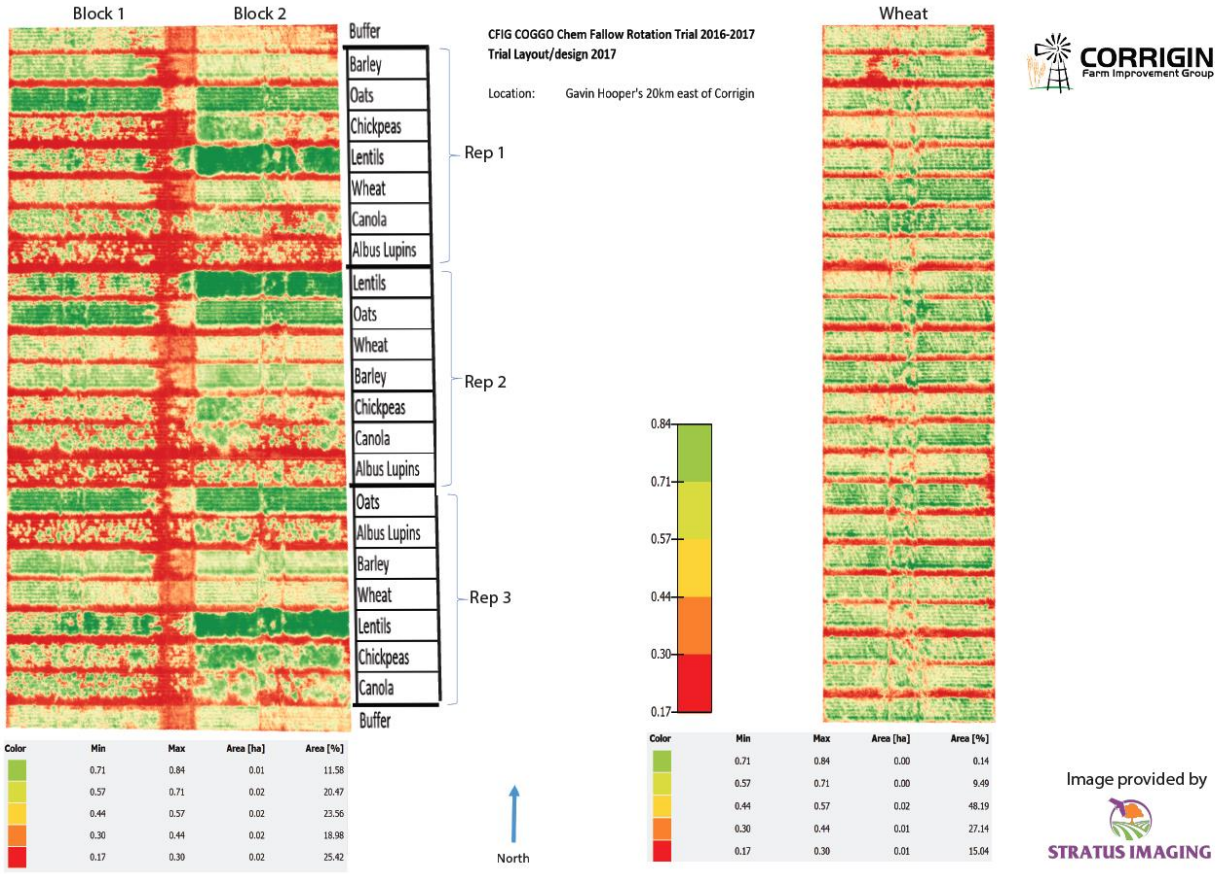


Figure 3. NDVI image taken on 18th September, 2017

Volumetric soil moisture measurements were also taken with a volumetric soil moisture probe at 10cm and 30cm on the 15th September, 2017 (Graph 9). For the pulse crops (chickpeas, lentils, lupins), the soil moisture levels at 30cm are generally higher for the fallow plots versus pulse plots sown on stubble (2016 cropped plots). Due to the poor establishment of the pulses on the fallow block there was likely lower demand for soil moisture throughout the growing season, therefore higher accumulation of moisture in the subsoil. This would have been expected to occur with canola as well but the results do not support this, which is possibly an anomaly with the results.

An NDVI image (Figure 3) taken on the 18th September shows the difference in biomass of the pulse crops sown on 2016 fallow (Block 1) versus sown on stubble (Block 2). The differences are not so pronounced for the cereal crops at this time of the season.

Results and Discussion

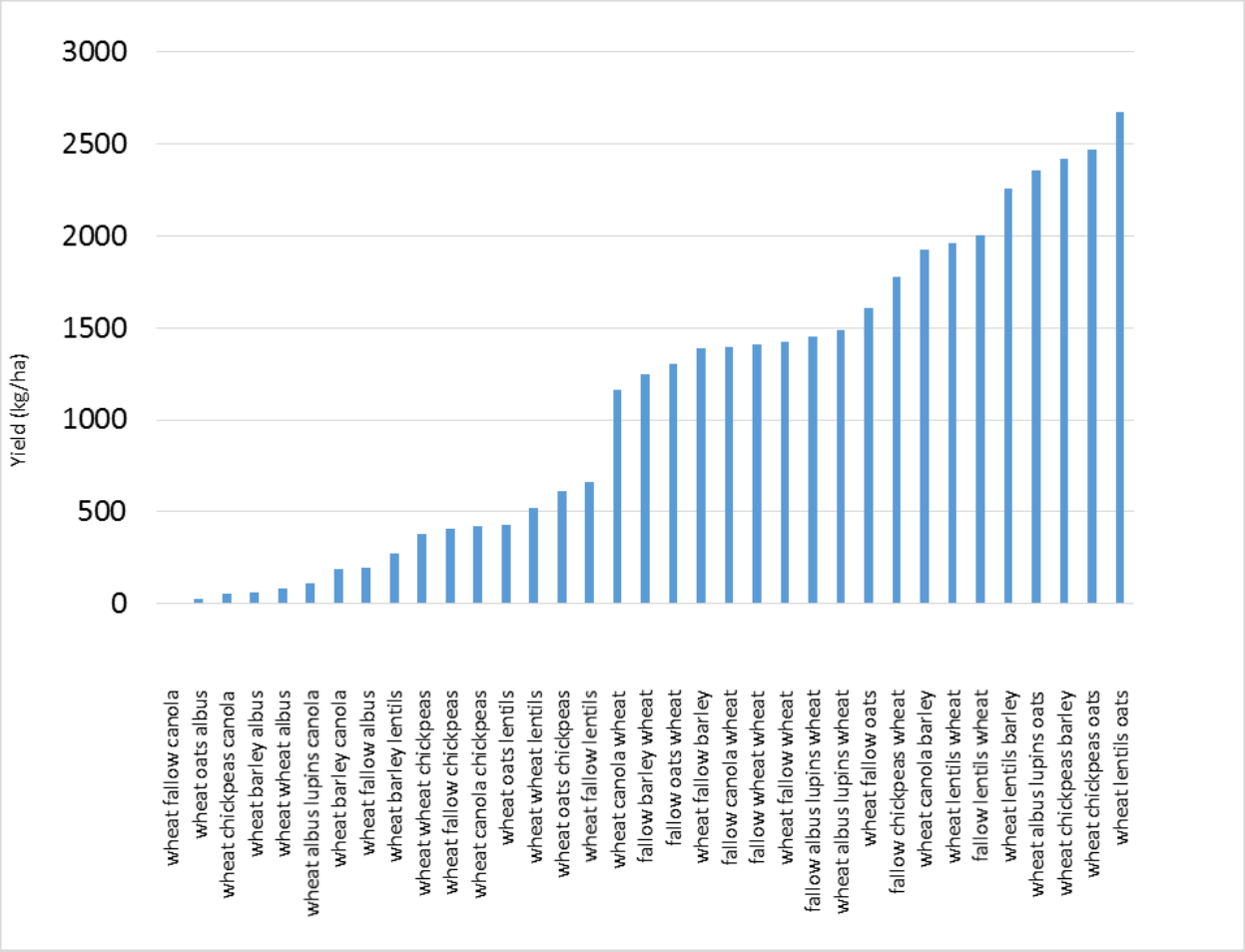
The 2017 results for yield and gross returns are presented so comparison can be made between each of the range of crop rotations tested over the three year period – ***most of these results are based on individual plots and are not replicated but some trends have occurred.*** Similar to the 2016 results, oats was the highest yielding crop in this trial, with oats sown on the lentil plot yielding 2671 kg/ha. Oats sown on chickpeas was the second highest yielding plot at 2468 kg/ha. Barley sown on 2016 lentils yielded 2420 kg/ha and was the third highest yielding plot. Cereals sown on 2016 legume plots tended to generally produced higher yields when compared with cereals sown on fallow, canola stubble or cereal stubble. Albus lupins and canola were both very poor yielding and likely the result of very poor crop establishment. (Graph 10).

When comparing crops sown on chemical fallow versus stubble (2016 cropped plots) Albus lupins and lentils were the only crop types to produce a yield benefit from growing them on chemical fallow (Table 7). For the Albus lupins this was a small yield gain and probably insignificant as the overall yield was very low (less than 200 kg/ha). For the lentils the yield increase when sown on fallow was 255 kg/ha higher than when sown on stubble and is a significant economic gain for a high value crop.

Barley and wheat were assessed for frost induce sterility due to the observation of some visual frost damage at the site. The damage was minor compared to the severe damage in 2016 (Table 8). The results indicate that the frost damage was worse on the block sown all to wheat in 2017 on the various different crop type plots from 2016. The block tended to establish early and likely may have been flowering earlier during the most susceptible time for frost damage.

Table 7. Yield gain or loss for chemical fallow treatments for each crop respectively.

2017	Yield (kg) loss/gain	% yield/loss gain
Albus Lupins	140	250%
Barley	-814	-37%
Canola	-117	-99%
Chickpeas	-66	-14%
Lentils	255	63%
Oats	-888	-36%
Wheat	-97	-6%



Graph 10. Ranking of average 2017 plot yield (kg/ha) for each crop rotation (2015 2016 2017)

Table 8. Frost Induced Sterility Assessment (Average % Frosted)

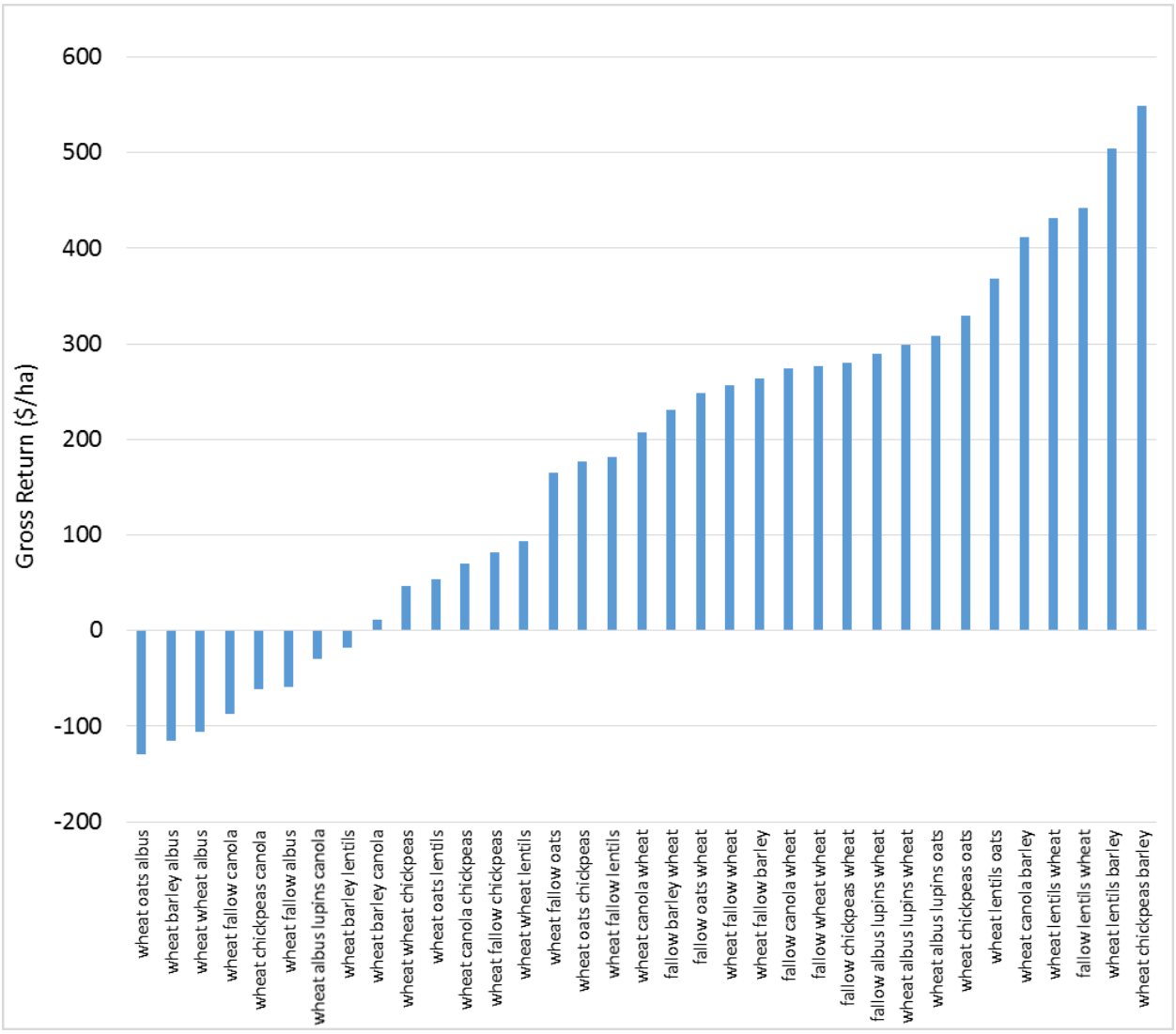
FALLOW 2016	**Average % Frosted**
Wheat	2.64%
Barley	1.43%
STUBBLE 2015	**Average % Frosted**
Wheat on Lentils	2.67%
Barley on Canola	1.37%
Wheat on Canola	2.03%
Barley on Lentils	2.50%
Wheat on Albus Lupins	3.27%
Barley on Chickpeas	0.97%
FALLOW 2015	**Average % Frosted**
Wheat on Canola	9.00%
Wheat on Albus Lupins	8.16%
Wheat on Wheat	8.71%
Wheat on Barley	13.34%
Wheat on Lentils	6.52%
Wheat on Chickpeas	6.88%
Wheat on Oats	10.52%

2017 Gross Returns

Barley produced the greatest gross return (income-input costs) in this trial. Barley sown on the chickpeas plot of 2016 produced the highest gross return of $549 / ha. All barley plots had quality suitable for malting grade in 2017. Barley sown on the 2016 lentil plot was the second highest gross return at $504/ha. Wheat sown on 2016 lentils was the third highest gross return at $442/ha and Hard 2 grade. Albus lupins and canola, as the results of very low yields produced losses on a gross return basis. When comparing the break crop, canola, lupins, lentils and chickpeas, it was the chickpeas and lentils that generally produced the highest returns in 2017 (Table 9, Graph 11).

Table 9. Trial Yield and Gross Returns for 2017
**Only cost of seed, fertiliser and chemical. Machinery costs not included but are the same for each crop in this trial.*

Crop Rotation (2015 2016 2017)	Yield (kg/ha)	Price $/t	Income ($/ha)	Seed, Fert, Chem Costs ($/ha)	Gross Return (Income - Input Costs) ($/ha)
wheat oats albus	28	420	12	141	-129
wheat barley albus	58	420	25	141	-116
wheat wheat albus	83	420	35	141	-106
wheat fallow canola	1	520	1	710	-709
wheat chickpeas canola	53	520	27	88	-61
wheat fallow albus	196	420	82	139	-57
wheat albus lupins canola	112	520	58	88	-30
wheat barley lentils	273	450	123	141	-18
wheat barley canola	190	520	99	88	11
wheat wheat chickpeas	377	550	208	161	47
wheat oats lentils	430	450	193	141	53
wheat fallow chickpeas	405	550	223	141	82
wheat canola chickpeas	420	550	231	161	70
wheat wheat lentils	521	450	234	141	93
wheat fallow lentils	663	450	298	117	181
wheat fallow oats	1610	190	306	141	165
wheat oats chickpeas	615	550	338	161	177
wheat canola wheat	1160	280	325	117	207
fallow barley wheat	1244	280	348	117	231
fallow oats wheat	1304	280	365	117	248
wheat fallow barley	1386	275	381	0	381
fallow canola wheat	1399	280	392	117	274
fallow wheat wheat	1410	280	395	117	277
wheat fallow wheat	1422	280	398	141	257
fallow albus lupins wheat	1454	280	407	117	290
wheat albus lupins wheat	1486	280	416	117	299
wheat albus lupins oats	2356	190	448	139	308
wheat chickpeas oats	2468	190	469	139	329
wheat lentils oats	2671	190	508	139	368
fallow chickpeas wheat	1777	280	497	117	380
wheat canola barley	1924	275	529	117	412
wheat lentils wheat	1958	280	548	117	431
fallow lentils wheat	1999	280	560	117	442
wheat lentils barley	2257	275	621	117	504
wheat chickpeas barley	2420	275	666	117	549



Graph 11. Ranking of 2017 gross returns for each crop type in rotation (2015 2016 2017) ($/ha)

Multiyear Gross Returns

The gross returns of every rotation possible of the three year period (2015-2017) was totaled and compared. A cost of $68.54 was allocated to any rotation with a fallow phase. The rotation that produced the highest total gross return for the 3 year period was 2015 wheat; 2016 chickpeas; and 2017 barley at $461/ha 3 year total. The benefit of the chickpea phase in 2016 to the barley yield in 2017 was likely a significant on this result.

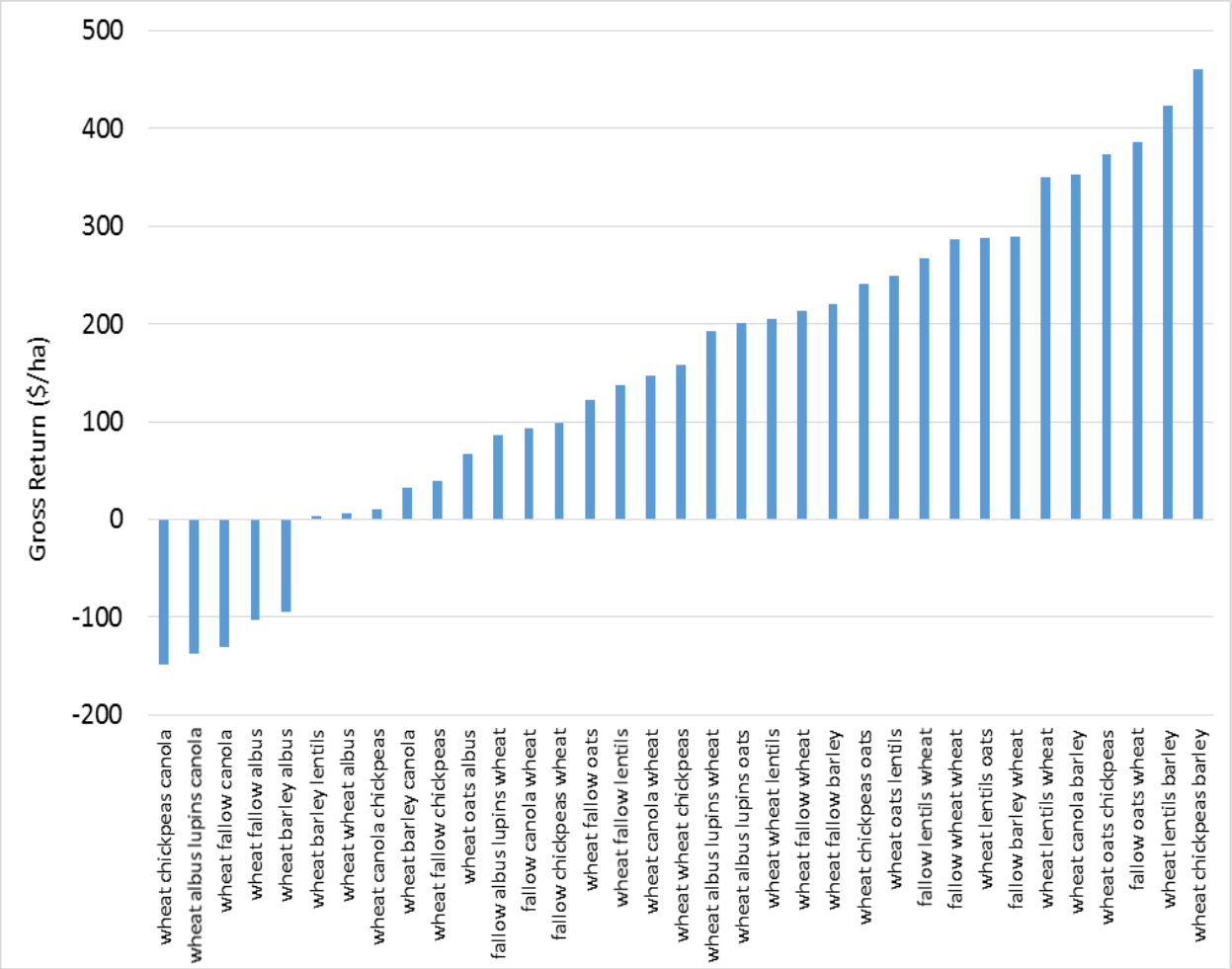
The rotation 2015 wheat; 2016 lentils; 2017 barley and 2015 fallow; 2016 oats; 2017 wheat, were the second ($424/ha) and third ($387) highest total gross returning rotations over the three year period.

The highest returning rotation with a fallow phase was 2015 fallow; 2016 oats; 2017 wheat, which was the third highest, producing a total of $387/ha accumulated gross return. Any rotation with canola or Albus lupins were generally the poorer performing gross returns with the exception of 2015 wheat; 2016 canola; 2017 barley. In this rotation the barley yielded relatively well in 2017 with 1924 kg/ha. Crop establishment did have a large influence over the performance of these two crops (canola and lupins) and this highlights the need to have appropriate seeding systems for different crop types.

The highest returning rotation with a double break was fallow 2015; lentils 2016; wheat 2016. This was the 10th highest returning rotation at $268 per hectare for the three year period.

Table 10. Accumulated Gross Return for Crop Rotations over a 3 year period

Crop Rotation (2015 2016 2017)	Total Gross Return for 3 year Period ($/ha)
wheat chickpeas canola	-149
wheat albus lupins canola	-137
wheat fallow canola	-130
wheat fallow albus lupins	-102
wheat barley albus lupins	-95
wheat barley lentils	3
wheat wheat albus lupins	6
wheat canola chickpeas	11
wheat barley canola	32
wheat fallow chickpeas	39
wheat oats albus lupins	68
fallow albus lupins wheat	86
fallow canola wheat	93
fallow chickpeas wheat	98
wheat fallow oats	122
wheat fallow lentils	138
wheat canola wheat	148
wheat wheat chickpeas	159
wheat albus lupins wheat	192
wheat albus lupins oats	201
wheat wheat lentils	205
wheat fallow wheat	214
wheat fallow barley	221
wheat chickpeas oats	241
wheat oats lentils	250
fallow lentils wheat	268
fallow wheat wheat	287
wheat lentils oats	288
fallow barley wheat	290
wheat lentils wheat	351
wheat canola barley	353
wheat oats chickpeas	374
fallow oats wheat	387
wheat lentils barley	424
wheat chickpeas barley	461



Graph 12. Ranking of accumulative 3 year gross returns (2015-2017)

APPENDICES

Appendix 1

2016 Rainfall

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Monthly Total	*74.5*		*53*	*39.5*	*41.5*	*19.25*	*31.25*	*56.5*	*17.25*	*4.25*		*29.5*

Total Rainfall 366.5mm
Growing Season Rainfall (April to October) 209.5mm

2017 Rainfall

	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Monthly Total	71	83.5	18.25	5.5	7.75	18.75	35.75	53	35.75	30.5	13.5	11.25

Total Rainfall 384.5mm
Growing Season Rainfall (April to October) 187mm

2016 24 hr Minimum Temperatures July – October (Source East Corrigin Weather Station)

1	1/08/2016	-2.7
2	29/09/2016	-2.7
3	2/08/2016	-2.6
4	17/09/2016	-2.6
5	24/07/2016	-2.4
6	18/09/2016	-2.4
7	21/10/2016	-2.2
8	26/06/2016	-2
9	20/07/2016	-2
10	12/07/2016	-1.5
11	13/08/2016	-1.5
12	14/08/2016	-1.5
13	23/08/2016	-1.5
14	24/08/2016	-1.3
15	24/09/2016	-1.2
16	1/07/2016	-1.1
17	13/07/2016	-1
18	15/09/2016	-1
19	26/09/2016	-1
20	4/07/2016	-0.9
21	30/09/2016	-0.9
22	2/09/2016	-0.8
23	14/09/2016	-0.7
24	10/10/2016	-0.6
25	2/07/2016	-0.5
26	25/08/2016	-0.5
27	19/07/2016	-0.4
28	19/08/2016	-0.4
29	14/07/2016	-0.2

2016 Soil Tests

Table 1. 2015 Wheat Soil Test Results (Source; Summit Fertilisers)

Paddock Name: STUBBLE			Site:	A	RMS16009				Site:	B	RMS16010			
Test	Unit	Code		Deficient	Low	Adequate	High	Excessive		Deficient	Low	Adequate	High	Excessive
Colwell P	mg/kg	9B	22						27					
Colwell K	mg/kg	9B	1063						1032					
Sulphur (KCL40)	mg/kg	10D1	24						17					
pH (CaCl2)		4B2	7.6						7.7					
PBI		9I2	142						171					
Nitrate N	mg/kg	7C2	21						22					
Ammonium N	mg/kg	7C2	0						0					
Copper (DTPA)	mg/kg	12A1	1.00						1.09					
Zinc (DTPA)	mg/kg	12A1	0.62						0.69					
Aluminium (CaCl2)		15G1	0.2						0.1					
Organic Carbon	%	6A1	0.93	Low					1.03	Medium				
E/Conductivity	dS/m	3A1	0.15	Non-Saline					0.14	Non-Saline				

Table 2. 2015 Chemical Fallow Soil Test Results (Source; Summit Fertilisers)

Paddock Name: FALLOW			Site:	A	RMS16007				Site:	B	RMS16008			
Test	Unit	Code		Deficient	Low	Adequate	High	Excessive		Deficient	Low	Adequate	High	Excessive
Colwell P	mg/kg	9B	22						26					
Colwell K	mg/kg	9B	921						1077					
Sulphur (KCL40)	mg/kg	10D1	28						20					
pH (CaCl2)		4B2	7.7						7.3					
PBI		9I2	210						219					
Nitrate N	mg/kg	7C2	35						45					
Ammonium N	mg/kg	7C2	1						1					
Copper (DTPA)	mg/kg	12A1	0.97						1.00					
Zinc (DTPA)	mg/kg	12A1	0.31						0.56					
Aluminium (CaCl2)		15G1	0.2						0.2					
Organic Carbon	%	6A1	0.96	Low					1.20	Medium				
E/Conductivity	dS/m	3A1	0.28	Non-Saline					0.20	Non-Saline				

Appendix 2 Soil Root Disease

Table 3. Soil Root Disease 2015 Wheat (Source; SARDI Predicta B Test)

Paddock history	2 years ago	Last year	This year
Crop / variety	Wheat	Wheat	

TEST	RESULT		DISEASE RISK*			
			Not Detected	Low	Med	High
CCN	<0.05	eggs /g soil				
Stem nematode	<0.5	nematodes/100 g soil				
Take-all	<0.8	log(pg DNA/g soil)				
Take-all - Oat Strain	<0.8	log(pg DNA/g soil)				
Rhizoctonia	1.5	log(pg DNA/g soil)				
Crown Rot	2.8	log(pg DNA/g soil)				
Pratylenchus neglectus	1.1	nematodes /g soil				
Pratylenchus thornei	<0.1	nematodes/g soil				
Blackspot	<1.2	log(pg DNA/g soil)				
Blackspot (Phoma koolunga)	<1.2	log(pg DNA/g soil)				

*Risk categories should be used as a guide only, may be subject to regional and seasonal differences, and may be revised over time.

Table 4. Soil Root Disease 2015 Chemical Fallow (Source; SARDI Predicta B Test)

Paddock history	2 years ago	Last year	This year
Crop / variety	Wheat	Fallow	

TEST	RESULT		DISEASE RISK*			
			Not Detected	Low	Med	High
CCN	<0.05	eggs /g soil				
Stem nematode	<0.5	nematodes/100 g soil				
Take-all	<0.8	log(pg DNA/g soil)				
Take-all - Oat Strain	<0.8	log(pg DNA/g soil)				
Rhizoctonia	0.8	log(pg DNA/g soil)				
Crown Rot	<0.6	log(pg DNA/g soil)				
Pratylenchus neglectus	1.4	nematodes /g soil				
Pratylenchus thornei	<0.1	nematodes/g soil				
Blackspot	<1.2	log(pg DNA/g soil)				
Blackspot (Phoma koolunga)	<1.2	log(pg DNA/g soil)				

*Risk categories should be used as a guide only, may be subject to regional and seasonal differences, and may be revised over time.

Appendix 3 2016 Cereal Quality Results

N		Wheat Stubble - East Plot			Treatments	Chem Fallow 2015 - West Plot		
	Treatments	Protein %	Hectolitre Weight kg/hL	Screenings		Protein %	Hectolitre Weight kg/hL	Screenings
Rep 1	Wheat	12.7	75.4	4.1	Wheat	13.8	75.6	1.7
	Oats	11.7	49.9	15.3	Oats	12.8	49.7	15.3
	Barley	13.3	47.9	20.9	Barley	14.7	52.9	12.0
Rep 2	Wheat	13.1	76.7	3.1	Wheat	14.4	76.3	1.5
	Oats	11.7	48.7	17.1	Oats	12.2	51.5	16.0
	Barley	15.7	46.7	19.4	Barley	14.9	56.6	10.9
Rep 3	Wheat	13.1	75.4	2.8	Wheat	14.1	75.8	1.5
	Oats	11.5	50.1	13.8	Oats	12.5	51.4	17.5
	Barley	14.2	46.2	20.3	Barley	15.9	52.3	11.6

Appendix 4. 2015 Wheat Gross Margin

2015 Wheat										
Yield (t/ha)	Price ($/t)	Income ($/ha)	Input Costs ($/ha)	Sprayer Passes ($/ha)	Seeder ($/ha)	Harvester ($/ha)	Freight ($/ha)	CBH ($/ha)	Total Costs ($/ha)	Gross Return ($/ha)
1.2	295	354	200.62	20	30	30	9.6	38.4	328.62	25.38