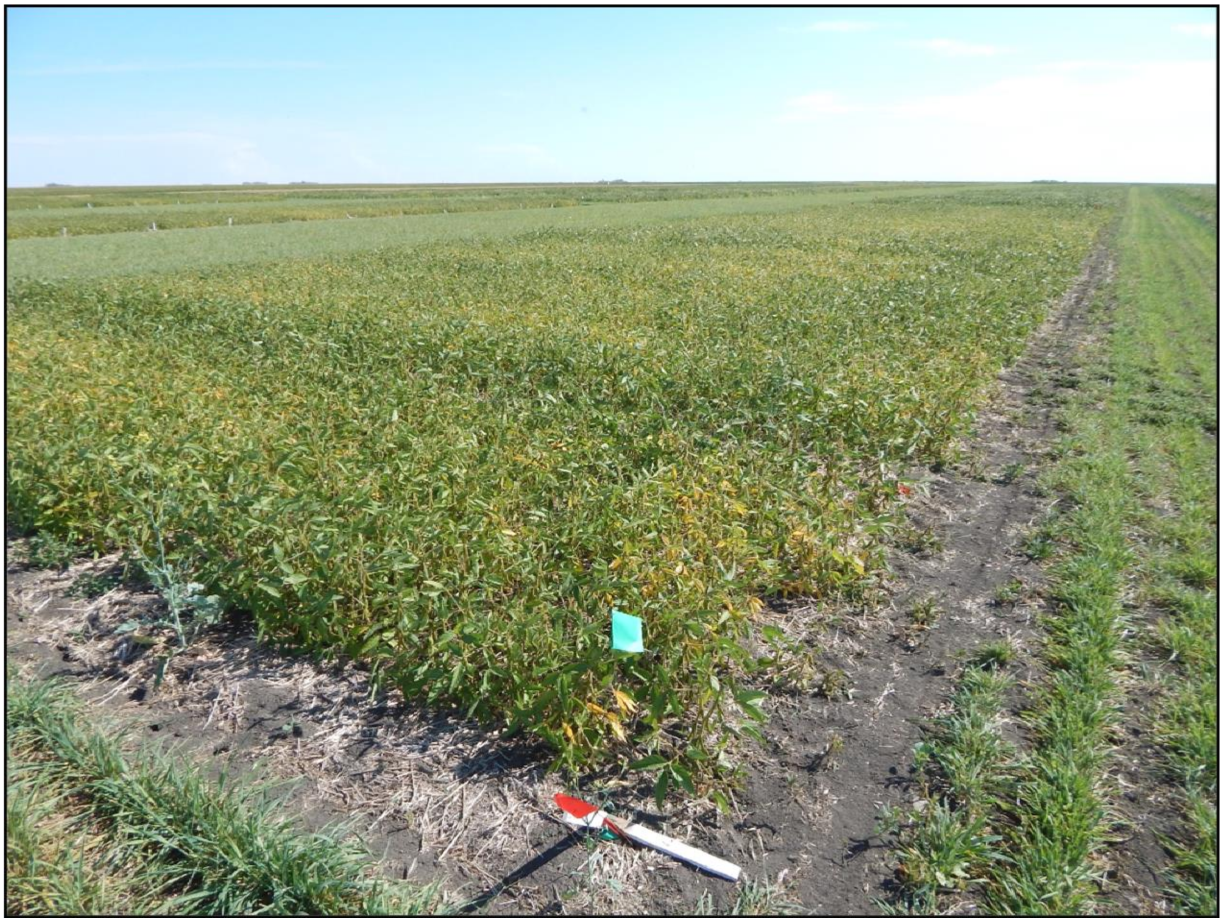
2017 Annual Report
for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Demonstrating Basic Soybean Inoculation Concepts & Options

(Project #20160398)



Principal Applicant: Chris Holzapfel, MSc, PAg

Indian Head Agricultural Research Foundation, Box 156, Indian Head, SK, S0G 2K0

Project Identification

1. **Project Title:** Demonstrating Basic Soybean Inoculation Concepts and Options
2. **Project Number:** 20160398
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation
4. **Project Location(s):** Indian Head, Saskatchewan, R.M. #156
5. **Project start and end dates (month & year):** April-2017 to February-2018
6. **Project contact person & contact details:**

Chris Holzapfel, Research Manager
Indian Head Agricultural Research Foundation
P.O. Box 156, Indian Head, SK, S0G 2K0
Phone: 306-695-4200

Objectives and Rationale

7. **Project objectives:**

The objective of this project was to demonstrate the importance of nitrogen (N) fixation in soybeans along with the relative effectiveness of various inoculation strategies and rescue N applications when poor nodulation is suspected.

8. **Project Rationale:**

Soybeans have become an increasingly popular crop option in southeast Saskatchewan with dramatic improvements in short season varieties over the past decade along with challenges growing more traditional pulse crops (i.e. peas and lentils) due to wet weather and disease issues. While soybeans are not a particularly difficult crop to grow, even under no-till management, adequate inoculation is critical to produce this crop successfully, especially in fields without a history of soybean production. Although most growers are aware that inoculation is important for successful soybean production (and pulses in general) there is a range of products and strategies to choose from. For example, growers might consider applying only a liquid inoculant, combinations of liquid and granular inoculant or granular inoculant on its own. Focussing on granular inoculant, there are products which are strictly *Bradyrhizobium japonicum* inoculants (i.e. Cell Tech®, Nodulator® XL SCG) versus combination products (TagTeam®, So-Fast® Plus) which contain both N fixing and phosphorus (P) solubilizing bacteria (*Penicillium billai*). In addition to formulations, there is often debate regarding appropriate rates of granular inoculant products and if the optimum rate differs depending on whether a seed-applied product is also utilized. Under adverse conditions, such as early season flooding or prolonged drought, poor nodulation can occur even with good inoculation practices. When inadequate nodulation is confirmed, late season N applications can effectively be utilized to 'rescue' the crop from severe N deficiency and reduce potential yield loss. While rescue applications can be reasonably effective, soybeans are large users of N; therefore, the preferred option is always to strive for adequate nodulation when planting. Early work in Manitoba found total N uptake (grain plus above-ground biomass) in a 46 bu/ac soybean crop 199 kg/ha. While soybeans are quite effective at fixing atmospheric N, unlike other pulses they do not typically provide much of an N benefit to subsequent crops due to their high use and, more importantly, removal rates. This project aimed to assist growers, particularly those growing soybeans on fields with limited or no history of this crop, in making better informed decisions regarding inoculation strategies and, if necessary, rescue N applications.

Methodology and Results

9. Methodology:

A field trial was initiated in the spring of 2017 near Indian Head, Saskatchewan (50.546 N, 103.603 W) to evaluate soybean response to various inoculation strategies along with late-season in-crop applications of N when nodulation is poor. Indian Head is situated in the thin-Black soil zone of southeast Saskatchewan and the soil is classified as an Indian Head clay with typical organic matter concentrations of 4.5-5.5%. The treatments included various combinations of (liquid) seed-applied inoculant, granular inoculant and in-crop N applications. The inoculation strategies ranged in intensity from completely uninoculated to seed-applied inoculant plus a 2x label rate of granular inoculant. All inoculant products were supplied by Monsanto Bio-AG and included Optimize (liquid / seed-applied), Cell Tech® (granular, *Bradyrhizobium japonicum*), Tag Team® (granular, *Bradyrhizobium japonicum* plus *Penicilium billai*). For two treatments (uninoculated and seed-applied only), poor nodulation was expected to be yield limiting and the potential benefits of late-season, surface applications of N (as dribble-banded UAN) were also demonstrated in these cases. Liquid inoculant was applied within 12 hours of seeding as per label recommendations while the granular products were placed in-furrow at either 4 or 8 kg/ha, 1-2x the label recommendation for 30 cm row spacing. The twelve N fertilizer treatments were arranged in Randomized Complete Block Design (RBCD) with four replicates and are described in Table 1.

Table 1. Treatment details in ADOPT Soybean Inoculation Demonstration at Indian Head, Saskatchewan (2017).

#	Seed-Applied Inoculant	Granular Inoculant	In-Crop N Fertilizer [Z]
1	None	None	None
2	None	None	55 kg N/ha
3	1x Liquid [Y]	None	None
4	1x Liquid	None	55 kg N/ha
5	1x Liquid	1x *Bradyrhizobium* [Y]	None
6	1x Liquid	2x *Bradyrhizobium* [Y]	None
7	1x Liquid	1x *Bradyrhizobium*	None
8	1x Liquid	2x *Bradyrhizobium*	None
9	None	1x *Bradyrhizobium* + *Penicillium bilai* [X]	None
10	None	2x *Bradyrhizobium* + *Penicillium bilai* [X]	None
11	None	1x *Bradyrhizobium* + *Penicillium bilai*	None
12	None	2x *Bradyrhizobium* + *Penicillium bilai*	None

[Z] Surface dribble-banded UAN applied at R3 stage; [Y] Optimize® liquid soybean inoculant, label rate; [X] 4 (1x) or 8 (2x) kg/ha Cell Tech® granular soybean inoculant; [W] 4 (1x) or 8 (2x) kg/ha Tag Team® granular soybean inoculant

Selected agronomic information is provided in Table 2. A composite soil sample (0-15 cm, 15-60 cm) was collected in the early spring and analysed for select quality parameters and residual nutrients. NSC Watson RR2Y soybeans, one of the earliest maturing varieties on the market, were direct-seeded into barley stubble on May 18 at a target rate of 56 seeds/m^2 (225,000 seeds/ac). Monoammonium phosphate (11-52-0) was side-banded in all treatments to supply 30 kg P_2O_5/ha and no K or S fertilizer was applied. Weeds were controlled using registered pre-emergent and in-crop herbicide applications and no fungicide or insecticide products were utilized. Pre-harvest glyphosate plus saflufenacil was applied at approximately 90% pod colour change and the centre five rows of each plot were straight-combined on September 17.

Table 2. Selected agronomic information for the ADOPT soybean inoculation demonstration at Indian Head, Saskatchewan (2017).

Factor / Field Operation	Indian Head 2017
Previous Crop	Barley
Pre-emergent herbicide	894 g glyphosate/ha (May-9-2017)
Soil Nutrient Sampling	May-13-2017
Variety / Seeding Rate	NSC Watson RR2Y 56 seeds/m^2
Seed Treatment	None
Seeding Date	May 18-2017
Row spacing	30 cm
kg P_2O_5-K_2O-S ha^{-1}	6-30-0-0 (side-banded in all plots), post-emergent UAN as per protocol
In-crop herbicide 1	894 g glyphosate/ha + 50 g imazethapyr/ha (Jun-16-2017) 894 g glyphosate/ha (July-7-2017)
In-crop N applications	July 24-2017 (early pod fill) (as per protocol)
Plant Height	Aug-16-2017 (mid pod fill)
SPAD measurements	Aug-26-2017 (late pod fill)
Pre-harvest herbicide	894 g glyphosate/ha + 50 saflufenacil/ha (Sept-11-2017)
Harvest date	Sep-17-2017

Various data were collected throughout the growing season and from the harvest samples. Plant height was recorded for 10 plants per plot during pod fill (August 17). A chlorophyll meter (SPAD-502) was used to measure leaf chlorophyll during late pod fill (August 26) with measurements always completed on the 2nd newest leaf. Grain yields were determined from the harvested grain samples and are corrected for dockage and to a uniform moisture content of 14%. Seed size was determined by counting and weighing a minimum of 300 seeds/plot. Daily temperatures and precipitation were recorded at the nearest Environment Canada weather station located approximately 3 km from the field site.

Response data were analysed using the Mixed procedure of SAS with the inoculant treatment effects considered fixed and replicate effects treated as random. Individual treatment means were separated using Fisher's protected LSD test while contrasts were used to compare predetermined groups of treatments. All treatment effects and differences between means were considered significant at $P \leq 0.05$. The specific contrast comparisons were: 1) No in-crop N versus 55 kg N/ha as dribble-banded UAN, 2) Seed-applied liquid inoculant alone versus liquid plus granular inoculant, 3) seed-applied plus granular inoculant versus granular inoculant applied alone, 4) *B. japonicum* versus *B. japonicum* plus *P. billai* inoculant, 5) 1x versus 2x label rate granular with seed-applied inoculant, and 6) 1x versus 2x label rate granular without seed-applied inoculant.

10. Results:

Growing season weather

Weather data for 2017 growing season at Indian Head is presented with the long-term (1981-2010) averages in Table 3. Despite less than normal precipitation through the winter months (60% of average from November 2016 through April 2017), initial soil moisture conditions were considered excellent with the wet fall. However, only 43% of the long-term average precipitation was received during the growing season (May through September 2017). Averaged across the five month period, temperatures were normal; however, May was warmer than the long-term average while August was cooler. Temperatures were approximately normal in June, July and September. Overall, low soil moisture, particularly late in the season, was the greatest yield limiting factor for soybeans at Indian Head in 2017.

Table 3. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2017 growing season at Indian Head, Saskatchewan.

Year	May	June	July	August	September	Avg. / Total
	------ Mean Temperature (°C) ------					
IH-2017	11.6	15.5	18.4	16.7	11.3	14.7
IH-LT	10.8	15.8	18.2	17.4	11.5	14.7
	------ Precipitation (mm) ------					
IH-2017	10.4	65.6	15.4	25.2	12.4	119
IH-LT	51.8	77.4	63.8	51.2	35.3	280

Field Trial Results

Residual soil nutrient levels are presented for the site in Table 4. Soil pH and percent organic matter were typical for the region at 7.7 and 5.5%, respectively. Estimated at 16 kg N/ha (0-60 cm), residual NO_3-N was very low which was ideal for the purposes of this demonstration. Residual phosphorus was also considered very low, while potassium and sulphur were sufficient; however, all nutrients other than N were intended to be non-limiting.

Table 4. Selected soil test results for ADOPT soybean inoculation demonstration at Indian Head, Saskatchewan (2017).			
Nutrient	0-15 cm	15-60 cm	0-60 cm
pH	7.7	–	–
S.O.M. (%)	5.5	–	–
C.E.C. (meq)	43.0	–	–
NO_3-N (kg/ha)^Z	9	7	16
Olsen-P (ppm)	5	–	–
K (ppm)	589	–	–
S (kg/ha)	13	47	60

Individual treatment means, overall F-test results and the contrast group comparisons are presented in Tables 5 and 6 of the Appendices while the means for individual response variables are presented in Figs. 1-4 below. The plants were short under the dry conditions, averaging only 38 cm (Fig. 1). The observed range was 36-40 cm and there were no significant differences between individual treatment means (*P* = 0.648) or groups of treatments (*P* = 0.45-0.87). With soybeans, tall plants are desirable in that they are easier to harvest and lodging is rarely an issue with this crop in Saskatchewan.

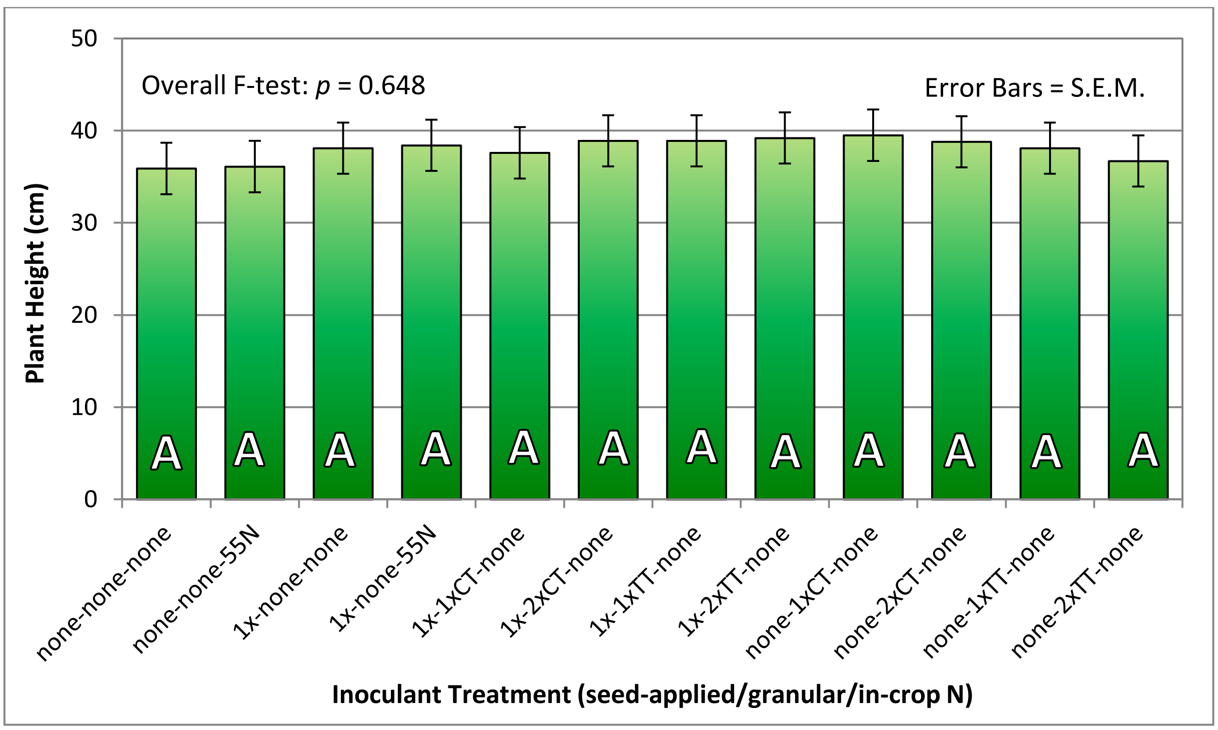


Figure 1. Soybean inoculation and rescue N application effects on plant height (Indian Head, 2017). Liquid inoculant was Optimize®. Granular inoculants were CellTech® (CT) or TagTeam® (TT) at 4 (1x) or 8 (2x) kg/ha. In-crop N was 55 kg N/ha as dribble-banded UAN (28-0-0).

The relative chlorophyll status of the crop was estimated using SPAD instruments at the late pod-fill stage, just prior to senescence and approximately three weeks after the in-crop UAN applications. The treatment effects were highly significant (*P* < 0.001; Fig. 2, Table 5) and showed substantial improvements with in-crop N in the poorly inoculated treatments and strong responses to inoculant overall, particularly the granular formulations. The observed SPAD values in the uninoculated control increased from 24.6 to 31.6 with late season UAN while, when liquid but no granular inoculant was applied, the values increased from 32 to 37. There were few differences amongst the treatments that received granular inoculant, regardless of product, rate or whether liquid inoculant was applied. Amongst these treatments the values ranged from approximately 37-40 and the SPAD values for seed-applied inoculant on its own (without supplemental N) were significantly lower than all individual treatments that received granular inoculant. While the difference between seed-applied only and dual inoculant was significant ($P < 0.001$) and favoured dual inoculant, SPAD values were similar between the dual inoculated and granular only treatments when averaged across rates and forms ($P = 0.457$; Table 6). The contrast comparisons did not detect any differences in SPAD values between granular inoculant types ($P = 0.856$). The SPAD value difference between the 1x and 2x granular inoculant rates (across products) was not quite significant when inoculant was also applied to the seed ($P = 0.094$) but was in higher at the higher rate without seed-applied inoculant. As would be expected, this suggested that nodulation was slightly more limiting at the 1x granular rate with no seed-applied inoculant when compared to the dual inoculated treatments.

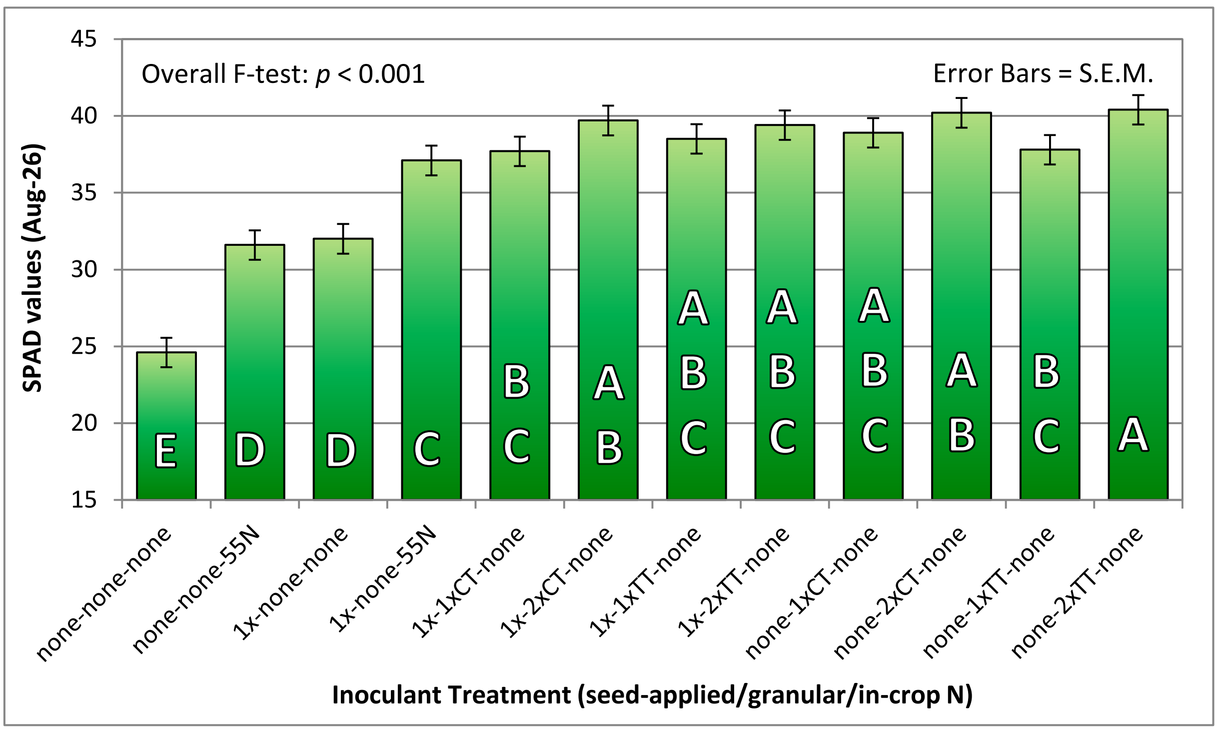


Figure 2. Soybean inoculation and rescue N application effects on leaf chlorophyll measurements at late pod-fill using a SPAD meter (Indian Head, 2017). Liquid inoculant was Optimize®. Granular inoculants were CellTech® (CT) or TagTeam® (TT) at 4 (1x) or 8 (2x) kg/ha. In-crop N was 55 kg N/ha as dribble-banded UAN (28-0-0).

Individual treatment means for seed yield are provided in Fig. 3 and Table 5 while contrast results are in Table 6. The overall F-test was highly significant ($P < 0.001$) with yields ranging from only 800 kg/ha (12 bu/ac) to 1341 (20 bu/ac); considerably lower than most previous years under the dry conditions. Overall, the treatment effects on yield were similar those for SPAD values. As predicted, yields were lowest in the uninoculated, unfertilized control. The in-crop N increased yields by 36% when no inoculant was applied, to the extent where yields were similar to what was achieved with seed-applied inoculant alone. Albeit to a lesser extent, in-crop N was also beneficial when liquid inoculant was applied alone and increased yields by 13% – statistically significant but to a much smaller extent than when no inoculant whatsoever was applied. While not always significant compared to what was achieved with seed-applied inoculant plus in-crop N fertilizer, individual treatment yields were generally higher when granular inoculant was applied, regardless of the rate, product, or additional seed-applied inoculant. Significant yield differences amongst the treatments that received granular inoculant were rare and somewhat inconsistent. The highest yielding treatment was also one of the most intensively inoculated (seed-applied plus 2x rate of CellTech®); however, it was only significantly higher than two other treatments where granular inoculant was applied (seed-applied plus 1x rate CellTech® and no-seed applied plus 1x rate TagTeam®) with no clear pattern detected. The group comparisons (Table 6) detected yield benefits to in-crop N with poor nodulation ($P < 0.001$) and to dual inoculation (seed plus granular) versus seed-applied on its own ($P < 0.001$) but not between dual inoculation versus granular applied on its own ($P = 0.252$) or granular inoculant products ($P = 0.878$). The average responses to granular inoculant rate were inconsistent depending on whether or not seed-applied inoculant was applied but not in the manner suggested by the SPAD measurements which was more easily explained. Yields were higher at the 2x granular inoculant rate when combined with seed-inoculant ($P = 0.032$) but not in its absence ($P = 0.551$). The opposite (i.e. greater benefit to 2x granular inoculant rate without supplementary seed-applied inoculant) would have been considered more typical and it is possible that the observed difference in response was more due to random variability.

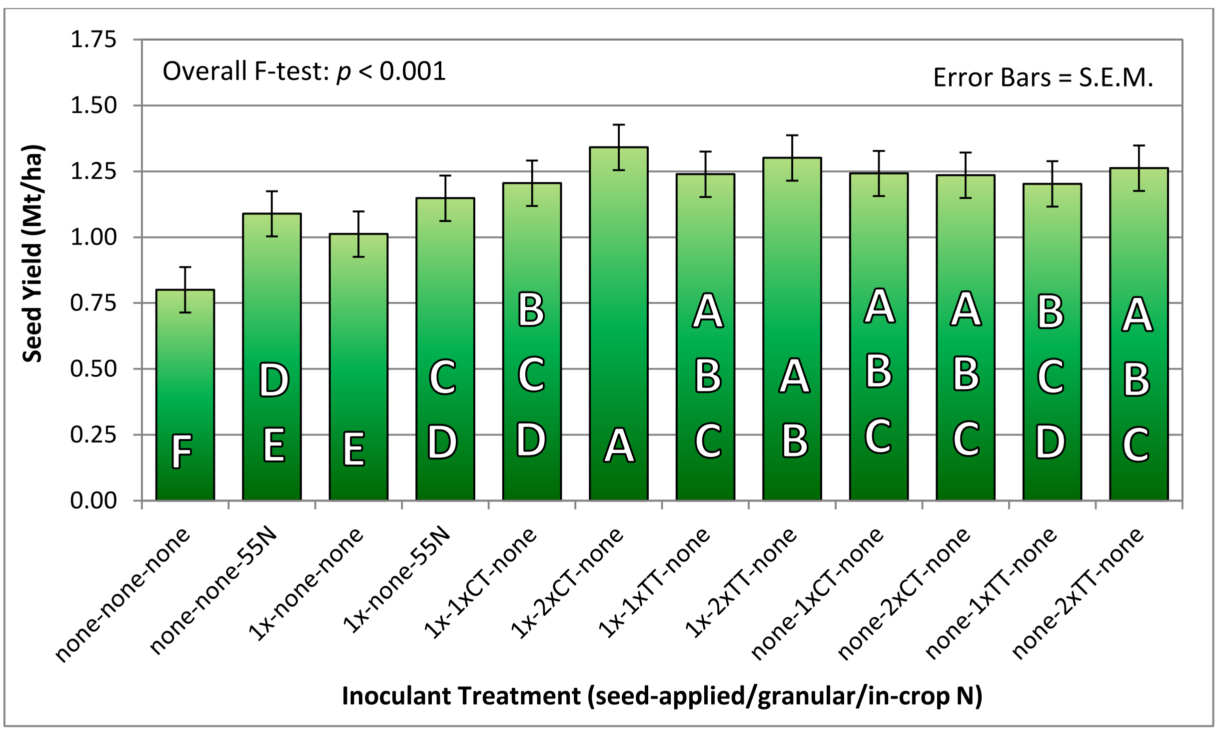


Figure 3. Soybean inoculation and rescue N application effects on seed yield (Indian Head, 2017). Liquid inoculant was Optimize®. Granular inoculants were CellTech® (CT) or TagTeam® (TT) at 4 (1x) or 8 (2x) kg/ha. In-crop N was 55 kg N/ha as dribble-banded UAN (28-0-0).

Inoculant and in-crop N treatment effects on seed size are presented in Fig. 4 along with Tables 5 and 6. The overall *F*-test was highly significant ($P < 0.001$) and, with one primary exception, the treatment effects were consistent with those observed for the SPAD and yield measurements. The key difference was that the in-crop N applications did not impact seed size; thus, the yield benefits associated with this practice must have come from another yield component (i.e. more pods per plant or seeds per pod). Seed-applied inoculant increased seed size by approximately 6% on average (over no inoculant) while granular inoculant increased seed size by an additional 5% over seed-applied on its own.

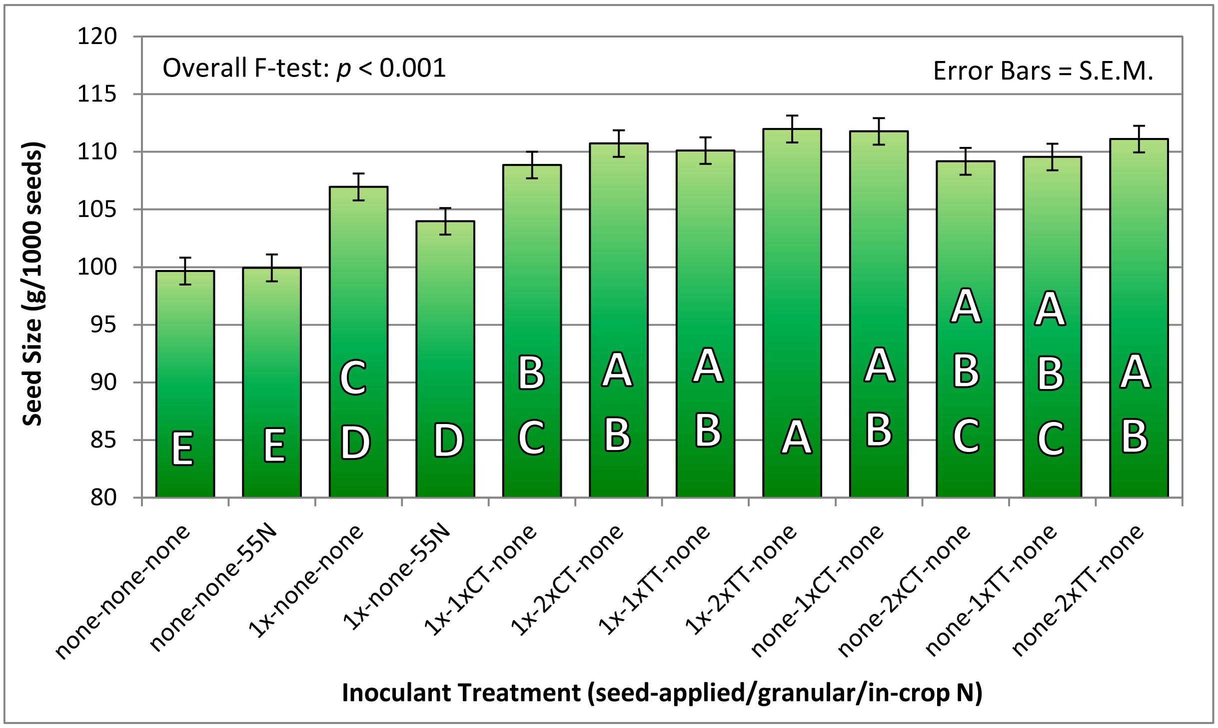


Figure 4. Soybean inoculation and rescue N application effects on seed size (Indian Head, 2017). Liquid inoculant was Optimize®. Granular inoculants were CellTech® (CT) or TagTeam® (TT) at 4 (1x) or 8 (2x) kg/ha. In-crop N was 55 kg N/ha as dribble-banded UAN (28-0-0).

Extension Activities and Dissemination of Results

While this project could not be shown at the Indian Head Crop Management Field Day on July 18, the site was toured during two smaller guided tours held for Federated Co-Op (July 13) and Richardson-Pioneer (July 21) agronomists. During these tours, the trial was discussed along with past results from soybean inoculant and N fertility trials completed in previous years. The full project report will be made available online (www.iharf.ca) and potentially elsewhere in the winter of 2017-18. Key observations were presented to approximately 200 people at the IHARF Winter Seminar & AGM. Results will also be made available through a variety of other media (i.e. oral presentations, popular agriculture press, fact sheets, etc.) as opportunities arise.

11. Conclusions and Recommendations

This project has demonstrated the tremendous importance of *Bradyrhizobium japonicum* inoculation for soybean production along with the potential for in-crop applications of N to help mitigate yield loss when nodulation is poor. Late season chlorophyll (SPAD) measurements were affected by the treatments and a good predictor of effects on yield. Seed-applied liquid inoculant produced substantial yield increases over the uninoculated control but had little impact when applied in addition to a granular product. Granular inoculant, regardless of product or rate, produced significantly higher soybean yields than liquid inoculant. Numerically, the highest yields were observed with one of the most intensive inoculation strategies; however, yield differences amongst any treatments where granular was utilized were rarely significant. Broadly speaking, the results of this project support the use of granular inoculant regardless of whether the seed is inoculated but it is less clear whether higher than normal label recommended rates or seed-applied inoculant over and above a granular product is required. There was no benefit to the product containing *Penicillium billai* compared to the conventional *Bradyrhizobium japonicum* product under the conditions encountered. In general, the project showed that good inoculation and subsequent nodulation are critical for optimizing soybean yields; therefore, dual inoculation or somewhat higher than recommended rates of a granular product are likely good practice for fields with little or no history of soybean production. Liquid seed-applied inoculant on its own is unlikely to be sufficient under such conditions, which is consistent with previous results at Indian Head and other Saskatchewan locations. Growers should assess nodulation at the start of flowering regardless of inoculation practices and, if considered insufficient (less than ~5 nodules per plant), surface applications of N fertilizer can help mitigate much, but not all, of the potential yield loss.

Supporting Information

12. Acknowledgements:

This project was supported by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. Soybean seed was provided in-kind by Northstar Genetics and all inoculant products were provided by Monsanto Bio-AG. The many contributions of IHARF staff Danny Petty, Christiane Catellier, Dan Walker, Karter Kattler, and Shaelyn Stadnyk are greatly appreciated.

13. Appendices

Table 5. Individual treatment means and overall F-test results for inoculant treatment effects on selected soybean variables (Indian Head, 2017).

Treatment [Z] (Seed-Gran-UAN)	Height (cm)	SPAD	Yield (kg/ha)	Seed Size (g/1000 seeds)
1) none-none-none	35.9 a	24.6 e	800 f	99.7 e
2) none-none-55N	36.1 a	31.6 d	1089 de	99.9 e
3) 1x-none-none	38.1 a	32.0 d	1012 e	107.0 cd
4) 1x-none-55N	38.4 a	37.1 c	1148 cd	104.0 d
5) 1x-1xCT-none	37.6 a	37.7 bc	1205 bcd	108.9 bc
6) 1x-2xCT-none	38.9 a	39.7 ab	1341 a	110.7 ab
7) 1x-1xTT-none	38.9 a	38.5 abc	1239 abc	110.1 ab
8) 1x-2xTT-none	39.2 a	39.4 abc	1301 ab	112.0 a
9) none-1xCT-none	39.5 a	38.9 abc	1242 abc	111.8 ab
10) none-2xCT-none	38.8 a	40.2 ab	1235 abc	109.2 abc
11) none-1xTT-none	38.1 a	37.8 bc	1202 bcd	109.6 abc
12) none-2xTT-none	36.7 a	40.4 a	1262 abc	111.1 ab
S.E.M.	2.78	0.96	86.9	1.16
Pr > *F*	0.648	< 0.001	< 0.001	< 0.001

[Z] Treatments were various combinations of seed-applied Optimize liquid inoculant (Seed), granular (gran) Cell Tech (CT) or TagTeam (TT) inoculant and late-season surface applications of 55 kg N/ha (UAN). Inoculant rates are based on label recommendations for 30 cm row spacing.

Table 6. Pre-determined group comparisons for soybean inoculation effects on selected response variables (Indian Head, 2017).

Contrast Comparison	Height (cm)	SPAD	Yield (kg/ha)	Seed Size (g/1000 seeds)
No gran – no UAN (1, 3) vs	37.0 a	28.3 b	906 b	103.4 a
No gran – UAN (2, 4)	37.3 a	34.4 a	1119 a	102.0 a
Pr > *F* (p-value)	0.874	< 0.001	< 0.001	0.206
Seed (3) vs	38.1 a	32.0 b	1012 b	107.0 b
Dual (5, 6, 7, 8)	38.7 a	38.8 a	1272 a	110.4 a
Pr > *F* (p-value)	0.811	< 0.001	< 0.001	0.006
Dual (5, 6, 7, 8) vs	38.7 a	38.8 a	1272 a	110.4 a
Granular only (9, 10, 11, 12)	38.3 a	39.3 a	1235 a	110.4 a
Pr > *F* (p-value)	0.683	0.457	0.252	0.987
Cell Tech (5, 6, 9, 10) vs	38.7 a	39.1 a	1256 a	110.1 a
TagTeam (7, 8, 11, 12)	38.2 a	39.0 a	1251 a	110.7 a
Pr > *F* (p-value)	0.637	0.856	0.878	0.462
Seed + 1x (5, 7) vs	38.3 a	38.1 a	1222 b	109.5 a
Seed + 2x (6, 8)	39.1 a	39.6 a	1321 a	111.3 a
Pr > *F* (p-value)	0.552	0.094	0.032	0.082
No seed – 1x (9, 11) vs	38.8 a	38.4 b	1222 a	110.7 a
No seed – 2x (10, 12)	37.8 a	40.3 a	1249 a	110.1 a
Pr > *F* (p-value)	0.454	0.030	0.551	0.619

[Z] Treatments were various combinations of seed-applied Optimize liquid inoculant (Seed), granular (gran) Cell Tech (CT) or TagTeam (TT) inoculant and late-season surface applications of 55 kg N/ha (UAN). Inoculant rates are based on label recommendations for 30 cm row spacing.

Figure 5. Uninoculated (no liquid or granular) soybeans at Indian Head in 2017.

Figure 6. Intensively inoculated (liquid plus 2x rate granular) soybeans at Indian Head in 2017.

Abstract

14. Abstract/Summary:

A field trial was conducted near Indian Head (2017) to demonstrate soybean response to various inoculation strategies along with in-crop nitrogen (N) applications when poor nodulation is confirmed. The variety NSC Watson RR2Y was seeded into barley stubble in mid-May with seed-applied inoculant, granular inoculant and in-crop N fertilizer varied as per protocol. Liquid inoculant was applied at label rate while, for granular products, CellTech® (*Bradyrhizobium japonicum*) or TagTeam® (*B. japonicum* plus *Penicillium billai*) were applied at either 1x (4 kg/ha) or 2x (8 kg/ha) the label rate. In-crop UAN (55 kg N/ha) was applied at early pod-fill specifically to treatments where no granular inoculant was utilized. Data collection included plant height, chlorophyll (SPAD) measurements, seed yield, and seed size. Despite good initial soil moisture, the season was dry and soybean yields were below average; however, strong treatment effects were evident and the project was considered a success. The soybeans were short (38 cm) and height was not affected by inoculation. SPAD measurements showed improvements over the control with both seed-applied inoculant and in-crop N and in-crop N was also beneficial when combined with seed-applied inoculant on its own. The highest SPAD values were generally observed with granular inoculant regardless of whether seed was inoculated and there were no consistent differences between granular inoculant rates or forms. Yields ranged from 800-1341 kg/ha (12-20 bu/ac) and responses were similar those observed with the SPAD meter. In-crop UAN increased yields by 13-36% when nodulation was poor with the strongest response detected when no inoculant whatsoever was applied. Liquid inoculant increased yields by 27% over the uninoculated, unfertilized control but the greatest yield increases were observed with granular inoculant, regardless of rate, form or whether seed-applied inoculant was utilized. Seed size was affected by the treatments in a similar manner as SPAD values and yield except it did not increase in-crop N; thereby suggesting the corresponding yield increases were a result of more pods/plant and/or seeds/pod as opposed to larger seeds. For fields with limited or no soybean history, these results support the recommendation for granular inoculant regardless of whether using inoculated seed; however, it is less clear if seed-applied inoculant is likely to be beneficial over-and-above a granular product or whether higher than label recommended rates are justifiable.
