2021 Annual Report

for the

Saskatchewan Ministry of Agriculture's

Agricultural Demonstration of Practices & Technologies (ADOPT) Program

Project Title: Dry Bean Response to Nitrogen Fertilizer Rate in Dryland, Solid-Seeded Production

(Project #20200509)

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Project Identification

1. **Project Title:** Dry bean response to nitrogen fertilizer rate in dryland, solid-seeded production
2. **Project Number:** 20200509
3. **Producer Group Sponsoring the Project:** Indian Head Agricultural Research Foundation
4. **Project Location(s):** Field trials were located at Indian Head (#156), Saskatchewan. Results from trials in Melfort (#428), Redvers (#61), and Yorkton (#244) are also provided in the Appendices.
5. **Project start and end dates(s):** April-2021 to February-2022
6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project Objectives:**
The objective of this project was to demonstrate the response of dryland, solid-seeded black beans to varying rates of nitrogen (N) fertilizer, across a range of environments in Saskatchewan.

8. **Project Rationale:**
Dry beans are a relatively high value human food crop that may have potential to add diversity to regions that usually produce peas, or soybeans as the sole pulse crop options. For many regions of Saskatchewan, pea production has been hindered by Aphanomyces root rot problems and one of the strategies for coping with this disease is to substitute field peas with non-host pulse crops like soybeans or, potentially, dry beans. Soybeans have seen increased uptake in Saskatchewan as a result of production issues with pea and lentil; however, production and acres of this crop have also declined recently due to drier conditions and subsequently poor yields. CDC Blackstrap (Bett 2015) is, arguably, the first commercially acceptable dry bean variety that is adapted to dryland, narrow-row production systems in Saskatchewan. These black beans can be seeded using no-till drills and straight-cut using a combine with a flex-header. The seeds are about half the weight of CDC Pintium, the variety dryland producers were encouraged to grow in the early 2000's. CDC Pintium seed was also highly susceptible to damage in the air seeder due to its large and fragile seeds. There has been very little commercial dry bean production in dryland areas prior to the introduction of CDC Blackstrap; however, black bean production can be profitable in the regions of Saskatchewan that receive sufficient August rainfall.

Dry beans, although they are a legume, are poor at fixing atmospheric nitrogen and production of effective inoculant products has been problematic for a variety of reasons (personal communication – Garry Hnatowich). Most commercial dry bean production does not utilize inoculant but, instead, relies on N fertilizer and soil N to meet the needs of the crop. Shirtliffe and Painchaud (2000) conducted some Saskatchewan dryland N fertility trials in 1999-2000 using CDC Camino and CDC Expresso. This work did show a positive response to N fertilizer applications, but overall productivity was low. In Maine, Liebman et al. (1995) found that dry bean yields increased linearly with N rates up to 135 kg N/ha for both no-till and conventional systems. There is some uncertainty regarding both the overall yield potential and optimal N rates for black beans under dryland production in Saskatchewan. This project was initiated to provide useful N fertility information to help potential producers improve their chances of success with this crop; however, it was also intended to demonstrate the broader yield potential for dryland dry bean production throughout the Black soil zone of Saskatchewan. This is of considerable interest to growers and agronomists seeking alternatives to field peas in these regions.

Literature Cited

Bett, Kirstin. 2015. Black Bean: CDC Blackstrap Variety Description. https://saskpulse.com/files/technical_documents/190328_CDC_Blackstrap_Variety_description.pdf

Liebman, M., Corson, S., Row, R. J., and W. A. Halterman. 1995. Dry bean responses to nitrogen fertilizer in two tillage and residue management systems. Agron. J. 87: 538-546.

Shirtliffe, S and J. Painchaud. 2000. The effect of nitrogen fertilizer on the yield of dry beans in Saskatchewan. Reports of Bean Improvement Cooperative and National Dry Bean Council Research Conference. Pg. 120-121.

Methodology and Results

9. Methodology:

Field demonstrations with CDC Blackstrap dry bean were conducted near Indian Head in 2020 and 2021. Similar trials were also conducted near Melfort, Redvers, and Yorkton. All of these locations are within the Black soil zone of Saskatchewan, which is also the region where dry bean production is most likely to succeed in the absence of irrigation. While activities from Melfort, Redvers, and Yorkton are not discussed in detail in this report, results from all locations are provided in the Appendices for added perspective. In 2020, the treatments were simply six N rates which included an unfertilized control, 45, 75, 105, 135, and 165 kg N/ha (soil residual plus fertilizer) with side-banded urea as the primary N source. In 2021, at the request of the Saskatchewan Ministry of Agriculture, the highest rate was reduced to 155 kg/ha; however, the treatments were otherwise unchanged. For the control, the only N available to the crop was provided by the soil and the monoammonium phosphate (11-52-0) that was applied. Aside from N, all nutrients were intended to be non-limiting; thus, a blanket application of 35 kg P_2O_5/ha was side-banded in all treatments.

Selected agronomic information is provided in Table 1 below. The plots were seeded directly into canaryseed stubble in 2020 and oat stubble in 2021. The same source of certified seed was utilized by all locations within each year and the seeding rate was 44 viable seeds/m^2 to target 40 plants/m^2. Seeding was completed using an 8 opener SeedMaster® plot drill on 30 cm row spacing and the final, trimmed plot length was 10.7 m. The seed was placed approximately 3 cm deep and the plots were rolled after seeding to break up any soil lumps and push any stones down so that they would not interfere with combining. Weeds were controlled using registered pre-emergent and in-crop herbicides. Fungicides were applied to reduce the potential for sclerotinia and other leaf diseases; however, the risk of disease was low in both years. Pre-harvest herbicides were utilized to assist with crop drydown and provide late-season weed control. The centre rows of each plot were straight-combined with a Wintersteiger plot combine when it was fit to do so.

Various data were collected over the course of the growing season and from the harvested seed. Residual nutrient levels were estimated from composite soil samples collected in the early spring for three depths, 0-15 cm, 15-30 cm, and 15-60 cm. Residual NO_3-N levels from the 0-30 cm depth were used to adjust the target N rates. Spring plant densities were determined by counting seedlings in 4 x 1 m sections of crop row after emergence was complete and calculating plants/m^2. Mean plant height was estimated by measuring 8 plants per plot to the nearest 1 cm. The plots were monitored for disease; however, none was observed in either year so data for this variable was neither analyzed nor reported. The maturity date, when 60% of the pods had reached the buckskin stage (beans turned yellow but pods still flexible), was recorded for each plot. Grain yields were determined from the harvested grain samples and are corrected for dockage and to 16% seed moisture content. Seed weight was determined by counting and weighing a minimum of approximately 250 seeds and calculating g/1000 seeds. Daily temperatures and precipitation amounts were recorded from the nearby Environment and Climate Change Canada weather station which was located within 2 km of the field trials each year.

Table 1. Selected agronomic information and dates of operations from dry bean nitrogen response demonstrations completed at Indian Head, Saskatchewan in 2020 and 2021.

Factor / Operation	Indian Head - 2021	Indian Head - 2021
Previous Crop	Canaryseed	Oat
Pre-emergent herbicide	894 g glyphosate/ha (May 14)	894 g glyphosate/ha + 18 g carfentrazone-ethyl/ha (May 30)
Seeding Date	May 17	May 17
Residual NO_3-N (0-30 cm)	18 kg/ha	23 kg/ha
kg N-P_2O-K_2O-S applied (excluding urea)	7-35-0-0	7-35-0-0
Plant Density	July 7	June 21
In-crop Herbicide	20 g imazamox/ha + 602 g bentazon/ha + 2 l UAN/ha (June 29)	20 g imazamox/ha + 602 g bentazon/ha + 2 l UAN/ha (June 24)
Foliar Fungicide	99 g fluxapyroxad/ha + 99 g pyraclostrobin/ha (July 16)	99 g fluxapyroxad/ha + 99 g pyraclostrobin/ha (July 22)
Disease Ratings	August 10 (none noted)	September 1 (none noted)
Plant Height	August 10	August 6
Pre-harvest herbicide	894 g glyphosate/ha + 50 g saflufenacil/ha (September 4)	894 g glyphosate/ha (September 14)
Harvest date	September 22	October 2

Response data were analyzed separately for each location-year using the generalized linear mixed model (GLIMMIX) procedure in SAS® studio. The effects of N rate were considered fixed and replicate effects were treated as random. Individual treatment means were separated using the conservative Tukey-Kramer test and orthogonal contrasts were used to test whether responses to N rate were linear, quadratic (curvilinear), or non-significant. All treatment effects and differences between means were considered significant at $P \leq 0.05$; however, p-values ≤ 0.1 may also be noted.

10. Results:

Growing season weather and residual soil nutrients

In terms of overall adaptation, dry beans have poor tolerance to spring or fall frost and do well under hot conditions with abundant moisture in July through August during flowering and pod fill. They do not tolerate saturated soils early in the spring and can struggle to emerge through heavy clay or crusted soils. Mean temperatures and total precipitation amounts for May through August of each year at Indian Head are presented alongside the long-term averages in Table 2. Overall, growing season temperatures were near average in 2020 and above-average in 2021 (Table 1). In 2021, the temperature patterns varied over the season in that May was cooler than normal but both June and July were unusually hot. Focussing on precipitation and overall moisture availability, initial soil moisture reserves were high in 2020 but the four-month growing season was extremely dry with only 113 mm of precipitation from May through August, 46% of the long-term average. Consequently, crop establishment was relatively poor in 2020 and the overall yield potential remained low over the entire season. In contrast, 2021 started with abnormally low initial soil moisture reserves; however, abundant precipitation in late May allowed for excellent establishment and timely rainfall events throughout the season helped to sustain the crop. Wet weather in the latter half of August was too late to benefit most crops in the region; however, with the later maturity of dry beans and high moisture requirements during pod fill, was ideal for this crop. Consequently, the overall yield potential and subsequent response to N was much greater in 2021 relative to the previous season.

Table 2. Mean monthly temperatures with long-term (1981-2010) averages for the 2020 and 2021 growing seasons at Indian Head (IH), Saskatchewan.

Year	May	June	July	August	May-Aug
	--------------------------------------- Mean Temperature (°C) ---------------------------------------				
IH-20	10.7	15.6	18.4	17.9	15.7 (101%)
IH-21	9.0	17.7	20.3	17.1	16.0 (103%)
IH-LT	10.8	15.8	18.2	17.4	15.6
	--------------------------------------- Total Precipitation (mm) ---------------------------------------				
IH-20	27.3	23.5	37.7	24.9	113 (46%)
IH-21	81.6	62.9	51.2	99.4	295 (121%)
IH-LT	51.8	77.4	63.8	51.2	244

Soil test results for the field trial sites in each of the two seasons are provided in Table 3. The soil at both sites was classified as an Indian Head Heavy Clay. Soil pH was 8.0 in 2020 and 7.6 in 2021 while the corresponding amounts of organic matter were 4.8 and 6.4. These were within the range of what is considered typical for the location. In both years, levels of residual NO_3-N were low which was ideal for this project. For the 0-30 cm depth in 2020, we measured 18 kg NO_3-N/ha in the upper 30 cm and 27 kg N/ha for the 0-60 cm depth. In 2021, we measured 23 kg NO_3-N/ha in the upper 30 cm of soil and 26 kg N/ha for the 0-60 cm depth. Residual phosphorus was relatively low in both years, especially 2020, while both potassium and sulfur were considered unlikely to limit yields.

Table 3. Soil test results for dry bean nitrogen (N) response demonstrations conducted at Indian Head, Saskatchewan in 2020 and 2021.

Depth	pH	SOM (%)	NO_3-N (kg/ha)	Olsen-P (ppm)	K (ppm)	S (kg/ha)
---------- Indian Head 2020 ----------						
0-15 cm	8.0	4.8	11	4	563	11
15-30 cm	–	–	7	–	–	11
30-60 cm	–	–	9	–	–	–
---------- Indian Head 2021 ----------						
0-15 cm	7.6	6.4	15	10	666	9
15-30 cm	–	–	8	–	–	9
30-60 cm	–	–	3	–	–	13

[Z] Target N rates were adjusted for 0-30 cm residual NO_3-N

Dry Bean Responses to Nitrogen Rates

For each of the response variables, detailed results from Indian Head in 2020 and 2021 are provided in Tables 4 and 5 of the Appendices, respectively. For easier interpretation, these results are also presented visually for each variable in Figs. 1-5 below. Detailed results for each year at Melfort, Redvers, and Yorkton are also provided in Tables 8-13 of the Appendices.

As alluded to in the previous section, overall dry bean establishment was poor in 2020, averaging 23 plants/m^2 across N treatments, but excellent in 2021 with an average of 44 plants/m^2 (Fig. 1). This was primarily attributed to differences in the specific environmental conditions encountered. In 2020, the soil was relatively wet during seeding but the weather that followed was unusually dry. In contrast, the soil was dry during seeding in 2021 but 80 mm of precipitation was received over the week that followed. While heavy rain following seeding can be problematic in tilled soils due to crusting, this was not the case under our no-till management with abundant cereal residues near the soil surface and extremely dry initial soil conditions. According to the overall F-tests, emergence was not affected by N rate in either 2020 (P = 0.945; Table 4) or 2021 (P = 0.578; Table 5). Further to this, the orthogonal contrasts did not detect any significant linear or quadratic responses; however, there was a slight trend (P = 0.078) for plant populations to decline with increasing N rates in 2021. That said, this result was not significant at the desired probability of $P \leq 0.05$ and overall plant populations were sufficiently high that it was unlikely to be problematic even if it were. Relative to the control, where no supplemental urea was applied, the observed reduction in 2021 was 4.1 plants/m^2, or 9%, at the 155 kg N/ha (soil plus fertilizer) rate.

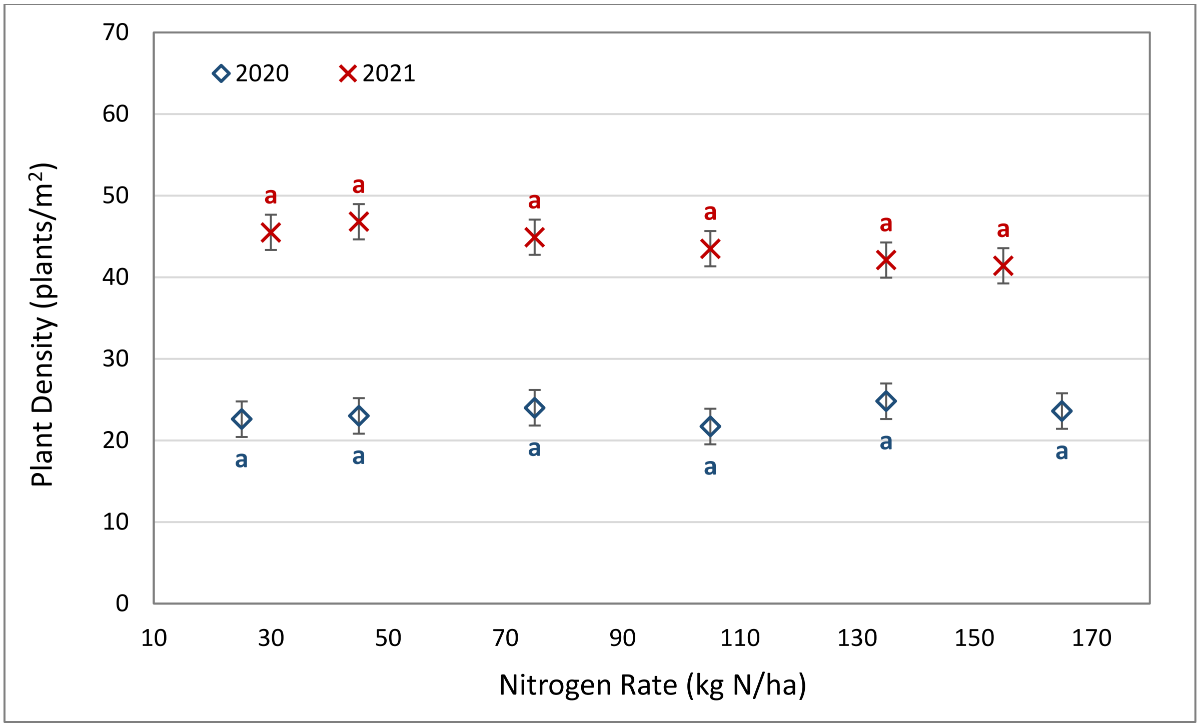

Figure 1. Total (soil plus fertilizer) nitrogen (N) rate effects on dry bean establishment at Indian Head in 2020 and 2021. Error bars are the standard error of the treatment means and values within a year denoted by the same letter do not significantly differ (Tukey-Kramer; *P* ≤ 0.05).

Slight increases in plant height are frequently observed with N fertilization in most crops that respond to this nutrient. While taller plants are not necessarily desirable in cereals or canola, with crops like dry beans or soybeans, taller plants are often easier to harvest, regardless of how or whether height is correlated with yield. Averaging 32 cm, the dry beans were taller in 2020 than in 2021 where the overall average height was 28.5 cm. In 2020, the overall F-test for plant height was not significant ($P = 0.181$); however, the linear orthogonal contrast indicated a trend for increasing height as the N rate was increased ($P = 0.064$). That said, the results were not particular consistent and the spread between the shortest and tallest treatments was only 3.1 cm (Table 4; Fig. 2). In contrast, the overall F-test for plant height was highly significant in 2021 ($P < 0.001$) with a strong, quadratic increase in height as N rate was increased ($P = 0.013$; Table 5). In the control treatment, the beans were only 24 cm tall while, at 155 kg N/ha, they were 31 cm. The nature of the quadratic response was such that heights increased rapidly going from 30-75 kg N/ha but the observed increases with further additions of N were minor. According to the multiple comparisons test, heights were statistically similar for N rates ranging from 75-155 kg N/ha.

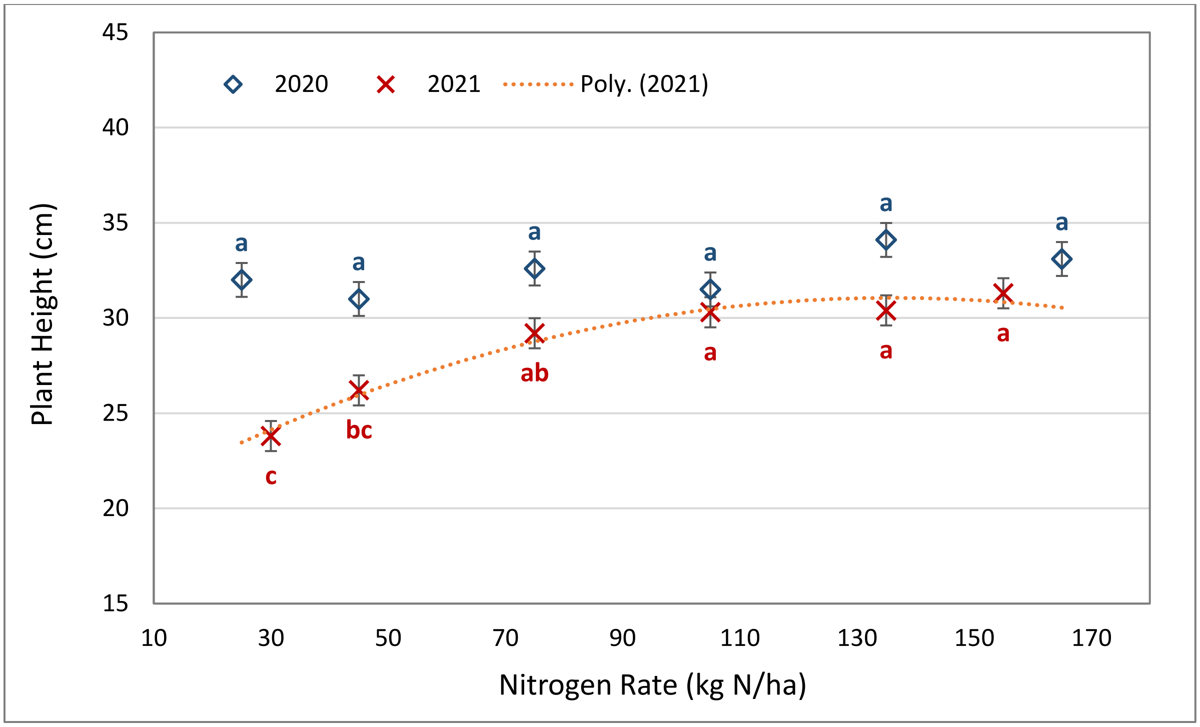

Figure 2. Total (soil plus fertilizer) nitrogen (N) rate effects on dry bean plant height at Indian Head in 2020 and 2021. Error bars are the standard error of the treatment means and values within a year denoted by the same letter do not significantly differ (Tukey-Kramer; $P \leq 0.05$).

It is common to observe minor delays in maturity as N fertility is increased for most crops. This does have some potential to be a concern with dry bean production in western Canada since this can be a relatively long-season crop with low frost tolerance. Maturity was declared when 60% of the pods had reached the buckskin stage, where they have turned yellow but are still somewhat flexible. At this stage, the plants can safely be desiccated and frost is unlikely to impact yield or seed quality. Under the dry conditions of 2020, the plants matured relatively early, averaging 101 days from seeding to maturity (Table 4). The overall F-test in 2020 was highly significant ($P < 0.001$) and the response was linear ($P < 0.001$), increasing gradually but consistently from 98.5 days in the control to 103.3 days at 165 kg N/ha (Fig. 3). In 2021, the crop took considerably longer to mature compared to the previous season, averaging 113 days from seeding. The overall F-test was, again, highly significant ($P < 0.001$); however, in this case the response was quadratic ($P < 0.001$). The quadratic response was such that maturity was delayed slightly in the control (113.8 days) relative to the more intermediate rates of 45-105 kg N/ha (112.0-112.8 days) but the 135-155 kg N/ha treatments took the longest to mature (114.3-115.0 days). Delays in maturity under severe nutrient deficiencies are occasionally observed; therefore, this result was not necessarily unexpected.

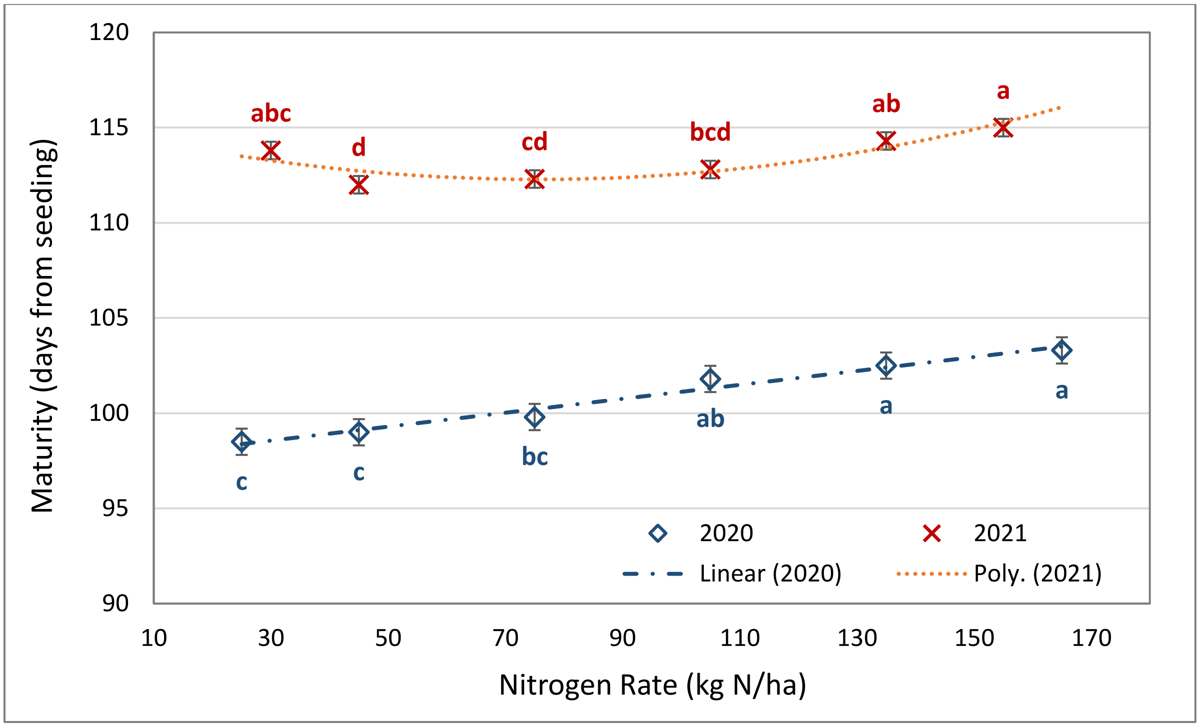

Figure 3. Total (soil plus fertilizer) nitrogen (N) rate effects on dry bean maturity at Indian Head in 2020 and 2021. Error bars are the standard error of the treatment means and values within a year denoted by the same letter do not significantly differ (Tukey-Kramer; *P* ≤ 0.05).

The overall seed yields varied dramatically between the two growing seasons (Table 4-5; Fig. 4), averaging 587 kg/ha across N rates in 2020 and 1205 kg/ha in 2021. In both years, the overall F-test was highly significant ($P < 0.001$) and so was the quadratic response ($P < 0.001$); however, the specific nature of the response differed between years. In 2020, under drought-limited and low yielding conditions, there was less variation across treatments and the maximum yields of 712 kg/ha were achieved at a modest rate of 75 kg N/ha. Although this was only 304 kg/ha higher than the control, the relative increase was 74%. Yields declined with further increases in N rate and, at 165 kg N/ha, were intermediate between the highest yielding treatment and the control. In 2021, under much higher yielding conditions, yields increased from only 396 kg/ha in the control to 1785 kg/ha at the highest N rate, a dramatic increase of 1389 kg/ha or 351%. Despite the fact that yields peaked at the highest rate, the response was quadratic in that the rate of the yield increase began to diminish as the total amount of N surpassed 105 kg N/ha. While yields were still showing signs of climbing past 135 kg N/ha, individual treatment means for 135 kg N/ha and 155 kg N/ha did not significantly differ ($P \leq 0.05$) according to the multiple comparisons test.

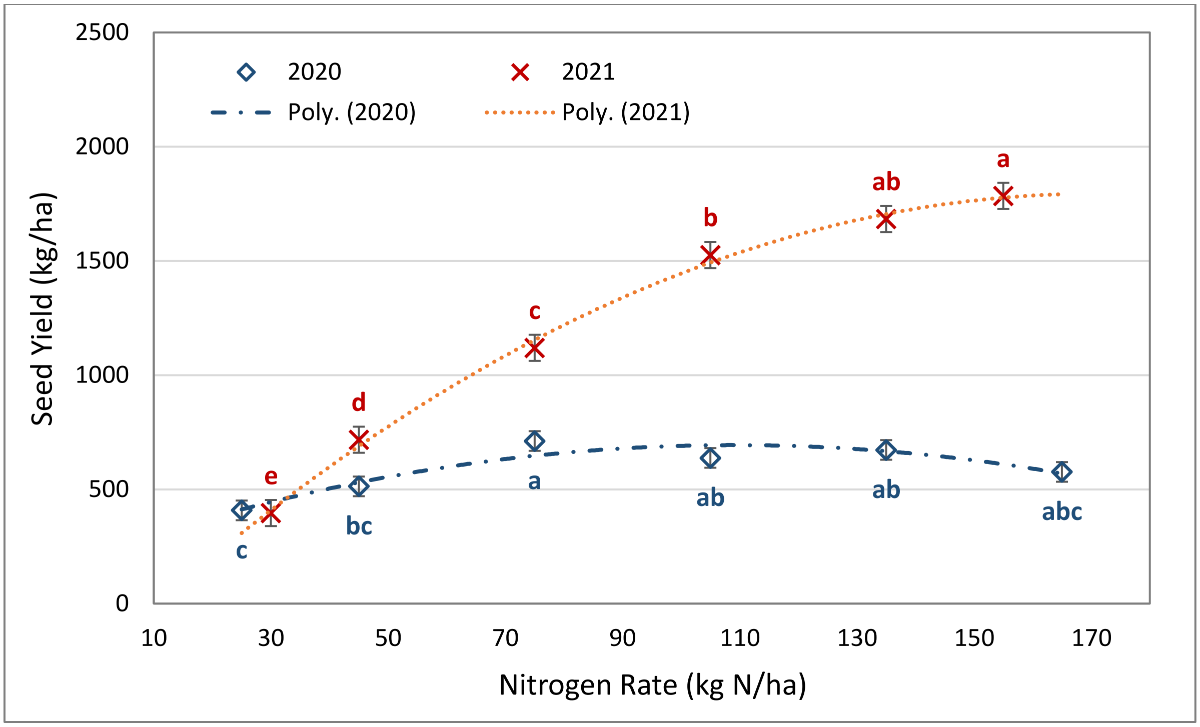

Figure 4. Total (soil plus fertilizer) nitrogen (N) rate effects on dry bean seed yields at Indian Head in 2020 and 2021. Error bars are the standard error of the treatment means and values within a year denoted by the same letter do not significantly differ (Tukey-Kramer; $P \leq 0.05$).

Seed weight is an important yield component for all crops which, in addition to genetics and environment, is also frequently affected by management. According to the 2022 Saskatchewan Seed Guide, CDC Blackstrap has an average seed weight of 195 g/1000 seeds. Averaged across N treatments, the seed weight was 179 g/1000 seeds in 2020 and 194 g/1000 seeds in 2021. In both years, the overall F-test indicated strong N rate effects on seed size ($P < 0.001$). The response differed between years and appeared to be related to the observed yield response to N rate. In 2020, seed weight increased quadratically ($P < 0.001$) with the values levelling off at 105 kg N/ha, slightly higher than what was required to achieve maximum yields. In 2021, the seed weight response was linear ($P < 0.001$) but not quadratic ($P = 0.392$), increasing right through the highest rates of N. Numerically, similar seed weights were observed between the control and 45 kg N/ha in 2021; thus, it would appear that the yield difference between these treatments was a result of more pods per plant and/or beans per pod as opposed to larger seeds. With further additions of N, increases in seed weight also contributed to the observed yield gains and likely became increasingly important as the other yield components reached their biological limits. In 2020, seed weight increased from 161 g/1000 seeds in the control to a maximum of 191 g/1000 seeds at the top N rate; however, this maximum value was only 2% higher than the seed weight of 187 g/1000 seeds observed at 105 kg N/ha. In 2021, the values ranged from 182 g/1000 seeds in the control to 210 g/1000 seeds at the top N rate, which was 6% higher than the 198 g/1000 seeds achieved at 105 kg N/ha. The generally higher seed weight values observed in 2021 were attributed to much more favourable environmental conditions for dry bean production.

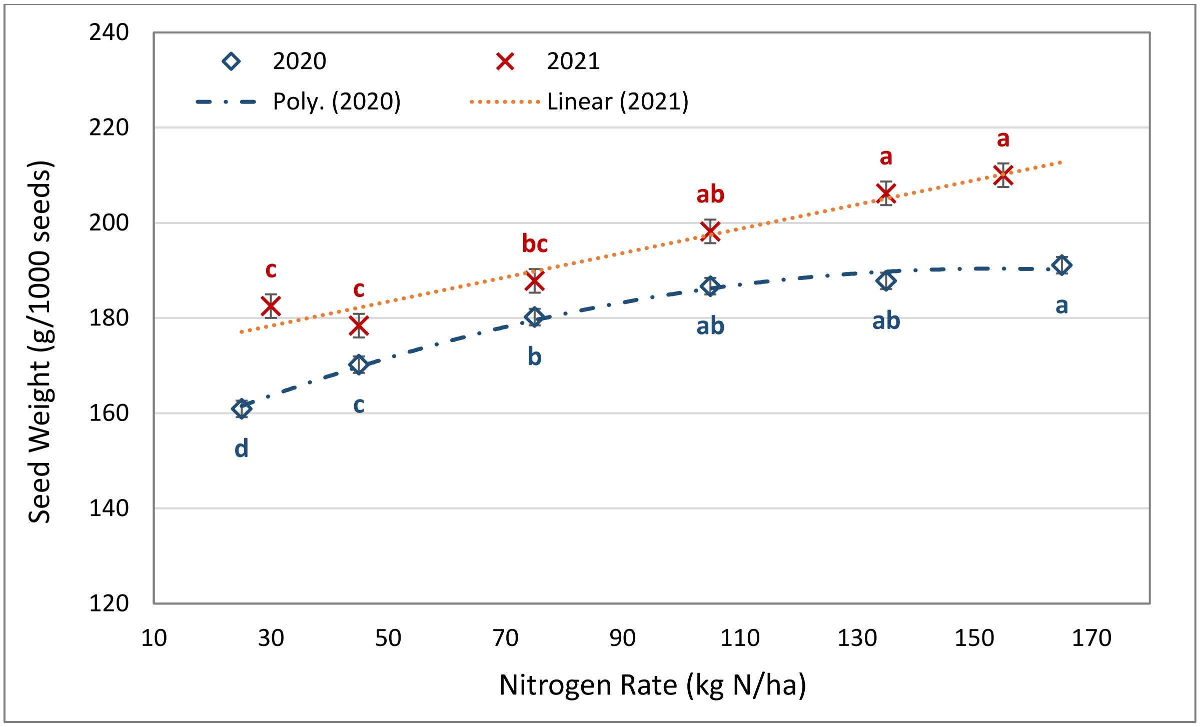

Figure 5. Total (soil plus fertilizer) nitrogen (N) rate effects on dry bean seed weight at Indian Head in 2020 and 2021. Error bars are the standard error of the treatment means and values within a year denoted by the same letter do not significantly differ (Tukey-Kramer; *P* ≤ 0.05).

Economic Analyses

In order to better understand the economic merits of fertilizing dry beans with potentially high rates of N fertilizer, a basic marginal economic analyses was completed with the treatment means. Only the estimated gross revenues and costs of N fertilizer were accounted for as these were the only factors varied in this project and the absolute production costs can vary widely across individual operations. For this analyses, we utilized the actual observed seed yields and applied urea rates, three bean price scenarios, and three urea price scenarios. The three bean prices we assumed were \$0.60/kg (\$0.27/lb), \$0.70/kg (\$0.32/lb), and \$0.80/kg (\$0.36/lb) while the three urea prices were \$500/Mt (\$0.49/lb N), \$750/Mt (\$0.74/lb N), and \$1000/Mt (\$0.99/lb N). Results from these analyses are provided in Tables 6 and 7 of the Appendices for 2020 and 2021, respectively. Notably, the most profitable treatment was always the treatment that produced the highest yield, regardless of the price of black beans or the cost of urea. Under the low yielding, drought limited conditions of 2020, the most profitable N rate was 75 kg N/ha (soil plus fertilizer) or 50 kg N/ha specifically from urea. In 2021, the top N rate of 155 kg N/ha (soil plus fertilizer), or 125 kg N/ha specifically from urea, was always the most profitable. As expected, marginal profits were highest when low urea prices were combined with high black bean prices and lowest when high urea prices were combined with low black bean prices.

Extension Activities

Due to COVID-19 restrictions in 2020 and logistic considerations in 2021, we were not able to show the field trials on any summer field tours or workshops during either the 2020 or 2021 growing seasons. The plots were, however, visited by several producers and industry representatives during multiple informal tours in 2021. Highlights of this work were presented by Chris Holzapfel at the

IHARF Winter Seminar and AGM on February 2, 2022. At this time, this presentation has been viewed approximately 185 times. Results from the project will continue to be shared where feasible going forward. Both this report and the 2020 multi-site report will be available online through and IHARF and/or Agri-ARM websites and other extension materials (i.e. fact sheets) may be developed. These results will also be shared amongst Agri-ARM sites to be presented during upcoming oral presentations wherever appropriate opportunities arise.

11. Conclusions and Recommendations

This project has demonstrated both dry bean responses to N fertilizer rate and the dramatic variation in overall yield potential that might be expected with this crop under dryland, solid-seeded production in Saskatchewan. The results from Indian Head showed that reasonably high yields are possible under favourable growing conditions; however, the risk of poor yields or even crop failure is also relatively high compared to more traditional crop options. Expanding our outlook to other locations in the Black soil zone showed similar ranges in yield potential and responses to N; however, both 2020 and 2021 were relatively dry and far from ideal for dry bean production. If wet conditions return to the Prairies, along with some of the challenges associated with more traditional pulse crop options in wet environments, CDC Blackstrap dry beans have potential to be a viable and profitable option. Provided that establishment is successful and late season moisture availability is adequate, this crop could also benefit from warming climate trends and longer growing seasons. This is especially true in more northern regions where moisture is less likely to be limiting but the frost-free period frequently can be.

Focussing on N management, we have demonstrated strong and reasonably consistent responses to fertilizer applications, especially at the higher yielding location-years but, somewhat surprisingly, also under quite low yielding conditions. When all four locations were considered over the two-year period, the yield response to N was linear 62.5% of the time (5 sites), quadratic 25% of the time (2 sites), and not significant 12.5% of the time (1 site). For one of the cases where the response was quadratic (Indian Head 2021), yields still increased right up to the highest N rate and this was also the most profitable treatment. Consequently, unless inoculant products become readily available and proven effective for western Canada, prospective dry bean growers in this region should plan on applying N fertilizer, potentially at quite high rates, to ensure optimum yields and more profitable production. That said, this is still a pulse crop with the ability to fix nitrogen, therefore utilizing check strips and regularly inspecting nodulation is still advisable, especially in cases where inoculant is applied, to ensure that this crop is being managed as efficiently as possible from both economic and environmental perspectives.

Supporting Information

12. Acknowledgements:

This project was supported by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canadian Agricultural Partnership bi-lateral agreement between the federal government and the Saskatchewan Ministry of Agriculture. Seed for the project was provided in-kind by Jeff Ewan. IHARF provided the land, equipment, and infrastructure required to complete this project at Indian Head and IHARF also has a strong working relationship and memorandum of understanding with Agriculture & Agri-Food Canada which helps to make work like this a possibility.

13. Appendices:

Table 4. Nitrogen fertilizer rate effects on dry bean response variables at Indian Head in 2020. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Nitrogen Rate	Emergence	Height	Maturity	Yield	Seed Weight
	-- plants/m^2 --	------ cm ------	----- days -----	---- kg/ha ----	g/1000 seeds
25 kg N/ha [Z]	22.6 a	32.0 a	98.5 c	408.0 c	160.9 d
45 kg N/ha	23.0 a	31.0 a	99.0 c	513.0 bc	170.2 c
75 kg N/ha	24.0 a	32.6 a	99.8 bc	711.6 a	180.2 b
105 kg N/ha	21.7 a	31.5 a	101.8 ab	637.6 ab	186.7 ab
135 kg N/ha	24.8 a	34.1 a	102.5 a	672.6 ab	187.8 ab
165 kg N/ha	23.6 a	33.2 a	103.3 a	576.3 abc	191.1 a
S.E.M.	2.18	0.89	0.69	43.05	1.73
	---------------- Pr > *F* (p-values) ----------------				
Overall F-test	0.945	0.181	<0.001	<0.001	<0.001
N Rate – linear	0.671	0.064	<0.001	0.003	<0.001
N Rate – quadratic	0.998	0.700	0.839	<0.001	<0.001

[Z] Residual NO_3-N plus the N provided by 11-52 was 25 kg N/ha at Indian Head in 2020

Table 5. Nitrogen fertilizer rate effects on dry bean response variables at Indian Head in 2021. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Treatment	Emergence	Height	Maturity	Yield	Seed Weight
	-- plants/m^2 --	------ cm ------	----- days -----	---- kg/ha ----	g/1000 seeds
30 kg N/ha [Z]	45.5 a	23.8 c	113.8 abc	396.3 e	182.5 c
45 kg N/ha	46.8 a	26.2 bc	112.0 d	717.2 d	178.4 c
75 kg N/ha	44.9 a	29.2 ab	112.3 cd	1119.4 c	187.8 bc
105 kg N/ha	43.5 a	30.3 a	112.8 bcd	1525.6 b	198.2 ab
135 kg N/ha	42.1 a	30.4 a	114.3 ab	1683.3 ab	206.2 a
155 kg N/ha	41.4 a	31.3 a	115.0 a	1784.8 a	210.0 a
S.E.M.	2.16	0.79	0.46	57.14	2.48
	---------------- Pr > *F* (p-values) ----------------				
Overall F-test	0.578	<0.001	<0.001	<0.001	<0.001
N Rate – linear	0.078	<0.001	<0.001	<0.001	<0.001
N Rate - quadratic	0.819	0.013	<0.001	<0.001	0.392

[Z] Residual NO_3-N plus the N provided by 11-52 was 30 kg N/ha at Indian Head in 2021

Table 6. Marginal profits (gross revenue less cost of urea) expressed in $/ha for dry beans (Black) at Indian Head in 2020. Values are presented for a range of fertilizer prices ($500, $750, or $1000/Mt urea) and black bean prices ($0.60/kg, $0.70/kg, or $0.8/kg).

Nitrogen Rate (kg urea/ha)	$500/Mt Urea	$750/Mt Urea	$1000/Mt Urea
	---------------------------- $0.60/kg black bean price ($0.27/lb) ----------------------------		
25 kg N/ha (nil)	$245	$245	$245
45 kg N/ha (43.5)	$286	$275	$264
75 kg N/ha (109)	$373	$345	$318
105 kg N/ha (174)	$296	$252	$209
135 kg N/ha (239)	$284	$224	$164
165 kg N/ha (304)	$194	$118	$41
	---------------------------- $0.70/kg black bean price ($0.32/lb) ----------------------------		
25 kg N/ha (nil)	$286	$286	$286
45 kg N/ha (43.5)	$337	$326	$316
75 kg N/ha (108.7)	$444	$417	$389
105 kg N/ha (80)	$359	$316	$272
135 kg N/ha (110)	$351	$291	$232
165 kg N/ha (140)	$251	$175	$99
	---------------------------- $0.80/kg black bean price ($0.36/lb) ----------------------------		
25 kg N/ha (nil)	$326	$326	$326
45 kg N/ha (43.5)	$389	$378	$367
75 kg N/ha (108.7)	$515	$488	$461
105 kg N/ha (80)	$423	$380	$336
135 kg N/ha (110)	$419	$359	$299
165 kg N/ha (140)	$309	$233	$157

Table 7. Marginal profits (gross revenue less cost of urea) expressed in $/ha for dry beans (Black) at Indian Head in 2021. Values are presented for a range of fertilizer prices ($500, $750, or $1000/Mt urea) and black bean prices ($0.60/kg, $0.70/kg, or $0.8/kg).

Nitrogen Rate (kg urea/ha)	$500/Mt Urea	$750/Mt Urea	$1000/Mt Urea
	---------------------------- $0.60/kg black bean price ($0.27/lb) ----------------------------		
25 kg N/ha (nil)	$238	$238	$238
45 kg N/ha (43.5)	$414	$406	$398
75 kg N/ha (109)	$623	$598	$574
105 kg N/ha (174)	$834	$793	$752
135 kg N/ha (239)	$896	$839	$782
165 kg N/ha (304)	$935	$867	$799
	---------------------------- $0.70/kg black bean price ($0.32/lb) ----------------------------		
25 kg N/ha (nil)	$277	$277	$277
45 kg N/ha (43.5)	$486	$478	$469
75 kg N/ha (108.7)	$735	$710	$686
105 kg N/ha (80)	$986	$946	$905
135 kg N/ha (110)	$1,064	$1,007	$950
165 kg N/ha (140)	$1,114	$1,046	$978
	---------------------------- $0.80/kg black bean price ($0.36/lb) ----------------------------		
25 kg N/ha (nil)	$317	$317	$317
45 kg N/ha (43.5)	$557	$549	$541
75 kg N/ha (108.7)	$847	$822	$798
105 kg N/ha (80)	$1,139	$1,098	$1,057
135 kg N/ha (110)	$1,232	$1,175	$1,118
165 kg N/ha (140)	$1,292	$1,224	$1,156

Table 8. Nitrogen fertilizer rate effects on dry bean response variables at Melfort in 2020. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Nitrogen Rate	Emergence	Height	Maturity	Yield	Seed Weight
	-- plants/m^2 --	------ cm ------	----- days -----	---- kg/ha ----	g/1000 seeds
50 kg N/ha [Z]	31.6 a	22.4 b	108.5 a	347.4 b	179.3 c
75 kg N/ha	30.8 a	24.5 ab	108.5 a	513.3 ab	179.3 c
105 kg N/ha	24.6 a	26.8 ab	108.5 a	651.0 ab	181.4 bc
135 kg N/ha	28.3 a	29.7 a	108.5 a	872.6 a	186.1 ab
165 kg N/ha	24.6 a	29.6 a	108.5 a	945.7 a	190.6 a
S.E.M.	4.21	1.40	0.62	117.01	2.29
	---------- Pr > *F* (p-values) ----------				
Overall F-test	0.634	0.012	1.000	0.007	<0.001
N Rate – linear	0.229	<0.001	1.000	<0.001	<0.001
N Rate – quadratic	0.757	0.398	1.000	0.685	0.074

[Z] Residual NO_3-N plus the N provided by 11-52 was 50 kg N/ha at Melfort in 2020

Table 9. Nitrogen fertilizer rate effects on dry bean response variables at Melfort in 2021. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Nitrogen Rate	Emergence	Height	Maturity	Yield	Seed Weight
	-- plants/m^2 --	------ cm ------	----- days -----	---- kg/ha ----	g/1000 seeds
50 kg N/ha [Z]	31.0 a	30.3 a	100.0 c	888.7 b	176.9 d
55 kg N/ha	35.9 a	30.9 a	100.0 c	923.7 b	181.5 d
75 kg N/ha	36.5 a	31.2 a	104.3 b	1036.4ab	192.3 c
105 kg N/ha	36.3 a	31.4 a	105.0 b	1075.7 ab	197.6 bc
135 kg N/ha	31. 0 a	28.7 a	106.8 a	1167.6 a	205.9 ab
155 kg N/ha	33.0 a	32.4 a	106.8 a	1201.6 a	212.1 a
S.E.M.	2.35	0.95	0.38	77.2	2.49
	---------- Pr > *F* (p-values) ----------				
Overall F-test	0.405	0.136	<0.001	0.001	<0.001
N Rate – linear	0.552	0.787	<0.001	<0.001	<0.001
N Rate – quadratic	0.234	0.572	<0.001	0.401	0.136

[Z] Residual NO_3-N plus the N provided by 11-52 was 50 kg N/ha at Melfort in 2021

Table 10. Nitrogen fertilizer rate effects on dry bean response variables at Redvers in 2020. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Nitrogen Rate	Emergence	Height	Maturity	Yield	Seed Weight
	-- plants/m^2 --	------ cm ------	----- days -----	---- kg/ha ----	g/1000 seeds
50 kg N/ha [Z]	54.2 ab	29.5 a	82.3 a	1046.6 a	156.8 c
75 kg N/ha	43.3 ab	30.4 a	82.3 a	1170.4 a	166.2 b
105 kg N/ha	43.3 ab	30.7 a	82.8 a	1277.5 a	173.9 b
135 kg N/ha	40.9 b	33.9 a	82.8 a	1507.1 a	182.2 a
165 kg N/ha	63.5 a	31.8 a	83.0 a	1615.4 a	182.1 a
S.E.M.	4.66	2.13	0.29	159.4	1.90
	---------- Pr > *F* (p-values) ----------				
Overall F-test	0.029	0.602	0.102	0.099	<0.001
N Rate – linear	0.273	0.231	0.012	0.009	<0.001
N Rate – quadratic	0.004	0.620	0.900	0.945	0.008

[Z] Residual NO_3-N plus the N provided by 11-52 was 50 kg N/ha at Redvers in 2020

Table 11. Nitrogen fertilizer rate effects on dry bean response variables at Redvers in 2021. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Nitrogen Rate	Emergence	Height	Maturity	Yield	Seed Weight
	-- plants/m^2 --	------ cm ------	----- days -----	---- kg/ha ----	g/1000 seeds
45 kg N/ha [Z]	44.8 a	31.8 bc	103.8 a	604.8 b	197.0 ab
52 kg N/ha	39.9 a	30.1 c	104.8 a	561.4 b	199.0 ab
89 kg N/ha	46.8 a	32.3 abc	98.0 b	710.2 b	187.0 b
127 kg N/ha	51.7 a	33.8 ab	97.8 b	1200.1 a	193.0 ab
165 kg N/ha	49.2 a	35.4 a	96.5 b	1480.5 a	198.0 ab
190 kg N/ha	46.8 a	35.3 a	97.3 b	1538.7 a	201.0 b
S.E.M.	3.44	0.88	0.80	88.7	2.86
	---------- Pr > *F* (p-values) ----------				
Overall F-test	0.138	<0.001	<0.001	<0.001	0.034
N Rate – linear	0.067	<0.001	<0.001	<0.001	0.290
N Rate – quadratic	0.092	0.730	<0.001	0.847	0.005

[Z] Residual NO_3-N plus the N provided by 11-52 was 45 kg N/ha at Redvers in 2021

Table 12. Nitrogen fertilizer rate effects on dry bean response variables at Yorkton in 2020. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Nitrogen Rate	Emergence	Height	Maturity	Yield	Seed Weight
	-- plants/m^2 --	------ cm ------	----- days -----	---- kg/ha ----	g/1000 seeds
25 kg N/ha [Z]	42.5 a	25.7 b	99.0 a	400.0 c	188.4 bc
45 kg N/ha	39.8 a	26.2 b	97.8 a	330.5 c	179.1 c
75 kg N/ha	44.3 a	29.5 ab	98.0 a	548.4 b	186.0 c
105 kg N/ha	40.5 a	32.8 a	99.3 a	647.6 b	206.8 ab
135 kg N/ha	36.3 a	29.5 ab	97.0 a	660.5 b	212.4 a
165 kg N/ha	38.8 a	29.7 ab	98.5 a	810.2 a	218.8 a
S.E.M.	6.39	1.42	1.41	28.6	5.10
	---------- Pr > *F* (p-values) ----------				
Overall F-test	0.513	0.017	0.510	<0.001	<0.001
N Rate – linear	0.205	0.009	0.677	<0.001	<0.001
N Rate – quadratic	0.770	0.020	0.710	0.958	0.253

[Z] Residual NO_3-N plus the N provided by 11-52 was 25 kg N/ha at Yorkton in 2020

Table 13. Nitrogen fertilizer rate effects on dry bean response variables at Yorkton in 2021. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Nitrogen Rate	Emergence	Height	Maturity	Yield	Seed Weight
	-- plants/m^2 --	------ cm ------	----- days -----	---- kg/ha ----	g/1000 seeds
65 kg N/ha [Z]	40.0 a	27.3 a	108.8 a	679.1 a	197.7 a
75 kg N/ha	37.8 a	27.3 a	110.5 a	676.1 a	206.1 a
105 kg N/ha	42.5 a	29.7 a	111.8 a	896.7 a	212.5 a
135 kg N/ha	38.4 a	27.4 a	111.8 a	713.5 a	208.3 a
155 kg N/ha	39.8 a	28.0 a	111.5 a	726.9 a	211.5 a
S.E.M.	3.86	1.19	0.92	100.2	6.10
	---------- Pr > *F* (p-values) ----------				
Overall F-test	0.827	0.543	0.047	0.390	0.291
N Rate – linear	0.962	0.705	0.014	0.665	0.108
N Rate – quadratic	0.688	0.295	0.062	0.157	0.266

[Z] Residual NO_3-N plus the N provided by 11-52 was 65 kg N/ha at Yorkton in 2021

Abstract

14. Abstract/Summary

Field trials were conducted near Indian Head in 2020 and 2021 with similar trials were near Melfort, Redvers, and Yorkton. The objective was to demonstrate dry bean response to nitrogen (N) fertilizer along with the overall adaptation of this crop under dryland, solid-seeded production in the Black soil zone of Saskatchewan. The variety was CDC Blackstrap, one of the most drought tolerant, early maturing dry bean varieties that is also relatively well-suited for straight combining. The treatments were six N fertilizer rates including a control, 45, 75, 105, 135, and 155-165 kg total N/ha, with rates adjusted for residual NO_3-N and N provided by other fertilizer products. Overall, conditions were more favourable in 2021 than in 2020 with respect to emergence, yield, and response to N fertilizer. Emergence was not significantly affected by N rate in either year. Plant heights were largely unaffected by N rate in 2020, but increased quadratically in 2021, levelling off at approximately 105 kg N/ha. Maturity was delayed at the highest N rates both years and also at the lowest rate in 2021. In 2020, yields peaked at 712 kg/ha at a modest 75 kg N/ha. In 2021, the highest yields were 1785 kg/ha at 155 kg N/ha. The yield response to N was quadratic both years, declining slightly at the highest N rates in 2020 but simply showing diminishing returns to increasing N at the highest rates in 2021. Seed weight increased with N rate both years. The increase was quadratic in 2020, levelling off at slightly higher N rates than yield. In 2021, with a much stronger yield response, seed weight increased linearly with N rate. Overall, the seeds were much larger in 2021 compared to 2020. A basic economic analyses showed that the N rates where yields were maximized were also the most profitable, regardless of the assumptions for bean price or cost of urea. Across all eight site-years, yields ranged widely and the response to N was linear 62.5% of the time, quadratic 25% of the time, and not significant 12.5% of the time. In conclusion, this crop has potential to be viable in Saskatchewan's Black soil but, unless inoculant products are readily available and proven effective, prospective growers must be prepared to provide adequate N fertility to achieve top yields.