Multi-Crop Intercrop trial (Pea-Oat-Canola-Wheat-Flax-Mustard)

(Adapted from a report written by Scott Chalmers, WADO)

Project duration: 2019-2021

Objectives: Evaluate agronomic performance of peas in a monocrop or when intercropped with oats, canola, spring wheat, flax or mustard

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Background

Choice of an intercropping system depends on many factors including: weather, machinery available for seeding, harvesting and separation of seed, economics and compatibility of the crops involved. Many organic agriculture farmers have turned to various intercropping systems to address weed and disease pressure, which often inhibits organic systems under monoculture situations (Pridham and Entz, 2007). Intercropping systems can help address climate change in ways such as biological control of insect pests, weeds and diseases. Biological control allows for less use of synthetic chemicals hence addressing the chemical resistance issues. Another benefit of intercropping is improving soil health at low cost considering residual nitrogen if a legume is included. In other studies, pea-wheat intercropping systems have been shown to be efficient in the use of nitrogen due to their spatial self-regulating dynamics, which allows pea to improve its interspecific competitive ability in fields with lower soil nitrogen and vice versa for wheat (Andersen et al., 2004 and Ghaley et al., 2005). This enables future options to reduce synthetic nitrogen inputs and negative environmental impacts of crop production. Compared to pea sole crop, pea-oats intercrop results in reduced pea lodging because of the support provided by oats to the pea crop, this also helps reduce harvesting difficulties and increase economic returns (Kontturi et al., 2010). This study evaluated various intercrop combinations that can be utilized by producers.

Materials and Methods

The trials were at Melita, Reston and Roblin in 2021. Soil tests were conducted to determine nutrient status before seeding at all sites (Table I). A randomized complete block design with 11 treatments and 4 replicates was used at each site. Fertilizer was applied according to soil test results during seeding, along with inoculant (Table I). Site description, agronomy and weather information for each trial is presented in Table II. Data collected from each site included: Counts at emergence and flowering, weed counts and biomass at flowering, grain yield, percentage of pea splits, and protein content. Disease severity data collected was for mycosphaerella, powdery mildew, rust, sclerotinia and fusarium wilt. Data were analyzed using Minitab 18 and means were separated using Fisher's LSD at 95% confidence.

Table I. Soil test results for Melita, Reston, and Roblin sites in 2021.

Soil Test:	**Nutrient**						
Location	**N** lb ac^{-1}	**P** ppm	**K** Ppm	**S** lb ac^{-1}	**Zn** ppm	**Organic Matter (%)**	**pH**
Melita	18	5	279	208	0.64	3.3	7.0
Reston	102	9	252	92	1.07	4.7	6.7
Roblin	120	52	670				

Applied:	**Nutrient**				
Location	**N**	**P**	**K**	**S**	**Zn**
	lb ac^{-1}				
Melita	12	28	20	12	1.6
Reston	15	28	20	12	1.6
Roblin	0	15	0	0	0

Table II. Agronomy and weather data from intercrop trial sites in Reston, Melita, and Roblin, MB in 2021.

Location	Reston, MB	Melita, MB	Roblin, MB
Legal Land Location	SE 11-7-27 W1	NW 27-3-27	NE 20-25-28 W1
Soil Series	Ryerson Loam	Alexander Loam	Erickson Clay Loam
Previous Crop	Spring Wheat	Spring wheat	Oat silage
Field Preparation	Harrowed, No-till	Harrowed, No-till	Vertical tillage
Pre-Emergent Herbicides	May 12: 0.65 L ac^{-1} Rival on canola, peas, flax and mustard, Authority on peas and flax	May 10: 0.65 L ac^{-1} Rival on Pea, Flax, mustard, and canola, 0.1 L ac^{-1} Authority in Pea and Flax	May 26: 0.54 L ac^{-1} Liberty
Soil Moisture at Seeding	Fair	Fair	Very poor
Seed Date	May 11	May 7	May 19
Seed Depth (inch)	1”	0.75”	0.75”
Herbicides	June 9: Basagran, Arrow, Axial, Odyssey	June 8: Basagran, Arrow, Odyssey	None
Insecticides	Flea beetles – June 1: 75 ml ac^{-1} Pounce, 10 gal June 10: 34 ml/ac Matador	Flea beetles - June 2: 75 ml ac^{-1} Pounce, 10 gal Blister beetles – June 28: 0.4 L ac^{-1} Cygon (15 gal ac^{-1}) on canola	None
Desiccation	August 6 – Roundup 0.5 L ac^{-1} + Reglone 0.5 L ac^{-1} + LI700 1 L ac^{-1}	August 10 – Roundup 0.5 L ac^{-1} + Heat 22 ml ac^{-1} + Reglone L ac^{-1} + LI700 @ 0.1%	None
Harvest Date	August 13, flax August 26	August 16 (Canola slightly too early)	September 24
Combine Settings			
Rotor	760	600 (1000 for flax)	800
cleaning fan	780	820	930
rotor-concave space	8 mm	12 mm	10 mm
Growing Season Report (Seeding – Harvest)			
Precipitation (mm)	154	175	246
Normal (mm)	259	260	265
Growing Degree Days	1252	1374	1466
Normal GDDs	1248	1213	1302

Results and Discussion

At the Melita site, peas intercropped with canola or mustard yielded significantly ($P<0.001$) greater than other intercrop combinations (Table a). Partial land equivalence ratio (PLER) of pea component crops followed the same trend, with peas from the pea-canola (0.54) and pea-mustard (0.51) intercrops having significantly ($P<0.001$) greater PLERs than the other intercrop combinations. However, the only intercrop with an average TLER greater than 1 was the pea-canola intercrop. While the pea-mustard intercrop produced high pea yields, PLER of the mustard component crop was lowest. This highlights a potential competition effect of pea on mustard.

Pea yields at the Reston site followed a similar trend as the Melita site, with the pea-canola and pea-mustard intercrops resulting in the greatest pea yields (Table b). In terms of pea PLER, the pea-canola intercrop resulted in a significantly ($P<0.001$) greater PLER than all other intercrops. The pea-flax

intercrop resulted in the lowest pea yield (28 kg ha-1) and PLER (0.07) of all intercrop combinations. The Reston pea-canola intercrop also resulted in the greatest average TLER (1.46), though this result was not significantly (P<0.001) different from that of the pea-mustard (1.13) or pea-oat (1.35) intercrop. The Reston pea-flax intercrop was the only combination which did not over-yield, though the TLER from this intercrop combination was not significantly (P<0.001) different from that of the pea monocrop.

Intercrops in Roblin displayed similar results as the Melita and Reston sites (Table c), with the pea-canola intercrop resulting in the greatest pea yield (432 kg ha-1), though this yield was not significantly (P = 0.003) different from that of the pea-mustard intercrop (270 kg ha-1). While analysis of variance for pea PLER of Roblin intercrops indicated a significant treatment effect (P = 0.038), Fishers LSD test was unable to separate means, indicating no significant difference between pea PLERs. The greatest TLER resulted from the pea-canola intercrop in Roblin, though this TLER was not significantly different from that of the pea-mustard, pea-oat, or pea-wheat intercrops. Like in the Reston trial, the lowest TLER resulted from the pea-flax intercrop. While TLERs observed at the Roblin site were much greater than those observed at the Reston or Melita sites, it is important to note that the pea monocrops in Roblin yielded much lower than the pea monocrops in Melita and Reston, therefore leading to greater pea partial land equivalence ratios.

Overall, pea yield at all sites was much lower than 2020 yields. However, similar trends were observed, with pea-canola and pea-mustard intercrops also consistently producing high pea yields and TLERs in 2020 as well. The flax-pea intercrop did perform much better in 2020 than in 2021, and poor performance of this intercrop combination in 2021 could be due to less accumulated precipitation in the 2021 growing season. Results from 2019, 2020, and 2021 sites will be combined and analyzed in a separate report, and may better illustrate which intercrop combinations perform best throughout both wet and dry years.

Table a. Mean Yield and Land Equivalence Ratio of various crops grown in monocrop or intercropped with pea at Melita, MB in 2021.

Crop	Yield (kg/ha)			LER		
	Sole	Crop-IC	Pea-IC	Partial Crop-IC	Partial Pea-IC	TLER
Pea	2209	-	-	-	-	1.00**b**
Flax	1314	1049	430**b**	0.80	0.19**b**	1.00**b**
Oat	2259	1768	464**b**	0.79	0.21**b**	1.00**b**
Wheat	1688	1171	618**b**	0.69	0.28**b**	0.98**b**
Canola	1278	788	1195**a**	0.63	0.54**a**	1.17**a**
Mustard	629	338	1118**a**	0.54	0.51**a**	1.00**b**
P value			**<0.001**		**<0.001**	**<0.001**
CV (%)			**12**		**11**	**5**

Values followed by the same letter are not significantly different by Fishers LSD method at 95% confidence.

Table b. Mean yield and Land Equivalence Ratio of various crops grown in monocrop or intercropped with pea at Reston, MB in 2021.

Crop	Yield (kg/ha)			LER		
	Sole	Crop-IC	Pea-IC	Partial Crop-IC	Partial Pea-IC	TLER
Pea	415	-	-	-	-	1.00**cd**
Flax	192	145	28**c**	0.71	0.07**c**	0.78**d**
Oat	3643	3346	175**b**	0.93	0.42**b**	1.35**ab**
Wheat	3198	2242	178**b**	0.71	0.42**b**	1.13**bc**
Canola	1806	1268	312**a**	0.72	0.75**a**	1.46**a**
Mustard	1387	835	216**ab**	0.62	0.52**b**	1.13**abc**
P value			**<0.001**		**<0.001**	**<0.001**
CV (%)			**22**		**19**	**13**

Values followed by the same letter are not significantly different by Fishers LSD method at 95% confidence.

Table c. Mean yield and Land Equivalence Ratio of various crops grown in monocrop or intercropped with pea at Roblin, MB in 2021.

Crop	Yield (kg/ha)			LER		
	Sole	Crop-IC	Pea-IC	Partial Crop-IC	Partial Pea-IC	TLER
Pea	274	-	-	-	-	1.00**b**
Flax	537	111	156**b**	0.21	0.60**a**	0.81**b**
Oat	1874	1754	162**b**	0.93	0.61**a**	1.55**ab**
Wheat	3068	2184	163**b**	0.72	0.71**a**	1.42**ab**
Canola	2000	1513	432**a**	0.76	1.80**a**	2.56**a**
Mustard	1364	1041	270**ab**	0.77	1.16**a**	1.93**ab**
P value			**0.003**		**0.038**	**0.004**
CV (%)			**36**		**55**	**35**

Values followed by the same letter are not significantly different by Fishers LSD method at 95% confidence.

Plant counts were conducted at emergence and at flowering to assess plant stand changes during the growing season, though plant stand change between these two stages was minimal. Average plants per square meter for the pea monocrop was adjusted prior to analysis of variance to reflect the reduced pea seeding rate in intercrop treatments. Analysis of variance of average peas per square meter revealed no significant difference between the monocrop pea stand (adjusted) and the intercrop pea stand at Melita, indicating no significant effect of intercropping on pea stand compared to monocropping (Table d). While weed biomass differences were observed between treatments, weed count was generally similar, so only weed biomass results are summarized here. In the Melita trial, average weed biomass in intercrops was greatest in the pea-mustard intercrop, though this was not significantly different than the average weed biomass of pea-oat and pea-wheat intercrops. Low weed biomass was observed in pea-flax (7 g m^{-2}) and pea-canola (5 g m^{-2}) treatments, though this biomass was not significantly different than that overserved in pea-oat intercrops (41 g m^{-2}). Pea grain quality was assessed by measuring the amount of split peas in

a harvest grain sample as well as the protein content of harvested peas. A significant ($P < 0.001$) treatment effect was observed in pea split incidence at the Melita site, with the highest pea split incidence observed in pea-flax intercrops (32.2%), and the lowest in pea-oat intercrops (5.2%). Pea protein was not significantly different across pea intercrop and monocrop treatments.

No significant difference was observed in pea stand across treatments at the Reston site, indicating that intercropping had little effect on pea stand compared to monocropping (Table e). Weed biomass in Reston was lowest in the pea monocrop (1041 g m^{-2}), though this biomass was not significantly different from that of pea-flax, pea-oat, pea-canola, or pea-mustard intercrops. This result indicates that, like in 2020, weed biomass was not effectively reduced by intercropping in 2021. Analysis of variance on pea split incidence and pea grain protein content was not done for the Reston site in 2021, as not enough sample from some pea-flax intercrop plots was collected to measure these variables.

Like other sites, no significant treatment effect on pea stand was observed at the Roblin site. Weed biomass data was unable to be collected across all replicates in 2021 at the Roblin site, so weed biomass data is not presented here. Pea split incidence and pea grain protein content was also not measured for the Roblin site.

Overall, no consistent reduction in weed biomass was observed in intercrops compared to the pea monocrop. Weed biomass of intercrops was significantly higher than that of the monocrop in some cases. A more consistent trend may emerge by analyzing data from all three trial years, and these results will be presented in a separate summary report.

Table d. Mean plant stand density at flowering, weed biomass per square meter, and grain quality of monocrops and pea intercrops grown at Melita, MB in 2021.

Crop	Final Emergence ppms			Weeds (g m^{-2})^		Pea splits (%/500 seeds)	Pea protein (% DM basis)
	Sole	Crop-IC	Pea-IC	Sole	Pea-IC		
Pea	34	-	17 (adj.)	17**bc**	**-**	16.0**b**	25.6
Flax	239	109	30	9	7**c**	32.2**a**	24.7
Oat	131	72	35	147	268**ab**	5.2**c**	25.3
Wheat	100	45	33	11	41**abc**	17.5**b**	25.0
Canola	37	20	32	12	5**c**	20.3**b**	25.5
Mustard	32	26	36	417	512**a**	18.8**b**	25.4
P value			0.931		**<0.001**	**<0.001**	0.074
CV (%)			29		**11**	**15**	2

Values followed by the same letter are not significantly different by Fishers LSD method at 95% confidence.
^Johnson transformation prior to ANOVA

Table e. Mean plant stand density at flowering and weed biomass per square meter of monocrops and pea intercrops grown at Reston, MB in 2021.

Crop	Final Emergence ppms			Weeds (g m^{-2})^	
	Sole	Crop-IC	Pea-IC	Sole	Intercrop
Pea	62	-	31 (adj)	1041**b**	-
Flax	274	146	26	2388	1870**ab**
Oat	143	71	31	2088	2593**ab**
Wheat	160	60	31	2755	2596**a**
Canola	43	23	37	2660	1549**b**
Mustard	38	17	37	3674	2490**ab**
P value			0.300		**0.005**
CV (%)			22		**4**

Values followed by the same letter are not significantly different by Fishers LSD method at 95% confidence.
^Johnson transformation prior to ANOVA

Table f. Mean plant stand density at flowering of monocrops and pea intercrops grown at Roblin, MB in 2021.

Crop	Final Emergence ppms		
	Sole	Crop-IC	Pea-IC
Pea	66	-	33 (adj.)
Flax	188	122	28
Oat	122	94	38
Wheat	129	98	34
Canola	104	39	25
Mustard	53	25	31
P value			0.214
CV (%)			24

Though net revenue was negative in almost all intercrops, significant net revenue differences were observed at all trial locations. In Melita, the pea-wheat intercrop resulted in the greatest mean net revenue loss (-$134), though this loss was not significantly (P<0.001) different from that of the pea-mustard intercrop (Table g). Mean net losses of the pea-flax, pea-oat, and pea-canola intercrops were not significantly different from that of the pea monocrop. While all intercrop combinations at this trial resulted in revenue loss, these results illustrate that of the intercrop combinations tested here, pea-flax, pea-oat, and pea-canola intercrops may be the most economically feasible.

Economic analysis of the Reston site revealed much different results, with the pea monocrop (-$260) and the pea-flax intercrop (-$292) resulting in the greatest loss in revenue (Table h). The pea-oat intercrop was the only intercrop treatment to result in positive net revenue ($49), though statistically this revenue was not different from that of the pea-wheat, pea-canola, and pea-mustard intercrops.

Net revenues of the Roblin intercrops followed a similar trend as the Reston intercrops, with the pea monocrop (-$275) and the pea-flax intercrop (-$286) resulting in the greatest revenue losses (Table i). The greatest intercrop revenue was observed in the pea-mustard intercrop ($45), though this revenue was not significantly (P < 0.001) different from that of the pea-canola intercrop ($2).

In general, pea intercrops resulted in less revenue loss than pea monocrops in 2021, though revenue generated from each intercrop treatment varied among sites. Analysis of economic results across all three years of the trial may reveal an intercrop treatment which consistently results in higher revenues than pea monocrops, and these results will be presented in a separate summary report.

Table g. Economic analysis of various crops in monocrop and in intercrop with pea grown at Melita, MB in 2021.

Crop	Economics per acre					
	Sole-COP	IC – COP	Mean Gross Revenue		Mean Net Revenue	
			Sole	IC	Sole	IC
Pea	$303	-	$230	-	-$74**a**	-
Flax	$289	$325	$267	$257	-$23	-$67**a**
Oat	$292	$318	$236	$233	-$56	-$86**ab**
Wheat	$308	$316	$169	$182	-$139	-$134**c**
Canola	$328	$339	$250	$279	-$77	-$61**a**
Mustard	$317	$336	$213	$231	-$104	-$105**bc**
P value						**<0.001**

Values followed by the same letter are not significantly different by Fishers LSD method at 95% confidence.

Table h. Economic analysis of various crops in monocrop and in intercrop with pea grown at Reston, MB in 2021.

Crop	Economics per acre					
	Sole-COP	IC – COP	Mean Gross Revenue		Mean Net Revenue	
			Sole	IC	Sole	IC
Pea	$303	-	$43	-	-$260**b**	
Flax	$289	$325	$39	$32	-$251	-$292**b**
Oat	$292	$318	$380	$367	$89	$49**a**
Wheat	$308	$316	$321	$243	$12	-$73**a**
Canola	$328	$339	$354	$281	$26	-$58**a**
Mustard	$317	$336	$470	$305	$153	-$31**a**
P value						**<0.001**

Values followed by the same letter are not significantly different by Fishers LSD method at 95% confidence.

Table i. Economic analysis of various crops in monocrop and in intercrop with pea grown at Roblin, MB in 2021.

Crop	Economics per acre					
	Sole-COP	IC – COP	Mean Gross Revenue		Mean Net Revenue	
			Sole	IC	Sole	IC
Pea	$303	-	$28	-	-$275**c**	
Flax	$289	$325	$109	$39	-$181	-$286**c**
Oat	$292	$318	$196	$200	-$96	-$118**b**
Wheat	$308	$316	$307	$236	-$1	-$80**b**
Canola	$328	$339	$392	$342	$64	$2**a**
Mustard	$317	$336	$462	$380	$145	$45**a**
P value						**<0.001**

References

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