



Intercropping to utilise rainfall for profit

Dr Meredith Mitchell, Brendan Christy, Kerry Stott, Dr Uttam Khanal and Dr Garry O'Leary
Agriculture Victoria

Key points

- Four dual-species mixes (field pea/canola, faba bean/canola, faba bean/wheat and barley/canola) were sown at different ratios at Rutherglen, Burramine and Caniambo during 2020.
- At all three sites, seasonal conditions during 2020 were exceptional, with excellent growing season rainfall (GSR) resulting in high yields across the trials.
- At the Rutherglen site, all the dual-species combinations resulted in positive yield benefits compared with the monoculture crops.
- At the Burramine and Caniambo sites, 75% of the dual-species combinations resulted in positive yield benefits compared with the monoculture crops.
- To achieve a superior economic return, when compared to a monoculture of either species, the intercrop land equivalent ration (LER) needed to be greater than 1.1.

Introduction

Intercropping involves sowing and growing two (or more) crop species together in the same paddock. This approach can increase the use of total available solar radiation and water per unit of land, offers an opportunity to diversify grain production and increase total grain yields and profit.

Traditionally, intercropping has been widely practiced on small-sized holdings and cropping systems in developing countries, however there is evidence of farmers adopting the practice in developed countries like Canada, particularly with field pea/canola mixtures. In Australia, intercropping is not widely practiced, possibly due to the additional labour requirements and the additional management complexity.

Aim

To determine if two crop species sown together (intercropping) could provide an opportunity to increase total grain yield compared to monocultures, diversify grain production and increase yield and profit in the Riverine Plains region.

Method

Four dual-species mixtures (field pea/canola, faba bean/wheat, faba bean/canola and barley/canola) were sown during 2020 at three experimental sites (Rutherglen, Caniambo and Burramine, Victoria) to compare the performance of cereals, legumes and oilseeds when grown as intercrops and monocultures (Figure 1).

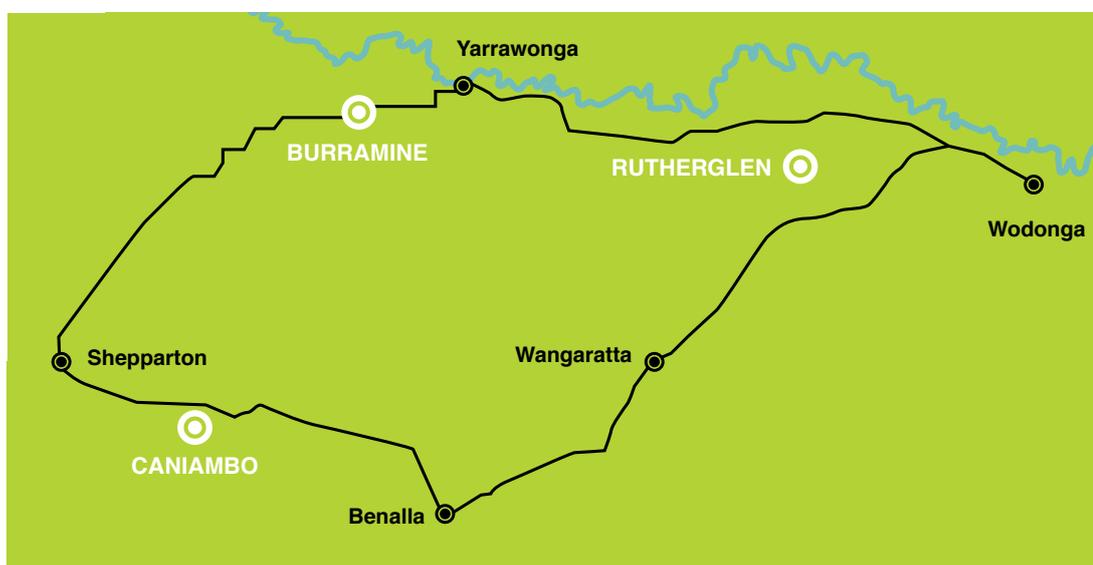
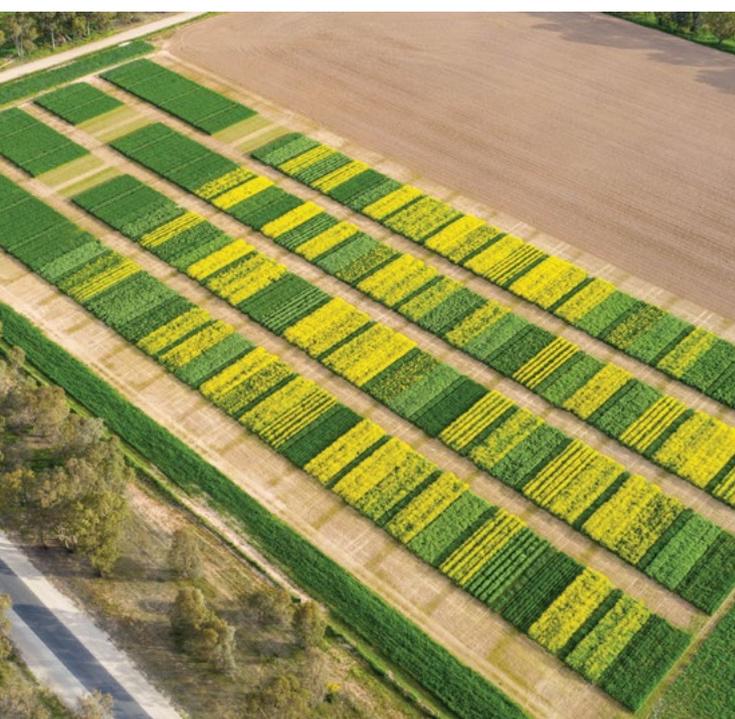


FIGURE 1 Location of the three experimental sites, Rutherglen, Burramine and Caniambo

Farmers inspiring farmers



Faba bean/canola 50:50 skip row plots (alternating two rows of each crop) at Rutherglen, 2020.



Experimental layout at Rutherglen, 2020, showing the blocked design of the intercropping experiment.

At the Rutherglen site, the dual-species mixtures were sown at different species ratio targets of 25:75 per cent, 75:25 per cent, 50:50 per cent, skip row (alternating two rows of each crop) and each species was also grown as a monoculture. The 50:50 per cent and the skip-row treatments were not sown at the Burramine and Caniambo sites.

Experimental sites were sown on 7 May, 13 May and 29 May, 2020, at Rutherglen, Caniambo and Burramine respectively. Cultivar selection was based on crops with a similar phenology and, except for field pea, herbicide tolerance, including: imidazolinone tolerance (CL) or triazine and imidazolinone tolerance (CT). Cultivars were obtained commercially, with seed treated to protect against pests and disease (Table 1).

At Rutherglen, seed was sown on 25cm row spacings and plot size was 4.5 x 20m, giving a total plot area of 90m². At Caniambo and Burramine, seed was sown at 23cm row spacings and plot size was 1.4 x 10m, giving a total plot area of 14m². There were four replicates of each treatment at each site.

During early August (3 and 5 August), 100kg/ha urea was applied to half the area of each plot to allow a comparison of 'with' and 'without' nitrogen (N) to be made for each treatment.

At the Rutherglen site, the field pea/canola plots were sprayed with 40g/ha Raptor[®] herbicide on 8 July, 2020, with the faba bean/canola, faba bean/wheat and barley/canola plots sprayed with 600mL/ha Intercept (Intervix) on 30 June, 2020. The main weeds being targeted at the site were wireweed, shepherd's purse and annual ryegrass. Ryegrass in the barley/canola treatments was effectively suppressed by crop competition, so was not problematic.

TABLE 1 Crops, cultivars and herbicide treatments for the intercropping experiments at Rutherglen, Burramine and Caniambo, 2020

Sowing fertiliser	100kg/ha of MAP	
Pre-sowing herbicides:	Terbyne [®] (0.85kg/ha), trifluralin (1.5L/ha), Hammer [®] (30mL/ha), and glyphosate (1.5L/ha)	
In-crop insecticides:	Pyrinex	
Crop	Cultivar	Herbicide tolerance
Barley	Spartacus CL	Imidazolinone
Canola	Hyola [®] 580 CT	Triazine and imidazolinone
Faba bean	PBA Bendoc	Imidazolinone
Field pea	PBA Butler	Nil
Wheat	Sheriff CL	Imidazolinone



Plant establishment was recorded as plants per square metre, from random areas within the plots seven weeks after sowing, with establishment rates close to the target populations. Both species in each dual-species mixture were harvested together with a header, with grain separated post-harvest using a small-scale seed grader.

Rainfall during 2020 was slightly above the long-term average at all three sites (Table 2). Plentiful rainfall during early April, combined with high rainfall totals during August, helped to maintain yield potential above what would be expected given the dry spring conditions following mid-October across all sites.

Results

Assessing the relative advantage of intercrops is more complex than for monocultures, with several approaches available. The most commonly used approach is the land equivalent ratio (LER), which describes the additional land needed to grow the same quantity of both species if they were grown as monocultures, rather than as dual-species crops. The LER calculation is as follows;

$$LER = (Y1_c \div Y1_m) + (Y2_c \div Y2_m)$$

Where $Y1_c$ or $Y2_c$ = yield of crop 1 or 2 as an intercrop
 $Y1_m$ or $Y2_m$ = Yield of crop 1 or 2 as a monoculture

The LER values for this trial were calculated using grain yield at harvest. An LER value greater than 1.0 means there is an advantage to growing the crops in a mixture compared to a monoculture (referred to as 'over-yielding').

The extent of the economic advantage (taking into account absolute yields, the proportion of each crop in the mix, crop prices and variable costs) was calculated using the net gross margin (net GM), as follows;

$$Net\ gross\ margin\ (net\ GM) = GM_c - GM_m$$

$$GM_c = [(Y_{1c} * P_1 + Y_{2c} * P_2) - C_3]$$

$$GM_m = [Z_{1c} * (Y_{1m} * P_1 - C_1) + Z_{2c} * (Y_{2m} * P_2 - C_2)]$$

Y_{1c} or Y_{2c} = yield of crop 1 or 2 as an intercrop

Y_{1m} or Y_{2m} = yield of crop 1 or 2 as a monoculture

Z_{1c} and Z_{2c} = proportional sown area of crops 1 and 2 in the intercrop

P_1 and P_2 are the five-year average of prices for crops 1 and 2

C_1 , C_2 and C_3 are the variable costs of production for crop 1, crop 2 and the intercrop plots respectively

GM_c = Gross margin from intercropping

GM_m = Gross margin from monoculture with same enterprise mix as in the mixture.

The five-year average (2016–20) real prices per tonne of barley, canola, faba beans, field pea and wheat were assumed to be: \$301, \$569, \$553, \$486 and \$302 respectively. The on-farm variable costs of producing a hectare of monoculture barley, canola, faba beans, field pea and wheat were assumed to be: \$388, \$545, \$419, \$371 and \$406 respectively. The cost of separating grains for the mixture after harvest was taken as \$24/t.

TABLE 2 Rainfall at Rutherglen, Burramine and Caniambo during 2020 compared with the long-term average

Month	Rutherglen		Burramine		Caniambo	
	2020 rainfall (mm)	Long-term average rainfall (mm)	2020 rainfall (mm)	Long-term average rainfall (mm)	2020 rainfall (mm)	Long-term average rainfall (mm)
January	29	37	46	33	38	34
February	18	39	31	31	19	32
March	104	39	75	31	64	34
April	136	42	97	33	123	38
May	30	50	28	45	42	46
June	41	56	32	41	45	50
July	16	63	34	48	34	55
August	73	60	58	44	65	54
September	39	54	30	42	28	49
October	67	57	40	41	64	44
November	22	46	25	39	31	41
December	25	45	18	38	33	39
Total	600	588	514	466	585	515
GSR (Apr – Oct)	403	382	319	294	400	334

i. Barley/canola intercrop

At the Rutherglen site, total grain yield expressed as the LER was between 1.11 and 1.15 in the barley/canola intercrop mix compared with the monoculture yields when no in-crop nitrogen was applied, showing a superior crop yield outcome with intercropping.

In terms of additional dollar return, the most profitable option was when barley formed 25% of the barley/canola crop mixture, returning an extra \$182/ha when grown as an intercrop compared with a monoculture of barley (Table 3).

When in-crop nitrogen was added, the 75:25 and 25:75 intercrop mixes of barley and canola returned a negative GM. This was due to improved canola growth, which impacted

barley yield in these mixtures. The 50:50 barley and canola skip-row mix benefited from nitrogen application, increasing the GM from \$90/ha, when no nitrogen was added, to \$161/ha with nitrogen.

At Burramine, combining barley and canola resulted in a negative LER, demonstrating crop losses due to growing in an intercrop system (Table 4). The crop loss was due to barley out-competing canola, which may have been caused by the later sowing advantaging the barley at that site. The addition of nitrogen improved the canola yield when grown in a dual-species mix.

At Caniambo, the positive LER of the barley/canola mix (between 1.04 and 1.07) showed benefits of intercropping with barley and canola when no in-crop nitrogen was added.

TABLE 3 Barley/canola intercrop treatment results for grain yield, land equivalent ratios (LER) and average net gross margin, Rutherglen, 2020

Planting ratio	Monoculture	75:25		50:50		50:50 Skip row		25:75		Monoculture
Species mix	Barley (100%)	Barley (75%)	Canola (25%)	Barley (50%)	Canola (50%)	Barley (50%)	Canola (50%)	Barley (25%)	Canola (75%)	Canola (100%)
No in-crop nitrogen										
Grain yield (t/ha)	8.6	7.6	0.8	5.3	1.7	3.8	2.5	3.4	2.5	3.4
LER*	1	1.12		1.11		1.15		1.14		1
Average Net GM# (\$/ha)	0	66		83		90		182		0
100kg/ha urea applied										
Grain yield (t/ha)	8.6	7.4	0.8	5.8	1.9	3.8	3.1	3.1	2.8	4.4
LER*	1	1.04		1.12		1.16		1.02		1
Average Net GM# (\$/ha)	0	-124		76		161		-128		0

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.

Average Net GM is the change in gross margin of growing crops as an intercrop system compared with a monoculture.

TABLE 4 Barley/canola intercrop treatment results for grain yield and land equivalent ratios (LER), Burramine and Caniambo, 2020

Planting ratio	Burramine						Caniambo					
	Monoculture	75:25		25:75		Monoculture	Monoculture	75:25		25:75		Monoculture
Species mix	Barley (100%)	Barley (75%)	Canola (25%)	Barley (25%)	Canola (75%)	Canola (100%)	Barley (100%)	Barley (75%)	Canola (25%)	Barley (25%)	Canola (75%)	Canola (100%)
No in-crop nitrogen												
Grain yield (t/ha)	6.5	5.3	0.09	4.7	0.3	2.0	4.7	4.6	0.2	3.5	0.7	2.4
LER*	1	0.87		0.89		1	1	1.07		1.04		1
100kg/ha urea applied												
Grain yield (t/ha)	6.6	6.5	0.12	5.2	0.4	2.1	6.3	5.4	0.4	3.6	1.2	2.9
LER*	1	1.04		0.97		1	1	1.01		0.99		1

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.



ii. Faba bean/canola intercrop

At the Rutherglen site, total grain yield (LER) was between 1.09 and 1.21 in the faba bean/canola intercrop mix compared with their monoculture yields when no in-crop nitrogen was applied, showing a positive yield outcome with intercropping (Table 5). The net gross margin compares the costs and benefits of the intercrop to the monocultures when grown on the same proportional area, with the 25 per cent faba bean crop mixture being the most profitable option, returning an extra \$599/ha.

The addition of in-crop nitrogen greatly increased both the LER and the averaged net GM for all crop mixtures during 2020, with the additional dollar returns ranging between \$365/ha to \$604/ha (Table 5).

At Burramine, there was a positive crop response based on LER when the intercrop mix was 25% faba bean and 75% canola (Table 6). When the mix was reversed, the LER response was negative, due to canola being outcompeted by the faba beans, possibly due to late planting at that site.

At Caniambo, the intercrop response was all positive, with in-crop nitrogen increasing yield and LER over the nil-nitrogen treatments.

iii. Field pea/canola intercrop

At the Rutherglen site, grain yield LER was between 1.01–1.21 for the field pea/canola intercrop mix compared with the monoculture yields when no in-crop nitrogen

TABLE 5 Faba bean/canola intercrop treatment results for grain yield, land equivalent ratios (LER) and average net gross margin, Rutherglen, 2020

Planting ratio	Mono-culture	75:25		50:50		50:50 Skip row		25:75		Mono-culture
		Faba bean (100%)	Faba bean (75%)	Canola (25%)	Faba bean (50%)	Canola (50%)	Faba bean (50%)	Canola (50%)	Faba bean (25%)	
No in-crop nitrogen										
Grain yield (t/ha)	5.7	4.6	1.1	3.8	1.5	3.9	1.6	3.4	2.4	3.8
LER*	1	1.09		1.07		1.10		1.21		1
Average Net GM# (\$/ha)	0	78		144		236		599		0
100kg/ha urea applied										
Grain yield (t/ha)	7.3	6.3	1.1	4.6	1.9	4.4	2.1	3.4	2.6	3.6
LER*	1	1.18		1.16		1.19		1.18		1
Average Net GM# (\$/ha)	0	365		412		393		604		0

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.

Average Net GM is the change in gross margin of growing crops as an intercrop system compared with a monoculture.

TABLE 6 Faba bean/canola intercrop treatment results for grain yield and land equivalent ratios (LER), Burramine and Caniambo, 2020

Planting ratio	Burramine						Caniambo					
	Mono-culture	75:25		25:75		Mono-culture	Mono-culture	75:25		25:75		Mono-culture
Species mix	Faba bean (100%)	Faba bean (75%)	Canola (25%)	Faba bean (25%)	Canola (75%)	Canola (100%)	Faba bean (100%)	Faba bean (75%)	Canola (25%)	Faba bean (25%)	Canola (75%)	Canola (100%)
No in-crop nitrogen												
Grain yield (t/ha)	4.3	3.0	0.4	1.3	1.6	2.0	5.9	4.1	0.8	1.7	1.8	2.3
LER*	1	0.95		1.11		1	1	1.05		1.05		1
100kg/ha urea applied												
Grain yield (t/ha)	4.7	3.2	0.5	1.5	1.6	2.2	6.1	4.7	0.9	2.4	1.9	2.9
LER*	1	0.92		1.06		1	1	1.10		1.06		1

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.

was applied, indicating a positive yield outcome with intercropping (Table 7). Growing field peas and canola in skip-rows (alternating two rows of each crop) resulted in a strong negative field pea yield. This negative response was caused when the field peas lost the trellising connection to the neighbouring canola plants post-flowering, which resulted in the field peas collapsing to ground level and falling under heavy shade from the canola. In the other intercrop mixes, the field peas could trellis up the canola plants, with the field pea plants growing to the same, or similar, height as the canola. In each of the intercrop mixes, field pea yield was lower compared with its monoculture, however the extra yield achieved by the canola in the intercrop mixes led to a high yield overall. In terms of extra dollars

returned due to intercropping, excepting the skip-row intercrop, the addition of in-crop nitrogen resulted in extra returns of \$256/ha (75% field pea, 25% canola) to \$452/ha (50% field pea, 50% canola) compared with growing crops as monocultures.

At Burramine, there was a positive LER when the intercrop mix was 25% field pea and 75% canola (Table 8). When the mix was reversed to 75% field pea and 25% canola, the LER response was negative, possibly due to the canola being out competed by the field peas as a result of the late planting.

At Caniambo, the intercrop response was all positive, with increased yield and LER when in-crop nitrogen was applied.

TABLE 7 Field pea/canola intercrop treatment results for grain yield, land equivalent ratios (LER) and average net gross margin, Rutherglen, 2020

Planting ratio	Monoculture	75:25		50:50		50:50 Skip row		25:75		Monoculture
Species mix	Field pea (100%)	Field pea (75%)	Canola (25%)	Field pea (50%)	Canola (50%)	Field pea (50%)	Canola (50%)	Field pea (25%)	Canola (75%)	Canola (100%)
No in-crop nitrogen										
Grain yield (t/ha)	5.8	3.4	2.4	2.9	2.8	1.4	3.1	1.7	3.1	4.2
LER'	1	1.18		1.21		1.01		1.08		1
Average Net GM# (\$/ha)	0	170		264		-244		-4		0
100kg/ha urea applied										
Grain yield (t/ha)	6.6	4.2	2.5	3.4	3.3	1.2	3.8	2.3	3.8	4.4
LER'	1	1.22		1.28		1.10		1.23		1
Average Net GM# (\$/ha)	0	256		452		-198		377		0

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.

Average Net GM is the change in gross margin of growing crops as an intercrop system compared with a monoculture.

TABLE 8 Field pea/canola intercrop treatment results for grain yield and land equivalent ratios (LER), Burramine and Caniambo, 2020

Planting ratio	Burramine						Caniambo					
	Monoculture	75:25		25:75		Monoculture	Monoculture	75:25		25:75		Monoculture
Species mix	Field pea (100%)	Field pea (75%)	Canola (25%)	Field pea (25%)	Canola (75%)	Canola (100%)	Field pea (100%)	Field pea (75%)	Canola (25%)	Field pea (25%)	Canola (75%)	Canola (100%)
No in-crop nitrogen												
Grain yield (t/ha)	3.5	2.4	0.4	1.6	1.0	1.7	6.1	4.4	0.8	3.1	1.6	2.5
LER'	1	0.89		1.13		1	1	1.08		1.17		1
100kg/ha urea applied												
Grain yield (t/ha)	4.3	3.1	0.7	2.0	1.1	2.2	5.5	5.0	0.9	2.1	2.6	2.7
LER'	1	0.94		1.07		1	1	1.17		1.34		1

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.



iv. Faba bean/wheat intercrop

Total grain yield LER, at the Rutherglen site, was between 1.16–1.28 for the faba bean/wheat intercrop mixes compared with their monoculture yields when no in-crop nitrogen was applied (Table 9). This showed a positive crop yield outcome with intercropping. For these treatments, there were large returns of \$363–644/ha, compared with growing crops as monocultures.

When in-crop nitrogen was added, the increase in wheat yield was offset by a larger decrease in faba bean yield, resulting in much lower (negative) returns.

The wheat/faba bean intercrops measured a positive yield response at both Burrumine and Caniambo, with the best response at Caniambo without the addition of in-crop nitrogen (Table 10). In general, the addition of in-crop nitrogen improved wheat yield, but decreased faba bean yield at these sites, leading to a decreased LER.

Observations and comments

This research demonstrates that intercropping with mixtures has the potential to increase productivity and profits across the cropping regions of southern Australia. These results are based on mean responses from the 2020 harvest, however full statistical analyses have not yet been completed.

TABLE 9 Faba bean/wheat intercrop treatment results for grain yield, land equivalent ratios (LER) and average net gross margin, Rutherglen, 2020

Planting ratio	Mono-culture	75:25		50:50		50:50 Skip row		25:75		Mono-culture
		Faba bean (75%)	Wheat (25%)	Faba bean (50%)	Wheat (50%)	Faba bean (50%)	Wheat (50%)	Faba bean (25%)	Wheat (75%)	
Species mix	Faba bean (100%)	Faba bean (75%)	Wheat (25%)	Faba bean (50%)	Wheat (50%)	Faba bean (50%)	Wheat (50%)	Faba bean (25%)	Wheat (75%)	Wheat (100%)
No in-crop nitrogen										
Grain yield (t/ha)	5.7	5.9	1.4	4.5	3.9	4.9	2.3	2.4	6.1	7.9
LER*	1	1.22		1.28		1.16		1.20		1
Average Net GM# (\$/ha)	0	502		644		446		363		0
100kg/ha urea applied										
Grain yield (t/ha)	7.4	6.0	1.8	4.9	3.8	4.2	2.6	2.3	6.3	8.5
LER*	1	1.03		1.10		0.87		1.07		1
Average Net GM# (\$/ha)	0	-58		265		-367		-3		0

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.

Average Net GM is the change in gross margin of growing crops as an intercrop system compared with a monoculture.

TABLE 10 Faba bean/wheat intercrop treatment results for grain yield and land equivalent ratios (LER), Burrumine and Caniambo, 2020

Planting ratio	Burrumine						Caniambo					
	Mono-culture	75:25		25:75		Mono-culture	Mono-culture	75:25		25:75		Mono-culture
Species mix	Faba bean (100%)	Faba bean (75%)	Wheat (25%)	Faba bean (25%)	Wheat (75%)	Wheat (100%)	Faba bean (100%)	Faba bean (75%)	Wheat (25%)	Faba bean (25%)	Wheat (75%)	Wheat (100%)
No in-crop nitrogen												
Grain yield (t/ha)	4.7	1.4	3.6	0.3	4.9	5.0	6.1	5.0	1.8	2.0	3.8	4.9
LER*	1	1.01		1.05		1	1	1.21		1.13		1
100kg/ha urea applied												
Grain yield (t/ha)	4.2	1.6	3.9	0.5	5.4	5.9	6.7	4.0	2.9	1.4	5.6	6.5
LER*	1	1.05		1.04		1	1	1.03		1.09		1

* LER is a measure of crop yield when grown as an intercrop compared with that same crop grown as a monoculture.

Farmers inspiring farmers

Results demonstrate that growing a pulse with canola as a dual-species mix can produce positive benefits in terms of yield and profit. The exception to this was when canola and field pea were grown in a skip-row configuration (where the field pea did not climb into the canola stand). The addition of in-crop nitrogen to these mixes enhanced both the LER and the net GM.

When wheat or barley were part of an intercrop system, the yield benefits occurred only when there was no additional nitrogen applied. The application of nitrogen to these systems led to wheat and barley outcompeting their pulse or oilseed intercrop, decreasing the yield of the intercrop and reducing total productivity and profit.

The different herbicide options available for use in these intercropping systems could also provide alternative management options for grain growers.

This research was part of a larger project that had field experiments sown at additional sites in north-west and south-west Victoria.

Acknowledgements

The work is supported by the Victorian Grains Innovation Partnership with Agriculture Victoria and the Grains Research and Development Corporation. The research sites at Burramine and Caniambo were sown and managed by Kaylx (Corowa). We would also like to acknowledge the landholder cooperators, Brendan Thompson and Nathan Lawless. ✓

Contact

Meredith Mitchell Agriculture Victoria Rutherglen

T: (02) 60 304 579

E: meredith.mitchell@agriculture.vic.gov.au

DEVELOP YOUR NETWORKS IN AGRICULTURE!



INNOVATION
GENERATION



Do you know a young
person studying or working
in agriculture?

Innovation Generation is
the event of the year to attend.

 /GrainGrowers /InnovationGenerationConference
 @GrainGrowersLtd @InnovGeneration
 @Innovation.Generation

 **Grain
Growers**