Faba-Flax, Faba-Buckwheat, Faba-Oat and Oat-Pea Intercropping dynamics

(Adapted from a report written by Justice Zhanda, WADO)

Project duration: May-September 2020
Objectives: (1) To determine the influence of row orientation on intercrops compared to monocrops; (2) To determine grain, forage and quality output obtained from intercrops involving oats
Collaborators: WADO, PCDF

Background

Intercroppings systems are growing in popularity in Canada because their use has contributed to enhanced livestock production due to improved grain yield and forage quality. The importance of including legumes in intercropping systems is fall grazing for integrated crop and livestock systems, which can also compliment grazing of crop residues (Andersen et al., 2020). This helps save stored forage resources for winter feeding, thus reducing feed costs. Fababean is one of the most important potential crops that can be used for this purpose. The crop has key environmental benefits in its ability to fix atmospheric nitrogen symbiotically under a wide range of environmental conditions making nitrogen available under diversified crop rotations (Kopke and Nemecek, 2010; Andersen et al., 2020). Fababean enhances sustainable agricultural systems through diversified intercrops which provide an environment for soil microbes to improve soil conditions such as aeration and organic matter content. In other studies, inclusion of fababean in intercropping systems has been shown to increase phosphorus mobilization making it more available to plants. When determining fababean intercropping options, it is crucial to select one that provides more benefits in terms of soil health improvement, dry matter yield and disease reduction. Previous studies have examined various fababean: non-legume seeding ratios such as 75%:25%, 50%:50% and 25%:75%. They found out that the most productive intercrop was that of fababean-oats at 25%:75% seeding ratio (Dhima et al., 2013). As a result of potentially higher dry matter and protein content for intercrops involving fababean, this can be an alternative to sole fababean in forage production. The purpose of this study was to evaluate the influence of row orientation on fababean and oat intercrops compared to sole crops and to determine grain, forage and quality output from these intercrops.

Figure 1: Intercrops at Roblin, (a) faba-oat; (b) faba-flax; (c) faba-buckwheat.

Materials and Methods

The trials were conducted at Melita on Newstead loam soils and Erickson clay loam soils at Roblin in 2020. Plots were established under no till practices with only harrowing necessary to evenly spread crop residues from the previous season. Treatments were arranged as randomized complete block design with four treatments replicated three times for each cropping system (Table 1).

Table 1: Treatment description (target seed rate in plants per meter square) for Flax-Oat, Flax-Buckwheat, Flax-Pea and Flax-Fababean at Melita in 2020

Faba-Oat	Faba-Buckwheat	Oat-Pea	Flax-Faba
1.Faba ‘Snowbird’ (54) *	Faba	Oat	Flax ‘Neela’ (500)
2.Oat ‘Summit’ (225)	Buckwheat ‘Horizon’ (161)	Pea ‘Amarillo’ (85)	Faba
3.Faba (75%), Oat (25%), mixed	Faba (75%), Buckwheat (25%), mixed	Oat (25%), Pea (75%), mixed	Flax (25%), Faba (75%), mixed
4.Faba (50% field rate), Oat (25%), alternate rows	Faba (50% field rate), Buckwheat (25%), alternate rows	Oat (25%), Pea (50% field rate), alternate rows	Flax (25%), Faba (50% field rate), alternate rows

‘Variety name’; (target seeding rate in plants per m square) *

Characterization and agronomic information for Melita and Roblin is presented in Table 2.

Table 2: Site characterization and agronomy information for Melita and Roblin in 2020

Description	Site Characterization	
	Melita	Roblin
Research Group	WADO	PCDF
Legal Land Location	SE 26-3-27 W1	NE 20-25-28 W1
Soil Series	Ryerson Loam	Erickson clay loam
Stubble	spring wheat	silage barley
Field Prep	harrowed, no till	harrowed, no till
Soil Test N-P-K (lbs/ac)	56-22-584	66-94-1224
Fertilizer App N-P-K-S-Zn (lbs/ac)	50-35-20-8-2	2-10-0-0-0
Seeder Type	Dual knife drill	Double Disc drill
Rows and Spacing (inches)	6 (9.5)	5 (9.5)
Burnoff Date/Product (Rate/ac)	Roundup 0.5L + Aim 15 ml May 11, Authority 80 ml + Rival 0.65L May 12; Buck-Faba: 0.5L Roundup + 15 ml Aim	May 29, Roundup (0.65L)
Seed Date	May 11, Buck-Faba May 21	27-May
Seed Depth	1.5" (Pea-Oat, Faba-Oat, Faba-Flax), 1" (Buck-Faba)	3/4" Faba-Oat; Pea-Oat, 1/2" all others
Herbicides	MCPA Amine500 @ 0.15L/ac Oat pea intercrop June 5	N/A
	Basagran + Arrow @ 0.91L/ac + 100 ml/ac + X-Act 0.5% June 10 on Faba-Flax	

Harvest Date	Faba-Oat, Pea-Oat Aug 17, Faba-Flax Aug 26 , Faba-Buck Sept 10	02-Oct
Forage Harvest Date	11-Jul	14-Aug
Growing Season	(May 11 - Sept 10)	27-May to 2-Oct
GGDs actual Base5*C	1526	1287
GGDs normal	1485	1271
Precipitation actual	167	236
Precipitation normal	299	263

GDD = growing degree days; B = broadcast; SB = side-banded; NA = not applied; growing season length = seeding date to harvest date

Combine settings for oat-faba, oat-pea and faba-flax were; 1300 rpm cylinder speed, 950 rpm wind speed and 3 mm concave clearance while adjustments were made to 600 rpm cylinder speed, 850 rpm wind speed and 12 mm concave clearance for faba-buckwheat. A mixed model ANOVA was run to determine differences between treatments. Cropping systems were considered as fixed factors while location (nested within reps) and reps were random factors. Treatment mean separation was done using Tukey's test at 95% confidence interval.

Results and Discussion

Grain Yield

There were significant differences in both fababean and oat grain yield in the faba-oat intercrop at Melita and Roblin. At Melita, fababean yield was 38% and 61% higher in sole crop compared to mixed and alternate cropping systems, respectively (P<0.001). Oat yield in the sole crop was not significantly different from alternate cropping system. Mixed and alternate cropping systems did not significantly differ in oat grain yield obtained. However, yield from sole crop oat was significantly higher than mixed cropping system (P=0.01). At Roblin, fababean grain yield was significantly higher (P<0.001) in sole crop compared to mixed and alternate cropping systems and the difference amounted to 67% and 70%, respectively. As expected also, sole crop oat had significantly higher (P=0.001) grain yield compared to mixed and alternate cropping systems that had 40% and 50% lower oat grain yield, respectively. A combined site analysis found significant differences in fababean grain yield between sole crop (P=0.047) and alternate cropping system but not with mixed cropping system. There were no significant differences in oat grain yield when the two sites were combined (Table 3).

Pea grain yield from cropping systems in pea-oat intercrop was significantly different at Melita and Roblin. At Melita, pea yield in the sole crop was 2440 kg ha^{-1} and 3812 kg ha^{-1} more (P<0.001) than mixed and alternate cropping systems, respectively. Mixed cropping system yielded significantly higher than the alternate cropping system also. As expected again, oat yield was significantly (P<0.001) higher in the sole crop (6212 kg ha^{-1}) compared to mixed (2528 kg ha^{-1}) and alternate (4301 kg ha^{-1}) cropping systems (Table 4). At Roblin, pea yield (479 kg ha^{-1}) in the sole crop was significantly (P=0.036) different from that of the alternate (409 kg ha^{-1}) cropping system but did not differ significantly with mixed (279 kg ha^{-1}) cropping system. Oat yield in sole crop was 42% and 37% significantly (P=0.005) higher than in mixed and alternate cropping systems, respectively. Generally, grain yields were very low at Roblin compared to Melita probably as a result of differences in agroecological regions. Fababean grain yield from cropping systems in faba-buckwheat intercrop was significantly (P=0.009) different at Melita. Fababean grain yield obtained from alternate cropping system was the lowest (2237 kg ha^{-1}) while mixed and sole crop yielded 36% and 42% more, respectively. Buckwheat yield in sole crop was significantly (P<0.001) higher than mixed and alternate cropping systems that had 7- and 4-times lower grain yield, respectively. At Roblin, fababean grain yield in sole crop was significantly (P=0.001) more than in mixed and alternate cropping systems by 44% and 59%, respectively. Buckwheat yield was significantly (P=0.005) more by about 50% compared with mixed and alternate cropping systems. There were no significant differences in grain yield between mixed and alternate cropping systems at both sites. A combined analysis of the sites did not find significant differences in grain yield, at least in the current season but there is a possibility that with additional site years of data, differences in yield can be observed (Table 5).

There were significant differences in grain yield from faba-flax intercrop at Melita and Roblin (Table 6). At Melita, fababean grain yield was significantly (P=0.002) lower than sole and mixed cropping systems by more than 1300 kg ha^{-1}. Flax grain yield was statistically the same between mixed and alternate cropping systems but was significantly (P<0.001) higher by 10 and 4 times, respectively, in flax sole crop. At Roblin, fababean grain yield was significantly (P=0.039) lower in the alternate cropping system compared to the sole crop by about 1500 kg ha^{-1} while there were no significant differences between sole crop and mixed cropping system. Flax yield was significantly (P<0.001) higher in sole crop than mixed and alternate cropping systems. There were no significant differences in grain yield between mixed and alternate cropping systems. Flax grain yield averaged over Roblin and Melita was significantly (P=0.014) higher in sole crop (2710 kg ha^{-1}) compared to mixed (744 kg ha^{-1}) and alternate (827kg ha^{-1}) cropping systems (Table 6).

Dry forage yield

Faba-Oat intercrop did not significantly influence dry forage yield at Melita but the yield ranged from 6699 kg ha^{-1} to 10149 kg ha^{-1} in 2020. However, at Roblin, dry forage yield was significantly (P=0.002) different between sole crop oat and sole fababean only. Yield from sole crop oat (12680 kg ha^{-1}) was not significantly different from mixed (10793 kg ha^{-1}) and alternate (8720 kg ha^{-1}) cropping systems. There were no significant differences in dry forage yield when the 2 sites were combined (Table 3).

Similar to faba-oat intercrop, there were no significant differences in dry forage yield observed in all cropping systems under pea-oat intercrop at Melita. Dry forage yields ranged from 9014 kg ha^{-1} to 10510 kg ha^{-1}. At Roblin, there were also no significant differences in dry forage yield and the ranges were 9260 kg ha^{-1} to 10553 kg ha^{-1} (Table 4).

Land equivalence ratio

At Melita, faba-oat intercrop LER for fababean and oat were significantly (P<0.001 and P=0.003) lower in mixed and alternate cropping systems compared to sole crops that had LER of 1. However, total LER was significantly (P=0.005) higher in mixed (LER=1.09) and alternate (LER=1.11) intercrops signaling a significant benefit of intercropping versus sole cropping (Table 3). At Roblin, LER was significantly lower (P<0.001) when faba and oat were analyzed separately. Total LER for both crops was also below 1, meaning there was no advantage of intercropping over sole cropping at Reston in 2020. When both sites were considered, sole crop prevailed compared to intercrop as the LER for the later were less than 1 for intercrops.

Pea and oat LER were significantly (P<0.001) low when crops were analyzed separately at Melita. Pea performed better in mixed compared to alternate intercropping system while the performance was vice versa for oat. Total LER suggested that there was a significant (P=0.004) benefit of pea-oat intercrop when an alternate cropping system (LER=1.13) is adopted compared to mixed (LER=1.05) or sole cropping system (LER=1) (Table 4). At Roblin, while partial LERs were significantly lower than 1 for oat or pea, total LER suggested a significant (P=0.039) benefit of intercropping pea with oats using either mixed (LER=1.40) or alternate (LER=1.19) cropping systems. A combined site analysis showed significant differences in partial LERs but there was no benefit in adopting any of the intercropping systems over sole crops and both mixed and alternate cropping systems did not have an advantage over the other.

Land equivalent ratio for sole (LER=1) fababean and mixed (LER=0.9) cropping systems was significantly (P=0.01) higher than alternate cropping system (LER=0.59) at Melita. Mixed cropping option had an advantage over alternate cropping system. Buckwheat LER was significantly (P<0.001) lower for mixed (LER=0.14) and alternate (LER=0.25) cropping systems compared to the sole crop (LER=1) (Table 5). The TLER was not significantly different, hence, similar benefits could be obtained from adopting either cropping systems. At Roblin, LER for fababean sole crop was significantly (P=0.001) higher than mixed and alternate cropping systems that had values less than 1. Buckwheat LER for the sole crop was also significantly (P=0.03) higher than the other two cropping systems (Table 5). Similar to results from Melita, there were no benefits of adopting either intercropping systems over sole crops at Roblin in 2020. However, a combined analysis of the two sites showed mixed (TLER=1.06) cropping system to be a significantly (P=0.005) better option than alternate (TLER=0.87) cropping system.

Land equivalent ratio for sole (LER=1) fababean and mixed (LER=1.04) cropping systems was significantly (P=0.002) higher than alternate (LER=0.73) cropping system for faba-flax intercrop at Melita (Table 6). Flax LER was significantly (P<0.001) lower for mixed and alternate cropping systems compared to sole crop. The TLER for mixed (TLER=1.13) cropping system was significantly (P=0.024) higher than alternate (TLER=0.98) cropping system. In this case, mixed cropping system would be a better option than alternating rows of flax and fababean. At Roblin, alternate cropping system had significantly (P=0.025) lower LER (0.73) compared to fababean sole crop. Flax LER in mixed and alternate cropping systems was also significantly (P<0.001) lower than flax sole crop. Neither cropping systems proved to be better options over sole crops at Roblin in 2020.

Protein content and seed weight

Oat protein ranged from 9.93% to 11.2% for faba-oat intercrop at Melita but there were no significant differences between cropping systems. However, at Roblin, alternate (11.08%) cropping system had significantly (P=0.034) higher protein content than sole (10.03%) crop oat. There were no significant differences between mixed and alternate cropping systems, and between mixed and sole crop (Table 7). Oat seed weight based on a 500 seed count was significantly (P=0.042) different at Melita. Oat seed in sole crop weighed 38.23 g per 500 seed count, while seed in mixed and alternate cropping systems weighed 33.84 g and 35.62 g per 500 seed count, respectively. Fababean seed weight was also measured for 500 seed count and there were significant (P=0.031) differences in seed weight at

Melita. Alternate cropping system produced fababean seed with 216.3 g per 500 seed count while mixed and sole crop had 6.79 g and 26.87 g lower seed weight, respectively. There were no significant differences in seed weight for faba-oat intercrop systems at Roblin in 2020.

Oat protein for pea-oat intercrop was significantly (P=0.006) higher in mixed (10.93%) and alternate (10.47%) cropping systems compared to sole crop (9.87%) at Melita. Similar trends were observed at Roblin with significantly (P<0.001) higher oat protein in mixed (10.98%) and alternate (10.81%) cropping systems compared to sole crop (9.93%) (Table 7). Pea seed weight at Melita was significantly (P=0.032) higher in alternate (129.25 g) cropping system while mixed cropping system seed weighed 121.64 g per 500 seed count. There were no significant differences in pea seed weight at Roblin. At all sites, there were also no significant differences in oat seed weight in 2020.

Table 3: Mixed Model Analysis of variance for Faba-Oat dry forage yield, grain yield and LER at Melita and Roblin in 2020

Location	Crop System	Dry Forage kg/ha	Grain Yield (kg/ha)		Land Equivalent Ratio		
			Faba	Oat	Faba	Oat	Total
Melita	MonoOat	10030	*	5597a	*	1a	1b
	MonoFaba	6699	4944a	*	1a	*	1b
	Mixed	8433	3070b	2571b	0.62b	0.47c	1.09a
	Alternate	10149	1941c	3972ab	0.39c	0.72b	1.11a
	P value	0.07	<0.001	0.01	<0.001	0.003	0.005
	CV	16	8	15	8	10	3
Roblin	MonoOat	12680a	*	4879a	*	1a	1a
	MonoFaba	6527b	2892a	*	1a	*	1a
	Mixed	10793ab	962b	2926b	0.33b	0.60b	0.93ab
	Alternate	8720ab	869b	2457b	0.30b	0.51b	0.81b
	P value	0.012	<0.001	0.001	<0.001	<0.001	0.007
	CV	16	12	8	6	6	5
REML (both sites)	MonoOat	11355	*	5238	*	1a	1
	MonoFaba	6613	3918a	*	1	*	1
	Mixed	9613	2016ab	2748	0.48	0.54b	1.01
	Alternate	9435	1405b	3215	0.35	0.61ab	0.96
	P value	0.1	0.047	0.112	†NH	0.043	†NH
	CV	9	7	8		6	

†NH= non homogenous data, therefore no statistical analysis done

Table 4: Mixed Model Analysis of variance for Pea-Oat dry forage yield, grain yield and LER at Melita and Roblin in 2020

Location	Crop System	Dry Forage kg/ha	Grain Yield (kg/ha)		Land Equivalent Ratio		
			Pea	Oat	Pea	Oat	Total
Melita	MonoOat	10510	*	6212a	*	1a	1b
	MonoPea	10030	6735a	*	1a	*	1b
	Mixed	9744	4295b	2528c	0.64b	0.41c	1.05b

	Alternate	9014	2923c	4301b	0.44c	0.69b	1.13a
	P value	0.256	0.001	<0.001	<0.001	<0.001	0.004
	CV	8	8	4	6	4	3
Roblin	MonoOat	10300	*	3771a	*	1a	1a
	MonoPea	10553	497a	*	1a	*	1a
	Mixed	10373	409ab	2181b	0.82ab	0.58b	1.40a
	Alternate	9260	279b	2373b	0.56b	0.63b	1.19a
	P value	0.621	0.036	0.005	0.029	0.003	0.039
	CV	16	17	10	15	9	13
REML (both sites)	MonoOat	10405	*	4991	*	1a	1
	MonoPea	10291	3616	*	1a	*	1
	Mixed	10058	2352	2355	0.73ab	0.49b	1.23
	Alternate	9137	1601	3337	0.50b	0.66b	1.16
	P value	0.181	†NH	†NH	0.034	0.016	†NH
	CV	6			7	5	

Table 5: Mixed Model Analysis of variance for Faba-Buckwheat grain yield and LER at Melita and Roblin in 2020

Location	Crop System	Grain Yield (kg/ha)		Land Equivalent Ratio		
		Faba	Buckwheat	Faba	Buckwheat	Total
Melita	MonoBuckwheat	*	1497a	*	1a	1
	MonoFaba	3878a	*	1a	*	1
	Mixed	3475a	212b	0.90a	0.14c	1.04
	Alternate	2237b	366b	0.59b	0.25b	0.82
	P value	0.009	<0.001	0.01	<0.001	0.118
	CV	11	13	11	6	10
Roblin	MonoBuckwheat	*	949a	*	1a	1
	MonoFaba	3461a	*	1a	*	1
	Mixed	1951b	494b	0.56b	0.53b	1.09
	Alternate	1427b	474b	0.41b	0.50b	0.92
	P value	0.001	0.005	0.001	0.003	0.087
	CV	11	14	10	12	6
	GM	2279.4854	639	1	1	1
	MSE	64205	8181	0	0	0
REML (both sites)	MonoBuckwheat	*	1223	*	1	1ab
	MonoFaba	3669	*	1	*	1ab
	Mixed	2713	353	0.73	0.33	1.06a
	Alternate	1832	420	0.50	0.38	0.87b
	P value	0.085	†NH	0.101	†NH	0.005
	CV	7		7		5

Table 6: Mixed Model Analysis of variance for Faba-Flax grain yield and LER at Melita and Roblin in 2020

Location	Crop System	Grain Yield (kg/ha)		Land Equivalent Ratio		
		Faba	Flax	Faba	Flax	Total
Melita	MonoFlax	*	2296a	*	1a	1ab
	MonoFaba	4875a	*	1a	*	1ab
	Mixed	5034a	223b	1.04a	0.10c	1.13a
	Alternate	3553b	569b	0.73b	0.25b	0.98b
	P value	0.002	<0.001	0.002	<0.001	0.024
	CV	5	12	5	5	5
Roblin	MonoFlax	*	3124a	*	1a	1
	MonoFaba	2947a	*	1a	*	1
	Mixed	1740ab	1265b	0.63ab	0.41b	1.03
	Alternate	1483b	1085b	0.52b	0.35b	0.86
	P value	0.039	<0.001	0.025	<0.001	0.426
	CV	23	7	19	6	13
REML (both sites)	MonoFlax	*	2710a	*	1a	1
	MonoFaba	3911	*	1	*	1
	Mixed	3387	744b	0.83	0.25b	1.08
	Alternate	2518	827b	0.62	0.30b	0.92
	P value	0.222	0.014	0.228	0.034	0.057
	CV	8	6	9	4	6

Table 7: Analysis of variance for Faba-Oat and Pea-Oat protein content and seed weight at Melita and Roblin in 2020

Location	Faba-Oat				Pea-Oat			
	Cropping System	Oat Protein %	Seed weight (g/500seeds)		Cropping System	Oat Protein %	Seed weight (g/500seeds)	
			Oats	Faba			Pea	Oats
Melita	MonoOat	9.93	38.23a	*	MonoOat	9.87b	*	42.19
	MonoFaba	*	*	189.43b	MonoPea	*	125.05ab	*
	Mixed	11.2	33.84b	209.51ab	Mixed	10.93a	121.64b	39.453
	Alternate	10.73	35.62ab	216.3a	Alternate	10.47a	129.25a	42.247
	P value	0.081	0.042	0.031	P value	0.006	0.032	0.261
	MSE	0.24444	1.883	62.65	MSE	0.03611	4.728	3.991
Roblin	MonoOat	10.03b	26.33	*	MonoOat	9.93b	*	26.333
	MonoFaba	*	*	205	MonoPea	*	124.67	*
	Mixed	10.71ab	25.33	218.33	Mixed	10.98a	129.33	29
	Alternate	11.08a	24.67	227.67	Alternate	10.81a	125.67	28.33
	P value	0.034	0.365	0.223	P value	<0.001	0.703	0.806

Conclusions

Protein content was significantly high in intercrops compared to sole crops. Seed weight also increased in alternate compared to mixed cropping system as observed in pea-oat and faba-oat intercrops. Land equivalent ratio increased in alternate and mixed cropping system compared to sole crops meaning that there were benefits in intercropping than sole cropping. This was especially observed in faba-buckwheat, pea-oat and faba-oat when individual sites were analyzed. Grain yield from mixed cropping system matched that of sole crop in some cases, indicating a potential for another option that farmers can choose from if their objectives include crop diversification. Forage yield was also promising and such cropping systems as the ones in this study could be useful for farmers who are integrate with livestock production. Results from this study are from 2 site-years and additional site-years of data are required to validate these findings and come up with recommendations that farmers can use in their respective areas of production.

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