INTERCROPPING LEGUMES AND NON-LEGUMES IN SASKATCHEWAN

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Introduction

Recently farmers in Western Canada have begun intercropping legumes with non-legumes to facilitate mechanical harvesting of legumes such as peas. Monocropped peas tend to lodge heavily, especially after early abundant vegetative growth. Losses caused by lodging can be considerable, predominantly due to increased disease problems and incomplete harvest. A non-legume, such as canola, helps prevent lodging.

There are several possible benefits of intercropping legumes with non-legumes. Several studies have reported a higher total yield from intercropping legumes with non-legumes (Searly et al., 1983; Murray and Swenson, 1985). Higher nutrient, light and water use efficiency have been reported in intercropped systems as compared to mono-cropped systems. A higher nitrogen content in the non-legume component has been found, and explained by possible excretion or transfer of N from the legume to the non-legume, or by the lower N uptake of the legume resulting in higher available soil N levels for the non-legume (Eaglesham et al., 1981; Vasalis and Ham, 1985). Also, higher N_2-fixation rates are reported for intercropped legumes as compared with monocropped legumes (Morris and Weaver, 1987).

Fertilizer applications, especially N, have to be adopted to this new cropping system. Whereas legumes can grow adequately without any N-fertilizer applications (Bremer and van Kessel, 1988), the non-leguminous component generally requires additional fertilizer N.

The objective of this study was to investigate the effect of intercropping legumes with non-legumes on yield, N_2-fixation, and fertilizer use efficiency. At five locations different legume and non-legume combinations were monocropped or intercropped under three levels of N.

Materials and Methods

A field study was conducted in 1987 at five locations where different legumes and non-legumes were monocropped or intercropped. The cropping systems tested and the soil characteristics of the sites are given in Table 1. The sites at Regina, Glenavon, Medstead, and Meadow Lake were seeded into stubble, whereas the site at Melville was seeded into a recently broken pasture. Mono- and intercropped legumes were seeded at recommended rates: lentils (var. Laird) at 36 kg/ha and pea (var. Trapper) at 125 kg/ha. Monocropped non-legumes were seeded at recommend rate, and intercropped non-legumes at half the recommended rate. This resulted in a seeding rate of the monocropped non-legumes of: flax (var. McGregor) at 36 kg/ha, canola (var. Tobin or Tribute) at 6 kg/ha, yellow mustard at 6 kg/ha and oats (var. Cascade) at 75 kg/ha. At the Regina site, intercropped lentils and flax were planted in alternate rows spaced at 18 cm. At the other four sites the legume was seeded in rows spaced at 18 cm, whereas the non-legume was broadcast. All sites received 30 kg P_2O_5/ha as triple superphosphate. Legume seeds were inoculated with commercial Nitragin 'C' inoculant. N treatments of 10, 30 and 50 kg/ha, applied as urea after seeding

Table 1. Cropping systems and soil characteristics.

Site	Legume	Non-legume	Soil	pH	Available soil nutrients NO$_3$	P	K	S	Growing season precipitation
					---------- kg/ha			----------	----- cm -----
Regina	Lentil	Flax	Clay	7.7	9	52	960	6	9.2
Glenavon	Pea	Canola	Loam	7.4	73	51	558	9	14.7
Melville	Pea	Yellow mustard	Loam	8.0	173	15	261	21	20.5
Medstead	Pea	Oats	Loam	6.6	33	23	209	8	34.2
Meadow Lake	Pea	Canola	Sandy loam	8.1	56	45	110	21	24.4

were superimposed on all cropping systems. Plots were arranged in a split plot design, with cropping system as the main plot treatment, and fertilizer N as the subplot treatment, replicated four times. ^{15}N microplots (1.0 x 1.05 m) were placed in the center of each subplot. ^{15}N-urea was dissolved in water, broadcast, and watered in.

Harvest occurred at maturity which coincided for both crops. The plots were hand-harvested, removing 6 m^2 in monocrop systems and 12 m^2 for intercrop systems. The samples were dried and threshed. Canola and pea, mustard and pea, and oats and pea were harvested and threshed together, then separated by sieving. Flax and lentils in the intercrop system were separated at harvest, and threshed separately.

Total N was determined by micro-Kjeldahl (Bremner and Mulvaney, 1982). ^{15}N was carried out by conversion of NH_4 to N_2 by LiBrOH (Ross and Martin, 1970; Porter and O'Deen, 1977) and the $^{15}N/^{14}N$ ratio was determined by a VG Micromass 602E isotope ratio mass spectrometer. Atom % ^{15}N excess was calculated using the value of 0.3663 atom % ^{15}N of atmospheric N_2 as background (Mariotti, 1983). Percent N derived from N_2 and fertilizer N was calculated as described by Rennie and Rennie (1983). Monocropped non-legume was used as the reference plant for measuring N_2-fixation activity of the monocropped legume. In intercropping systems, the intercropped non-legume was used as the reference plant.

Land equivalent ratio (LER) was calculated as follows:

$$LER = \frac{\text{Yield of intercropped legumes}}{\text{Yield of monocropped legumes}} + \frac{\text{Yield of intercropped non-legumes}}{\text{Yield of monocropped non-legumes}}$$

Data were analyzed using analysis of variance procedures. At significant F values, means were separated by LSD (0.05).

Results and Discussion

Intercropping Characteristics

Intercropping has gained acceptance among many Saskatchewan farmers because it reduces lodging of the legume crops. In this project, reduced legume lodging was noted at each site. Pea tendrils successfully twined onto canola, mustard and oats. Lentils did not extensively twine onto flax, but the flax did hold the lentils more erect by giving physical support and providing a wind barrier. At Meadow Lake, a weak stemmed variety of canola ('Tribute') was used; as a result, the combined crop severely lodged, and the canola yield was sharply reduced.

As in all cropping systems, a moist seedbed is desired for intercropping. The pea and lentil could be sown deeper, and always into moist soil. However, as at Glenavon, the smaller seed of canola had to be sown shallow, into a dry seedbed. This resulted in uneven canola emergence and legume dominance in the intercrop.

All of the crops except the lentil and flax were harvested and threshed together, then cleaned without any difficulty. The flax and lentil intercrop was harvested separately. Although the lentil and flax can be easily separated, there may be difficulty in threshing them together.

Yields

The seed size and expected yields of the legume and non-legume crops grown are very different. Also, the seeding rates and plant survival are not the same under the two cropping systems. Therefore, it is difficult to statistically compare yields of monocrops to intercrops. Monocrop and intercrop yields are shown in Table 2. Yields of both the legumes and non-legumes were reduced in the intercrop system. The extent of yield reduction for each crop was very site specific. For example, at Glenavon the pea crop established quickly, while the canola emergence was delayed because of the dry seedbed. As a result, the pea crop dominated, and its yield was reduced less than the canola yield. In comparison, the ideal growing conditions at Medstead allowed the more competitive oat crop to dominate the pea when intercropped.

LER can give some indication of the success of an intercrop yield in comparison to monocrop yields (Table 2). Again, these values are site specific; the canola-pea intercrop at Glenavon had an average LER of 1.00, while the canola-pea intercrop at Meadow Lake produced an average LER of 1.26.

Fertilizer N had little effect on crop yield, indicating the relatively high soil NO_3 levels (Table 1). Significant ($P > 0.05$) responses to fertilizer N were measured at Medstead and Regina. At Medstead, the oat crop yield increased more with N application than did the pea crop ($P > 0.10$).

Generally, intercropping stabilized yield. The potential value of intercropping yield can be further measured by economic return (Table 3). The sites at Regina and Meadow Lake showed an increase in monetary return through intercropping. At the other three sites, the highest economic return came from monocropped legume, with intercropping returns second highest. Plots were harvested by hand and harvest losses were small. In field-scale operations, losses to incomplete harvest of the legumes could occur and result in lower economic returns. Overall, intercropping increased or at least stabilized yields and economic returns.

Table 2. Yields and land equivalent ratios (LER) of monocropped and intercropped legumes and non-legumes, as affected by N fertilizer use.

Site	N rate (kg/ha)	Legume yield M*	Legume yield IC**	Non-legume yield M	Non-legume yield IC	LER
		kg/ha				
Regina	10	461	316	712	540	1.44
	30	490	354	895	577	1.37
	50	512	260	920	729	1.30
Glenavon	10	3508	2062	1960	542	0.86
	30	3034	2745	1966	509	1.16
	50	3400	2384	1858	539	0.99
Melville	10	2981	1234	1197	699	1.00
	30	3191	1343	1196	714	1.02
	50	3100	1108	1176	795	1.03
Medstead	10	1916	576	2052	1255	0.91
	30	1814	574	2574	1481	0.98
	50	1728	461	3062	1800	0.85
Meadow Lake	10	1162	885	409	277	1.44
	30	1152	870	428	283	1.42
	50	1103	901	478	202	1.24

*M = monocropped; **IC = intercropped

Table 3. Value of crop in different cropping systems.

Site	Cropping system	Crop value* ($/ha)
Regina	Mono lentil	193
	Mono flax	133
	Intercrop	213
Glenavon	Mono pea	499
	Mono canola	403
	Intercrop	463
Melville	Mono pea	454
	Mono yellow mustard	262
	Intercrop	343
Medstead	Mono pea	267
	Mono oats	161
	Intercrop	174
Meadow Lake	Mono pea	118
	Mono canola	92
	Intercrop	183

*Value of crops used ($/tonne): canola (209); mustard (220); oats (63); flax (158); pea (147); lentil (375).

Percent Fertilizer Use Efficiency

Fertilizer use efficiency (% FUE) was significantly affected by crop type and by fertilizer application at several sites (Tables 4 and 5). At all sites, % FUE was low, a result of high initial soil N levels (Table 1). At most sites, monocrop non-legumes had the highest % FUE, monocrop legumes the lowest % FUE, while the intercrops were intermediate. At only one site (Meadow Lake) was the intercrop % FUE significantly higher. In this case, poor growing conditions prevented the monocrop canola from exploiting the fertilizer N efficiently. At four sites, % FUE increased with higher N rates. An interaction effect was measured only at Medstead, where the % FUE of the oat crop increased significantly with added fertilizer as compared with the monocropped pea.

Table 4. Significance of F values as determined by analysis of variance for % fertilizer use efficiency (% FUE), percent N derived from N_2-fixation (% Ndfa) and kg N fixed for monocropped and intercropped systems under different levels of N applications.

Site	Factor	Total plant N	% FUE	% Ndfa	kg N fixed
Regina	CS[1]	***	***	*	***
	N rate	**	**	NS[2]	**
	CS x N	NS	NS	*	NS
Glenavon	CS	**	NS	NS	NS
	N rate	NS	***	NS	NS
	CS x N	NS	NS	NS	NS
Melville	GS	***	NS	**	NS
	N rate	*	***	***	***
	CS x N	NS	NS	NS	NS
Medstead	CS	***	***	NS	***
	N rate	NS	**	NS	NS
	CS x N	NS	*	NS	NS
Meadow Lake	CS	**	*	NS	NS
	N rate	NS	NS	NS	NS
	CS x N	NS	NS	NS	NS

[1]Cropping system, intercropped versus monocropped.

[2]Not Significant.

*,** and *** F value is significantly different at the 10, 5 and 1% level, respectively.

Table 5. Percent fertilizer use efficiency (% FUE) of the two cropping systems at the different sites as affected by N fertilizer rates.

Site	N rate	Cropping system: Monocrop legume	Monocrop non-legume	Intercrop	LSD(CS)*	LSD(N)**
		---------------- % FUE	----------------			
Regina	10	0.8	4.2	5.7	3.2	4.6
	30	1.2	12.8	7.4		
	50	3.2	10.9	12.5		
Glenavon	10	10.0	9.4	8.5	NS†	3.0
	30	14.3	12.9	13.7		
	50	11.3	12.2	11.6		
Melville	10	11.4	9.0	12.4	NS	5.0
	30	17.2	13.6	15.2		
	50	20.0	13.1	13.6		
Medstead	10	4.1	6.9	5.9	2.2	2.9
	30	3.0	13.6	7.7		
	50	3.7	12.6	7.8		
Meadow Lake	10	1.5	3.7	6.6	3.9	NS
	30	2.6	4.9	6.7		
	50	3.0	6.2	8.0		

*Least significant difference (P >0.05) between cropping systems per site.
**Least significant difference (P >0.01) between N rates per site.
†NS = Not significant.

Total Grain N

Grain N was strongly affected by cropping system (Tables 4 and 6). At Glenavon, Melville and Medstead, total grain N per hectare was highest in the legume monocrop, and intercropping grain N was next highest. At Regina and Meadow Lake, total grain N was highest in the intercrop system. At Medstead the improvement of N yield in the intercrop over the monocrop of oats may be important if this combination is used as a forage source. With the intercrop, the forage will be both high yielding, and have a higher protein content.

Nitrogen Fixation

Nitrogen fixation per hectare is reduced when a legume is intercropped as a result of non-legume competition (Table 7). In addition, N-fertilization reduces N_2-fixation in both systems.

Competition from the non-legume crop induced the legume to significantly increase the percentage of N_2 fixed in legumes at Melville and Regina (Table 7). When N fertilizer was added, there was a trend for N_2-fixation activity to be reduced more in the monocrop than in the intercrop legume. This trend was significant (P >0.10) only at Regina.

Table 6. Total N of monocropped and intercropped legumes and non-legumes as affected by N fertilizer rate.

Site	N rate (kg/ha)	Cropping system: Mono-crop legume	Inter-crop legume	Mono-crop non-legume	Inter-crop non-legume	Total IC	LSD(CS)[1]	LSD(N)
		total grain N (kg/ha)						
Regina	10	18.1	11.0	23.3	18.5	29.5	6.8	7.5
	30	20.4	12.9	29.6	21.2	34.1		
	50	19.7	9.5	32.0	26.7	36.4		
Glenavon	10	111.0	70.7	67.9	19.8	90.5	26.1	NS
	30	100.8	83.8	67.9	19.3	103.1		
	50	108.7	69.8	71.3	19.0	88.8		
Melville	10	73.6	35.9	57.8	34.0	69.9	13.9	18.6
	30	108.8	46.1	62.3	35.8	81.9		
	50	93.9	31.9	59.3	40.1	72.0		
Medstead	10	62.2	18.1	30.9	14.4	32.5	13.5	NS
	30	55.4	19.5	31.3	19.0	38.5		
	50	53.2	15.7	38.9	24.5	40.2		
Meadow Lake	10	25.2	30.5	12.8	11.6	42.1	16.1	NS
	30	33.2	29.7	14.2	11.0	40.7		
	50	25.0	30.1	15.6	8.0	38.1		

[1]See Table 5 for explanation.

Table 7. Percent N and kg N derived from N_2-fixation in monocropped and intercropped legumes.

Site	N rate (kg/ha)	Cropping system: Mono-crop legume	Inter-crop legume	LSD[1] (CS)	LSD (N)	Mono-crop legume	Inter-crop legume	LSD (CS)	LSD (N)
		% Ndfa				kg Ndfa/ha			
Regina	10	77.0	75.4	4	NS	13.6	7.9	3	4
	30	80.0	72.1			16.3	9.2		
	50	54.6	76.5			9.6	7.6		
Glenavon	10	37.5	33.1	NS	NS	40.8	27.0	NS	NS
	30	30.8	21.8			28.3	26.7		
	50	37.8	29.2			42.6	28.2		
Melville	10	27.7	33.7	14	15	19.9	12.7	NS	15
	30	27.0	46.3			29.6	21.5		
	50	4.6	24.4			4.2	8.5		
Medstead	10	79.5	86.3	NS	NS	49.8	15.8	11	NS
	30	86.8	86.7			48.0	17.0		
	50	81.8	84.2			44.0	13.1		
Meadow Lake	10	77.6	87.6	NS	NS	19.7	26.9	NS	NS
	30	82.4	81.1			26.5	24.9		
	50	74.1	64.1			17.8	21.9		

[1]See Table 5 for explanation.

Although N_2-fixation per area is reduced in an intercrop compared to a monocrop legume, the value of the N_2-fixation must be recognized. It may potentially reduce fertilizer requirements for intercropping schemes.

Conclusions

Intercropping legumes with non-legumes produced manageable crops which reduced legume lodging and improved harvest conditions. Individual yields of the legumes and non-legumes were reduced in the intercrop systems. However, LER indicated that overall yields per area could be increased by intercropping, especially when growing conditions are poor.

% FUE of the intercrops was generally less than the monocrop non-legume, but greater than for monocrop legume. At one site, under poor growing conditions, the % FUE was increased by intercropping.

Total N_2 fixed per area was reduced in an intercrop as a result of non-legume competition. However at two sites, competition from the non-legume induced the legume to significantly increase N_2-fixation activity.

This initial study of legume intercropping in Saskatchewan provides a first step in improving the agronomics of this farming system. Further investigations are required on seeding rates, fertilization, seeding dates and methods, harvest and separation methods, and weed control.

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