The potential for intercropping in Australian farming systems and pathways to adoption

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Abstract

Intercropping is known to increase productivity and whilst it has not yet achieved high levels of adoption, intercropping is increasingly practiced in broad-acre farming systems both internationally and in Australia. The aim of intercropping is generally to produce a greater yield than growing monocrops, but there is also interest in the other documented benefits including reduced input costs, reduced incidence of disease, improved resource-use efficiency, rotational benefits and soil improvements over the longer term. A recent review of historical Australian intercropping research has shown a 14 and 31% increase in productivity in cereal-legume and pea-canola intercrops, respectively. In more recent experimental data from nine field experiments with up to eight intercrop combinations, 43% of combinations over-yielded, with yield gains of 29 to 120% for chickpea-canola, lentil-canola and vetch-canola combinations. Together these experimental results confirm the potential for mixed species cropping systems in the Australian dryland farming system. The pathway to adoption will require researchers and farmers to work together to overcome the real and perceived barriers at farm-scale, building on the small networks of early adopters across the country.

Keywords

Mixed cropping, over-yielding, LER, pulse, oilseed.

Introduction

Farming systems in Australia and globally face the challenge of balancing production, finance and environmental goals and there is a need to develop more resilient systems to address these business challenges. Intercropping, the practice of growing two or more grain crops on the same piece of land at the same time, is a production system adopted by a small number of Australian producers in dryland farming systems for its production, cost-saving and environmental benefits. Farmers in other developed countries such as Canada are already adopting such systems by overcoming some of the logistical issues associated with intercropping (Smith, 2014; Fletcher and Kirkegaard 2020), with increasing interest and a network of early adopters emerging in Australia.

Managing the complexity of intercropping, and understanding the longer-term rotation benefits, and the species combinations best adapted to such systems are areas of ongoing interest. Further research is required to support early farmer adoption and to provide greater farmer confidence in these systems (Fletcher et al. 2016). This paper summarises the results of historical intercropping experiments in Australia and more recent intercropping research undertaken in South Australia and Victoria and discusses pathways forward to increase grower confidence and adoption of intercropping systems.

Methods

LER Calculation for Productivity

To determine the relative productivity benefit of intercropping, compared to growing crops as monocultures, land equivalent ratio (LER) values were calculated. The LER is expressed as:

$$LER = LA + LB = YA/SA + YB/SB$$

Where LA and LB are the LER for the individual crop yield components, YA and YB are the individual crop yields in the intercrop combinations, and SA and SB are the yields of the monocultures (adapted from Mead and Willey, 1980). An LER value of <1.0 means the productivity of the intercrop components are less than the monocultures, while an LER value >1.0 means the intercrop components are more productive than the monocultures (Khanal et al. 2021).

Historical Summary
The historical results were grouped into cereal-legume intercrops and pea-canola intercrops (peaola) and analysed separately. All the trial data were from replicated field experiments. However, many of the industry reports did not include a measure of the variation or the raw data. We were therefore unable to complete a formal-meta analysis. Instead we treated the means of each treatment as a separate sample and calculated simple summary statistics. For each group we report the median LER and the proportion of treatments with an LER exceeding 1. The latter was statistically compared using a simple chi-square contingency table. This dataset and the analysis have been reported previously (Fletcher et al. 2016, 2021). They are shown here for completeness and comparison with the more recent field results.

Recent field research (2016-2020)
This paper summarises productivity gains from nine field experiments from seasons 2016 to 2020 in South Australia. Thirty-two treatments were included from nine combinations: chickpea-canola, faba bean-canola, field pea-canola, lentil-canola, vetch-canola, chickpea-linseed, chickpea-faba bean, lentil-faba bean, vetch-faba bean. Chickpea-oilseed intercropping experiments that aimed to lower cost of production were sown in 2019 and 2020 in a split plot design, with crop species randomly assigned to the whole plot and management strategy randomly assigned to the sub-plot. Crop combinations included intercropped chickpea-canola and chickpea-linseed and sole plots of chickpea, linseed and canola. Sub-plot treatments included nil, foliar fungicide and fungicide plus desiccation. Productivity gains (LER) and grain yield were analysed using ANOVA in Genstat 20th edition.

Results and Discussion

Productivity gains from intercropping
In total there were 73 cereal-legume intercropping treatments in the historical data set of 12 experiments. These experiments were carried out around Australia between 1977 and 2014. The median LER of these experimental treatments was 1.14 and 68% of these treatments had LER that exceeded 1 (p= 0.0016) (Figure 1a). In total there were 81 individual peaola treatments taken from 12 experiments. These experiments were carried out around Australia between 1992 and 2009. The median LER for these peaola treatments was 1.31 and 91% had a LER that exceeded 1 (p=9.7e-14) (Figure 1b). These results indicate the productivity benefits that are possible using intercrops.

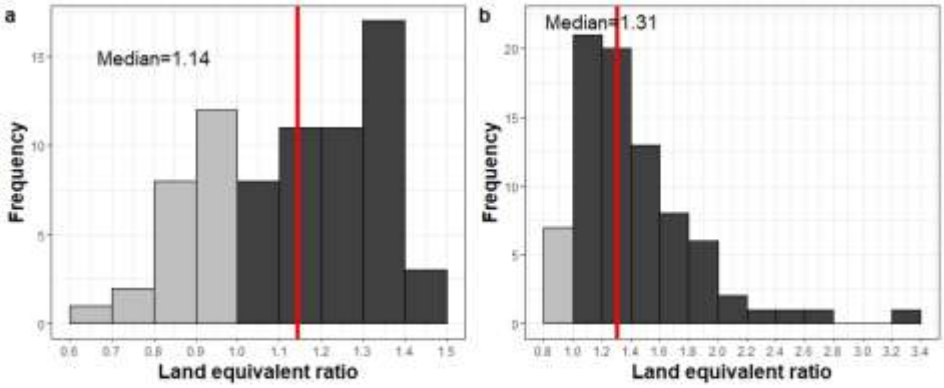

Figure 1. Histogram of LER for historical a) cereal-legume intercrops and b) peaola intercrops. Light grey bars are treatments with LER less than 1 and dark grey have LER greater than 1. The vertical red lines represent the median LER.

Productivity gains, LER>1, were achieved in 14 of 32 combinations in a range of environments and with combinations including pulse-pulse and pulse-oilseed. Combinations with the highest proportions of overyielding were chickpea-canola, lentil-canola and vetch-canola, whilst chickpea-linseed and vetch-faba bean did not over-yield in these studies. Further, recent experiments in Victoria that included combinations of pulse and oilseed showed LER > 1 (Mitchell et al. 2021). LER are one measure of intercropping advantage and may not be the best measure in unbalanced combinations. Gross margins are increasingly being used to measure and compare the profitability of intercrops with monocultures. However, gross margins are also limited as they do not factor in other farming systems advantages and challenges, such as any future benefit from growing break crops.

Table 1. Productivity gains measured using LER representing a range of environments and crop combinations for nine experiments in South Australia (Booleroo, Hart, Roseworthy, Tooligie, Waikerie, Wudinna), 2016 - 2020. Mean LER with standard error presented in parentheses.

Treatment	BOO20	HAR19	HAR20	TOO20	WAI16	WAI17	WAR19	WAR20	WUD19
CP+CA	0.89 (0.20)		1.29* (0.10)	1.37* (0.10)			1.11 (0.23)	1.84* (0.23)	1.08 (0.23)
CP+FB				1.24* (0.10)					
CP+LI		0.97 (0.11)	0.98 (0.10)						
FP+CA	1.31* (0.20)				1.21* (0.13)	1.05 (0.20)	1.11 (0.23)	1.12 (0.20)	1.02 (0.23)
LE+CA	1.13 (0.23)			1.33* (0.12)		1.77* (0.20)	1.01 (0.23)	2.20* (0.20)	1.34* (0.23)
LE+FB	1.03 (0.20)			1.24* (0.10)				0.90 (0.20)	
VE+CA	1.06 (0.20)				1.34* (0.13)	1.38* (0.20)	0.92 (0.23)	1.46* (0.20)	1.19 (0.23)
VE+FB	0.81 (0.20)							1.09 (0.20)	

Key: All means denoted with * have a lower bound of the 95% confidence interval greater than 1.
CP = chickpea, CA = canola, FB = faba bean, LI = linseed, FP = field pea, LE = lentil, VE = vetch.

Quantifying systems benefits

An important factor that is often not considered in evaluating intercrops is the potential to reduce costs and manage climate and market risk. A series of five field experiments tested the potential to reduce the cost and risk of chickpea production, including reduced fungicide applications to control ascochyta blight, removing the need for a dessicant spray, and reduced nitrogen fertiliser input. There were no differences in the yield or quality of the chickpea seed intercropped with linseed or canola given a full fungicide and dessication regime compared with those untreated (Table 2). Whilst this is likely to be seasonally dependent, it is possible that intercropping may reduce the need for multiple fungicides and dessication, reducing input costs and increasing profit margins. It is important to note that the 2019 and 2020 seasons were not conducive to severe disease, and more experiments are required to confirm these results under different environmental conditions. Additionally, there was no differences in the grain yield of linseed-chickpea intercrop under a nil fertiliser regime compared to a high N high P (50 kg N and 20 kg P per hectare) fertiliser regime, suggesting intercropping could facilitate reduced fertiliser inputs, but again this requires further work (Roberts and Dowling, 2020).

Table 2. Chickpea intercropping yield following fungicide and/or dessicant treatments, Hart, South Australia, 2019 - 2020. Yield was not affected by treatments of fungicide or dessication. Different letters in the same column indicate a significant difference between mean yields across sub-plot treatments.

Year	**2019**			**Mean yield (t/ha)**	**2020**			**Mean yield (t/ha)**
	Sub-Plot Treatment				**Sub-Plot Treatment**			
Whole Plot	**Nil**	**FF**	**FF+DES**		**Nil**	**FF**	**FF+DES**	
Sole CP	0.45	0.50	0.54	0.50 *a*	1.26	1.46	2.02	1.58 *a*
Sole LI	0.31	0.27	0.38	0.32 *bc*	1.03	0.93	0.79	0.91 *b*
Sole CA					0.72	0.63	0.78	0.71 *bc*
CP+LI double skip	0.21	0.24	0.19	0.22 *cd*	0.65	0.51	0.62	0.59 *c*
CP+LI mixed row	0.19	0.18	0.18	0.18 *d*	0.40	0.19	0.48	0.36 *d*
CP+CA double skip	0.32	0.31	0.37	0.33 *bc*	0.69	0.67	0.47	0.61 *c*
CP+CA mixed row	0.27	0.37	0.34	0.33 *bc*	0.28	0.66	0.57	0.50 *cd*
	LSD whole plot **(P<0.001) = 0.117**				**LSD** whole plot **(P=0.002) = 0.23**			

Key: LSD = least significant difference, n.s. = not significant at the 95% confidence interval. FF = foliar fungicide, DES = dessication, CP = chickpea, LI = linseed, CA = canola.

Whilst research has demonstrated the benefits of intercropping at plot-scale it is important to acknowledge the barriers to adoption on a broadacre scale (Fletcher et al 2016). These barriers include the complexity of agronomic management and the technical challenges presented by mixed species cropping, including weed management. Pairing species from different crop types (e.g. pulses and oilseeds) makes in-season weed control difficult. However, the recent developments in herbicide tolerance technology allow pairings of different species with the same herbicide tolerance trait, broadening in-crop weed management options. The additional complexity of intercropping systems includes logistical challenges at sowing, harvesting, handling and storage of grain. Some types of intercropping lend themselves to a more seamless integration into current farming practices than others. For example, in terms of ease-of-sowing, mixed row intercropping can still be achieved in one pass by putting both seed types into the same box, or by utilising both the seed and fertiliser distribution systems. To support an increase in adoption of intercropping systems there is a need to support growers through a combination of peer-to-peer learning, participatory research, and further focused research at the farming system level.

Conclusion

Intercropping research in Australia has confirmed potential productivity benefits in a range of environments and farming systems at the plot-scale. Additionally, initial results have shown likely additional benefits of intercropping systems by reduced cost of production, with further work required to quantify this.

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