Intercropping improves productivity in low to medium rainfall environments

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Abstract
There is a need for a more robust break crop system in the low to medium rainfall zones where traditional break crop systems are not yield stable and leave paddocks at risk of erosion. Intercropping is shown to be a system that can provide production and sustainability benefits in low to medium rainfall cropping systems. Seven field trials in four years were conducted across a range of environments in South Australia, focused on investigating break crop species mixes suited to low and medium rainfall zones. Productivity gains (measured using the common land equivalent ratio metric) of up to 48% were achieved, 40-50% of the time where chickpea, lentil and vetch was intercropped with canola compared to growing the crops as monocultures. Gross margin returns were generally similar or more favourable than the sole crops for field pea, chickpea, and lentil intercropped with canola. Early season ground cover was improved in some intercrop combinations over traditional monoculture systems. This work demonstrates that intercropping has the potential to increase both productivity and gross margin return in low to medium rainfall environments of South Australia.

Keywords
Oilseed-pulse intercrop, low rainfall zone, medium rainfall zone, groundcover.

Introduction
Farming systems in the low to medium rainfall (<350 mm to 400 mm annual rainfall) zones of southern Australia were traditionally focused around a mixed livestock-cropping system. However, there has been a shift to more intensive cropping systems in these regions. While the traditional livestock-cropping systems included a pasture break phase, these intensive cropping systems are dominated by cereals, up to 75-95% of the crop rotation (McBeath et al. 2015). The risk of maintaining high intensity cereal dominant cropping systems is well understood, including greater risk of increased grass weeds, soil borne diseases, and nitrogen depletion. Improving yields through agronomy can be achieved through the following levers in dryland farming systems: variety selection, sowing date, density, and in-crop management. Intercropping, the practice of growing two grain crops on the same piece of land at the same time, is a production system adopted by a small number of producers in dryland farming systems for its productivity and environmental benefits. A recent review identified the potential for intercropping to provide production benefits in dryland cropping systems (Fletcher et al. 2016). However, managing the complexity of the system, the longer-term rotation benefits, and the species best adapted to such systems are not well understood, particularly in the dry environments of Australia. The focus of the study reported in this paper is on intercrops comprising broadleaf break crop intercrops, as these systems have demonstrated the highest level of potential adoptability in the focus region.

Methods
Sites and management
Seven trials were undertaken over four years at four locations in South Australia. The trial sites were located near Booleroo and Tooligie in 2020 (S32°52'51.28" E138°21'1.89" and S33°47'49.21" E135°50'43.62"), Warnertown in 2019 & 2020 (S33°17'36.52" E138° 7'35.26"), Wudinna in 2019 (S33° 2'15.73" E135°28'7.22") and Waikerie in 2016 & 2017 (S34° 19' 29.46" E140° 04' 58.46"). Rainfall varied across year and site, with below average, average and above average conditions experienced across the range of trials. The experimental design was either a randomised block or a split plot design with either 3 or 4 replications depending on site and year. All treatments were sown with the same fertiliser rate, the same pest management was applied to all treatments, and where required, monoculture treatments were given top up fertiliser in the growing season. Treatments included both intercrops and the monoculture components. The seeding rate was maintained for the target intercrop species, the pulse, and was equivalent to the monoculture, while the canola seeding rate was reduced to 1 kg/ha in the intercrop treatments compared to the monoculture seeding rate of 2.5 kg/ha.

Intercropping Productivity

The most common method of calculating the land equivalent ratio (LER) is the sum of the relative yields of each species compared to their monoculture yields. To determine the relative 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).

Gross Margin was calculated using the Farm Gross Margin Guide Calculator (Rural Solutions, 2020). The average cash prices used were, \$550/t canola, \$700/t chickpea, \$400/t field pea, \$570/t lentil and \$600/t vetch. The intercrop components were calculated separately and added together to provide the intercrop gross margin figure. A cost per tonne (\$30/t) for seed cleaning was included in the intercropping gross margins for seed separation.

Analysis of variance (ANOVA) was used to determine treatment differences for data presented. This analysis was done using GenStat Version 20.1 (Release 2021 VSN International Ltd Hetfordshire UK). Levels of probability greater than 0.05 (P>0.05) were considered non-significant, and least significant differences (l.s.d.) were calculated to compare treatment means when ANOVA P-values were less than 0.05. Confidence limits (CL) were used to determine over-yielding effects for LER values. We concluded that over-yielding occurred when the 95% lower CL was >1.

Results and Discussion

Productivity gains from intercropping

The combined results include 31 intercrops from the seven trials with the same combinations represented at multiple locations and/or years. Nine intercrops over-yielded, where the 95% lower confidence limit was greater than 1 (Figure 1). Of the combinations chickpea-canola, field pea-canola, lentil-canola and vetch-canola, all had one or more incidence of over-yielding. The combinations chickpea-canola, lentil-canola and vetch-canola are the most promising, over-yielding 40-50% of the time, whilst field pea-canola over-yielded on only one occasion out of the seven representations in field trials. LER gives an indication of productivity, however, it assumes equal value of the two crops. In these unbalanced combinations gross margin provides an important measure of financial benefits/loss of intercropping.

Gross margins of intercrop systems

Gross margin comparison of the sole crops and intercrops provides a financial measure of productivity of the mixed crop system. The gross margin for intercrops includes the additional seed cleaning cost associated with intercropping compared to the sole crop. Five of the six trials growing canola as a sole crop were not profitable (Figure 2). The gross margins for sole field pea and intercrop field pea-canola were similar when the return was profitable, whilst the loss was reduced in the intercrop compared to the sole crop when the gross margin was negative and this response was similar for chickpea. At five of the six locations intercropping lentil and canola was more profitable than growing lentil as a sole crop. The opposite response was true for vetch, where the returns were better when sown as a sole crop.

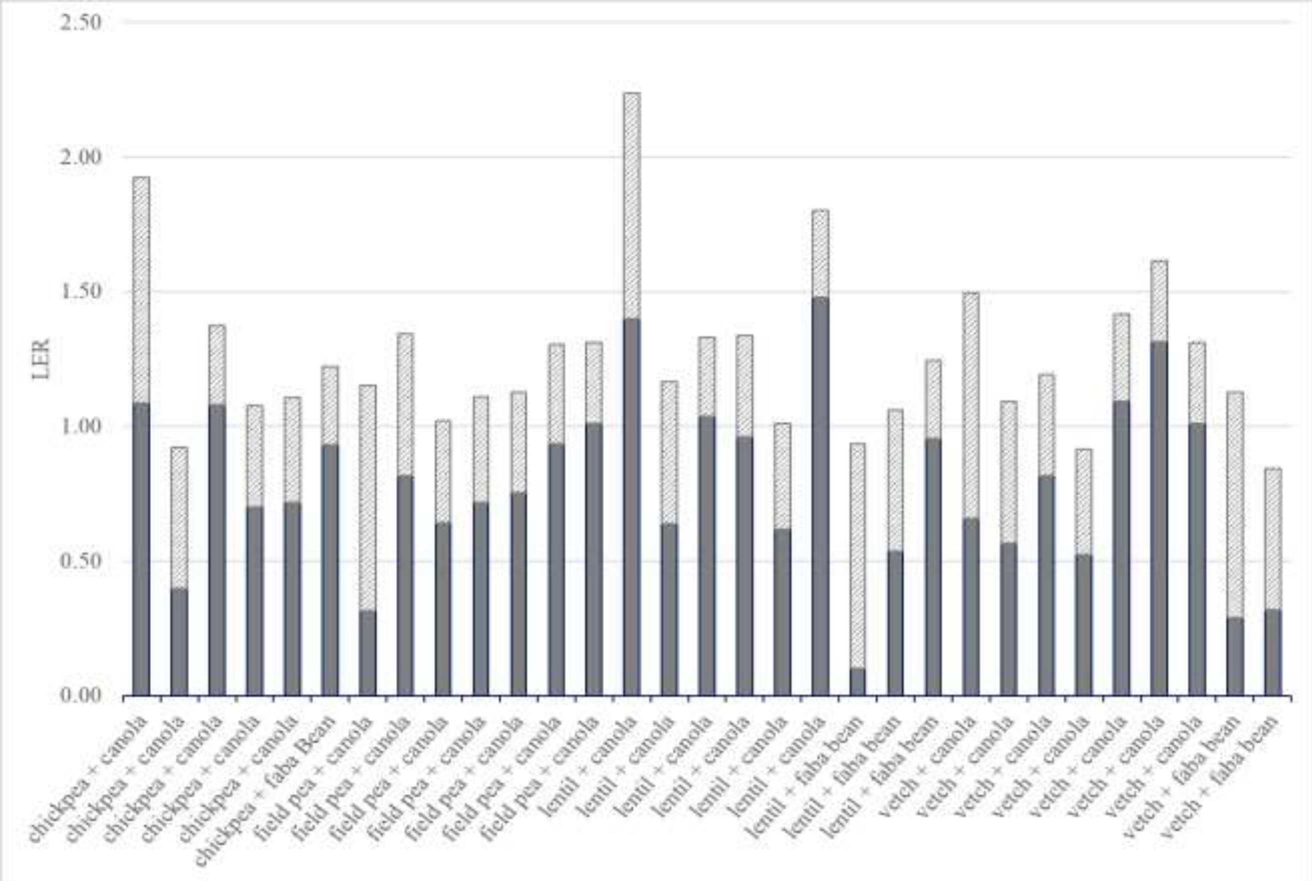

Figure 1. Intercrop productivity using LER (whole bar) representing a range of environments and crop combinations from eight trials in South Australia, 95% lower CL indicated by dark shading, 2016 - 2020.

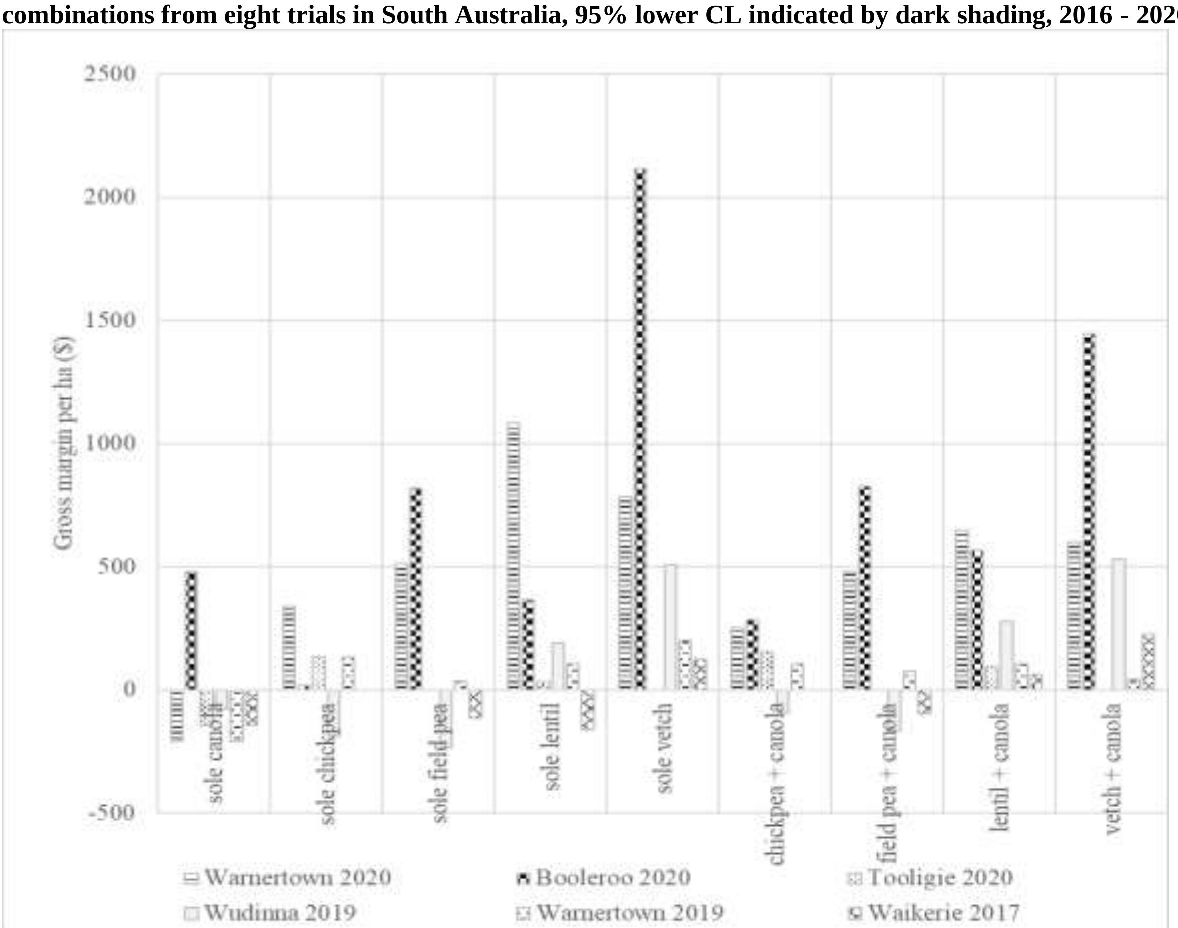

Figure 2. Gross margin returns from sole and intercropped combinations of chickpea, field pea, lentil, and vetch from six trials, South Australia. Gross Margin was calculated using the Farm Gross Margin Guide Calculator (Rural Solutions, 2020).

Conclusion

This work demonstrated the potential of pulse intercrops in the low to medium rainfall environments of South Australia. Intercropping can be more productive than growing the components as monoculture crops, with pulse-oilseed combinations chickpea-canola, lentil-canola and vetch-canola demonstrating productivity potential. However, the mechanisms for the over-yielding are not well understood and developing this understanding will allow for improvements in species and variety selection to reduce inter-species competition and enhance over-yielding outcomes.

Intercropping systems are more complex and present increased challenges for adoption compared to traditional monoculture systems, including challenges during sowing, harvest, grain handling, grain storage and cleaning. To overcome these barriers to adoption intercropping needs to present a favourable economic and risk advantage. The gross margin analysis demonstrates that an economic return similar to, or more favourable than the monoculture crop is possible. In addition to production and economics, there is growing interest in the quantification of the secondary benefits of intercropping the systems, with more work required to quantify this.

This work has demonstrated productivity and gross margin benefits from pulse-canola intercrops in the low to medium environments of South Australia. To support and accelerate the current level of broadacre adoption of these systems a combination of peer-to-peer learning and further focused research including a better understanding of the systems benefits of intercropping is essential.

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References

Fletcher AL, Kirkegaard JA, Peoples MB, Robertson MJ, Whish J, Swan AD (2016). Prospects to utilise intercrops and crop variety mixtures in mechanised, rain-fed, temperate cropping systems. Crop and Pasture Science 67(12), 1252–1267.

Fletcher AL, Kirkegaard JA, Swan T (2021). Is there a role for intercropping in Australian dryland cropping systems to increase yield and reduce risk – a review. Proceedings of the Intercropping for sustainability virtual conference.

Khanal U, Stott KJ, Armstrong R, Nuttall JG, Henry F, Christy BP, Mitchell M, Riffkin PA, Wallace AJ, McCaskill M, Thayalakumaran T, O'Leary GJ (2021). Intercropping—Evaluating the Advantages to Broadacre Systems. Agriculture (11): 453.

Mead R, Willey RW (1980). The concept of a land equivalent ratio and advantages in yields from intercropping. Experimental Agriculture 16(3), 217–228.

McBeath TM, Gupta VVSR, Llewellyn RS, Davoren CW and Whitbread AM (2015) Break-crop effects on wheat production across soils and seasons in a semi-arid environment. Crop and Pasture Science 66, 566-579.

Rural Solutions (2020). https://www.pir.sa.gov.au/__data/assets/pdf_file/0011/357608/Gross_Margin_and_Enterprise_Planning_Guide_2020.pdf