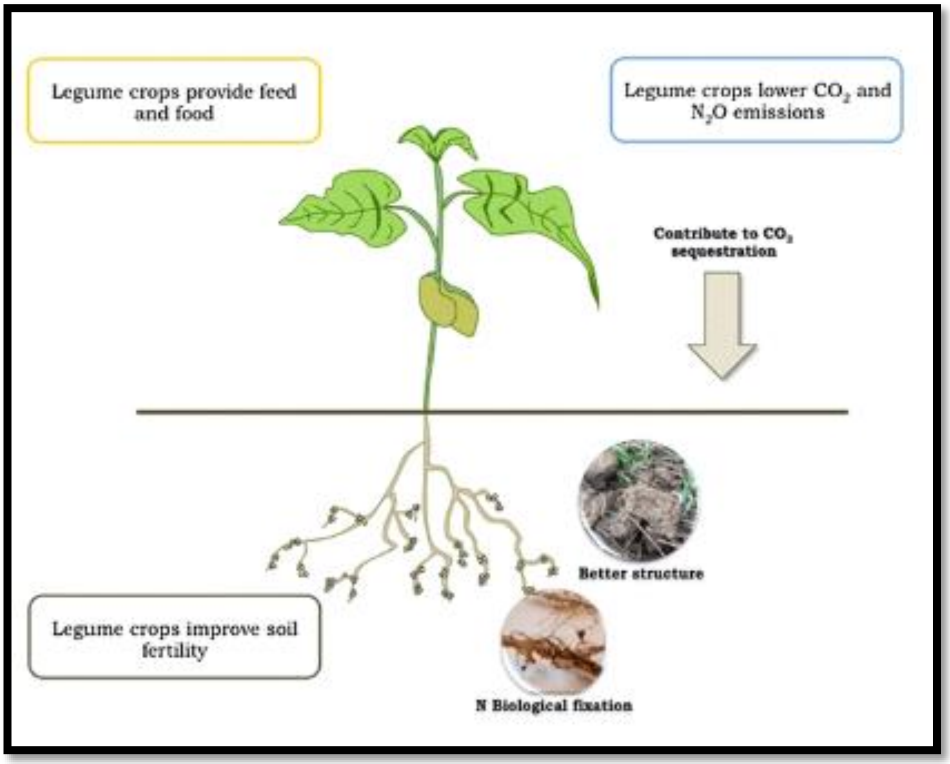
# 2017 Annual Report for the Agriculture Demonstration of Practices and Technologies (ADOPT) Program




**Project Title:** Nitrogen Benefits of adapted grain legumes to succeeding crops in NW SK

**Project Number:** 20150375

**Producer Group Sponsoring the Project:** Western Applied Research Corporation

**Project Location(s):**

- Scott Saskatchewan, R.M. #380 Legal land description: NE 17-39-20 W3

**Project start and end dates (month & year):** May 2016 and completed January 2018

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## Objectives and Rationale

### Project objectives:

The objective of this experiment was to determine the contribution of legume crops to soil nitrogen and succeeding crop yield.

### Project Rationale:

Nitrogen-fixing legume crops offer many rotational benefits in a cereal dominated crop rotation, and annual grain legumes have the potential to offer additional benefits related to their N-fixing capabilities. Thus, benefits of grain legumes in annual crop rotations include soil nitrogen (N) contributions plus non-N rotational benefits. Non-N benefits include the interruption of disease cycles, reduced weed populations, and increased availability of other nutrients, improved soil structure, and release of growth substances from legume residue (Przednowek et al. 2004). A comprehensive study on rotational benefits of several grain legumes including field pea, dry bean, lentil, and chickpea was conducted in the semiarid zone of the Canadian prairies (Miller et al. 2002). Also, researchers in other parts of Canada and the world have reported significant rotational benefits contributed by other annual grain legumes such as soybean (Ding et al. 1998) and chickpea (Marcellos et al. 1998). Production of grain legumes has increased in western Canada in recent years and there is a recent need to add faba bean in rotations around NW SK. Other than peas and lentils, most legume crops are low in acres; therefore, there is a need to demonstrate their contribution to the N budget of subsequent crops. Legumes that were included in this study were faba bean, chickpea, soybean, lentils, and peas for which their rotational benefits have not been evaluated for NW SK. In order to focus on the apparent N benefits of the annual grain legumes, flax was chosen as the non-legume reference crop in this study. The intent of the study was to compare the rotational benefits of five annual grain legumes and an annual non-legume reference crop on a subsequent wheat crop in NW SK. Information on N benefits from legume stubble under NW Saskatchewan conditions is necessary to develop a more accurate fertilizer recommendation for crops that will be grown on the legume stubble in rotation.

## Methodology and Results

### Methodology:

This demonstration was conducted at the AAFC Scott Research Farm in 2016 and 2017 growing season, where wheat was seeded on the 2016 legumes and flax stubble. A randomized complete block design with four replications was used in both growing seasons. There were six treatments (five legume crops and a non-legume crop) (Table 1). Fertilizer was applied to the non-legume (flax) and all the legumes were inoculated with their respective registered inoculants at recommended rates at seeding in the 2016 growing season (see Appendix A for complete agronomic details). Pesticides were also applied as and when they were required in both years. Plots were harvested at separate dates based on their maturity in 2016 but in 2017 growing season, all the wheat plots were harvested at the same time after desiccation. Soil analyses were done prior to seeding and after harvest to determine the residual soil nitrogen (N) when the soil temperature was not rife for further mineralization. Following visible rows, spring plant densities were assessed for both crops to determine if each crop has attained its recommended plant stands. This was assessed by counting two 1 m rows in the front and back of the plot for a total of four rows per plot. The average of the four rows was converted to plants $m^{-2}$ based on 10-inch row spacing.

All treatments were straight-combined using a wintersteiger plot combine after .The grain was cleaned and corrected to the required moisture content of 14.5 % in 2017.

**Table 1:** Demonstration treatment list for 2016 and 2017 growing seasons

| Treatment | 2016 Crop type | 2017 Crop type |
|---|---|---|
| 1 | Non-legume (flax) | Wheat on flax stubble |
| 2 | Faba bean | Wheat on faba bean stubble |
| 3 | Peas | Wheat on peas stubble |
| 4 | Chickpea | Wheat on chickpea stubble |
| 5 | Lentils | Wheat on lentils stubble |
| 6 | Soybean | Wheat on soybean stubble |

**Data Collection:**

Residual soil nutrients levels were collected prior to seeding legumes and prior to seeding wheat. Plant densities were determined by counting numbers of emerged plants on 2 x 1-meter row lengths per plot approximately two (WAE). Yields were determined from cleaned harvested grain samples and corrected to 14.6% moisture content. Several seed quality indicators were conducted including grain protein, thousand kernel weights (TKW), and bushel weight (BW). Grain N content, total grain N yield and legume N credit were also collected (grain N yield after legume- grain N yield after flax/1000 kg/ha). Weather data was recorded from the online database of Environment Canada weather station.

**Growing Conditions:**

The 2017 growing season started with great soil moisture in April and May with 30.9 mm and 69 mm of precipitation, respectively. Midseason growing conditions in June and July were very dry with 51% and 68% less precipitation compared to the long-term average. Throughout the growing season, the temperature was very similar to the long-term average. Frost occurred on several occasions with a nightly low of -0.02 ºC, -1.6 ºC, -2.7 ºC on May 15$^{th}$, 16$^{th}$ and 18$^{th}$, respectively. Growing degree days were higher than the long-term average for the months of May and July and lower for the remaining months (Table 2).

**Table 2.** Mean monthly temperature, precipitation and growing degree day accumulated from April to September in 2016 and 2017 at Scott, SK.

| Year | April | May | June | July | August | Sept. | Average /Total |
|---|---|---|---|---|---|---|---|
| ---*Temperature (°C)*--- | | | | | | | |
| **2016** | 5.9 | 12.4 | 15.8 | 17.8 | 16.2 | 10.9 | 13.2 |
| **2017** | 3.0 | 11.5 | 15.1 | 18.3 | 16.6 | 11.5 | 12.7 |
| **Long-term$^z$** | 3.8 | 10.8 | 14.8 | 17.3 | 16.3 | 11.2 | 12.4 |
| ---*Precipitation (mm)*--- | | | | | | | |
| **2016** | 1.9 | 64.8 | 20.8 | 88.1 | 98.2 | 22.2 | 296 |
| **2017** | 30.9 | 69.0 | 34.3 | 22.4 | 53 | 18.9 | 228.5 |
| **Long-term$^z$** | 24.4 | 38.9 | 69.7 | 69.4 | 48.7 | 26.5 | 277.6 |
| ---*Growing Degree Days*--- | | | | | | | |
| **2016** | 58.9 | 224.9 | 303 | 398.7 | 343.8 | 176.2 | 1505.5 |
| **2017** | 16.6 | 202.7 | 283.3 | 399.1 | 348.4 | 194.8 | 1444.9 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Long-term**$^z$ | 44 | 170.6 | 294.5 | 380.7 | 350.3 | 192.3 | 1432.4 |

$^z$Long-term average (1985 - 2014)

## Analysis:

An analysis of variance (ANOVA) was conducted on plants emergence, yield, thousand kernel weight (TKW), bushel weight (BW), protein content, grain N content, total grain N yield and legume N credit. All the analyses were done using the Mixed Procedure in SAS 9.4. Crop was considered a fixed-effect factor and replication was considered a random effect factor. The assumptions of ANOVA (equal variance and normally distributed) were tested using a Levene's test, and Shapiro-Wilk. The data were normally distributed; therefore, no data transformation was necessary. Treatment means were separated using Tukey's Honestly Significant Difference (HSD) and considered significant at $P < 0.05$. Weather data was estimated from the nearest Environment Canada weather station (Table 2).

## Results & Discussion:

### *Plant density*

Plots were seeded with a target of 250 plants $m^2$, as expected no differences among the plots were observed (P=0.9296). Average means of every treatment are shown in Table 3 as a guide.

### *Grain yield*

Grain yield was expected to show some differences among treatments according to the residual N measured after the growing season in 2016. However, no differences were found regardless of the stubble that the wheat was seeded (P = 0.4087). Despite these results, a trend was observed for some of the plots. Wheat seeded on pea stubble had the highest yield followed by lentil stubble (Figure 1). Also, a strong positive correlation was found between grain yield and N credit (r= 0.70).

### *Thousand kernel weight and Bushel weight*

TKW and BW did not differ among all the plots (P = 0.1133 and P = 0.8291). Although, a trend was observed for all variables. The plots seeded on flax stubble had the lowest values indicating a slight quality loss for these two variables (Table 3).

### *Grain N content*

Grain N content is calculated as a percentage and this variable did not have any difference among the stubble type. From the raw data, grain N contents ranged from 1.77 to 2.16% with an average mean of 2% for all treatments (Table 3).

***Grain N yield***

Grain N yield values are calculated by multiplying grain N concentration by grain yield. As grain N content was similar among all the samples results were expected to be similar to grain yield and no differences were found for this variable (P = 0.6545), and the same trend as grain yield was observed (Table 3 and Figure 1).

***N credit***

N credit in the soil in kilograms per hectare did not have any difference irrespective of the seeded legumes during the 2016 season (P = 0.7213). Residual N contents were lower than expected but data shows a trend. Only three legumes returned a positive N credit. Peas with 1.1, lentils with 0.6 kg/ha and faba beans with 0.2 kg/ha (Table 3).

**Table 3.** Plant density, yield, seed quality (thousand kernel weight and bushel weights), protein, and N contents (grain N, grain N yield and N credit) of wheat seeded in different legume stubble types at Scott, SK in 2017. Values represent means (n = 4).

| Stubble Type | Plant density (plants/m$^2$) | Yield (bu/ac) | TKW (g) | BW (kg/hL) | Protein (%) | Grain N content (%) | Grain N yield (kg/ha) | N credit (kg/ha) |
|---|---|---|---|---|---|---|---|---|
| **Flax** | 158.7 | 52.3 | 35.1 | 16.6 | 10.3 | 1.95 | 6930 | 0 |
| **Faba bean** | 156.7 | 53.9 | 36.6 | 16.7 | 10.2 | 1.97 | 7150 | 0.2 |
| **Pea** | 163.1 | 60.7 | 36.4 | 16.7 | 10.1 | 1.95 | 7991 | 1.1 |
| **Chickpea** | 155.0 | 50.8 | 35.5 | 16.7 | 10.2 | 2.0 | 6821 | -0.1 |
| **Lentil** | 162.2 | 55.8 | 35.5 | 16.7 | 10.2 | 1.99 | 7486 | 0.6 |
| **Soybean** | 158.2 | 50.8 | 36.4 | 16.7 | 10.2 | 2.01 | 6855 | -0.1 |

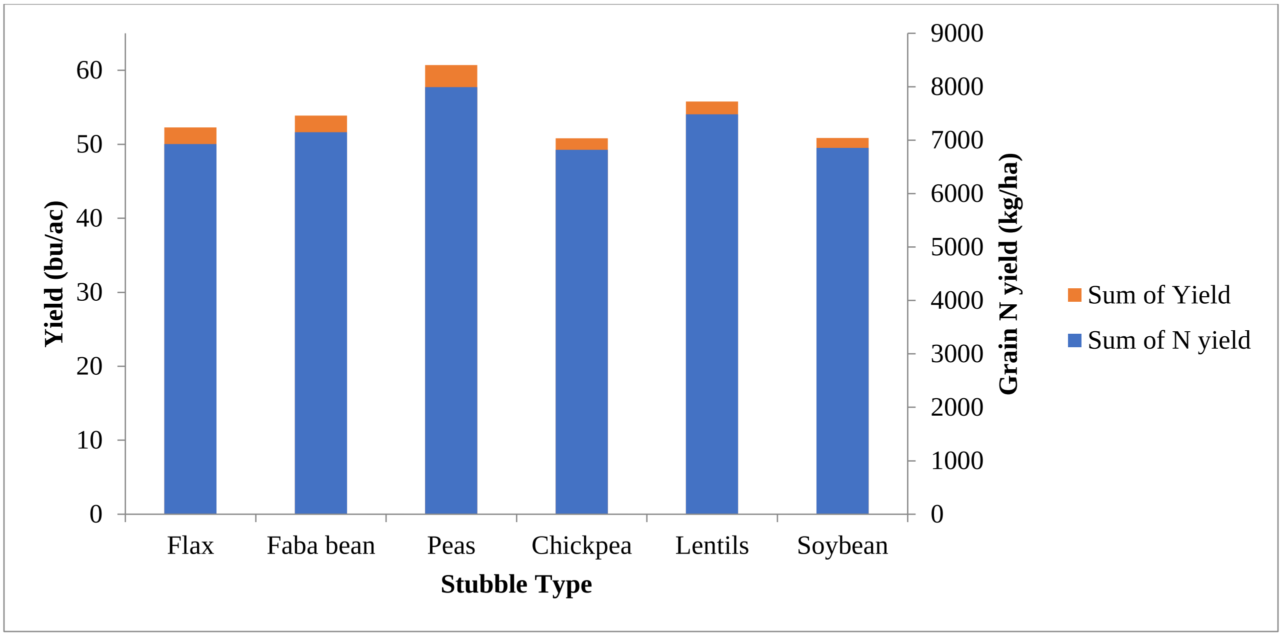


**Figure 1.** Total yield and grain N yield of wheat seeded on flax and five legume stubble types at Scott, SK in 2017.

***Effects of legumes on residual soil nitrogen and cereal yield***

Although pulses occupy less area than wheat and canola, they have a strong foothold in Saskatchewan's agriculture and can contribute to meet current and future global protein demands. They are particularly valuable in crop rotations due to their ability to fix N.

Improved cereal grain yields following pulse crops compared to cereal monoculture are well documented with an approximate yield increase for cereals of 54%. However, yield responses can vary from 0 to 100% (Evans et al. 1991; Gan et al. 2003; Miller et al. 2003; Miller and Holmes 2005; Adderley et al. 2006; Krupinsky et al. 2006; Tanaka et al. 2007; Bremer et al. 2011), with the yield increases attributed to both N and non-N benefits (Stevenson and van Kessel 1996a; Stevenson and van Kessel 1996b). For example, Miller et al. (2002) reported a 21 % increase in wheat yields when grown on pulse crop stubble, relative to yields grown on wheat stubble.

However, even when there is a net depletion of N following legume crops, positive N benefits to the yield and grain protein content of subsequent crops may still occur (Soon and Lupway 2008). For instance, by relying on N fixation, pulses spare soil inorganic N for subsequent crops relative to non-legumes (Jensen 1994; Herridge et al. 1995). This happens when a pulse crop takes up less N than would be required for a non-pulse crop, due to pulse crop N requirements being met via biological nitrogen fixation (BNF). Nitrogen sparing along with the release of mineral N from pulse crop residues can build soil $NO_3^-$ and can supply $NO_3^-$ to subsequent cereal crops (Herridge et al. 1995). For example, Miller et al. (2002) reported a 21 % increase in wheat yields when grown on pulse crop stubble, relative to yields grown on wheat stubble. In Australia, Marcellos (1984) documented a yield benefit on wheat after legumes. Wright (1990), in North East Saskatchewan, got a positive yield response on barley seeded on pulse stubble. However, studies done in brown and dark brown soils did not have a positive yield response on cereals seeded after legumes (Townley-Smith, 1988; Campbell et al., 1992; Brandt, 1996). The results from this study are in agreement to those mentioned above, as no yield benefit on wheat after pulses in a dark brown soil were recorded. As Beckie and Brandt (1997) suggested, it is possible that an incomplete mineralization can mask the effects of crop yield and nutrient uptake.

Also, the trend in the residual N among the crops in this study may be due to differences in mineralization rates due to the C and N contents of the crops. For example, studies found that N mineralization from soil and crop residues is negatively correlated to the C to N ratio (Heal et al. 1997; Booth et al. 2005) and positively correlated to N content (Lupwayi and Kennedy 2007), although other residue quality factors (e.g., lignin content) also affect N mineralization (Heal et al. 1997). As a result, N mineralization rates (Soon and Arshad 2002; Lupwayi et al. 2006) and the supply of N to subsequent crops (Soon and Arshad 2004) varies among residues of different crop species. The results of the residual N from the study were lower than anticipated based on previous work on the N fixed by various legumes. Estimates of N fixation based on global averages of pulse crops grown in the Canadian prairies amounted to 58, 86, 51, 107, and 23 kg N $ha^{-1}$ for chickpea, field pea, lentil, faba bean, and common bean, respectively (Herridge et al. 2008; Gan et al. 2011). The trend in this study, however, may be due to the higher grain yield in the crops as studies showed that a high proportion of plant N is removed from the field when pulse crop seeds are harvested (Peoples et al. 2009). As a result, the return of N in pulse crop residues to soil can be low (Lupwayi and Kennedy 2007), and may not contribute to a net input of fixed N to the soil (Walley et al. 2007).

Albeit no differences were found among the variables assessed the most commonly used pulses in in rotations in Western Canada Peas and Lentils had the higher N credits and yield for the subsequent crop. The apparent enhanced N availability after pea stubble could be attributed to the greater amount of root exudates produced by pea roots that stimulate mineralization of N (Adderley et al. 2006).

## Conclusions and Recommendations:

Nitrogen is recycled primarily through the decomposition of crop residues that are returned to the soil. Although this study did not result in the anticipated N benefits associated with legumes, there are several advantages associated with a legume based crop rotation that producers could utilize. Legume roots can also acidify root zone and solubilize calcium phosphates common in prairie soils, this explains why pulses/legumes are sometimes not highly responsive to P fertilization. The non-N benefits may also include the interruption of disease cycles, reduced weed populations, and increased availability of other nutrients, improved soil structure, and release of growth substances from legume residue. Even though there was not a statistically significant difference for wheat yield, a trend towards a higher yield was observed after seeding peas, lentils and faba beans.

We recommend including pulses in the crop rotation, as lentils, peas and faba beans were able to provide a slight residual N benefit. Furthermore, both crops are a viable pulse option as they are adapted to the conditions of Northwestern Saskatchewan.

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## Supporting Information

### Acknowledgements

We would like to thank the Ministry of Agriculture for funding this project through the ADOPT program. We would like to acknowledge Herb Schell and our summer staff for their technical assistance with project development and implementation.

## Appendices

## Abstract

Although pulses occupy less area than wheat and canola, they are very important from an economic and environmental point of view. They are particularly valuable in crop rotations due to their ability to fix N. Apart from their N benefits; legumes can often mobilize and access P already present in the soil. Legume roots can also acidify root zone and solubilize calcium phosphates common in prairie soils. They also offer benefits such as the interruption of disease cycles, reduced weed populations, and increased availability of other nutrients, improved soil structure, and release of growth substances from legume residue. This demonstration was conducted in 2016 and 2017. In 2016 five legumes; faba bean, pea, chickpea, lentil, and soybean and a non-legume; flax were seeded. In 2017, wheat was seeded on the stubble to assess the potential benefits provided by the legumes.

No yield or quality benefits were observed for wheat seeded on various legume stubble types. Although a trend towards an increased yield and quality were observed when wheat was seeded on pea, lentil and faba bean stubble. A small N credit was detected for peas, lentils and faba beans. Faba beans, lentils and peas are already adapted to the conditions of northwestern Saskatchewan makes them a viable alternative for crop rotations.

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## Extension Activities

This report will be distributed through WARC's website and included in WARC's annual report. In March 2017 summary of results will be discussed with farmers and producers under the topic "*Soil health and rotational benefits"* during WARC's Crop Opportunity Update and a poster presentation will be done at Soils and Crops Conference.

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## Appendix A
## Agronomic information for 2017 demonstration

**Table A.1.** Selected agronomic information for the 'Nitrogen benefits of adapted grain legumes to succeeding crops in NW SK' trial at Scott, SK.

| **Seeding Information** | **2017** |
|---|---|
| **Seeder** | R-Tech Drill, 10-inch row spacing, knife openers |
| **Seeding Date** | May 09, 2017 |
| **Cultivar and Seeding Rates** | Wheat; Shaw @ 250 seeds/$m^2$ |
| **Stubble Type** | Flax<br>Faba bean<br>Peas<br>Chickpea<br>Lentils<br>Soybean |
| **Fertilizer applied** | MAP (11-52-0) @ 100 lbs/ac |
| **<u>Plot Maintenance Information</u>** | |
| **Pre-plant herbicide** | Roundup RT 540 @ 1 L/ac (May 6, 2017)<br>Bromoxynil @ 0.4 L/ac (May 6, 2017) |
| **In-crop herbicide** | Axial @ 0.5 L/ac<br>Infinity @ 0.33 L/ac<br>Ammonium sulphate @ 0.4 L/ac |
| **Fungicide** | Caramba @ 400 mL/ac (July 14, 2017) |
| **<u>Data Collection</u>** | |
| **Emergence Counts** | June 6, 2017 |
| **Harvest Date** | September 12th, 2017 |

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