Project Identification

1. **Project Title:** Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation.

2. **Project Number:** 20160365

3. **Producer Group Sponsoring the Project:** Saskatchewan Forage Seed Development Commissions (SFSDC)

4. **Project Location(s):**
Northeast Agriculture Research Foundation (NARF)
Agriculture & Agri-Food Canada Research Farm
Box 1240
Melfort, SK S0E 1A0

5. **Project start and end dates (month & year):** March 2, 2017 to March 31, 2020

6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project objectives:**
   - To demonstrate the effect a cover crop can have on Red and Alsike clover grown for seed production;
   - To demonstrate Odyssey and Viper ADV herbicides for weed control in Red and Alsike clover;
   - To demonstrate the effect short-term legume seed crop(s) have on reducing the nitrogen (N) fertilizer requirement for wheat in crop rotations; and
   - To demonstrate direct seeding of wheat into Red and Alsike clover terminated the previous fall by herbicide.

8. **Project Rationale:**
Northeast Saskatchewan is the centre of forage seed production in the province. In Saskatchewan, Red clover is the 2nd most commonly grown forage seed crop following alfalfa. Alsike clover is also commonly grown for seed in the area. These clover crops, when harvested for seed, fit well into crop rotations. Both clovers are often seeded with a cover crop in the seedling year and harvested for seed in the second year. The cover crop provides multiple opportunities such as a sellable commodity in year 1, increased weed control, among many other benefits. Weed control is an important management practice in clover crops grown for seed, and thus this demonstration will also highlight newly registered herbicide options. Wheat will be direct seeded into the terminated clover

stubble in year three to take advantage of the increased soil nitrogen provided by the clovers (forage legumes) and annual legume crop. The contribution of soil nitrogen from Red and Alsike clover has not been measured or demonstrated with these two forage legumes in the area recently. Note: in year 3 (2019/2020) the project was fully funded by the SFSDC.

Methodology and Results

1. **Methodology:**

In the spring of 2017, an area of wheat stubble was selected at the Agriculture and Agri-Food Canada (AAFC) Research Farm near Melfort, SK, which is located in black (clay) soil zone. Soil samples from an adjacent area were taken and submitted for analysis of available N, P_2O_5, K, S, and Zn, as well as soil organic matter. A pre-seed weed control application of glyphosate (Roundup Ultra II) was made on May 30, 2017. Five different crop rotations were evaluated as outlined in Table 1. Treatments were selected to evaluate effects of growing Red or Alsike clovers either alone or with a cover crop of canola in year one, and compared to canola alone (monocropped). In year 2, the clover crops were harvest for seed and compared to field peas. In year 3, the clovers were terminated and all five crop rotations were seeded to Spring wheat. In an effort to identify the nitrogen benefit from the clover seed crops and field peas, the annual crop phase (Treatment 5) was sub-divided into 5 five nitrogen rates (0, 40, 80, 120 and 160 kg/ha of fertilizer N) in year 3.

The plot size was 8m x 7m, organized in a randomized complete block design (RCBD), with 4 replications.

2017: All crops were seeded on June 6, 2017 with a 3.75 m wide Conserva-Pak air drill seeding on a 9-inch row spacing to a seeding depth of ¼ to ½ inch. To accommodate the five different nitrogen rate treatments in 2019, two passes of the Conserva-Pak air drill were required for each plot. When the clovers and cover crop were seeded in the same treatment, canola was seeded in the side-band and the clovers were seeded through the seed boot, into alternate 18-inch rows. When crops were seeded alone, plots were seeded in 9-inch rows. The canola (Clearfield variety 46H75) was planted at 5.6 kg/ha (5 lb/ac), along with Red clover (variety Altaswede) at 2.8 kg/ha (2.5 lb/ac) and Alsike clover (variety Dawn) at 2.8 kg/ha (2.5 lb/ac). All plots seeded to canola received fertilizer N at 146 lb/ac as urea (46-0-0) side-banded, plus P_2O_5 at 34.5 lb/ac as 11-52-0. All plots seeded to Red or Alsike clover alone received 13.3 lb/ac of P_2O_5 as 11-52-0. For weed control in 2017, plots seeded to clover alone were mowed (above the crop canopy) in July and August, while those with canola did not receive an in-crop herbicide application(s). Application of Odyssey in-crop herbicide was intended, however, weather conditions did not allow for timely application.

Canola yield was measured by harvesting 5 rows from each plot containing canola, with a Wintersteiger plot combine on September 25, 2017. Following harvest, the canola seed was dried to 10 per cent moisture content then cleaned and weighed. The canola yield data was analysed as a RCBD.

Table 1. Crop rotations and nitrogen rate specifications for 9 treatments planted at Melfort in 2017, 2018 and 2019.

Rotation	2017	2018	2019 (kg/ha)
1	Red clover / Clearfield canola	Red clover seed	Wheat
2	Red clover	Red clover seed	Wheat
3	Alsike clover / Clearfield canola	Alsike clover seed	Wheat
4	Alsike Clover	Alsike clover seed	Wheat
5	Clearfield canola	Peas	Wheat-0N
6	Clearfield canola	Peas	Wheat-40N
7	Clearfield canola	Peas	Wheat-80N
8	Clearfield canola	Peas	Wheat-120N
9	Clearfield canola	Peas	Wheat-160N

2018: Prior to seeding in the spring of 2018, soil samples were collected for residual soil nutrient levels (Table 2). The canola alone treatment was replaced by pea (variety AC Carver) at 90 plants/m^2 for comparison between forage and grain legume residual N contributions. Pea plots received 6 kg/ac (5.34 lb/ac) of Cell-Tech Pea inoculant plus 70 lb/ac of 11-51-0 fertilizer, while the clover crops were unfertilized in 2018.

On May 29, 2018, when the clover was 2.5 to 7.5 cm (1 to 3 inches) tall, plant density was calculated using the line-transect method. This accounts for the number of 10 cm with at least one plant present along 1 meter of crop row and then was converted to a percent scale.

In 2018 all treatments received in-crop herbicide applications of Viper ADV at 400 mL/ac on June 6, 2018 and Assure II at 300 mL/ac on June 25, 2018.

On July 26, 2018 flower petals were collected from individual clover plots and submitted to Quantum Biosciences for sclerotinia detection to determine if under seeding clovers to canola increases the risk of disease, most notably sclerotinia.

On August 30, 2018 Reglone Ion at 1.09 L/ac was applied to the entire trial area to desiccate the crops prior to harvest. Due to differing dry down times, combining with a Wintersteiger plot combine took place on different dates for each crop. The peas were harvested on September 4, 2018, Alsike clover on September 6, 2018, and Red clover on October 5, 2018. A cleaned composite sample of clover seed from each treatment was submitted for purity and germination quality analysis. Due to the early winter, the clover crops were not terminated with glyphosate as planned and were scheduled for termination in the spring of 2019.

Table 2: Residual soil nutrient levels (0-12”) found in Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation in Melfort 2018 & 2019.

		Residual Soil Levels			
Year	***Treatment***	***Nitrogen (lb/ac)***	***P_2O_5 (ppm)***	***K_2O (ppm)***	***Sulphur (lb/ac)***
2018	1	69	5	397	50
	2	43	5	441	24
	3	67	5	441	30
	4	51	6	416	36
	5	50	5	366	24
2019	1	39	6	391	46
	2	45	6	369	38
	3	46	4	418	46
	4	45	3	337	46
	5	49	6	398	32

2019: In 2019, all treatments were soil sampled for residual nutrient levels prior to seeding, with treatments 5-9 sampled as one treatment (Table 2). On May 30, 2019 CDC Landmark was seeded at 250 seeds/m^2 into Red clover, Alsike clover, and pea stubble depending on treatment number. Seeding was completed with a ConservaPak air drill on 9-inch row spacing, at a 1-1.5-inch depth. Fertilizer was applied based on soil nutrient residual levels and a 55 bu/ac wheat yield target for treatments 1-4. In treatment 5, all nitrogen was applied based on treatment indications of 0, 40, 80, 120 and 160kg/ha of N. All nitrogen was side-band as urea (46-0-0) at seeding. Phosphorus was seed-placed at seeding at 39 lb/ac of P_2O_5 and was applied as 11-52-0 for all 9 treatments. No additional potassium or sulphur fertilizers was applied.

Glyphosate at 1L/ac was applied to terminate the clover crops and as a pre-emergent herbicide on May 17th. Unfortunately, clover termination was not fully accomplished by the glyphosate application although the in-crop herbicide application resulted in complete termination. In-crop herbicide application was completed using Prestige XC (0.13L/ac of A and 0.6L/ac of B) on July 4th. No fungicides, insecticides, or desiccants were applied to this trial.

Data collection consisted of plant density, maturity date, lodging, yield, and protein. All plots were harvested on October 3rd, with various crop rows collected depending on treatment type.

Results:

Environmental Conditions:

Weather conditions were quite variable throughout the 3-year duration of this trial (Table 3). 2017 had a much warmer growing season in comparison to 2018 and 2019. May and June 2017 were comparable to the long-term average in temperature and precipitation, leading to good crop emergence and only minor delays in seeding. July, August and September all had higher average temperatures than the long-term average, contributing to the increase in average growing season temperature. Adequate spring rainfall and drier conditions within the last two months of the season, provided optimal early growth and an early harvest in 2017. May and June of 2018 were slightly warmer than the long-term average, but rainfall was quite comparable to the long-term average. This again led to good crop emergence and only minimal delays in seeding. July and August were both warmer than the average with rainfall that led to good crop maturity, however a wet and cold September caused less than optimal harvest conditions. Regardless of the delay, harvesting was completed before the snow set in. In 2019 a cold, dry May led to no delays in seeding, however crop emergence was very variable, as the first substantial rainfall did not occur until mid-June. This led to variable crop staging and crop stress in the early parts of the season. An increase in rainfall during June helped crop growth, but slightly cooler temperatures in July and August prolonged crop maturity, causing a late harvest. In addition to the cool temperatures, precipitation was slightly greater in September which led to wet field conditions that contributed to a later harvest. Overall, 2019 was a challenging growing season, however all plots were harvested prior to snowfall.

Table 3: Mean temperatures and precipitation collected from the Environment Canada Weather Station at Melfort, SK., May through September of 2017, 2018 and 2019.

	May	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Average/Total**
	--- Temperature (°C) ---						
2017	10.8	15.2	18.7	17.2	12.5	4.3	13.1
2018	13.9	16.7	17.5	15.9	6.9	0.9	12.0
2019	8.8	15.3	16.9	14.9	11.2	1.0	11.4
Long-Term[x]	10.7	15.9	17.5	16.8	10.8	3.3	12.5
	--- Precipitation (mm) ---						
2017	46.4	44.1	33.3	3.1	13.2	43.5	183.6
2018	38.5	46.6	69.5	43.2	42.0	8.9	248.7
2019	18.8	87.4	72.7	30.7	43.0	11.9	264.5
Long-Term[x]	42.9	54.3	76.7	52.4	38.7	27.9	292.9

[x] Long-Term Climate Normal from Melfort Environment Canada Weather Station (1981-2010)

Residual Nutrient Levels:

Residual soil nutrient levels in 2018 and 2019 were relatively similar between treatments (Table 2). However, in 2018, both treatments that were seeded with a canola cover crop had slightly increased residual nitrogen levels. This result was not anticipated as one would expect residuals to be similar or less than the mono-cropped clover treatments. This suggests that the nitrogen applied for successful canola production was greater than required. In 2019, the only treatment that had a slight reduction in residual N was the Red clover with canola. This effect was not anticipated and is likely due to soil sampling error (ie. Randomly picked an area, lower in soil N then another area in the same plot). One would expect it to be closer to the Red clover mono-crop. Overall, these crop rotations had the greatest effects on soil residual N, while there were minimal effects on residual P, K, and S.

Plant Densities:

In 2018 the line-transect method was used to determine crop establishment in Red and Alsike clover grown with or without the use of canola as a cover crop in the previous year. Red and Alsike clover grown without a cover crop demonstrated significantly higher plant stands in 2018 (p<0.0003**; Figure 1; Table 4). Alsike clover did tend to show higher average plant establishment with a cover crop as compared to Red clover with a cover crop; However, both demonstrated less establishment as compared to their monocrop equivalents (Figure 2).

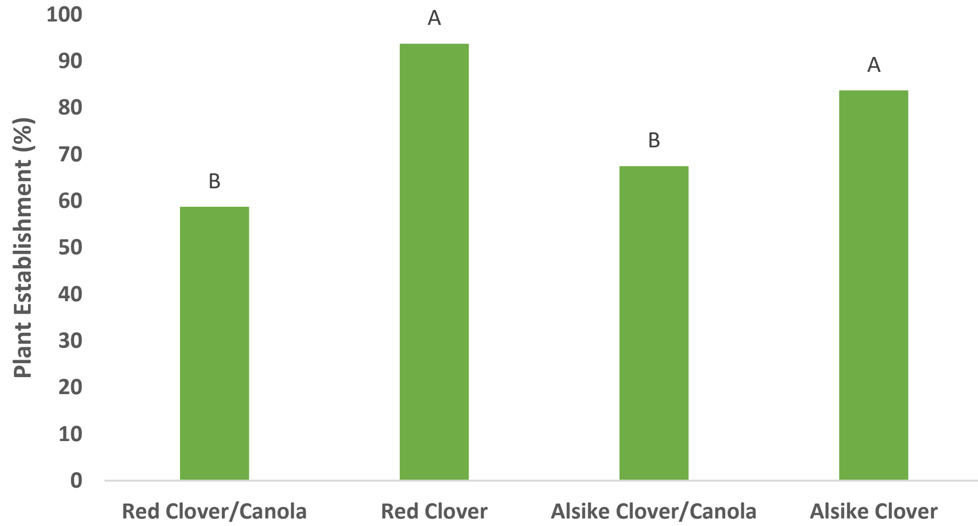

Figure 1: Plant densities of Red and Alsike clover in year 2 of Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation in Melfort, SK 2018.

Figure 2: Alsike Clover grown alone (left) vs. with canola cover crop on June 14th, 2018. *Photo Credit: Ray McVickar*

Table 4: Statistical analysis and means for plant establishment and populations in Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation in 2017, 2018, and 2019 in Melfort, SK.

	2018[yz]	**2019[yz]**
p-value	0.0003**	0.0521
Grand Mean	7.59	196.7
CV	9.33	16.14
Treatment		
R. clover w/canola	5.9b	208.9a
R. clover	9.4a	142.7b
A. clover w/canola	6.8b	211.1a
A. clover	8.4a	174.4ab
canola/pea/wheat - 0 N	NA	194.7a
canola/pea/wheat - 40 N		197.9a
canola/pea/wheat - 80 N		211.1a
canola/pea/wheat - 120 N		209.4a
canola/pea/wheat - 180 N		220.4a

[y] * significant; *** highly significant
[z] Values with the same letter are statistically similar

In 2019, wheat plant populations were determined by counting the number of plants in 4 1-meter rows per plot, and averaging to determine plants/m^2. Plant populations were very comparable across all treatment types and no significant difference was found between treatments ($p<0.0521$; Figure 3 & Table 4). This suggests that stubble type, did not greatly impede the successful germination and establishment of the clovers. However, as clover seeds are small, trash management within the stubble canopy should be taken into consideration. The most notable differences in wheat plant populations were when Red and Alsike clover were grown without the use of canola, and more so with Red clover alone. This finding is likely due to clover re-growth in the spring of 2019. The regrowth was not suppressed until an in-crop herbicide application was made, and thus the clover re-growth was able to compete with the wheat seedlings at the beginning of the season.

Figure 3: Wheat plant population in year 3 of Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation in Melfort, SK 2019.

Sclerotinia Petal Testing:

On July 26th, 2018 flower petals were collected from individual clover plots and submitted for sclerotinia detection. This was done to assess if the risk of sclerotinia would increase in year 2, given that two sclerotinia susceptible crops were grown together in year 1, and another susceptible crop was grown in year 2. There was considerable variability between the individual plots of each treatment, which led to a high error cv (41.5; Table 5). Therefore, petal collection and testing may not be the best method to test the associated risk with growing multiple sclerotinia susceptible crops. However, the results do suggest that companion cropping canola and clover did not significantly increase the risk of sclerotinia in the year of seed production (p=0.2902) (Table 5). Both Red clover treatments were classified as having medium risk. The Alsike with canola treatment was classified as low risk, which was only numerically lower than Alsike alone which also has low risk. However, due to the variability between treatments these risk results may vary from year to year.

Table 5: Statistical analysis and means for sclerotinia petal testing in Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation in 2018 in Melfort, SK.

	Petal Testing
p-value	0.2902
Grand Mean	29.7
CV	41.5
Treatment	
R. clover w/canola	34.4a
R. clover	34.4a
A. clover w/canola	18.8a
A. clover	31.3a
canola/pea/wheat	NA

[y] * significant; *** highly significant

[z] Values with the same letter are statistically similar

Maturity:

Maturity was only accounted for in the final year of the study. Maturity was considered on the day in which the majority of wheat kernels per plot had reached the hard dough stage (Zadoks 87). Maturity was found to be significantly different amongst the different treatments ($p<0.0359$*) (Table 4). As expected, there were no significant differences in maturity attributed to the two different clovers (Figure 4). Also, as expected, nitrogen application numerically delayed days to maturity; However, this delay was not always statistically significant. Applying 160 kg N/ha resulted in a 9-day delay in maturity, which can be a significant concern in some growing seasons. When 40, 80, and 120 kg N/ha were applied, maturity was similar to the 0 kg N/ha treatment. As well, 40, 80, and 160 kg N/ha also had statistically similar maturities. Therefore, increasing nitrogen rate can cause significant delays in maturity, although the magnitude and significance of this delay is dependent on other environmental and agronomic factors.

Table 6: Statistical Analysis and Means for maturity in Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation in 2019 in Melfort, SK.

	2019[yz]
p-value	0.0359*
Grand Mean	122.4
CV	2.89
Treatment	
R. clover w/canola	123.5 abc
R. clover	126.0 ab
A. clover w/canola	118.5 c
A. clover	121.0 bc
canola/pea/wheat - 0 N	118.5 c
canola/pea/wheat - 40 N	123.5 abc
canola/pea/wheat - 80 N	123.5 abc
canola/pea/wheat - 120 N	121.0 bc
canola/pea/wheat - 180 N	127.4 a

[y] * significant; *** highly significant
[z] Values with the same letter are statistically similar

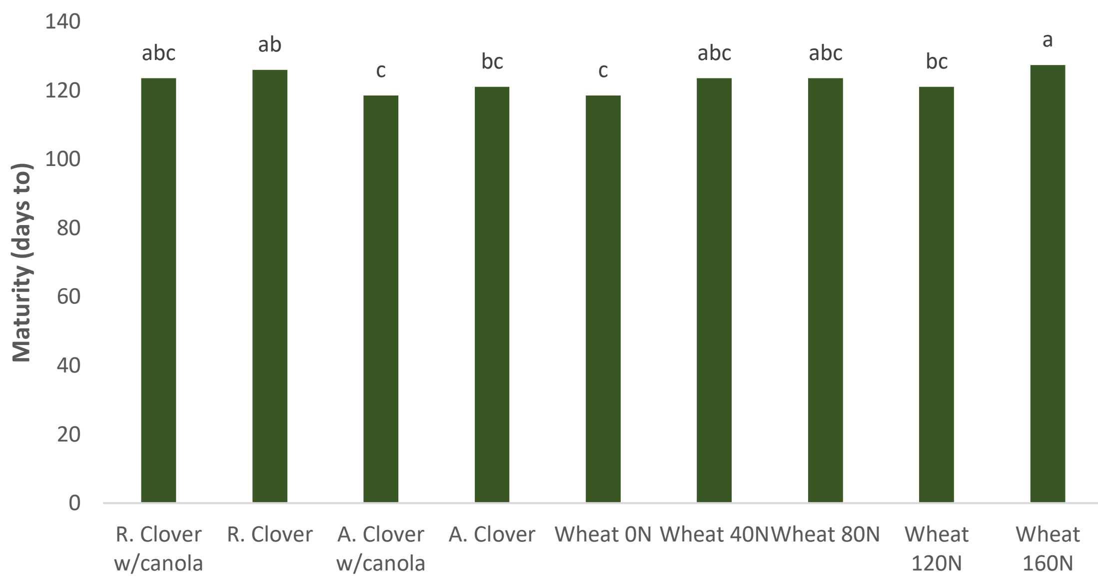

Figure 4: Wheat maturity in year 3 of Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation in Melfort, SK 2019.

Yield:

In all three years of this trial, yields were determined by drying, cleaning, and weighing all harvested samples and then correcting for a consistent moisture. In 2017, canola yields were not found to be significantly different across treatments (Table 7). As expected, there were no significant differences in canola yield, whether it had Red or Alsike clover under seeded. Furthermore, canola yields were similar to the monocropped canola. This suggests that growing canola as a cash crop option in the first year of clover establishment is a viable option.

Table 7: Statistical analysis and means for yield in Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation in 2017, 2018, and 2019, in Melfort, SK. Yield values for forages (alsike and red clover) are in lbs/ac and all grain crops (canola, peas, wheat) are in bu/ac.

	2017	**2018**	**2019**
p-value	0.4117	<0.0001***	0.0804
Grand Mean	49.1	559.1	58.7
CV	13.4	19.7	14.6
Treatment			
R. clover w/canola	27.6 a	547.4 b	51.1 bc
R. clover	NA	949.3 a	47.5 c
A. clover w/canola	29.0 a	473.0bc	59.1 abc
A. clover	NA	300.0 c	62.4 ab
canola/pea/wheat - 0 N	29.9 a	69.8	62.3 ab
canola/pea/wheat - 40 N	NA	NA	63.5 ab
canola/pea/wheat - 80 N	NA	NA	56.1 abc
canola/pea/wheat - 120 N	NA	NA	59.3abc
canola/pea/wheat - 180 N	NA	NA	66.8 a

[y] * significant; *** highly significant
[z] Values with the same letter are statistically similar

In 2018, clover yields were significantly different between treatments (p<0.0001***) (Table 7). Red clover yields were approximately 400 lb/ac greater when seeded alone, than when seeded with canola (Figure 5). In contrast, Alsike clover yielded approximately 170 lb/ac lower when grown as a monocrop than with a cover crop in year 1, although the difference was statistically similar (Figure 5). Although initial plant stands were reduced for both clovers when grown with a cover crop, this finding suggests Alsike clover maybe able to better overcome this initial setback.

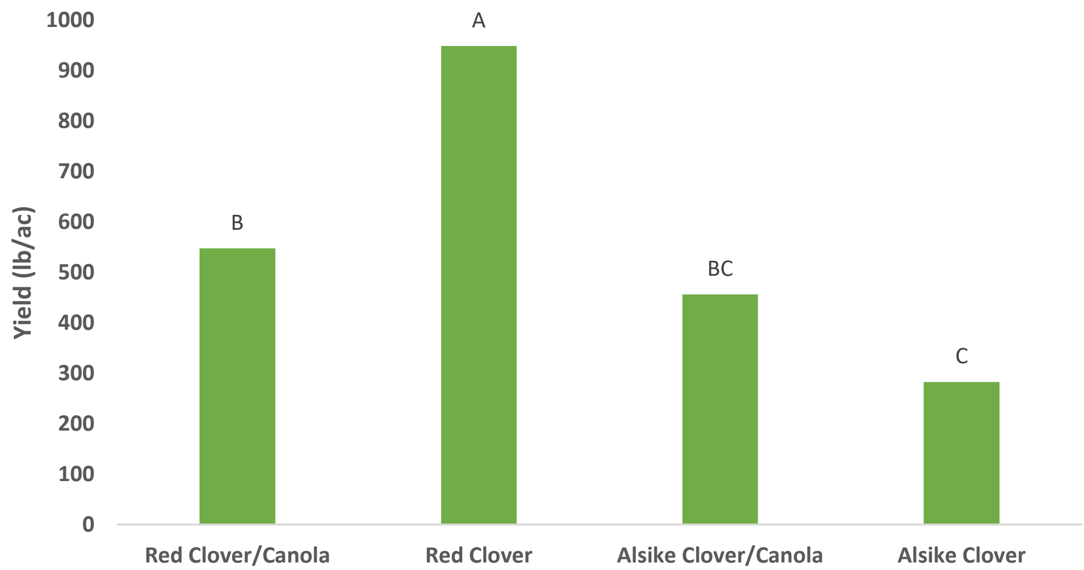

Figure 5: Clover yield differences in year 2 of Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation in Melfort, SK 2018.

In 2019 wheat yield was not significantly different between the treatments (Table 7). The highest average yield was found when 160 kg/ha of N was applied, and the lowest average yield occurred in the red clover monocrop treatment. Wheat yields were statistically similar regardless clover type, or how the clover was seeded. The numeric reduction in wheat yield from Red clover seeded alone, was likely due to the initial reduction in the wheat population cause by early competition from the Red clover re-growth. Although this finding also suggests that the wheat was able to tiller and produce more seed to compensate from this early competition. Wheat yields were similar across applied nitrogen rates and similar to when 0N was applied. This suggests that the residual N provided by the peas in year 2, along with the nitrogen applied was adequate for yield production in a drier growing season. These results also suggest that Alsike clover may provide similar residual N benefits as peas, whereas Red clover may provide slightly less.

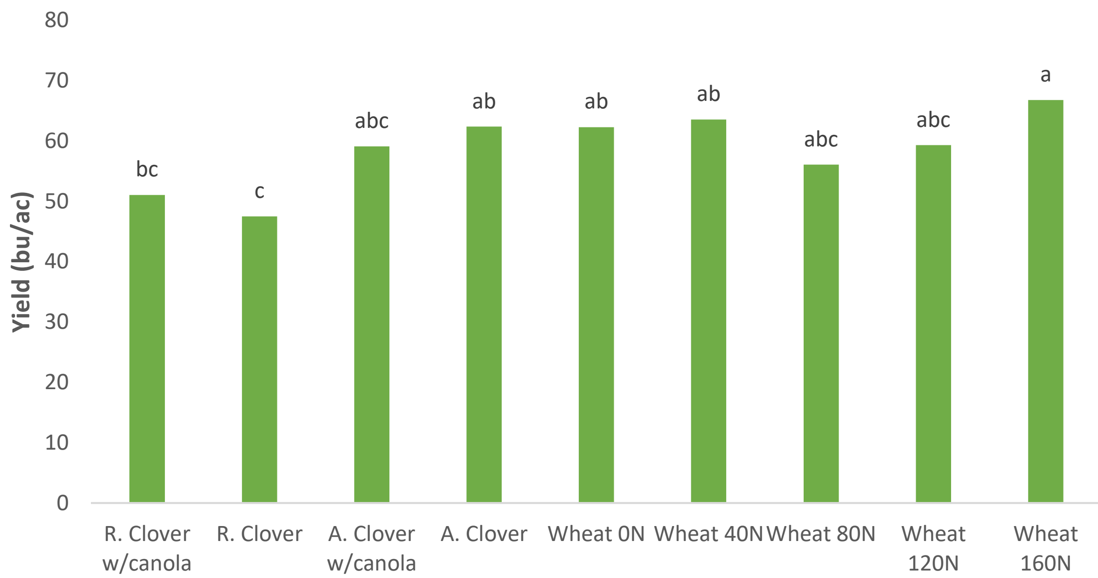

Figure 6: Wheat yield differences in year 3 of Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation in Melfort, SK 2019.

Purity and Germ

In 2018, a cleaned, composite sample of clover seed from each treatment was submitted for purity (%) and germination (%) quality analysis. Both purity and germination were similar across the four clover treatments. Red clover with canola was 98.6% pure and germinated at 97%, while red clover alone was 99.3% pure and had 96% germination. Alsike clover with canola was 98.2% pure and germinated at 96%, while Alsike clover alone was 99.2% pure and 95% germination. The primary weeds found in the seed sample were cleavers, lamb's quarter, sweet clover, alfalfa, volunteer canola, Canada thistle, stinkweed, barnyard grass, and annual sow thistle.

Protein:

Protein was only determined in year 3 from composite samples of each cleaned, and dried wheat treatment. As the wheat samples were composites of the 4 replicates statistical analysis was not carried out. However, some inferences can be made. As expected, the application of 160 kg/ha of N had the highest protein levels of 14.4% (Table 8). The increase in protein when 80 to 160 kg N/ha was applied, suggests that the additional nitrogen in these treatments was not required for yield and was used for protein creation. This was further supported by the finding that the 0N supplemented treatment, which would have only had residual soil N, had comparable protein levels to all 4 clover treatments. Lastly, protein levels were similar between all clover treatments regardless of whether the clover was grown with a cover crop in year 1, although the Red clover treatments demonstrated slightly greater wheat protein than the Alsike treatments.

Table 8: Statistical Analysis and Means for Protein in Demonstrating the Effects of Red and Alsike Clover Seed Crops in Rotation in 2019 in Melfort, SK.

Treatment	Protein
R. clover w/canola	12.5
R. clover	12.8
A. clover w/canola	12.1
A. clover	12.1
canola/pea/wheat - 0 N	13.1
canola/pea/wheat - 40 N	13.1
canola/pea/wheat - 80 N	13.5
canola/pea/wheat - 120 N	14.0
canola/pea/wheat - 180 N	14.4

[y] * significant; *** highly significant
[z] Values with the same letter are statistically similar

Conclusions: In year 1, canola yields proved to be comparable regardless of whether they were seeded alone or with a Red or Alsike clover. This finding supports that canola can be grown as a successful cash cover crop. In year 2, Alsike and Red clover establishment was significantly reduced when grown with a cover crop and resulted in significantly decreased yields in Red clover, but not in Alsike clover. Alsike clover was able to compensate for the decrease in establishment and produce greater yields than its monocrop equivalent. In year 3, wheat yields were greatest when supplemented with 160 kg/ha N, however yields of all 9 treatments were not statistically different from each other. This suggests that the amount of residual N provided by the clovers and peas was sufficient enough for yield creation in 2019. This is further supported from the results of the wheat protein levels, where supplementing high levels of N (80-160 kg/ha) resulted in higher levels of protein. Thus, in a drier growing season, residual N levels provided by Red and Alsike clover and annual legumes, can provide enough nitrogen for yield, while supplemental N can be used for increasing wheat protein. Overall, canola can be a viable option for establishing clover crops, when a cash crop is required for economic reasons. However, there is a penalty in clover establishment when canola is used. Thus, economic considerations for each grower should be considered when deciding if a cash crop is required during the year of establishment. Due to the closed dense knit canopy provided by canola, it may be that the use of a more open canopy crop, such as faba bean may be a better cash crop option for under seeding clovers, than canola. Nevertheless, the amount of canopy cover provided by the cash crop, is still something that needs to be researched.