Intercropping with Soybeans and Peas

Kristen P. MacMillan, Research Agronomist
University of Manitoba
kristen.macmillan@umanitoba.ca
@kpmacmillanUM

Project duration
2019- 2020

Objectives
1. Gain experience in intercropping: observe and evaluate agronomic performance of intercropping compared to mono-cropping
2. Evaluate yield potential, land use equivalency and profitability of intercropping compared to mono-cropping
3. Overall, start a knowledge base on if and how intercrops can be utilized in cropping systems in the Interlake

Collaborators
Prairies East Sustainable Agriculture Initiative Inc. (PESAI) – Arborg, MB

Project Findings
This was the second successful year of experimenting with intercropping in the Interlake region of Manitoba. Treatments included three seeding rate combinations of pea-canola, soybean-flax, pea-flax and pea-oat compared to pea, canola, flax, soybean and oat monocrops. Results of the experiment including treatment descriptions, agronomic practices, yield, gross and marginal revenues and general observations are listed in Tables 2 and 3 and each intercrop treatment is discussed at the end of the report. The 2020 growing season at Arborg was dry with 70% of normal growing season precipitation (Table 1) compared to 55% of normal precipitation in 2019.

In both years of study, flax and pea have produced the highest marginal revenue of the monocrops. Canola was challenged with flea beetles and grasshoppers in 2020. Pea-canola was the only intercrop to consistently over-yield in 2019 and 2020 (Fig. 1) while marginal revenues were impressive for pea, pea-oat and pea-flax (Fig. 2). After two years of study in Arborg, we have been able to draw some conclusions on optimum seeding rate ratios, consistency of over-yielding and profitability (see individual intercrop treatment discussions). The pea-oat intercrop was sampled for total dry matter and forage nutrient analysis (Table 4) which will be helpful for livestock farmers.

Results

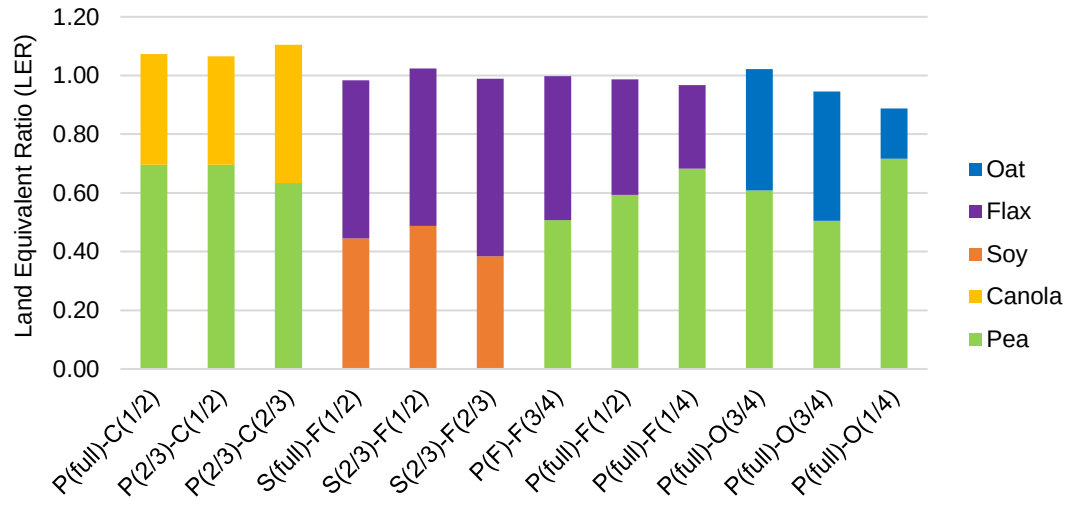

Figure 1. *Average total Land Equivalent Ratio (LER) for each intercrop treatment composed of each partial LER crop component (n=3) at Arborg, MB in 2020.*

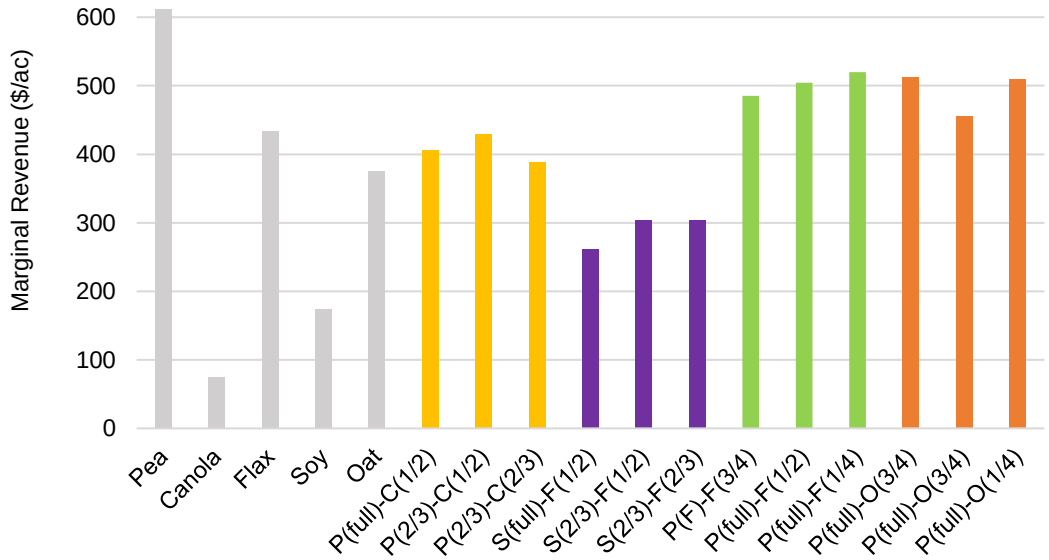

Figure 2*. Average marginal revenue of monocrop and intercrop treatments at Arborg, MB in 2020.*

Table 1. Seasonal growing degree days, crop heat units and precipitation at Arborg in 2020.

	May	June	July	August	May-August
Growing degree days (GDD)	177	364	466	417	1425
Normal % growing degree days	86	108	107	108	104
Crop heat units (CHU)	314	557	741	660	2293
Normal % crop heat units	85	101	104	103	100
Precipitation (mm)	12	83	61	33	190
Normal % precipitation	23	107	101	42	70

Source: https://web43.gov.mb.ca/climate/SeasonalReport.aspx

Table 2. Seeding rates, varieties, seed depth, plant stand, plant height, yield and profit of intercrop treatments in 2020 at Arborg, MB.

No.	Treatment	Crop	Seed rate strategy	Variety	Seeding rate (seeds/m^2)	Plant stand* (plants/m^2)	Land Equivalent Ratio ¥	Height (cm)	Yield † (bu/ac)	Gross ‡ revenue ($/ac)	Marginal revenue ‡ ($/ac)
1	Pea	Pea	Full	CDC Amarillo	100	80	1.0	68	90.4	722.94	612.47
2	Canola	Canola	Full	5545 CL	108	52	1.0	83	19.3	217.20	74.78
3	Flax	Flax	Full	CDC Glas	700	394	1.0	55	35.7	500.15	433.66
4	Soybean	Soybean	Full	NSC Watson	49	47	1.0	55	25.5	290.34	173.77
5	Oats	Oats	Full	Souris	355	149	1.0	77	105.2	394.48	376.35
6	Pea-canola	Pea Canola	Full 1/2	CDC Amarillo 5545 CL	100 54	86 25	1.07	60 76	62.9 7.3	585.17	406.21
7	Pea-canola	Pea Canola	2/3 1/2	CDC Amarillo 5545 CL	67 54	42 33	1.07	60 79	62.8 7.2	583.13	429.56
8	Pea-canola	Pea Canola	2/3 2/3	CDC Amarillo 5545 CL	67 72	53 36	1.10	57 74	57.3 9.1	560.56	388.13
9	Soy-Flax	Soybean Flax	Full 1/2	NSC Watson CDC Glas	49 350	47 223	0.98	44 58	11.3 19.2	398.59	261.91
10	Soy-Flax	Soybean Flax	2/3 1/2	NSC Watson CDC Glas	33 350	35 185	1.02	45 62	12.4 19.2	409.80	304.00
11	Soy-Flax	Soybean Flax	2/3 2/3	NSC Watson CDC Glas	33 467	35 335	0.99	46 61	9.8 21.6	413.92	303.97
12	Pea-Flax	Pea Flax	Full 3/4	CDC Amarillo CDC Plava	100 525	62 273	1.0	57 62	45.8 17.5	611.98	485.46
13	Pea-Flax	Pea Flax	Full 1/2	CDC Amarillo CDC Plava	100 350	68 175	0.99	60 61	53.6 14.1	625.60	504.31
14	Pea-Flax	Pea Flax	Full 1/4	CDC Amarillo CDC Plava	100 175	76 86	0.97	67 55	61.7 10.2	635.79	519.75
15	Pea-Oat	Pea Oat	Full 3/4	CDC Amarillo Souris	100 266	78 100	1.02	59 78	55.0 43.6	602.94	513.28
16	Pea-Oat	Pea Oat	Full 1/2	CDC Amarillo Souris	100 178	80 90	0.95	64 77	45.6 46.4	538.70	455.53
17	Pea-Oat	Pea Oat	Full 1/4	CDC Amarillo Souris	100 89	79 36	0.89	62 71	64.8 18.0	585.65	509.63

**Optimum plant stands for monocrops: peas (7-8 plants/ft^2 or 70-80 plants/m^2), canola (5-7 plants/ft^2 or 50-70 plants/m^2), flax (37-56 plants/ft^2 or 396-599 plants/m^2), soybean (4 plants/ft^2 or 40 plants/m^2) and oats (18-23 plants/ft^2 or 194-248 plants/m^2).*

† Average crop yields in the Bifrost-Riverton municipality: 36.8 bu/ac peas, 30.1 bu/ac canola, 17.8 bu/ac flax and 31.3 bu/ac soybean (MASC, 1993-2019).

‡ Profit margins were calculated as follows: Gross revenue ($/ac) = Yield x Market price
Marginal revenue ($/ac) = Gross revenue – Seed – Fertilizer – Pesticide – Separation ($0.25/bu)
(Market prices from Manitoba Agriculture 2021 Costs of Production: $8.00/bu peas, $11.25/bu canola, $14.00/bu flax, $11.40/bu soybean and $3.75/bu oats)

¥ Land equivalent ratio (LER) = $\frac{\text{yield of intercrop species 1}}{\text{yield of monocrop species 1}} + \frac{\text{yield of intercrop species 2}}{\text{yield of monocrop species}}$

Table 3. Seeding depth, weed control, fertility and general notes/observations of intercrop treatments in 2020 at Arborg, MB.

No.	Treatment	Crop	Seed rate	Depth	Herbicides/weed control*	Fertilizer applied†	General notes and observations
1	Pea	Pea	Full	1.5”	Pre-emerge: Authority In-crop: Odyssey	15 lbs/ac P_2O_5	Pea aphids were sprayed July 20. Harvest date Aug 26.
2	Canola	Canola	Full	0.75”	Pre-emerge: None In-crop: Odyssey	38 lbs N/ac; 15 lbs/ac P_2O_5	Sprayed for flea beetles in June and for flea beetles and grasshoppers in August. Desiccated Sept 2.
3	Flax	Flax	Full	0.75”	Pre-emerge: Authority 480 In-crop: Clethodim	15 lbs/ac P_2O_5	Desiccated Sept 4.
4	Soybean	Soybean	Full	1”	Pre-emerge: Authority 480 In-crop: Glyphosate	15 lbs/ac P_2O_5	Harvest date Sept 15.
5	Oats	Oats	Full	1.5”	Pre-emerge: None In-crop: None	15 lbs/ac P_2O_5	Harvest date Aug 19.
6	Pea-canola	Pea	Full	0.75”	Pre-emerge: None In-crop: Odyssey	15 lbs/ac P_2O_5	Pea-canola was sprayed for flea beetles in June and for a late season attack of flea beetles and grasshoppers in August. Pea-canola was desiccated Sept 2.
		Canola	1/2				
7	Pea-canola	Pea	2/3	0.75”		None	
		Canola	1/2				
8	Pea-canola	Pea	2/3	0.75”		None	
		Canola	2/3				
9	Soy-Flax	Soybean	Full	0.75”	Pre-emerge: Authority 480 In-crop: Clethodim	15 lbs/ac P_2O_5	To achieve row separation, soybean was seeded down the mid-row resulting in 4.5-inch separation from the flax row. Maturity of both crops aligned well. Harvest date was Sept 15.
		Flax	1/2				
10	Soy-Flax	Soybean	2/3	0.75”		None	
		Flax	1/2				
11	Soy-Flax	Soybean	2/3	0.75”		None	
		Flax	2/3				
12	Pea-Flax	Pea	Full	1”	Pre-emerge: Authority 480 In-crop: Clethodim	None	Pea-flax was desiccated Sept. 4.
		Flax	3/4				
13	Pea-Flax	Pea	Full	1”		15 lbs/ac P_2O_5	
		Flax	1/2				
14	Pea-Flax	Pea	Full	1”		None	
		Flax	1/4				
15	Pea-Oat	Pea	Full	1.5”	Pre-emerge: None In-crop: None Hand weeding for wild oat patches	None	Wild oats were a problem in the trial area. Hand-weeding was done but the weed pressure may be a confounding factor. Harvest date was Aug 26.
		Oat	3/4				
16	Pea-Oat	Pea	Full	1.5”		15 lbs/ac P_2O_5	
		Oat	1/2				
17	Pea-Oat	Pea	Full	1.5”		None	
		Oat	1/4				

**There was a wild oat patch running through Replicate 2 that was hand weeded in all treatments. Pea-oat and oat treatments were also hand weeded for wild oats.*

†*All intercrop treatments were to receive 15 lbs P_20_5/ac but only 1 of each intercrop treatment received the starter P due to human error.*

Table 4. Forage nutrient analysis of oat monocrop and pea-oat intercrop from Arborg 2020. Samples were collected on July 9, 2020 at pea flowering (R2) and oat heading (inflorescence).

	Feed Basis	Oat	Pea-Oat
Moisture (%)	As Fed	3.0	4.2
Dry Matter (%)	As Fed	96.8	95.8
Crude Protein (%)	As Fed	10.0	14.5
Relative Feed Value	Dry Matter	96.0	110.0
Total Dry Matter (lbs/ac)	Dry Matter	10,220	9,002
Calcium (%)	As Fed	0.2	0.7
Phosphorus (%)	As Fed	0.3	0.3
Magnesium (%)	As Fed	0.2	0.4
Potassium (%)	As Fed	2.6	2.7
Sodium (%)	As Fed	0.4	0.3
Acid Detergent Fibre (%)	As Fed	33.6	33.3
Neutral Detergent Fibre (%)	As Fed	58.2	51.1
Non Fibre Carbohydrates (%)	As Fed	18.4	19.9
Total Digestible Nutrients (%)	As Fed	59.7	58.9
Metabolizable Energy (Mcal/kg)	As Fed	2.2	2.2
Net Energy for Lactation (Mcal/kg)	As Fed	1.4	1.3
Digestible Energy (Mcal/kg)	As Fed	2.6	2.6
Net Energy for Maintenance (Mcal/kg)	As Fed	1.3	1.3
Net Energy for Gain (Mcal/kg)	As Fed	0.8	0.0

Pea-Oat

The pea-oat treatments produced LERs from 0.89 to 1.02 indicating that over-yielding did not occur compared to oat and pea monocrops. Among the intercrop treatments, the pea (full rate)-oat (3/4 rate) produced the highest LER (1.02) and marginal revenue ($513/ac) but marginal revenue was still lower than monocrop peas which yielded 90 bu/ac. In 2019, we could not calculate LER (no oat monocrop in the trial) but the pea (full rate)-oat (1/2 rate) was more economical than both crops seeded at 2/3 rate. ***From two years of study at Arborg, the over-yielding benefit and optimum seeding rate ratio for pea-oat intercropping remains somewhat unclear. It is likely that a full pea seeding rate should be maintained and that there is good weed suppression (no in-crop herbicide has been required).***

In 2020, we also collected above ground biomass samples at pea flowering and oat heading for forage analysis. Samples were collected from each replicate of the oat monocrop and pea (full)-oat (1/2 rate) intercrop treatments. The overall average values for each treatment are in Table 4. Pea-oat intercrop dry matter was slightly lower but CP and RFV were higher. It is important to note that grain varieties were used and different results may be expected with forage varieties.

Pea-canola

All pea-canola treatments produced a land equivalent ratio (LER) greater than 1 (Table 2), indicating that over-yielding occurred. Over-yielding also occurred in all treatments in 2019. Peas yielded very well in the intercrop (57-63 bu/ac) and monocrop treatments (90 bu/ac). Canola yielded poorly in the monocrop (19 bu/ac) and the intercrop treatments (7-9 bu/ac), likely due to early and late season insect damage and above average temperatures through flowering. The mean daily temperature in July 2020 was 20.0°C compared to the long-term average of 18.6°C. The pea-canola treatment where both crops were seeded at 2/3 of a full rate produced a slightly higher LER than the other two treatments. The pea-canola treatment with peas seeded at 2/3 rate and canola at ½ rate resulted in the highest marginal revenue ($430/ac) which was $24-42/ac higher than the other two treatments but much lower than the monocrop peas ($613/ac). In both years of study, the established plants stand of the pea (2/3 rate)-canola (1/2 rate) treatment were similar - 21 pea plants/m^2 and 17-24 canola plants/m^2 which is 31% establishment for pea and 35% establishment for canola.

Intercropping pea and canola in 2019 and 2020 consistently resulted in over-yielding (LER from 1.07 to 1.20). Seeding peas at 2/3 rate (67 seeds/m^2) and canola at a ½ rate (54 seeds/m^2) resulted in the most economic pea-canola intercrop. Overall, intercrop peas produced 70 to 106% of monocrop pea yield and canola produced 16-37% of monocrop canola yield.

In both years, the additional cost of a higher canola rate was not offset by increased yield. In 2020, a third treatment was included that used a full rate of pea and ½ rate of canola, but the additional seed cost of a higher pea rate was not offset by increased yield. Marginal revenues of canola treatments in both 2019 and 2020 were reduced due to insecticide applications. More favorable growing conditions for canola would shift the economics for monocrop canola and may alter the yield ratio between pea and canola in the intercrops.

Pea-canola intercrops have been well studied in Manitoba and has consistently over-yielded compared to pea and canola monocrops. At Carman and Kelburn, MB from 2001-2003[1], Dr. Martin Entz's research team found that pea-canola resulted in over-yielding 100% of the time under conventional management with an average LER of 1.21. Pea-canola intercrops were studied in on-farm trials at Carman, MB in 2015[2] and 2016[3]. Peas and canola were seeded in the same mixed row at ~2/3 of a full rate (110 lbs/ac peas and 3-4 lbs/ac canola; 180 lbs/ac monocrop peas; 5-6 lbs/ac monocrop canola) with three supplemental N rate comparisons. Increasing N rate in the intercrops increased canola yield, reduced pea yield and reduced marginal revenue. In both years of on-farm study at Carman, LERs ranged from 1.04 to 1.16 and marginal revenue was highest with the 0N or low N rate.

Soybean-Flax

The soybean-flax treatments produced a land equivalent ratio close to 1 (0.98 to 1.02) indicating that over-yielding did not occur. Flax yielded very well in the monocrop treatment (36 bu/ac) while soybeans were below average (26 bu/ac). In the intercrop treatments, flax yielded 19-22 bu/ac (54-61% of monocrop flax) and soybean yielded 10-12 bu/ac (38-49% of monocrop soybean). Among the intercrop treatments, LERs were similar but marginal revenue was highest where soybean was seeded at 2/3 rate (33 seeds/m^2) and flax at a ½ rate to 2/3 rate (350-395 seeds/m^2). At 36 bu/ac flax, however, the intercrop treatments were not as profitable as monocrop flax in 2020.

From two years of study at Arborg, intercropping soybean and flax has produced LERs from 0.55 to 1.02 and has not been consistently economical compared to monocrop flax. Out of the seeding rate combinations tested, a soy-flax intercrop should be seeded in separate rows with a 2/3 rate of soybean (33 seeds/m^2) and ½ to 2/3 rate of flax (350-395 seeds/m^2).

In 2019, soybean and flax were seeded in the same row which resulted in the flax outcompeting soybean. This has also been observed at Melita (Scott Chalmers, personal communication). Variety choice is an important consideration to ensure that both crops mature at a similar time. With CDC Glas flax, we used S007Y4 soybean in 2019 which matured later than the flax and in 2020, we used NSC Watson, which matured earlier and closer to flax. The intercrops were not desiccated.

Pea-Flax

Pea-flax treatments produced a land equivalent ratio (LER) close to 1 (Table 2), indicating that over-yielding did not occur. Marginal revenue for all intercrop treatments ($485-520/ac) was higher than monocrop flax ($434/ac) which yielded 36 bu/ac but lower compared to monocrop peas ($613/ac) which produced an exceptional yield of 90 bu/ac. Among the intercrop treatments, the LERs were similar (0.97-1.0), but the marginal revenue was highest with the pea (full rate)-flax (1/4 rate). In 2019, we tested pea (full rate)-flax (1/2 rate) and pea (2/3 rate)-flax (2/3) rate - both the LER and marginal revenue of the two seeding rate combinations were similar. In both years of study, peas matured ahead of flax and a desiccant was applied to facilitate timely harvest.

From two years of study at Arborg, intercropping pea and flax has resulted in LERs from 0.98 to 1.02. Marginal revenue of intercropping in 2019 was lower than flax and pea monocrops and in 2020, pea-flax marginal revenue was higher than flax but lower than peas. More work is needed to identify the optimum seed rate ratio for pea-flax

intercropping. In 2019, it was also observed that flax chlorosis may be reduced with intercropping.

Background / References / Additional Resources

Intercropping is the practice of seeding, growing and harvesting two or more crops together. The concept is to utilize crop combinations that complement one another through mechanisms such as resource use efficiency and potentially result in over-yielding and greater profitability compared to monocropping. Careful consideration needs to be given to how the crops are be seeded, managed, harvested and separated. The most common intercrop grown commercially in Manitoba is pea-canola. Beginning in 2019, we started to test pea-canola, soybean-flax, pea-flax and pea-oat intercrop combinations at Arborg, MB. For each intercrop combination, 2-3 seeding rate ratios were tested and compared to pea, soybean, canola, flax and oat monocrops.

To assess the productivity of intercrops compared to their component crops grown in monoculture, the land equivalent ratio (LER) is used. LER is a ratio of the individual crop yields from the intercrop divided by the respective monocrop yield. It is desirable to achieve a LER > 1 which indicates over-yielding (more would be required to produce the same yield with as individual monocrops compared to the intercrop). Gross and marginal revenues are also calculated because seasonal growing conditions and market prices are important variables that affect the productivity, yield and economic return of cropping in a given year.

Pea-canola intercropping has consistently over-yielded and gross revenues have been highest for peas, flax and intercrops containing peas

[1] *Agronomic Benefits of Intercropping Annual Crops in Manitoba. (n.d.). University of Manitoba Department of Plant Science Natural Systems Agriculture. https://www.umanitoba.ca/outreach/naturalagriculture/articles/intercrop.html*

[2] *Manitoba Pulse & Soybean Growers. 2015. On-Farm Evaluation of Peaola Intercropping. https://manitobapulse.ca/wp-content/uploads/2018/02/On-Farm-Evaluation-of-Peaola-Intercropping-2015.pdf*

[3] *Manitoba Pulse & Soybean Growers. 2016. On-Farm Evaluation of Peaola Intercropping. Retrieved https://manitobapulse.ca/wp-content/uploads/2018/02/On-Farm-Evaluation-of-Peola-2016.pdf*

Materials & Methods

The intercropping trial was seeded into tilled wheat residue on May 21, 2020 at Arborg, MB with a plot seeder on 9” row spacing. All intercrops were seeded in the same, mixed row except soybean-flax where soybean was seeded down the mid-row fertilizer tube to achieve row separation (4.5”). Soil type at the research site is a heavy clay (Fyala series) and background soil test levels were 112 lbs N/ac and 11 ppm P_20_5. Specific agronomic practices used for each intercrop treatment are listed in Tables 2 and 3.

Data collection:

1) Plant density 5 weeks after seeding (# of plants on 2m or row x 2 rows)
2) General observations and pictures (disease, insects, weeds, lodging)
3) Plant staging July 1 (stage crops on a whole plot basis)
4) Maturity (record date of maturity for each crop)
5) Biomass and forage nutrient analysis for pea-oat and oat treatments (At oat heading, collect above ground biomass from 0.25m2 in 2 areas of the plot (front and back) and combine for a composite sample for each plot)
6) Canopy height at maturity in 3 areas of the plot (front, middle, back)
7) Grain yield and moisture