Risks and rewards of growing pulse crops in the low rainfall Mallee cropping region

Michael Moodie[1], Todd McDonald[1], Nigel Wilhelm[2], and Ray Correll[3]

[1] Frontier Farming Systems, 7B Byrne Ct, Mildura, Victoria, 3500, www.frontierfarming.com.au, michael@frontierfarming.com.au
[2]South Australian Research & Development Institute, PO Box 397, Adelaide, South Australia 5001
[3]RHO Environmetrics, PO 366 Highgate, SA, 5064

Abstract
The adoption of pulse crops in low rainfall cropping regions such as the Mallee is increasing. While the farming system benefits of pulse crops are clear, there is a lack of regionally available data to support grower decisions on the most profitable pulse crops to select. Over three contrasting seasons, we directly compared pulse crop productivity on four regionally important soil types in the South Australian Mallee. Overall, most pulse crops had similar productivity potential but the yields were highly influenced by seasonal conditions and soil type. Season had the greatest impact on productivity with yields almost four times more in a high rainfall (decile 8-10) year than in a low (decile 2-4) rainfall season. Pulse crop yields also varied by up to 60 percent between soil types. The highest and least variable grain yields were achieved on the sandy loam – loam soil types, with lower productivity and high yield variability obtained on both the heavy and sandy soils. Subsequent Monte Carlo simulation using @Risk quantified the risk and reward profile of each crop for Mallee farming systems. The analysis showed that lentils had both the greatest profit potential and lowest financial risk of all pulse crops over the long term. Vetch, chickpea and field pea are expected to generate long term gross margins of more than $200/ha. Chickpea and field pea are expected to have a negative gross margin in more than 30% of years but a high gross margin (>$500/ha) is expected in nearly one in five seasons. This information will allow Mallee growers to make more informed selections of the most appropriate pulse crops for their farming system.

Key Words
Field pea, vetch, lentil, faba bean, chickpea, lupin, rotations

Introduction
The adoption of pulse crops in low rainfall cropping regions such as the Mallee is increasing as a response to recent research that has demonstrated the benefits of break crops to Mallee crop sequences. McBeath et al. (2015) measured cumulative break crop effects of over 1 t/ha in the wheat crops following the break phase at Karoonda in the South Australian Mallee and primarily attributed the break benefit to beneficial effects on the cycling and supply of nutrients. Moodie et al. (2017) reported cumulative break crop benefits of 0.5 – 1.5 t/ha and increased profit up to $100/ha per year by including break crops such as pulses in low rainfall crop sequences, relative to maintaining continuous wheat.

While the farming system benefits of pulse crops are clear, there is a lack of regionally available data to support grower decisions on the most profitable pulse crops to select. This study compared pulse crop productivity and profitability on four major soil types in the Mallee region to identify the most appropriate option for local farming systems. The aim was to provide farmers with information on the relative productivity and profitability of legume break crops in this low rainfall region.

Methods
Field Trials
One current commercial variety of each of six pulse crops of interest to farmers in the low rainfall Mallee region were compared over three seasons (2015-2017) on four regionally important soil types. The pulse crops used were field pea (var. PBA Wharton), vetch (var. Rasina), Lupin (var. PBA Barlock), Lentil (var. PBA Hurricane), Faba bean (var. PBA Samira) and Chickpea (var. Genesis 090).

The trials were located at Waikerie (-34.26°S 140.00°E) and Loxton (-34.53°S 140.53°E) and at each site two trials were located on contrasting soil types within the same paddock. A brief description of each of the four soil types is provided below:
- Loxton Flat: Red loam located in a swale
- Loxton Sand: Deep yellow sand located on the top of an east-west dune

- Waikerie Flat: Heavy red-grey soil with limestone present 20-30 cm below the surface
- Waikerie Sand: Red sandy loam located mid-slope

Each trial was sown after the break of the season into moist soil soon to ensure successful rhizobial inoculation. Trials were sown on the following dates in each season:
2015: Loxton, 28 April; Waikerie, 1 May
2016: Loxton, 26 May; Waikerie, 30 May
2017: Loxton, 5 May; Waikerie, 9 May

Each treatment at each site was managed independently to ensure it reached its potential. Agronomic management differences included herbicide choice, fertiliser rates and fungicide and pesticide applications. All trials were machine harvested across multiple dates in each season to ensure grain yield was measured soon after crops matured and to minimise losses.

Seasonal conditions
Figure 1 shows the annual rainfall received at Loxton and Waikerie for each of the three trial years. In 2015 and 2017, rainfall was generally below average, with growing season rainfall (GSR) at Loxton decile 5 and 3 and at Waikerie decile 3 and 2 for 2015 and 2017 respectively. Both seasons had good April rainfall allowing for timely sowing in early May. In 2016, both sites received exceptional GSR, especially in spring, with a decile 10 GSR recorded at Loxton and decile 8 GSR at Waikerie.

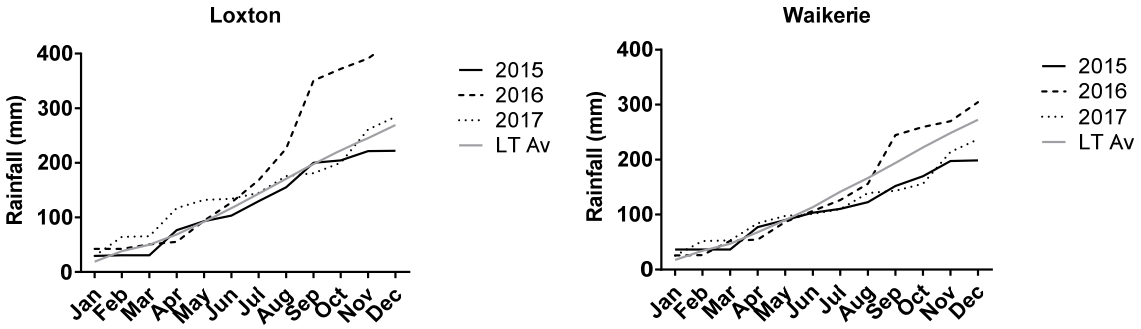

Figure 1 Cumulative annual rainfall for Loxton and Waikerie locations for the three trial years (2015-2017) and the long-term average (LT Av)

Profit risk modelling
A gross margin analysis was undertaken using Monte Carlo simulation with the Microsoft Excel add-inn @Risk. Gamma distributions were created for the grain yield of each crop using the 12-soil type x season yield outcomes that were generated by the field trials (Table 1). Log logistic distributions of grain price were developed for each crop using long term (2003 – 2017). January grain prices from the Rural Solutions Farm Gross Margin and Enterprise Planning Guide. The yield and price distributions were used to undertake 5000 iterations to generate a new gross margin distribution for each crop. The parameters for each crop used to create the Gamma yield and Log Logistic price distributions in @Risk are provided in Table 2.

Table 2. Parameters used for fitting Gamma distributions for grain yield and Log Logistic distributions for grain price in @Risk to represent pulse crops in the Mallee region.

Crop	Gamma Grain Yield Distribution			Log Logistic Price Distribution			
	Mean (t/ha)	Alpha	Beta	Mean ($/t)	5th Percentile ($/t)	Median ($/t)	95th Percentile ($/t)
Field Pea	1.45	1.152	1258.180	322	211	305	484
Lupin	1.12	1.867	598.802	276	197	270	374
Chickpea	0.77	1.46	529.101	609	288	600	960
Lentil	1.08	1.653	653.594	684	401	630	1136
Faba Bean	0.95	1.393	684.931	386	246	370	576
Vetch	1.14	1.942	584.795	431	313	500	600

Results

Productivity

Field pea was the best yielding pulse crop with an average yield of 1.3 t/ha over all soil types and seasons. All other crop types averaged between 1-1.1 t/ha except for chickpea which had an average grain yield of 0.8 t/ha.

There was a high level of variation in break crop yields both between seasons and between soil types. For example, the average yield of all break crops in 2016 was nearly four times greater in 2016 than in 2015 and 2017 (Table 1). The pattern of rainfall and temperatures within years was also important. In 2015, a hot and dry spring favoured crops with early maturity: field peas, vetch and lentils produced the highest average yield. In contrast, frosts in August and September and significant rainfall in October 2017 favoured later maturity crops with chickpea and lupins producing the highest yields.

Pulse crops were most productive on the loamy soil of the Loxton flat site with all pulse crops averaging 1.45 t/ha for the three seasons. However, average pulse crop yield on the sandy soil at Loxton were only 60 percent of those achieved on the loam, despite the sites located just 250 m apart. Lentils, chickpea and faba bean performed particularly poorly on the sandy soil, producing 50 percent of the grain yield achieved on the better soil type. At Waikerie the best production was on the sandy loam soil (Waikerie sand) with an average yield of 1.1 t/ha across all crops and seasons. In comparison, the average yield at the Waikerie flat site was 0.9 t/ha. However, performance at this site was highly variable with seasonal conditions, being almost as productive as the Loxton and Waikerie sand sites in 2016 but extremely poor in 2015 and 2017.

Table 1. Pulse crop grain yields (t/ha) on four Mallee soil types for three seasons (2015-2017). Mean grain yield ± Standard Error of the Mean (SEM) is provided in the table.

Year	Site	Chickpea	Faba bean	Lentils	Lupin	Vetch	Field Pea
2015	Loxton Flat	0.43±0.09	0.83±0.11	0.96±0.11	0.71±0.11	0.77±0.14	0.58±0.21
	Loxton Sand	0.22±0.03	0.55±0.05	0.64±0.05	0.60±0.09	0.86±0.03	0.71±0.05
	Waikerie Flat	0.05±0.03	0.29±0.03	0.47±0.07	0.20±0.07	0.19±0.02	0.16±0.18
	Waikerie Sand	0.45±0.01	0.46±0.04	0.82±0.07	0.49±0.05	0.69±0.04	1.21±0.03
	Average (all sites)	**0.29**	**0.53**	**0.72**	**0.50**	**0.63**	**0.66**
2016	Loxton Flat	1.55±0.36	2.92±0.33	3.13±0.45	2.88±0.32	2.84±0.25	3.02±0.48
	Loxton Sand	0.65±0.08	1.50±0.18	0.88±0.16	2.06±0.15	2.03±0.09	1.67±0.64
	Waikerie Flat	1.15±0.06	1.65±0.15	2.53±0.05	1.81±0.35	1.81±0.31	3.58±0.07
	Waikerie Sand	2.48±0.07	1.66±0.20	1.90±0.21	1.55±0.15	2.19±0.13	3.25±0.15
	Average (all sites)	**1.46**	**1.93**	**2.11**	**2.07**	**2.22**	**2.88**
2017	Loxton Flat	1.01±0.15	0.93±0.18	0.86±0.14	1.27±0.25	0.78±0.11	0.73±0.11
	Loxton Sand	0.36±0.05	0.18±0.12	0.31±0.07	1.18±0.04	0.68±0.07	0.4±0.07
	Waikerie Flat	0.39±0.07	0.37±0.06	0.28±0.04	0.25±0.19	0.33±0.09	0.29±0.06
	Waikerie Sand	0.51±0.10	0.10±0.07	0.20±0.04	0.46±0.08	0.47±0.10	0.60±0.07
	Average (all sites)	**0.57**	**0.39**	**0.41**	**0.89**	**0.57**	**0.50**
	Average (all years)	***0.77***	***0.95***	***1.08***	***1.12***	***1.14***	***1.35***

Profit risk modelling

Monte Carlo simulation showed that lentils are not only the most profitable break crop but are also the least risky (Table 3). The average gross margin from lentils is $500/ha and a negative return from growing lentils is expected in only 14% of seasons. Vetch was the next most profitable break crop with an average gross margin of $300/ha. However, vetch as grain is predominantly sold for seed to plant fodder and hay crops. While there have been some high prices received for vetch in recent years, the grain market is limited and becomes easily flooded, which is not reflected in the @Risk simulation.

Chickpea and field pea had similar profitability and risk outcomes with both having simulated mean long-term gross margin of $217/ha. Both crops also had similar risks of not achieving a breaking even gross margin (33-36%) while both crops had an 18% probability of the gross margin exceeding $500/ha. Despite both crops having a similar profitability and risk profile, our observations from the trials were that they could be complementary within a farm enterprise mix. Field peas matured early and tended to perform well in frost-free situations with terminal drought and/or high levels of heat in spring. Conversely chickpea matured late and performed well at sites which were frosted in early spring and in situations where soil moisture was available late in the season.

Lupin and faba bean had lowest simulated long-term gross margins of $132/ha and $114/ha respectively. Faba beans are also the riskiest crop and are expected to not break even in 44% of seasons. The downside risk of lupins is comparable to field pea and chickpea but lupins has the lowest probability of achieving a high gross margin of more than $500/ha. This is due to low long-term price outcomes for lupins relative to other pulse crops.

Table 3. Mean gross margins for pulse crops and the probability of gross margin which are less than $0/ha or greater than $500/ha generated with @Risk simulations.

Crop	Mean ($/ha)	Probability <$0/ha	Probability $0 - $500/ha	Probability >$500/ha
Lentil	498	14%	49%	38%
Vetch	300	16%	63%	22%
Chickpea	217	36%	47%	18%
Field Pea	217	33%	60%	18%
Lupin	132	29%	66%	5%
Faba Bean	114	44%	46%	10%

Conclusion

Overall, most pulse crops had similar productivity potential, however the yields achieved in any one season were highly influenced by seasonal conditions (e.g. amount and distribution of seasonal rainfall, frost and heat events) and soil type. Season had the greatest impact on productivity with yields almost four times more in a high rainfall (decile 8-10) year than in a low (decile 2-4) rainfall season. Pulse crop yields also varied by up to 60 percent between soil types. The highest and least variable pulse crop grain yield were achieved on the sandy loam – loam soil types, with lower productivity and high yield variability obtained on both the heavy and sandy soils. As all of these soil types are encountered within a typical Mallee paddock, management options to improve pulse productivity and reliability on these constrained soils are required.

Monte Carlo simulation showed that lentils had both the greatest profit potential and lowest financial risk of all pulse crops over the long term. Vetch, chickpea and field pea are expected to generate long term gross margins of more than $200/ha. Chickpea and field pea are expected to have a negative gross margin in more than 30% of years, however a high gross margin (>$500/ha) is expect in in nearly one in five seasons. This information will allow Mallee growers to make more informed selections of the most appropriate pulse crops for their farming system.

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