2016 Annual Report for the Agriculture Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Residual effects of faba bean and faba bean inoculants on yield and protein of succeeding wheat crop

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Objectives and Rationale

Project Objective

The objective of this experiment was to determine the rotational impact of faba bean stubble, treated with different inoculant combinations, on succeeding wheat yield and protein and to provide the overall economic outcome from each system.

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 northwestern (NW) Saskatchewan. This is because optimizing crop rotations is always on the minds of producers when developing a seeding program and providing producers with additional cropping opinions only strengthens their rotation, and their economic bottom line. In 2015, the introduction of faba beans into the crop rotation in NW Saskatchewan came along with a wide recommendation of inoculant types, inoculant rates, and various combinations of each to optimize faba bean yield. However, the residual N benefits of faba bean stubble, and these various inoculant combinations, on a succeeding wheat crop have not been established. Therefore, it is important to determine the effect of faba bean on wheat production, if this crop is to become a viable candidate in crop rotations. The intent of the study was to determine the effects of different inoculant combinations and formulations on yield and yield components of succeeding wheat crop and to determine the most economical for producers. Information on the best formulation and rates under NW Saskatchewan condition is necessary to develop a more economical option (s) for producers when including faba bean in their rotations.

Methodology and Results

Methodology

This demonstration was conducted at the AAFC Scott Research Farm in spring 2016. A randomized complete block design with four replications was used; adopting 2015 plots seeded to two faba bean varieties with varying amounts of inoculant (Nodulator peat and TagTeam granular). In 2016, wheat was seeded into the faba bean stubble to determine the effects of faba bean and different inoculant combinations on wheat yield and protein. There were 16 treatments (two faba bean verities and eight inoculant options) (Table 1). Fertilizer was applied to the target 60 bu/ac wheat crop at seeding (see Appendix A for complete agronomic details). Pesticides were also applied as and when they were required. Soil analysis was done prior to seeding to get nutrient application recommendation. Following visible rows, spring plant densities were assessed for both crops to determine if either variety or inoculant combinations had any effects on plant density. 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 crops were straight-combined using a wintersteiger plot combine after desiccation with a registered product at the recommended rate. The grain was cleaned and corrected to 14.5 % moisture content; this was used to determine whether different inoculant formulations and rates provided an economic benefit to producers.

Table 1: Demonstration treatment list for 2016 growing season

Treatment	Faba bean variety	Inoculant formulation and rate
1	Snowdrop	Un-inoculated check
2	Snowdrop	Nodulator peat for faba bean
3	Snowdrop	0.5x rate TagTeam Granular for faba bean
4	Snowdrop	1x rate TagTeam Granular for faba bean
5	Snowdrop	2x rate TagTeam Granular for faba bean
6	Snowdrop	Nodulator peat for faba bean + 0.5x rate TagTeam Granular for faba bean

7	Snowdrop	Nodulator peat for faba bean + 1x rate TagTeam Granular for faba bean
8	Snowdrop	Nodulator peat for faba bean + 2x rate TagTeam Granular for faba bean
9	FB9-4	Un-inoculated check
10	FB9-4	Nodulator peat for faba bean
11	FB9-4	0.5x rate TagTeam Granular for faba bean
12	FB9-4	1x rate TagTeam Granular for faba bean
13	FB9-4	2x rate TagTeam Granular for faba bean
14	FB9-4	Nodulator peat for faba bean + 0.5x rate TagTeam Granular for faba bean
15	FB9-4	Nodulator peat for faba bean + 1x rate TagTeam Granular for faba bean
16	FB9-4	Nodulator peat for faba bean + 2x rate TagTeam Granular for faba bean

Statistical Analysis

An analysis of variance (ANOVA) was conducted on plants emergence, plant vigour, plant height, grain yield and grain quality (% protein, thousand kernel weights and bushel weight) using the Mixed Procedure in SAS 9.4. Faba bean variety and inoculant formulations and rates were considered fixed effect factors 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-Wilks. The data was normally distributed; therefore, no data transformation was necessary. Treatment means were separated using Tukey's Honestly Significant Difference (HSD) and considered significant at $P < 0.05$. Economic analysis was also done to determine whether different inoculant formulations and rates provided an economic benefit to producers. Weather data was estimated from the nearest Environment Canada weather station (Table 2).

Results

Growing season weather conditions

In Scott, the 2015 growing season started very dry with only 4.1 mm and 19.4 mm accumulated precipitation during the month of May and June, respectively. In contrast, August received approximately 39 % more moisture compared to the long-term average. The mean monthly temperatures were comparable to the long-term values (Table 2). Also, the 2016 growing season started out very dry in April with only 1.9 mm of precipitation. However, May, July, and August were far above the long-term average, with 40 %, 21 %, and 50 % increase, respectively. Overall, when looking at the accumulated amount of precipitation in 2016 from April to October, there was 38.5 mm more than the long-term total. Throughout the growing season the temperature was very similar to the long-term average. Growing degree days were higher than the long-term average for the months of April – July, and lower for the remaining months (Table 2).

Table 2. Mean monthly temperature, precipitation and accumulated growing degree days from April to October for the 2015 and 2016 growing seasons at Scott, SK

Year	April	May	June	July	August	Sept.	Oct.	Average /Total
	---*Temperature (°C)*---------------------------------------							
2015	-	9.3	16.1	18.1	16.8	10.9	-	14.24
2016	5.9	12.4	15.8	17.8	16.2	10.9	1.6	11.5
Long-term[z]	3.8	10.8	14.8	17.3	16.3	11.2	3.4	11.1
	---*Precipitation (mm)*--							
2015	-	4.1	19.4	46.4	74.5	49.6	-	194.0
2016	1.9	64.8	20.8	88.1	98.2	22.2	33.1	329.1
Long-term[z]	24.4	38.9	69.7	69.4	48.7	26.5	13.0	290.6
	--*Growing Degree Days*---------------------------------------							
2015	-	140.3	332.0	405.1	365.8	179.8	-	1423.0
2016	58.9	224.9	303.0	398.7	343.8	176.2	12.5	1518.0
Long-term[z]	44.0	170.6	294.5	380.7	350.3	192.3	42.5	1474.9

[z]Long-term average (1985-2014)

Table 3: The effects of faba bean variety, inoculant combinations and their interactions on measured response variables in wheat in the 2016 growing season at Scott, SK.

Effects	Plant density (plants/m^2)	Vigor (1-5 scale)	Height (cm)	Yield (bu/ac)	TKW (g/1000s)	Bushel weight (kg/hL)	Protein (%)
	---*P-values*---						
Variety (VAR)	0.8961	0.5828	0.6198	0.7351	0.3246	***0.0022***	1.000
Inoculants (INOC)	0.0692	0.8432	0.5851	0.9473	0.6567	0.2129	0.4816
VAR x INOC	0.6583	0.5673	0.4607	0.7719	0.7338	0.8946	0.6579

Effects of variety, inoculants and their interaction on measured response variables

Analysis of variance showed that both variety and inoculants and their interaction had no significant effects on plant density, plant vigor, plant height, grain yield, thousand kernel weight and % protein (Table 3). However, there is a significant effect of variety on bushel weight (Table 3), with FB9-4 recording significantly higher bushel weight than the snowdrop variety, 78.2 kg/hL and 77.9 kg/hL, respectively.

The trend in wheat yield was that, yields on snowdrop stubble that received the recommended rate of granular inoculant were higher yield relative to the control followed by those with half rate of granular combined with recommended rate of peat inoculant (Figure 1). However, on the FB9-4 stubble, the trend was that, wheat yield on stubble that received half rate of granular had the highest yield, followed by the those with recommended rate of granular and then the those with recommended peat rate (Figure 1). The general trend in wheat yield on both stubbles was that, yields on stubble with granular inoculant components were consistently higher, more consistent on snowdrop than on FB9-4 stubble (Figure 1). The consistent performance of granular inoculant over the peat-based inoculant may be due to the superiority of the granular relative to competing formulations. Studies have found the proven effects of granular inoculant over seed-applied inoculant (Clayton et al., 2004; Kyei-Boahen et al., 2002). In particular, Gan et al. (2005) reported that granular inoculants increased lentil seed yield by 19 % over seed-applied inoculants. The study concluded that, granular inoculants applied to the soil allowed *Rhizobium* to become more uniformly distributed in the rooting zone and allow for greater root-*Rhizobium* contact. This allows for greater inoculation which promotes better nodule formation and consequentially results in greater yields and seed mass (Gan et al., 2005).

Despite the non-significant effects of the faba bean varieties and inoculant combinations on the wheat yield, faba bean can still offer rotational benefits, however slight, for the subsequent cereal even if is not used as a green manure but as a grain crop (McEwen et al., 1990; Dyke and Prew, 1983; Jensen et al., 2010; Thomas et al., 2010). In this study, there seem to be no advantage of inoculant combinations on yield of succeeding wheat. This may due to the fact, the different formulations did not help the faba bean much as it might have relied on resident *Rhizobium leguminosarum* in the soil, and therefore there was no advantage of one formulation over the other. The other reason may be due low residual N of faba bean. A study reported residual N under faba bean to be recalcitrant, with only < 20% taken up by the following crop; it however, can reduce N fertilization of a cereal by up to 30-50 kg N ha^{-1} without yield loss, compared to a cereal-cereal rotation (Prew and Dyke, 1979; Köpke and Nemececk, 2010).

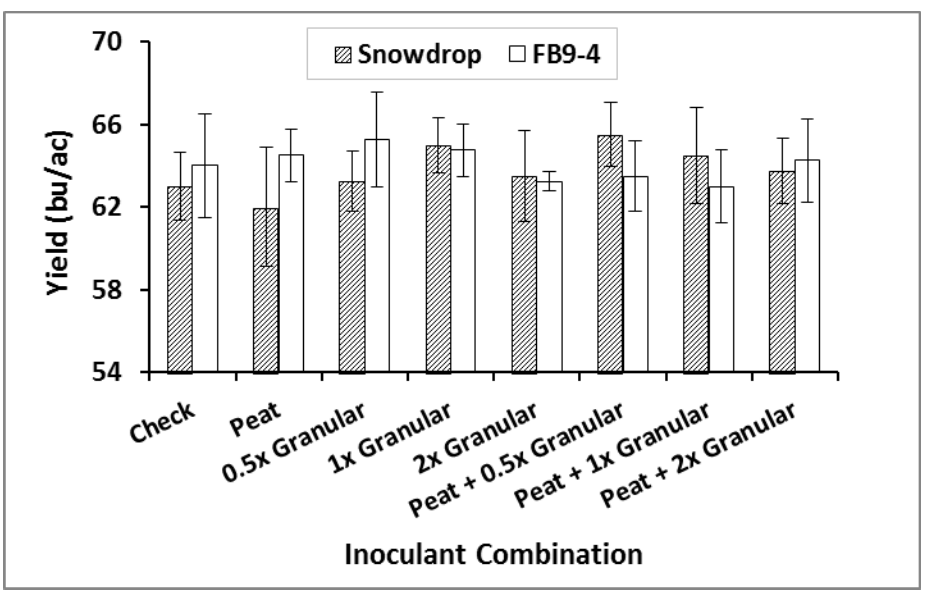

Figure 1: Effects of faba bean variety and inoculant combinations on yield (bu/ac) of succeeding wheat in 2016 growing season at Scott, SK.

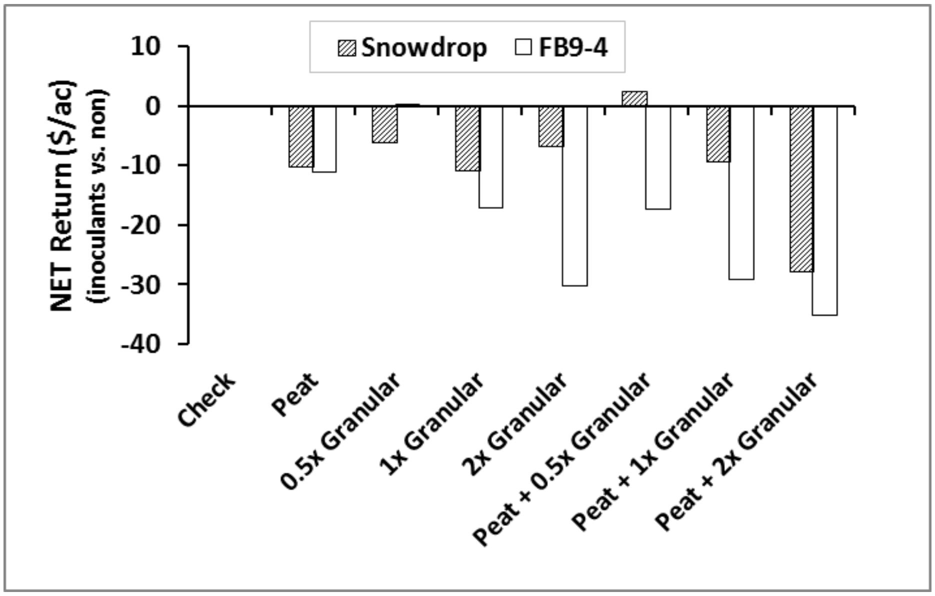

Figure 2: Economic comparison ($/ac) (*inoculant treatments vs. check*) of faba bean variety and inoculant combinations in succeeding wheat in 2016 growing season at Scott, SK.

Interactive effects of variety and inoculants on Net Economic Return ($/ac)

The net return of wheat on the stubble of both varieties was calculated as a difference between individual treatments and the check (no inoculants) (Figure 2). The only net gain ($ 2/acre) was in snowdrop with half rate of granular combined with recommended rate of peat inoculant as well as a breakeven ($0/acre) in FB9-4 with half rate of granular inoculant (Figure 2). The loss was higher when wheat was grown on FB9-4 stubble relative to the snowdrop, especially when peat inoculant was part of the inoculant combination. This may be because the peat was applied based on weight and the FB9-4 variety was heavier per plot relative to snowdrop but they yielded about same.

With fertilizer prices fluctuating and generally increasing in recent years, there is an economic benefit from the production of N fixing crops. Pulse production also reduces the amount of N fertilizer needed in subsequent crops. Also, with canola and wheat grown on millions of hectares every year and receiving millions of dollars in fertilizer applications, a reduction in the amount of fertilizer applied following a pulse crop would reduce the input costs for each of these crops.

Conclusions and Recommendations

Nitrogen is recycled primarily through the decomposition of crop residues that are returned to the soil but a considerable amount of N is also available to succeeding crops through below-ground residual N. Also, apart from their N benefits, pulses can also mobilize and access P already present in the soil. 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. Results from this study showed a consistent better performance of wheat on faba bean stubble in plots that received granular inoculant relative to peat-based inoculant. Economically, there was no advantage in double-inoculating faba bean or using a different inoculant formulation over the granular or even higher rates of granular inoculants. At best, farmers can stick to the recommended rate of granular. Finally, yields from the 2015 faba bean was typical of the target yield for faba bean, so faba bean still remains a viable option for inclusion into existing crop rotations around northwestern Saskatchewan. This study is worth repeating, especially after wet years, as the year the faba bean (2015) was grown was dry.

Supporting Information

Acknowledgements

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Appendices

Appendix A – Agronomic information for the demonstration in the 2016 growing season

Abstract

Abstract/Summary

Diverse crop rotations are an important part of sustainable agricultural systems. The inclusion of N-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/pulses in annual crop rotations include soil nitrogen (N) contributions plus non-N rotational benefits. Despite these benefits, the contribution of legumes/pulses in terms of N depends on how effectively they fix N and different inoculant combinations dictates this fixation capability. The intent of the study was to determine the effects of different inoculant combinations and formulations on yield and yield components of succeeding wheat crop and to determine the most economical for producers. The demonstration was conducted at the AAFC Scott Research Farm in spring 2016 using 2015 faba bean stubble. All plots were seeded to wheat in randomized complete block design with four replications. Results from this study showed a consistent better performance of wheat on faba bean stubble in plots that received granular inoculants relative to peat-based inoculants. Economically, there was no advantage in double-inoculating faba bean or using a different inoculant formulation over the granular or even higher rates of granular inoculants. At best, farmers can stick to the recommended rate of granular.

Appendix A
Agronomic information for 2016 demonstration

Table A.1. Selected agronomic information for the 'Residual effects of faba bean and faba bean inoculants on yield and protein of succeeding wheat crop' trial at Scott, SK.

Seeding Information	2016
Seeder	R-Tech Drill, 10 inch row spacing, knife openers
Seeding Date	May 18, 2016
Cultivar	Wheat- CDC Shaw
Seeding Rate	250 seeds/m^2
Stubble Type	Faba bean
Fertilizer applied	Blend of 12-20-10-13 @ 80 lbs/ac and 20 lbs/ac 11-52-0 seed-placed
<u>Plot Maintenance Information</u>	
Pre-plant herbicide	Glyphosate @ 1.5L/ac + Bromoxynil @ 0.48L/ac (May 1, 2016)
In-crop herbicide	Curtail M @ 0.81L/ac + Florasulam @ 40mL/ac (June 9, 2016)
Fungicide	Priaxor @ 120 mL/ac (July 5, 2016)
Insecticide	N/A
Desiccation	Glyphosate @ 720 gai/ac (August 24, 2016)
<u>Data Collection</u>	
Emergence Counts	May 26, 2016
Harvest Date	September 6, 2016

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