# Intercropping to exploit winter and summer rainfall for profit in Victoria

**O'Leary GJ**[1,2], Wallace AJ[1], Nuttall JG[1,2], Armstrong RD[1,2], Jha V[1], Thayalakumaran T[3], Christy BP[4], Mitchell ML[4], Riffkin PA[5], Henry FJ[5], McCaskill MR[5], Khanal U[1] and Stott KJ[3]

[1] Agriculture Victoria, 110 Natimuk Road, Horsham, VIC 3400, Email: garry.oleary@agriculture.vic.gov.au, gjoleary@yahoo.com [2] Centre for Agricultural Innovation, The University of Melbourne, Parkville, VIC 3010
[3] Agriculture Victoria, Centre for AgriBioscience, Bundoora, VIC 3083
[4] Agriculture Victoria, 124 Chiltern Valley Road, Rutherglen, VIC 3685
[5] Agriculture Victoria, 915 Mt Napier Road, Hamilton, VIC 3300

**Abstract**
Intercropping is the farming practice of growing crops of different species together, where part or all their crop cycles overlap. Potential advantages include higher combined yields, increased profit in the short term and more sustained productivity over the long term. Disadvantages include management difficulties (in large mechanised farms) with weed control, harvesting and sowing methods leading to higher potential risks. During 2019 and 2020 field experiments were established at Hamilton, Horsham and Rutherglen, representing different agroecological zones within Victoria. In 2019 at Hamilton, in a high rainfall zone, significant differences ($P = 0.034$) in net gross margin between treatments was observed but were less profitable than the monoculture reference crops. Similarly, the yield ratio at Horsham (medium rainfall zone) was high ($P = 0.060$) as well as at Rutherglen ($P = 0.078$) but did not result in significantly higher value or profit than the respective monocultures. Experimental and modelling results show positive indications that intercropping has potential for gains in productivity (> 20 %) but were mostly unprofitable options in 2019, which experienced dry spring conditions, showing that testing across a range of seasons is needed. Simulation modelling is currently being used to assess the longer-term benefits and risks including the magnitude and duration of any such effects. A series of presentations show details of results, achieved to date in a new initiative in the grains southern region.

**Keywords**
Companion cropping, crop competition, economics, diversification, modelling, risk.

**Introduction**
Intercropping is the agronomic practice of growing different crop species or cultivars together (Vandermeer 1992). There is large diversity of how this can be achieved, ranging from random mixtures, to structured row crops separated in space and also in time as a relay where crops are sown or harvested at different times from the same field (Howard 2016). The objective is to enhance sustained productivity and profitability through better resource management and reducing pests and diseases.

Intercropping is common in small holder farms in developing countries and has been well researched over many decades globally (e.g. Ngwira et al. 2012). It is, however, much less common in large scale mechanized agriculture, where targeted breeding for monoculture, modern herbicides and technology raises the question - can it be economically viable in large enterprise production systems? Productivity advantages as large as 50% more than monoculture have been observed in Australia (Fletcher et al. 2016). There is increasing interest in Australia, Europe and north and south America to determine if sustained benefits can be demonstrated (Soetedjo and Martin 2003, Howard 2016, Dowling et al. 2020, Tilman 2020).

Benefits reported are higher productivity, but growing crops together, particularly very different crop species raises the risk of lower yields because of competition for resources and greater complexity of management, especially in environments where water is often limiting. For such systems to be successful and enduring, the mechanistic basis for productivity gains or lower costs or risks must be established. This can be achieved through measuring the response of intercropping systems at a plot scale for a range of potential growing environments, and also demonstrated at the farm-scale. A clear understanding of the causal mechanisms is also essential for validating crop biophysical models and the subsequent extrapolation of intercropping systems to other environments.

A project commenced in Victoria in 2019 to evaluate winter intercropping systems. We focused initially on field and modelling experiments in contrasting environments across Victoria, considering the economics of production and risk assessments. Ultimately, our aim is to develop system design criteria that will assist growers in selecting profitable crop combinations considering production economics, soil, location and climate and their variability across southern Australia.

**Experimental methods**

Our investigation covers two lines of enquiry: (1) winter companion cropping and (2) double cropping with a summer crop rotated between two winter crops. Field and modelling experiments were established at selected sites in consultation with a grower reference panel to maintain local relevance and interest of growers. The modelling aims to extrapolate the observed field results beyond the field sites in space and time providing realistic site and seasonal variability in our quest to develop design criteria for such systems. Both the field and modelling data are being analysed from an economic perspective where profitability is of primary concern.

*Field experiments*

Three field experimental sites were established in 2019 at Horsham (420 mm long term annual rainfall), Hamilton (690 mm) and Rutherglen (583 mm). These were expanded in 2020 in consultation with our grower reference panel and six additional satellite sites were established across Victoria (Netherby, Curyo, Burramine South, Caniambo, Inverleigh and Willaura, Figure 1). These sites were designed to measure responses of a range of species mixtures on different soil types and under different climatic conditions to demonstrate the potential of the system to local growers.

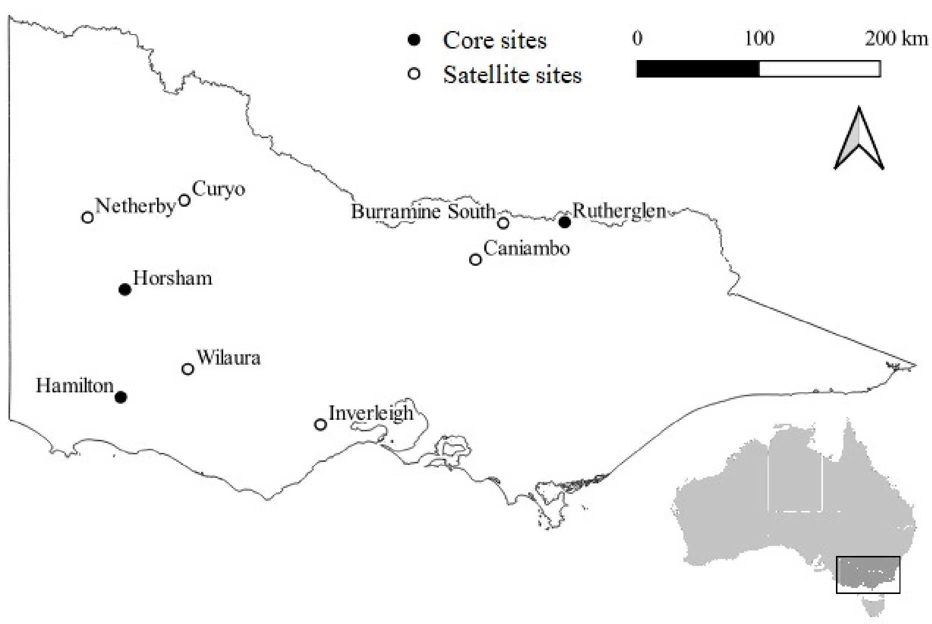


**Figure 1. Three core experimental sites established at Hamilton, Horsham and Rutherglen in 2019 and six satellite demonstration experimental sites established in 2020 (Inverleigh, Willaura, Netherby, Curyo, Burramine South and Caniambo).**

*Modelling experiments*

Biophysical modelling allows the mechanistic extrapolation of empirical response of crops to various treatment scenarios beyond the field experimental locations and seasons. We know that crops grown in mixtures sometimes undergo morphological changes compared to their respective monocultures, therefore, a review considering how various biophysical models were designed to account for crop mixtures was undertaken (Githui et al. 2021). The Australian Agricultural Production Systems sIMulator (APSIM) model handles intercrops primarily through resource sharing (light, water and N nutrition). The extent to which APSIM can adequately simulate observed intercropping responses remains to be demonstrated but we found some encouraging results from initial testing against five crops in 2019. Our double cropping systems tested in APSIM also showed versatile systems suitable for southern Australia (McCaskill et al. 2021).

*Economics*

A review of the metrics used to evaluate intercropping was also undertaken (Khanal et al. 2021). The most common metric used to evaluate intercropping is the land equivalent ratio (LER), but this appears inadequate for modern large-scale agriculture because it does not account for value of individual species, enterprise mix ratio and costs of production that drive profit. We therefore widened the evaluation to include factors such as value of crop species, enterprise mix, specific costs and risks of production and personal risk attitude (Khanal et al. 2021). Combining field results with modelling and economics is challenging but necessary to rigorously determine what potential benefits can be realised in a broadacre agriculture context.

**Table 1. Land equivalent ratio (LER), Yield ratio (YR), Value ratio (VR) and net gross margin (GM) measured in 2019 at Hamilton (HAM), Horsham (HOR) and Rutherglen (RUT) for crop mixtures (Mix) barley (B)-canola (C), fababean (F)-canola (C), fababean (F)-wheat (W) and field pea (P)-canola(C) at 25:75% and 75:25% mix ratio compared to their equivalent monoculture densities and their respective residual standard errors (se).**

| Mix | LER (ha/ha) | | | YR (kg/ha)/(kg/ha) | | | VR ($/ha)/($/ha) | | | Net GM ($/ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HAM | HOR | RUT | HAM | HOR | RUT | HAM | HOR | RUT | HAM | HOR | RUT |
| 25B75C | 0.85 | 1.01 | 1.10 | 0.88 | 1.84 | 1.44 | 0.84 | 1.39 | 1.35 | -464 | 140 | 97 |
| 75B25C | 0.94 | 0.98 | 1.04 | 0.93 | 1.17 | 1.04 | 0.94 | 1.09 | 1.03 | -288 | -22 | -90 |
| 25F75C | 1.08 | | 0.93 | 0.98 | | 0.82 | 0.99 | | 0.82 | -160 | | -110 |
| 75F25C | 0.93 | | 1.14 | 0.78 | | 0.79 | 0.79 | | 0.80 | -851 | | -184 |
| 25P75C | 0.93 | | 1.16 | 0.88 | | 1.16 | 0.89 | | 1.17 | -375 | | 47 |
| 75P25C | 0.85 | | 1.01 | 0.79 | | 1.00 | 0.81 | | 1.02 | -712 | | -21 |
| 25F75W | 1.01 | | 1.124 | 1.02 | | 1.27 | 0.91 | | 1.18 | -456 | | -5 |
| 75F25W | 0.92 | | 0.89 | 0.93 | | 1.40 | 0.79 | | 1.09 | -923 | | -33 |
| se | 0.13 | 0.14 | 0.28 | 0.12 | 0.32 | 0.33 | 0.11 | 0.26 | 0.31 | 329 | 140 | 206 |

## Results

In the first year, 2019, there were small, but statistically insignificant intercropping benefits of the mixtures at Rutherglen (field pea and canola and barley and canola) and Horsham (barley and canola) (Table 1). Mixture treatment metrics were analysed by ANOVA using a restricted randomised complete block design, excluding non-mixture metrics because monoculture response is already included in the mixture metrics. There were some significant losses too. At Hamilton, significant differences ($P = 0.034$) in net gross margin between treatments was observed but these were not different to the respective monoculture reference crops. Similarly, the yield ratio at Horsham was high ($P = 0.060$) as well as at Rutherglen ($P = 0.078$), but, it did not result in significantly higher value or profit than the respective monocultures. For the mixture to be economically advantageous over monocultures grown in the same proportion, the net GM needs to be greater than zero. However, the magnitude and probability of such gains or losses needs to be resolved to give growers confidence for enduring adoption. In 2020 at Rutherglen there were highly significant intercropping benefits seen in almost all mixtures tested (Mitchell et al. 2021). Other investigations include disease epidemiology (Henry et al. 2021), water use (Wallace et al. 2021) and competition (Suraweera et al. 2021).

**Conclusions**

Intercropping winter species in mixtures potentially offers great productivity gains. Differences between years is expected because of resource supply and is the subject of ongoing investigations. Initial results of the two years of experiments indicate that the inclusion of a grain legume with oilseeds appears to be beneficial at some mix ratios and locations in Victoria.

**Acknowledgements**

This project was supported by Agriculture Victoria and the Grains Research and Development Corporation through the Victorian Grains Innovation Partnership - Bridging the profitability gap: Increasing grower profitability by reducing the impact of biotic and abiotic constraints on crop water-use efficiency to bridge the yield gap, manage costs and enterprise risk. We also thank the growers and industry members of our reference panel who provided insight in the selection and management of the crop species used across our region for experimentation. Technical assistance was provided by Matthew May, Terry McClean, Ashley Purdue, Peter Harris, Tim Whitehead, Jamie Smith, Tony Dickson, Darren Keane, Greg Mason, Irma Grimmer, Dilnee Suraweera, Janaka Puran Kumburage, Russell Argall and Mel Munn.

**References**

Choudhary V K, Dixit A and Chauhan BS (2016). Resource-use maximisation through legume intercropping with maize in the eastern Himalayan region of India. Crop and Pasture Science 67(5), 508-519.

Dowling A, Sadras VO, Roberts P, Doolette A, Zhou Y, Denton MD (2021). Legume-oilseed intercropping in mechanised broadacre agriculture – a review. Field Crops Research Available from URL https://doi.org/10.1016/j.fcr.2020.107980 [accessed 15 November 2020].

Githui F, et al. (2021). Modelling intercropping highlights importance of resource competition and possibly direct plasticity effects, these proceedings.

Henry F, et al. (2021). Old solutions to New problems: Intercropping reduces chocolate spot severity in faba bean, these proceedings.

Fletcher AL, et al. (2016). Prospects to utilise intercrops and crop variety mixtures in mechanised, rain-fed, temperate cropping systems. Crop and Pasture Science 67(12), 1252–1267.

Howard A (2016) The potential for companion cropping and intercropping on UK arable farms. A Nuffield Farming Scholarships Trust Report Award sponsored by AHDB Cereals and Oilseeds. p88.

Khanal U, et al. (2021). Metrics for evaluating intercropping in broadacre farming systems, these proceedings.

McCaskill M, et al. (2021). Opportunities for summer crops in non-irrigated winter cropping systems in southern Australia., these proceedings.

Mitchell M, et al. (2021). Winter intercropping shows advantages in northeast Victoria, these proceedings.

Ngwira AR, Aune JB and Mkwinda S (2012). On-farm evaluation of yield and economic benefit of short-term maize legume intercropping systems under conservation agriculture in Malawi. Field crops research 132, 149-157.

Soetedjo I N P and Martin LD (2003). Intercropping with canola improves the productivity and sustainability of field pea. Proceedings of 11th Australian Agronomy Conference, 2003. http://www.regional.org.au/au/asa/2003/c/4/martin.htm

Suraweera et al. (2021). Vegetative competition between crops grown in intercropping systems, these proceedings.

Tilman D (2020). Benefits of intensive agricultural intercropping. Nature Plants, 1-2.

Vandermeer JH (1992). The ecology of intercropping. Cambridge University Press.

Wallace A, et al. (2021). Water use of cereal, oilseed and grain legume crops within intercropping systems of southern Australia, these proceedings.