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On-farm testing of strip intercropping of annual crops for forage yield and quality

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Abstract

Four annual crops were used for the following 5 strip intercrop treatments over 2 years: (1) barley- field peas-oat, (2) barley-field peas-canola, (3) barley-canola-oat, (4) barley-canola, and (5) oats-canola. The crops within each strip intercrop treatment were seeded side be sided. Forage harvest for dry matter (DM) and nutritive value was done across the crops within each treatment. Also, the four crops used (barley, canola, field peas and oat) were examined for their individual DM and forage nutritive value. The forage DM was not different among strip intercrop treatments as well as among individual crops. Forage DM was generally higher in 2011 than 2010, with a difference of 2494 kg ha^{-1} between the two years for strip intercrops and 3190 kg ha^{-1} for individual crops. The forage crude protein (CP) and CP fractions, and CP yield (CPY) were not significantly different among strip intercrop treatments. For individual crops, forage CP and only two of the CP fractions showed significant differences among individual crops. The two cereals used (oat and barley) consistently showed lower CP, acid detergent insoluble nitrogen (ADICP) and digestible crude protein (DCP) values than field peas and canola for the individual crops. Inclusion of canola in some of the strip-intercrops seemed to have some positive effects on forage calcium (Ca) content compared to when canola was not included. Peas on its own had the highest Ca content of all the individual crops, but did not have any significant effect when it was present in the crop combinations.

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Introduction

In Alberta, Canada, feed accounts for 50-70% of the total cost of cow-calf production, bulk of which occurs during the winter months. Providing more tonnage per hectare of high quality forage dry would therefore optimize the productivity of the animals, improve feeding efficiency and reduce of cost of protein or energy supplementation. In Alberta, oat is commonly used for greenfeed (hay). However, it also presents some less desirable characteristics such as low protein content (6.45 to 7.84%) compared to other cereals (barley and triticale) used for other forms of livestock feeding systems such as swath grazing and silage (Omokanye *et al.*, 2013). Also, its fiber concentration may be high, with neutral detergent fiber (NDF) content varying between 56.6 and 63.0% (Omokanye *et al.*, 2013), which may limit potential forage consumption by cattle when such values exceed 55% (Van Soest, 1965). These conditions require finding alternatives to improve forage quality without sacrificing forage dry matter yield (Reta Sanchez *et al.*, 2010). Such alternatives could also reduce cost of protein and mineral supplementation in beef cattle production.

Combining annual crop species for improved forage productivity should clearly have nutritional and financial benefits in the overall livestock production. The review on intercropping of cereals and legumes for forage production by Eksandari *et al.* (2009) further identified the potential benefits of combining crops for intercropping systems to include: high productivity and profitability, improvement of soil fertility through the addition of nitrogen by fixation and excretion from the component legume, efficient use of resources, reducing damage caused by pests, diseases and weeds, reduction in accumulation of nitrate-N in soil profile, and improvement forage quality through the complementary effects of two or more crops grown simultaneously on the same area of land. Legumes are good source of protein and can be used to compensate cereal protein shortage in livestock feeds (Gebrehiwot *et al.*, 1996). Recent report in the present study area showed that cereal-field pea intercrop appeared to improve forage nutritive value (such protein, macro-mineral elements and NDF) than monoculture cereals (Omokanye, 2014).

Intercropping is growing two or more crops in the same field at the same time. Strip intercropping is growing two or more crops in the same field at the same time in wide, alternating strips. These strips are usually the width of the seeder. Strip intercropping of two or more annual crops may be a viable alternative to monoculture cropping or intercropping for better forage production and quality. Studies on narrow strip intercropping of annual crops have been carried out in different parts of the world (for instance, Cruse, 2008; Reta Sanchez *et al.*, 2010; Carr *et al.*, 2004; Ross *et al.*, 2004; Strydhorst *et al.*, 2008). But the present study was intended to look at wider strips using the full width of a particular type of a no-till crop seeder (Agrow drill). The objective of this study was to evaluate the forage yield and nutritive value potential of annual crop combinations in a strip-intercrop system using a no-till drill.

Materials and methods

Site description

The experiment was conducted on a cow-calf producer's farm in Fairview (56° 04' 53" N, 118° 26' 05" W; 670 m above sea level), in the Peace Region of Alberta, Canada. The soil at the site belongs to the dark gray-gray luvisols. Long-term average (20 years) annual precipitation including snowfall is 475.6 mm. But total rainfall received during the trial was 85.4 mm in 2010 and 273.4 mm in 2011. But rainfall received from seeding to harvest in 2010 was 85.4 mm and in 2011 it was 273.4 mm. The site was initially sown to a mixture of perennial forages consisting of alfalfa (*Medicago sativa* L.) and meadow brome grass (*Bromus riparius* Rehm.) but was later dominated mainly by quackgrass (*Elytrigia repens*) and some tall fescue (*Festuca arundinacea*) & timothy (*Phleum pratense* L.). The site was used strictly for pasture for 10 years and had declined in productivity over the years. Initial soil test from 0-15cm soil depth in 2010 before the trial commenced showed 7.84 kg N ha^{-1}, & 25.8 kg P ha^{-1}, 416 kg K ha^{-1}, and 14.6 kg S ha^{-1}, 6.0% organic matter and a pH of 6.3. Soil texture was a silt loam consisting of 20.6% sand, 57.1% silt and 22.3% clay.

Treatments design and seeding procedure

Four annual crops consisting of two cereals (barley (*Phleum pratense* L.) and oat (Avena sativa L.)), one legume (field pea, Pisum sativum L.) and an oil seed crop (canola, *Brassica napus* L.) were seeded in the following five strip intercrop treatments (Figure 1): (1) barley – field pea - oat, (2) barley – field pea – canola, (3) barley – canola – oats, (4) barley – canola, and (5) oats – canola. The experimental design was randomized complete block design of two replicates. The crops within each treatment were strip-intercropped (sequential or alternate seeding). The crops were planted in a west – east orientation in alternating strips that were 6 m wide and 213 m long in size. There were 1m gaps between treatments. Plot sizes were 18 m x 213 m (for treatments 1-3) and 12 m x 213 (for treatments 4-5). The crops were seeded at 46 kg ha^{-1} (Cowboy barley variety), 49 kg ha^{-1} (Mustang oat variety), 93 kg ha^{-1} (Eclipse field pea variety) and 2.5 kg ha^{-1} (Invigor canola variety). In the first year (2010) of the trial, the plot was sown on May 19, 15 days after the glyphosate treatment. In the second year (2011), the plot was sown on May 24. No prior spraying was needed before seeding. Seeding and fertilizer application were carried out on May 19, 2010 and May 24, 2011 with a 3-m Agrowdrill (AD 100 Series) drawn by a 108 HP John Deere tractor. Fertilizer blend (28% N:26 % P:0 % K) was applied in the seed row at 45 kg ha^{-1} to all crops. Granular inoculants at 3 kg ha^{-1} were used for field pea at seeding.

Forage sampling and feed quality analysis

At harvest, for forage yield determination, a crop plot combine harvester, which was 1.25 m wide, was used to cut the crop across the width of the different strip intercrop treatments in the north–south direction. This was done at four times at four different locations within a particular treatment. All cut materials within a particular strip intercrop treatment were raked, weighed fresh and sub-sampled, whereby the sub-sampled materials were dried for dry matter yield estimation. A subsample of approximately 2kg was randomly selected from the harvested portion of each plot and dried for dry matter (DM) yield estimation. The area harvested per plot was 90 m^2 for treatments 1-3 and 60 m^2 for treatments 4-5. Harvest was done for all crop treatment combinations on August 7, 2010 and August 18, 2011. This corresponded to the soft dough stage for the Cowboy barley, late milk/early dough for the Mustang oats and mid-pod for both Invigor canola and Eclipse field pea.

For each strip intercrop treatment, each of the crops used was hand-cut individually from two inner rows, 6 m long, for individual forage DM yield estimation. Samples of each crop, as well as those of the crop treatment combination, were analyzed for forage nutritive value. After forage sampling, the site was swathed and baled for greenfeed by the collaborating producer. Other observations included notes taken on seedling emergence/plant counts, weed counts and assessment of crop health (data not shown).

The forage nutritive values (reported on dry matter basis) were determined in a commercial laboratory using standard wet chemistry procedure. Nitrogen content was measured by Dumas Method (dried, ground tissue combusted with oxygen and analysed by thermal conductivity). For wet chemistry procedures, the dried ground tissue was digested with aqua regia on a hot block digester and the digest analysed by ICP-OES (Western States Laboratory Proficiency Testing Program, 1997). Laboratory reported values included the following: dry matter (DM), crude protein (CP), insoluble protein (IP, soluble protein (SP), acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent insoluble nitrogen or crude protein (ADIN or ADICP), (minerals (Ca, P, K Mg & Na), total digestible nutrients (TDN), net energy (NE), animal's energy needs for body maintenance (NE_M), lactation (NE_L), or body weight gain (NE_G), digestible energy (DE), metabolizable energy (ME), relative feed value (RFV).

The following variables were calculated from the measured laboratory parameters:

1. Crude protein yield (CPY, kg CP ha^{-1}) = CP x DM
2. Digestible crude protein (DCP, %DM) = 0.929CP-3.52 (Dermarguilly & Weiss, 1970)
3. Dry matter intake (DMI, % of body weight) = 120/NDF (Undersander & Moore, 2002)
4. Dry matter digestibility (DDM, %DM)=88.9-0.779ADF (Undersander & Moore, 2002)

where TDN, CP, NDF, and ADF are total digestible nutrients, crude protein, neutral detergent fibre, and acid detergent fibre, respectively.

Data analysis

The data were subjected to analysis of variance (ANOVA) as a split-plot design, with years as main plot and the strip intercrops or individual crop as sub-plots, using the GLM procedure (SAS, 1990). Where ANOVA indicated significant treatment effects, the means were separated by the least significant difference (LSD) at the 0.05 probability level. Significant differences in the text refer to $P<0.05$. For the strip intercrop treatments, of the 25 measured field and laboratory parameters, the ANOVA for only 4 parameters (CP yield, Ca, P and Mg) indicated significant treatment × year interaction. Therefore, in this paper, data were averaged across the 2 years for the strip intercrop treatments and across the 5 strip intercrop treatments for the years.

Results

Forage DM yield

The forage DM was not different ($P>0.05$) among strip intercrop treatments. But DM was higher in 2011 than 2010, with a difference of 2494 kg ha^{-1} between the two years.

Forage DM was also similar ($P>0.05$) among individual crops, but not between years. The DM was significantly ($P<0.05$) higher in 2011 (7105 kg ha^{-1}) than 2010 (3915 kg ha^{-1}).

Forage CP & CP fractions, and CP yield

The forage CP and CP fractions, and CPY were not significantly ($P>0.05$) different among strip intercrop treatments. Forage CP and DCP did not vary between the two years. Other CP fractions such as ADICP, ADIN and CPY varied significant ($P<0.05$) between years, with 2011 showing higher values than 2010. In 2011, ADICP, ADIN and CPY were respectively higher by 0.35%, 3.34% and 233 kg ha^{-1} than 2010.

For the individual crops, forage CP and two of the CP fractions (ADICP and DCP) showed significant differences among individual crops. The forage CP, ADICP and DCP values were higher for canola than other individual crops. The two cereals used (oat and barley) consistently showed lower CP, ADICP and DCP values. Except for CPY, the other CP fractions (IP, SP and ADIN) had similar values among the individual crops. The forage CPY for individual differed significantly among crops, and this varied from 436 CPY kg ha^{-1} for barley to 945 CPY kg ha^{-1} for canola. The forage CP and four of the CP fractions (IP, SP, ADICP and DCP) did not differ between 2010 and 2011. But the other two CP fractions (ADIN and CPY) showed significant ($P<0.05$) higher values in 2011 than 2010. Both ADIN and CPY were respectively higher by 1.81% and 377 kg ha^{-1} in 2011 than 2010.

Detergent fibers

The two forage detergent fibers (ADF and NDF) analysed for did not vary ($P>0.05$) among the strip intercrop treatments as well as between 2010 and 2011. Also, both ADF and NDF were similar ($P>0.05$) for among the individual crops. The forage ADF was significantly higher in 2011 than 2010. But NDF showed similar values for 2010 and 2011.

Macro-Minerals

Of the macro-minerals (Ca, P, Mg, K and Na) tested for as well as the resulting Ca:P ratios, only Mg showed some differences ($P<0.05$) among strip intercrop treatments. The significant forage Mg content was higher for barley-canola-oat & oat-canola strip intercrop treatments. Forage Ca, P and Mg all showed significant differences between 2010 and 2011. 2011 consistently had higher Ca (0.48%, P (0.29% and Mg (0.26%) contents than 2010. Other macro-minerals (K and Na) did not differ among strip intercrop treatments.

For the individual crops, forage Ca and P, and the resulting Ca:P ratios were similar among individual crops. But Mg, K and Na showed significant differences among individual crops. Peas had higher Mg values, while canola and barley respectively appeared to have higher K and Na values than other individual crops. None of the macro-minerals tested for, as well as Ca:P showed significant values in any of the two years.

Table1. Forage dry matter (DM) yield, crude protein (CP) & CP fractions (IP, SP, ADICP, ADIN, DCP & CPY), and detergent fiber (ADF & NDF) contents as influenced by strip intercrops and individual crop over a 2-year growing season.

	DM	CP	IP	SP	ADICP	ADIN	DCP	CPY	ADF	NDF
Treatment/year	(kg ha^{-1})	(%)	(%)	(%)	(%)	(%)	(%)	(kg ha^{-1})	(%)	(%)
Strip intercrop	Mean across the 2010-2011 years									
Barley-field pea-oat	5977	9.90	6.73	3.19	1.07	10.7	5.69	586	42.2	64.9
Barley-field pea-canola	6108	10.4	6.33	4.01	0.79	7.60	6.09	635	41.1	64.3
Barley-canola-oat	5802	11.9	6.20	5.71	0.90	7.54	7.54	684	39.2	61.3
Barley-canola	5638	10.4	5.77	4.60	0.94	9.14	6.10	582	40.3	61.6
Oat-canola	5167	11.0	5.94	5.07	1.08	8.58	6.71	566	40.5	63.9
$LSD_{0.05}$	*817*	*2.08*	*1.43*	*2.09*	*0.36*	*3.80*	*1.92*	*175*	*9.20*	*11.6*
Significance	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
	Mean across the strip intercrops									
2010	4491	10.4	6.26	4.16	0.78	7.06	6.16	494	39.4	63.8
2011	6985	11.0	6.12	4.87	1.13	10.4	6.69	727	41.8	62.6
$LSD_{0.05}$	518	1.31	0.91	1.32	0.22	2.40	1.21	110	5.82	7.33
Significance	***	*NS*	*NS*	*NS*	*	*	*NS*	**	*NS*	*NS*
Overall mean	*5738*	*10.7*	*6.19*	*4.51*	*0.95*	*8.71*	*6.42*	*610*	*40.6*	*63.2*
CV, %	*5.55*	*7.56*	*9.00*	*18.0*	*14.4*	*16.9*	*11.6*	*11.2*	*8.81*	*7.14*
Individual crop	Mean across the 2010-2011 years									
Oat	5116	9.85	5.72	4.12	0.84	7.02	5.62	490	35.1	58.4
Field pea	6013	14.4	7.45	6.90	1.16	7.23	9.79	855	28.3	40.5
Canola	5751	16.3	6.12	7.60	1.47	7.42	11.7	945	38.7	56.5
Barley	5161	8.45	5.03	3.42	0.77	7.67	4.32	436	30.1	54.4
$LSD_{0.05}$	*1653*	*2.41*	*2.80*	*9.22*	*0.31*	*1.42*	*2.27*	*207*	*13.7*	*25.6*
Significance	*NS*	**	*NS*	*NS*	*	*NS*	**	*	*NS*	*NS*
	Mean across the individual crop									
2010	3915	12.4	5.53	5.60	1.12	6.43	8.03	493	27.4	47.2
2011	7105	12.1	6.63	5.42	1.00	8.24	7.66	870	38.7	57.7
$LSD_{0.05}$	1168	1.71	1.97	6.52	0.22	1.01	1.57	288	9.67	18.1
Significance	***	*NS*	*NS*	*NS*	*NS*	*	*NS*	*	*	*NS*
Overall mean	*5510*	*12.2*	*6.08*	*5.51*	*1.06*	*7.33*	*7.84*	*681*	*33.0*	*52.4*
CV, %	*9.43*	*6.21*	*14.5*	*21.6*	*9.27*	*6.10*	*8.92*	*18.8*	*13.0*	*15.3*

CP- crude protein, IP-insoluble protein, SP-soluble protein, ADICP- acid detergent insoluble crude protein, ADIN-_acid detergent insoluble nitrogen, DCP- digestible crude protein, ADF- acid detergent fibre, NDF-neutral detergent fibre.

NS- not significant.

*, ** and *** refer to significant at P<0.05, P<0.01 and P<0.001, respectively.

Energy

None of the forage TDN and other forms of energy measured showed significant differences among strip intercrop treatments and between years. Similarly for individual crops, no significant differences existed among the crops and also between the two years for all measured forms of energy.

Table 2. Forage macro-mineral contents and Ca:P ration as influenced by strip intercrops and individual crop over a 2-year growing season.

	Ca	P	Ca:P	Mg	K	Na
Treatment/year	(%)	(%)	(%)	(%)	(%)	(%)
Strip intercrop	Mean across the 2010-2011 years					
Barley-field pea-oat	0.29	0.24	1.21	0.20	2.13	0.17
Barley-field pea-canola	0.35	0.22	1.53	0.17	2.09	0.20
Barley-canola-oat	0.45	0.27	1.61	0.26	2.16	0.11
Barley-canola	0.42	0.22	1.86	0.22	1.70	0.20
Oat-canola	0.44	0.24	1.89	0.26	1.83	0.15
$LSD_{0.05}$	*0.13*	*0.07*	*0.83*	*0.06*	*0.56*	*0.25*
Significance	*NS*	*NS*	*NS*	*	*NS*	*NS*
	Mean across the strip intercrops					
2010	0.29	0.19	1.54	0.18	1.95	0.11
2011	0.48	0.29	1.70	0.26	2.01	0.22
$LSD_{0.05}$	*0.07*	*0.05*	*0.53*	*0.04*	*0.35*	*0.19*
Significance	**	**	*NS*	**	*NS*	*NS*
Overall mean	*0.39*	*0.24*	*1.62*	*0.22*	*1.98*	*0.16*
CV, %	*12.7*	*12.4*	*19.9*	*11.2*	*10.9*	*21.5*
Individual crop	Mean across the 2010-2011 years					
Oat	0.30	0.20	1.60	0.16	1.65	0.36
Field pea	1.03	0.19	5.58	0.39	1.18	0.11
Canola	0.72	0.24	3.02	0.29	2.31	0.32
Barley	0.24	0.17	1.44	0.13	1.36	0.42
$LSD_{0.05}$	*0.83*	*0.06*	*4.16*	*0.15*	*0.60*	*0.12*
Significance	*NS*	*NS*	*NS*	*	*	*
	Mean across the individual crop					
2010	0.55	0.19	2.92	0.22	1.56	0.26
2011	0.59	0.21	2.91	0.25	1.68	0.34
$LSD_{0.05}$	*0.59*	*0.04*	*2.94*	*0.10*	*0.42*	*0.10*
Significance	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Overall mean	*0.57*	*0.20*	*2.91*	*0.24*	*1.62*	*0.30*
CV, %	*25.8*	*8.77*	*22.8*	*19.4*	*11.6*	*13.5*

NS- not significant.

* and ** refer to significant at P<0.05 and P<0.01, respectively.

Forage DMI, DDM & RFV

The calculated DMI, DDM and RFV were all similar among strip intercrop treatments and between years. Also for individual crops and years, DMI, DDM and RFV were not significantly different.

Discussion

The economic value of cereal forage for feeding cattle is dependent on both its yield and feeding value (i.e., chemical composition, digestibility and animal performance). The findings from the present study relating to including a legume (field peas) and a brassica (canola) in cereals based cropping systems for silage, green feed and swath grazing with focus on yield and nutrition in beef cattle production are discussed below.

Generally, forage DM yield of strip intercrops showed similar pattern to those of individual crops. The lack of any significant differences among strip intercrop treatments in spite of different crop types and combination is difficult to explain. But judging from the DM of individual crops, one can probably conclude or suggest that all the crop types will usually have similar forage yield. The observation that crops used in strip intercrops had similar DM with individual crops has also been reported by Reta Sanchez *et al.* (2010). Selecting crops to be used in such alternate cropping/strip intercrop is a critical task. Keeping in mind that strip-intercrop should be technically, socially, environmentally, and most importantly economically acceptable to beef cattle or other livestock producers. Field notes taken during crop growth showed some edge effects for strip intercrop treatments which had peas. Both barley and oats when seeded next to peas grew taller at the edges, but this did not seem to contribute any overall significant effects on DM over strip intercrop treatments, which had excluded field pea (barley-canola-oats, barley-canola, and oats-canola). A further long-term study than 2-year reported here is needed for ideal crop types, crop combination and seeding dates (same or different for different crops). Such studies should help give an insight into agronomic compatibility and crop complimentary characteristics. The higher DM obtained in 2011 than 2010 for both strip intercrops and individual crops were a result of the different amounts of rainfall received during the growing season in each year. 2010 was drier than 2011 by approximately 31 % during the growing season.

Table 3. Total digestible nutrients (TDN, %) and other forms of energy (ME, DE, NE_L, NE_M & NE_G, Mcal kg^{-1} as influenced by strip intercrops and individual crop over a 2-year growing season.

Treatment/year	TDN	ME	DE	NE_L	NE_M	NE_G
Strip intercrop	Mean across the 2010-2011 years					
Barley-field pea-oat	57.0	2.06	2.51	1.28	1.21	0.65
Barley-field pea-canola	57.6	2.08	2.54	1.29	1.23	0.66
Barley-canola-oat	59.1	2.12	2.58	1.32	1.26	0.69
Barley-canola	58.1	2.10	2.56	1.30	1.24	0.67
Oat-canola	58.0	2.09	2.55	1.30	1.24	0.67
LSD	*5.05*	*0.16*	*0.21*	*0.51*	*0.15*	*0.14*
Significance	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
	Mean across the strip intercrops					
2010	58.6	2.11	2.57	1.31	1.26	0.69
2011	57.3	2.07	2.52	1.28	1.21	0.65
LSD	3.20	0.10	0.13	0.45	0.10	0.09
Significance	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Overall mean	*57.9*	*2.09*	*2.55*	*1.30*	*1.24*	*0.67*
CV, %	*3.92*	*3.02*	*3.15*	*5.11*	*4.77*	*8.22*
Individual crop	Mean across the 2010-2011 years					
Oat	63.5	2.42	3.50	1.42	1.40	0.81
Field pea	66.1	2.52	2.96	1.51	1.55	0.95
Canola	58.0	2.11	2.56	1.24	1.21	0.63
Barley	63.0	2.25	3.59	1.41	1.39	0.81
LSD	*14.2*	*0.82*	*2.27*	*0.46*	*0.53*	*0.50*
Significance	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
	Mean across the individual crop					
2010	66.5	2.52	3.72	1.47	1.50	0.90
2011	58.8	2.12	2.59	1.32	1.27	0.70
LSD	*10.0*	*0.58*	*1.61*	*0.32*	*0.38*	*0.35*
Significance	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*
Overall mean	*62.7*	*2.32*	*3.15*	*1.39*	*1.38*	*0.80*
CV, %	*7.11*	*11.1*	*22.6*	*10.3*	*12.12*	*19.7*

NS- not significant, TDN-total digestible nutrients, ME-metabolizable energy,

DE- digestible energy, NE_L-net energy for lactation, NE_M-net energy for maintenance, NE_G- net energy for gain.

NS- not significant.

Forage nutritive value can be expected to vary depending on crop variety, agronomic practices, environmental conditions during growth and the proportion of legume in the intercrop mixtures. An annual crop with adequate amount of energy, CP and CPY in forage would be a valuable feed for beef cattle production. Forage cereal crops such as barley and oat ensile well and their value as green feed, silage or for swath grazing has also been reported (Baron *et al.*, 2012; Entz *et al.*, 2002; McCartney *et al.*, 2004; McCartney *et al.*, 2008).

Table 4. Dry matter intake (DMI), digestible dry matter (DDM) and relative feed value (RFV) as influenced by strip intercrops and individual crop over a 2-year growing season.

	DMI	DDM	RFV
Treatment/year	(%)	(Mcal kg-1)	
Strip intercrop	Mean across the 2010-2011 years		
Barley-field pea-oat	1.86	56.1	81
Barley-field pea-canola	1.87	56.9	83
Barley-canola-oat	1.96	58.4	89
Barley-canola	1.97	57.6	88
Oat-canola	1.84	57.5	82
$LSD_{0.05}$	*0.37*	*7.15*	*22*
Significance	*NS*	*NS*	*NS*
	Mean across the strip intercrops		
2010	1.89	58.2	85
2011	1.91	56.4	84
$LSD_{0.05}$	*0.23*	*4.52*	*18*
Significance	*NS*	*NS*	*NS*
Overall mean	*1.88*	*57.3*	*84*
CV, %	*7.56*	*4.86*	*12.3*
Individual crop	Mean across the 2010-2011 years		
Oat	2.15	61.5	105
Field pea	3.02	66.9	158
Canola	2.13	58.8	97
Barley	2.24	65.5	115
$LSD_{0.05}$	*1.03*	*10.6*	*70*
Significance	*NS*	*NS*	*NS*
	Mean across the individual crop		
2010	2.63	67.6	139
2011	2.14	58.8	98
$LSD_{0.05}$	*0.73*	*7.51*	*49*
Significance	*NS*	*	*NS*
Overall mean	*2.38*	*63.2*	*118*
CV, %	*13.6*	*5.29*	*18.5*

DMI-dry matter intake, DDM- digestible dry matter, RFV-relative feed value.

*refers to significant at $P<0.05$.

Considering the protein requirements for beef cows from the second trimester to post calving (NRC, 2000), all strip intercrops examined in the present study met the recommended values of 7-9% CP requirement for pregnant beef cows. Also, all strip intercrop treatments were within the 10-11% CP recommended after calving. For the individual crops, oat, field peas and canola field all met the 7-11% CP of a dry gestating and lactating cow. And both field peas and canola far exceeded these requirements, while barley was only able to have sufficient amount of CP needed by a dry gestating cow in the second trimester stage.

The CPY, which is expressed in kg ha^{-1}, is important to beef cattle producers for determination of winter feed value and in determining supplemental protein feed. Knowledge of this value may be beneficial in the reduction of winter feed costs (USDA–NRCS, 2008).

Though all strip intercrop treatments as well as individual crops in the present study did not have significant differences in CPY (566-684 kg CPY ha^{-1}). As expected, CPY was higher for both field peas and canola, which was as a result of their significantly higher CP contents. The CPY in 2011 was more than 2010 by 233 kg CPY ha^{-1} for the strip intercrops crop combinations and by 377 kg CPY ha^{-1} for the individual crops. The low CPY in 2010 was a result of lower DM following low rainfall for that year.

Table 5. Suggested nutrients requirements for beef cows (NRC 2000).

	Requirement		
Nutrient	Growing & finishing calves	Dry Gestating cows (544 kg)	Lactating cows (544 kg)
CP, %	12-13	7-9*	10-12
Ca, %	0.31	0.18	0.42
P, %	0.21	0.16	0.26
Mg, %	0.1	0.12	0.2
K, %	0.6	0.6	0.7
Na, %	0.06-0.08	0.06-0.08	0.1
NE_M, MCal kg^{-1}	1.08-2.29	0.97-1.10	1.19-1.28
NE_G, MCal kg^{-1}	0.53-1.37	NA[Y]	NA
TDN, %	65-70[W]	49-54[Z]	57-62

*, 7% for middle 1/3 of pregnancy, 9% for late 1/3 of pregnancy

[Z], 49% for middle 1/3 of pregnancy, 54% for late 1/3 of pregnancy

[Y], NA, not available

[W], 6-10 months old growing bulls.

The major minerals in cattle nutrition include calcium (Ca), phosphorus (P), sodium (Na), magnesium (Mg) and potassium (K) that have been tested for in the present study. They are required at comparatively high levels in diet as percent or grams per day. The strip intercrops as well as individual crops evaluated met the Ca and P requirements of a dry gestating beef cow (NRC, 2000 – see Table 5). For the suggested Ca amount needed by a lactating cow, 3 of the strip intercrops (barley-canola-oat, barley-canola and oat-canola), and field peas and canola for the individual crops appeared to have met the suggested 0.42% Ca. Inclusion of canola in some of the strip-intercrop crop combinations (treatments 2-4) seemed to have some positive effects on forage calcium (Ca) content compared to when canola was not included (treatment 1). Peas on its own had the highest Ca content of all the individual crops, but did not have any significant effect when it was present in the crop combinations (treatments 1-2).

Only barley-canola-barley had sufficient P needed by a lactating beef cow. None of the individual crops met the P requirement of a lactating beef cow. Forage phosphorus (P) content on the other hand, seemed to be slightly favored by the inclusion of oats in the crop combinations of treatments 1, 3 & 5. Both the K and Mg contents in all the varieties were within the recommended levels for pregnant and nursing cows (except for barley for Mg), and generally within the maximum tolerable concentrations of 3.0% for K and 0.4% for Mg (NRC, 2000). All strip intercrops and individual crops exceeded the recommended values of 0.06-0.08% Na during gestation period of beef cows and 0.10% Na in their early lactating stage (NRC, 2000). The Ca:P ratio for a mature beef cow should be within the range of 2:1 and 7:1 (Alberta Agriculture and Rural Development, 2004), assuming actual required grams of each are adequate. But in the present study, Ca:P was generally low (1.23:1 to 1.96:1) for all strip-intercrop crops combinations. For the individual crops, peas and canola, respectively, had 5.58:1 and 3.02:1 Ca:P.

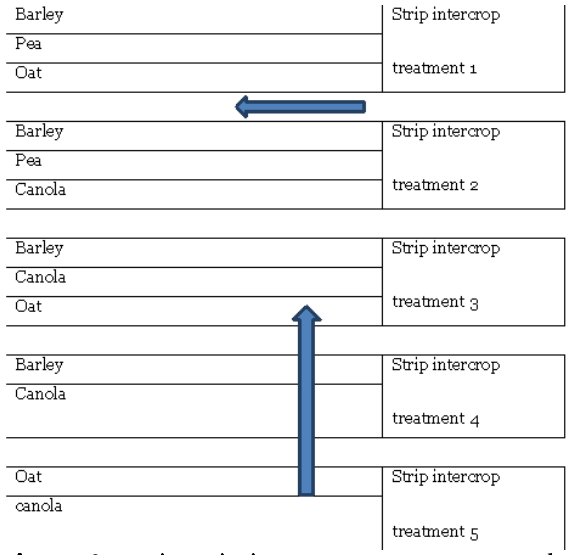

Fig. 1. Crops in strip intercrop treatments 1-5. The horizontal arrow shows the direction of seeding. The vertical arrow shows the direction of forage harvest across the strips of crops within a particular treatment, which was done with the objective of creating forage blends for each treatment.

Protein is a building block and energy gives the ability to use the building blocks for growth and other productive purposes. Energy is probably the most important nutritional consideration in beef cattle production. A range of 55-65% TDN and 0.90-1.32 Mcal kg.$^{-1}$ NE_M have been recommended for beef cows (NRC, 2000). The NE_M is an estimate of the energy value of a feed used to keep an animal in energy equilibrium, i.e., neither gaining nor losing weight. Generally, all strip intercrops and individual crops examined had sufficient amounts of TDN and NE_M needed for mature beef cattle during the mid- and late-pregnancy stages and and nursing of calves (NRC 2000, Table 5). The ability of tested crops to be able to meet beef cows energy requirements is important to cow-calf producers, particular during winter in Canada, as this will mean a substantial savings in feed energy costs (Gill *et al.*, 2013).

Relative feed value (RFV) provides an indication of the digestibility and how much forage an animal can eat. It's an easy method of ranking a forage and more accurate than using protein content alone as a quality indicator. According to a quick guide to forage allocation by cattle class (Schroeder, 1996), all strip intercrops fell short of the suggested RFVs for beef cows (90-115 RFV), but all individual crops were generally within these ranges. Only 2 of the individual crops (field peas and barley) were within the ranges suggested for replacement heifers (115-135 RFV) and none of the strip intercrops had sufficient RFV for replacement heifers. Generally, none of the strip intercrops and individual crops were within the ranges suggested for back grounding stockers (125-150 RFV).

Conclusion

When strip-intercrop crop combinations were compared with individual crop (monoculture) systems, there were no apparent forage yield advantages of the strips, but the resulting forage quality indicates, that in most cases, it was significantly improved by the strip-intercropping systems compared to the barley and oat monoculture system. Strip-intercropping with common annual crops is feasible and should produce quality feed for a greenfeed system. Producers would have to make sure that strips are of equal width to accommodate this rotation scheme, and also use a strip width compatible with their seeding equipment. Different varieties of the component crops and other agronomic practices, such as changing varying fertility and seeding rates in a strip-intercropping system, could be tested to see if they have the ability to improve forage yield compared to a monoculture system.

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References

Agriculture and Rural Development. 2004. Beef Ration Rules of Thumb. Agdex 420/52-4. Retrieved from: [March, 2013].

Baron VS, Aasen A, Oba M, Dick AC, Salmon DF, Basarab JA, Stevenson CF. 2012. Swath-Grazing Potential for Small-Grain Species with a Delayed Planting Date. Agronomy Journal **104,** 393-404.

Carr PM, Horsley RD, Poland WW. 2004. Barley, Oat, and Cereal–Pea Mixtures as Dryland Forages in the Northern Great Plains. Agron. J. **96**, 677-684.

Cruse RM. 2008. Strip intercropping: ACRP conversion option. Conservation reserve program: issues and options. CRP-17. Reviewed June 2008. Iowa State University, University Extension, Ames, Iowa, USA.

Demarguilly C, Weiss P. 1970. Tableau de la valeur alimentaire des fourrages. Paris, INRA.

Entz MH, Baron VS, Carr P, McCaughey PM, Smith SR, Cash D. 2002. Potential of forages to diversify Canadian and American northern great plain cropping systems. Agronomy Journal **94,** 240–250.

Eskandari H, Ghanbari A, Javanmard A. *2009.* Intercropping of Cereals and Legumes for Forage Production. Notulae Scientia Biologicae **1,** 7-13.

Gebrehiwot L, McGrow RL, Assefu, G. *1996.* Forage yield and quality profile of three annual legumes in the tropical highlands of Ethiopia. Journal of Agriculture **73,** 83-98.

Gill KS, Omokanye AT, Pettyjohn JP, Elsen M. 2013 . Agronomic performance and beef cattle nutrition suitability of forage oat varieties grown in the Peace Region of Alberta, Canada. Journal of Agricultural Science **5,** 128-145.

McCartney D, Basarab JA, Okine EK, Baron VS, Depalme AJ. 2004. Alternative fall and winter feeding systems for spring calving beef cows. Canadian Journal of Animal Science **84,** 511–522.

McCartney D, Fraser J, Ohama A. 2008. Annual cool season crops for grazing by beef cattle. A Canadian review. Canadian Journal of Animal Science **88,** 517-533.

Omokanye AT. 2014. Peace Region Forage Industry. 2014 Peace Region Forage Agronomy Update (sponsored by the Peace Region Forage Seed Association), Rycroft, Alberta, Canada, Tuesday, March 25th, 2014.

Reta Sanchez DG, Espinosa Silvia JT, Palomo Gil A, Serrato Corona JS, Cueto Wong JA, Gaytan Mascorro A. 2010 Forage yield and quality of intercropped corn and soybean in narrow strips. Span J Agric Res **8,** 713–721

Ross SM, King JR, O'Donovan JT, Spaner D. 2004. Intercropping Berseem Clover with Barley and Oat Cultivars for Forage. Agron. J. **96,** 1719-1729.

SAS Institute, Inc. 1990. *SAS user's guide: Statistics*, Version 6. 4th ed. SAS Institute Inc., Cary, NC.

Schroeder JW. 1996. *Quality Forage for Maximum Production and Return.* North Dakota State University. Retrieved from: [March, 2013]. as1117w.

Strydhorst SM, King JR, Lopetinsky KJ, Harker KN. 2008. Forage Potential of Intercropping Barley with Faba Bean, Lupin, or Field Pea. Agron. J. **100**:182-190.

Undersander D, Moore JE. 2002. *Relative forage quality (RFQ) indexing legumes and grasses for forage quality.* University of Wisconsin Extension. Retrievedfrom: [February, 2013].

USDA–NRCS (Natural Resources Conservation Service). 2008. *Total Digestible Nutrients and Protein per Acre Produced by Five Indiangrass Cultivars*. Booneville Plant Materials Center, Plant Materials Technical Report CP 512 – Pasture & Hay Planting. Retrieved from: [February, 2013].

Van Soest PJ. 1965. Symposium on factors influencing the voluntary intake of herbage by ruminants: voluntary intake in relation to chemical composition and digestibility. J. Anim. Sci **24,** 834-843.

Western States Laboratory Proficiency Testing Program. 1997. *Soil and Plant Analysis Methods*, version 4 (Inductivity Coupled Plasma Emission Spectroscopy – Method 6001 EPA).