2022 Annual Report

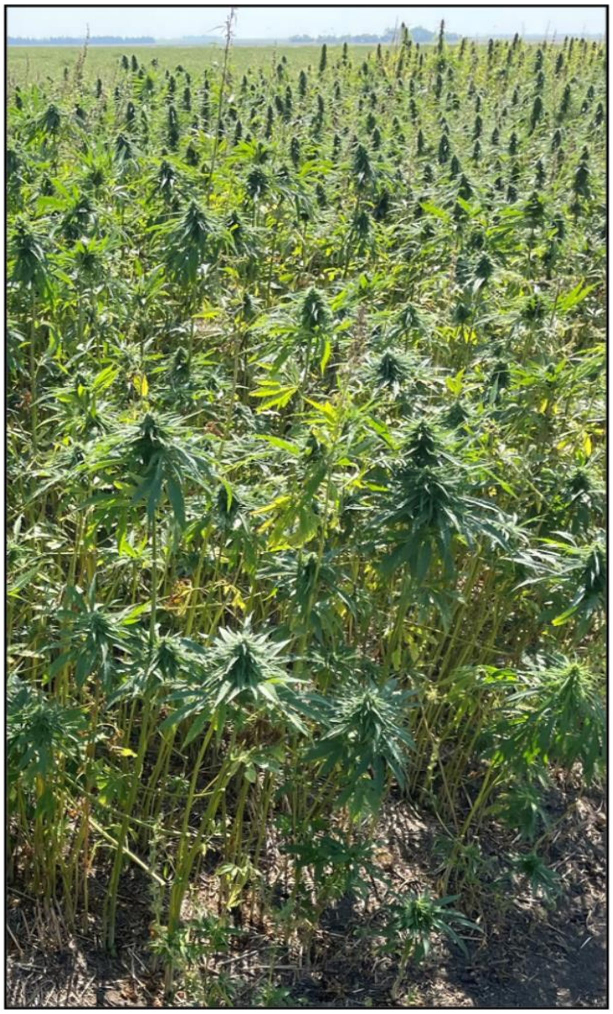
for the

Saskatchewan Ministry of Agriculture's

Agricultural Demonstration of Practices & Technologies (ADOPT) Program

Project Title: Regional Adaptation and Response to Nitrogen of Hemp and Quinoa in Saskatchewan

(Project #20211064)



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Project Identification

1. **Project Title:** Regional adaptation and response to nitrogen of hemp and quinoa in Saskatchewan
2. **Project Number:** 20211064
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(s):** September-2021 to February-2023
6. **Project contact person & contact details:**

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Objectives and Rationale

7. **Project Objectives:**
   The objectives of this project were:
   1. To gain experience with and information on the overall productivity and adaptation of two specialty crops, hemp (*Cannabis sativa*) and quinoa (*Chenopodium quinoa*), across a range of soil climatic zones in Saskatchewan.
   2. To demonstrate the overall yield response of hemp to increasing nitrogen (N) fertilizer rates.
   3. To demonstrate the overall yield response of quinoa to increasing nitrogen (N) fertilizer rates.
8. **Project Rationale:**
   While specialty crops such as hemp and quinoa are unlikely to be a fit for all commercial grain operations in Saskatchewan, many producers are quite receptive to profitable, alternative cropping options and seeking to diversify their crop rotations. Quinoa and hemp are not without their production challenges; however, both crops have been grown successfully in many regions of Saskatchewan and have potential to be quite profitable. The proposed demonstration aims to increase exposure of these crops to producers and agronomists in the areas where the work will be conducted while also generating basic, regionally relevant, yield and N response data. Gaining first-hand experience with hemp and quinoa will better enable the collaborating applied-research groups and those who work closely with them to provide insights and basic agronomic advice regarding the production of these crops. Nitrogen fertility has been identified as one of the most important and expensive inputs for quinoa and hemp production.

   Most of the quinoa production in western Canada is under contract and the total acreage is unclear; however, the largest producer of this crop in North America (Northern Quinoa Production Corporation, NorQuin) is based in Saskatoon and much of the value adding and distribution of this crop occurs right here in Saskatchewan. Published research on quinoa response to N fertility is limited; however, several agronomists and research groups in the province have gained limited experience with this crop over the past several years. Generally, NorQuin recommends that quinoa has similar fertilizer requirements as canola. A private industry funded trial conducted by IHARF in 2019 found that peak yields of 1700-1835 kg/ha were achieved with 137-157 kg N/ha but saw no benefit to split applications (Chris Holzapfel, personal communication). In Bangladesh, Biswas et al. (2021) achieved a maximum yield of 1171 kg/ha with 150 kg N/ha. In Thailand, under irrigation and with split application of N, Kansomjet et al. (2017) achieved maximum yields of 1754-2642 kg/ha with 94-188 kg N/ha, depending on the location.

Focusing on hemp, most research has shown that this crop also responds quite well to N fertilizer. Under relatively low yielding conditions, Vera et al. (2004) reported increasing hemp yields with N rates ranging from 80-120 kg N/ha, depending on the variety. Averaged over nine Saskatchewan location-years in the Dark Brown and Black soil zones, Vera et al. (2010) found that yields continued to climb right to 200 kg N/ha with the grain variety Finola; but the greatest rates of increase occurred with 50-150 kg N/ha. Under generally higher yielding conditions in eastern Canada, Aubin et al. (2015) found that yields frequently still had not plateaued at 200 kg N/ha, but P or K fertilizer applications had little effect on biomass or seed yields. A recent review article (Wylie et al. 2021) reported that most North American studies found hemp to be responsive to N, with optimal rates ranging from as low as 60 kg N/ha to as high as 200 kg N/ha.

While this report focusses solely on the results from Indian Head in 2022, it is acknowledged that similar demonstrations were conducted at Outlook, Melfort, and Swift Current. With only a single year of data, the results should be interpreted with some caution because the overall yield potentials and subsequent responses to N may vary widely over time, even at a single location.

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Methodology and Results

9. Methodology:

Field demonstrations with hemp and quinoa were established near Indian Head, Saskatchewan for the 2022 growing season. The treatments were simply five N fertility levels ranging from 60-220 kg N/ha, adjusted for fall residual soil NO_3-N. The specific rates were 60, 100, 140, 180, and 220 kg N/ha (soil plus fertilizer) and the N sources included monoammonium phosphate (11-52-0), ammonium sulphate (21-0-0-24), and urea (46-0-0). Monoammonium phosphate, ammonium sulphate, and potash rates were held constant across all treatments to provide 28-40-20-20 kg N-P_2O_5-K_2O-S/ha, while the rate of urea was adjusted as required to achieve the target N rates. The rationale for setting the lowest N rate to 60 kg N/ha was to allow for modest soil residual N levels and the N that would be provided by P and S fertilizer sources. All fertilizer was side banded approximately 3.75 cm (1.5") beside and 1.4 cm (0.75") below the seedrow. The N fertility treatments were arranged in a randomized completed block design (RCBD) and replicated four times. The hemp and quinoa were treated as two separate trials (situated adjacent to each other) with respect to both how they were laid out / managed in the field and statistical analyses of the response data.

Selected agronomic details and dates of operations are provided in Table 3 of the Appendices. The plots were seeded directly into oat stubble on June 1 for hemp and May 24 for quinoa. The varieties were X59 hemp and NQ Red quinoa seeded at 49 kg/ha and 11 kg/ha, respectively. The hemp seeding rate was higher than normal to account for poor germination. Weeds were controlled using a combination of a pre-seed burn-down, an in-crop application of a graminicide, and supplemental hand weeding throughout the vegetative growth stages. Quinoa can be targeted by a variety of insects and foliar insecticides were applied to keep such pests at acceptably low levels and help ensure good N response data; however, growers should consult with buyers (i.e., NorQuin) prior to using any crop protection products to ensure that they are both safe and permissible. No pre-harvest herbicides or desiccants were used and the centre rows of each plot were straight combined on October 5 for hemp and October 8 for quinoa.

Various data were collected prior to establishing the trials, during the growing season, and from the harvested seed samples. Initial residual soil nutrients and basic properties were estimated from a composite soil sample collected prior to seeding and submitted to AGVISE Laboratories for analyses. Notably, this spring composite was not used to adjust the N rates used in the demonstration. Instead, a fall site composite showing 10 kg NO_3-N/ha (0-60 cm) was used for this purpose. Establishment was evaluated by counting the number of seedlings in 4 x 1 m sections of crop row, after emergence was complete, and converting the values to plants/m^2. Average plant heights for each plot were estimated during the reproductive growth stages, after the plants had finished elongating, by measuring eight plants per plot to the nearest 1 cm. Yields were determined by cleaning and weighing the harvested grain samples and converting the values to kg/ha. For both crops, the yields were adjusted for dockage and, for the hemp, to a uniform seed moisture content of 8%. Quinoa moisture content could not be determined; however, the samples were aerated off the combine and stored indoors for an extended period prior to weighing and, as such, assumed to be of uniform moisture content at the time of yield determination.

The emergence, height, and yield data were statistically analyzed using the GLIMMIX procedure of SAS Studio with the effects of N rate treated as fixed and replicate effects treated as random. Individual treatment means were separated using the Tukey-Kramer test and orthogonal contrasts were utilized to test whether responses to N rate were linear or quadratic (curvilinear). Treatment effects and differences between means were considered significant at $P \leq 0.05$; however, p-values ≤ 0.1 may also be acknowledged as marginally significant.

10. Results:

Growing season weather and residual soil nutrients

Mean monthly temperatures and total precipitation amounts for May-September are presented in Table 1 for 2022 at Indian Head, alongside the long-term (1981-2010) averages. The rationale for including the September weather data was that these crops are relatively late to mature and were not combined until early October. With above normal snowpack and a relatively late spring melt, initial soil moisture was abundant. Furthermore, precipitation for the month of May was nearly twice the long-term average. While June was relatively dry, the wet weather resumed in July with 180% of average precipitation received in that month. Temperatures in May, June, and July were close to average; however, August and September were both dry and hot, which was beneficial for bringing the crops to maturity. Over the five-month period (May-September), temperatures were 0.7 °C above normal (105%) and cumulative precipitation was 20 mm above normal (107%). The first hard fall frost (≤ 2 °C) occurred early in October and, as such, had no detrimental effects on either crop. The killing frost was actually quite beneficial in drying down the quinoa stem and flower material which was still quite wet and would have been difficult to harvest prior to this. Ideally, the hemp should have been harvested earlier than it was, as the straw was starting to dry down and created major issues with wrapping behind the cylinder as it was being combined. Hemp is generally easier to harvest and less prone to wrapping when the straw is relatively green.

Table 1. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) averages for the 2022 growing season at Indian Head, SK. Due to the relatively long growing season requirements for hemp and quinoa, weather data for September is also reported.

Year	May	June	July	August	September	May-Aug
	---------- Mean Temperature (°C) ----------					
2022	10.9	16.1	18.1	18.3	13.7	15.4 (105%)
LT	10.8	15.8	18.2	17.4	11.5	14.7
	---------- Total Precipitation (mm) ----------					
2022	97.7	27.5	114.5	45.9	14.5	300 (107%)
LT	51.8	77.4	63.8	51.2	35.3	280

The soil at Indian Head is classified as a clay texture with an estimated 58% clay, 23% silt, and 19% sand on this site. Results for the spring composite soil samples are presented in Table 2. Again, the N rates used in the project were adjusted based on soil test from results from a broader site composite collected in the fall which showed 10 kg NO_3-N/ha as opposed to the 21 kg NO_3-N/ha detected in the spring composite. This discrepancy was considered relatively minor and could easily be explained by spatial variability and/or mineralization of organic N or conversion of NH_4-N to NO_3-N that occurred in the early spring. Other soil properties were considered typical for the site with a pH of 8.1, C.E.C. of 59.5 meq/100 g, and 4.3% organic matter. Residual P levels were low while K and S were relatively high; however, these nutrients were intended to be non-limiting and were supplemented with fertilizer additions at uniform rates across all N treatments.

Table 2. Spring soil test results (AGVISE Laboratories) for hemp and quinoa N fertility demonstrations conducted at Indian Head in 2022.

Depth (cm)	pH	C.E.C. (meq)	S.O.M. (%)	NO_3-N (kg/ha)	Olsen-P (ppm)	K (ppm)	S (kg/ha)
---------- 2021 ----------							
0-15	8.1	59.5	4.3	4	2	583	13
15-60	8.2	–	–	17	–	–	40
0-60	–	–	–	21	–	–	53

Hemp Adaptation and Response to Nitrogen Rate

Response data for the hemp demonstration at Indian Head in 2022 is summarized in Table 4 of the Appendices and Figs. 1, 2, and 3 for plant density, plant height, and seed yield, respectively.

According to the Saskatchewan Ministry of Agriculture, plant densities of 100-125 plants/m^2 are optimal for hemp grain production. In the current project, plant populations were not affected by N rate (P = 0.930); however, we did not achieve these optimal stands, with an overall average of only 72 plants/m^2. The seed source did have lower than optimal germination (70%); however, rates were adjusted accordingly to 49 kg/ha compared to the typical recommended range of 22-34 kg/ha. The poorer stands were likely mostly attributable to poor seedbed conditions during seeding because of excessive soil moisture followed by an extended dry period after seeding.

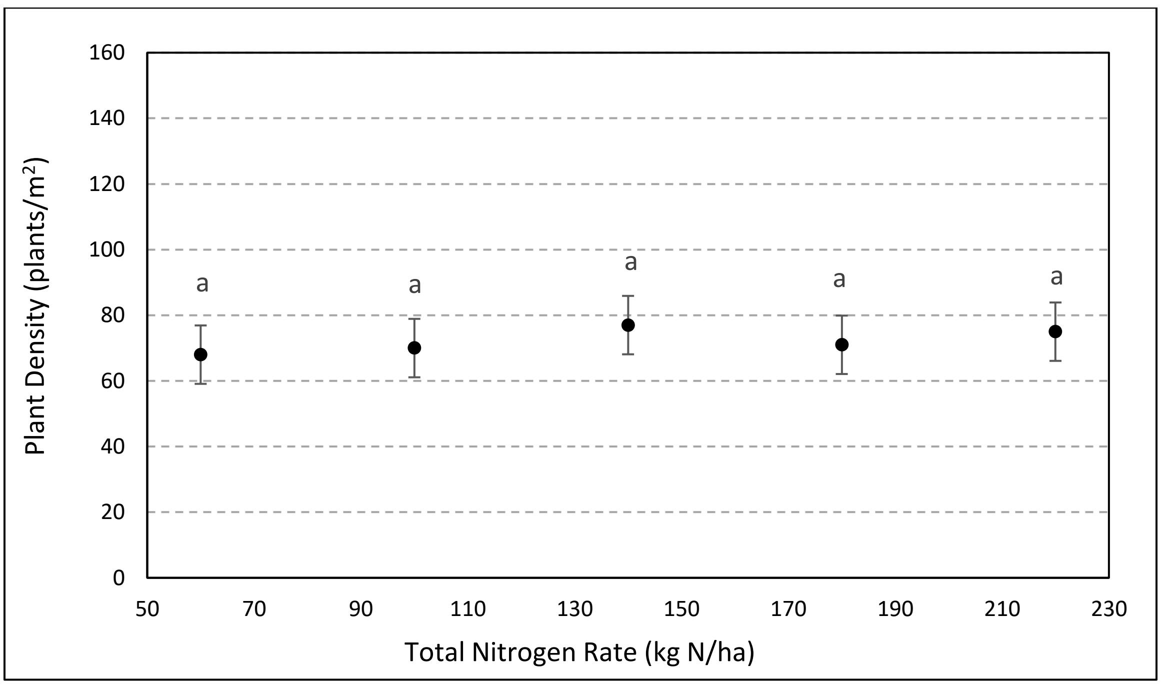

Figure 1. Side-banded nitrogen (N) rate effects on hemp plant densities at Indian Head in 2022.

Taller plants in grain hemp production are not particularly desirable as this crop can be challenging to harvest due to its tall stature and fibrous straw; however, plant height does typically increase with N fertility to a certain extent. Plant heights of the X59 hemp at Indian Head in 2022 ranged from 121-146 cm. While the shortest and tallest plants were observed at the lowest and highest N rates, respectively, the response was quadratic (P = 0.033) with heights beginning to level off at approximately 140 kg N/ha, according to the multiple comparisons tests. The greatest height increases, by far, occurred when the N rate was increased from 60 kg N/ha to 100 kg N/ha.

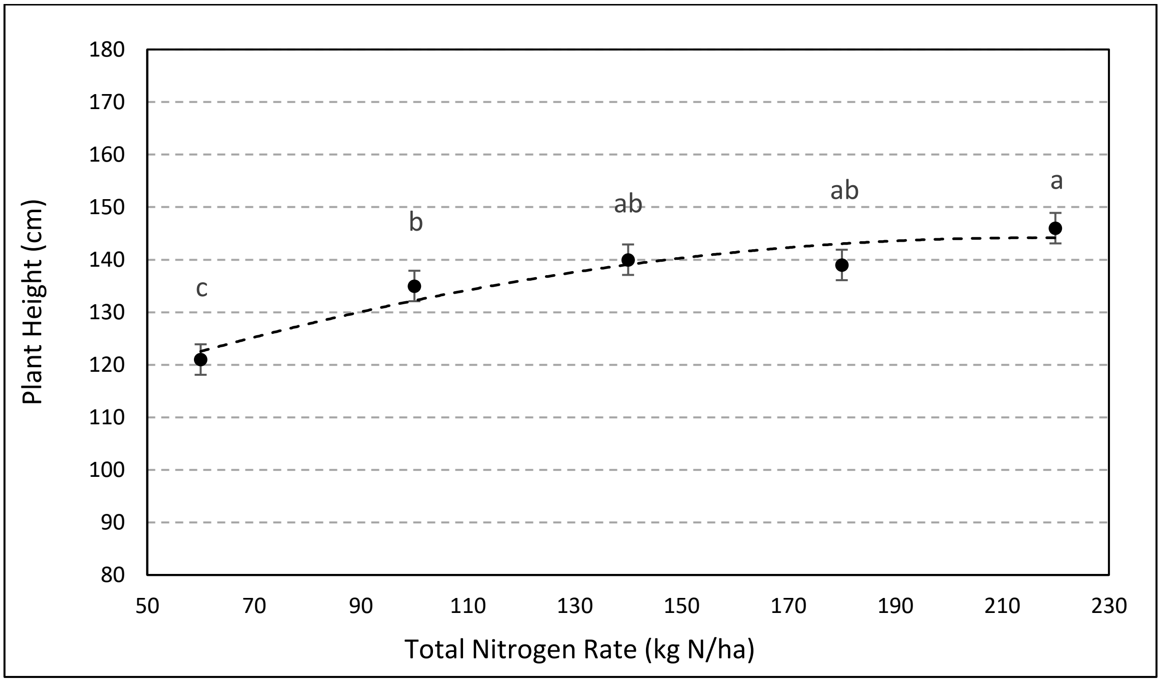

Figure 2. Side-banded nitrogen (N) rate effects on hemp plant height at Indian Head in 2022.

The hemp was remarkably responsive to increasing N rates with respect to seed yield. Yields were lowest at 60 kg N/ha and significantly increased right to highest N rate of 220 kg N/ha. The response was linear ($P < 0.001$), but not quadratic ($P = 0.454$) and the observed range in seed yields was from 893-1853 kg/ha. This worked out to a maximum yield increase of 108% going from 60 kg N/ha to 220 kg N/ha (soil plus fertilizer). While yield responses to such high N rates are not unheard of for this crop, past research has shown that hemp yield potential and responses to N can be variable. This work would have to be repeated over multiple years to develop more concrete, regionally relevant, recommendations. Overall, these yields were quite high. For context, average commercial yields in Manitoba from 2011-2020 ranged from 687-970 kg/ha (www.gov.mb.ca/agriculture/crops/crop-management/hemp.html).

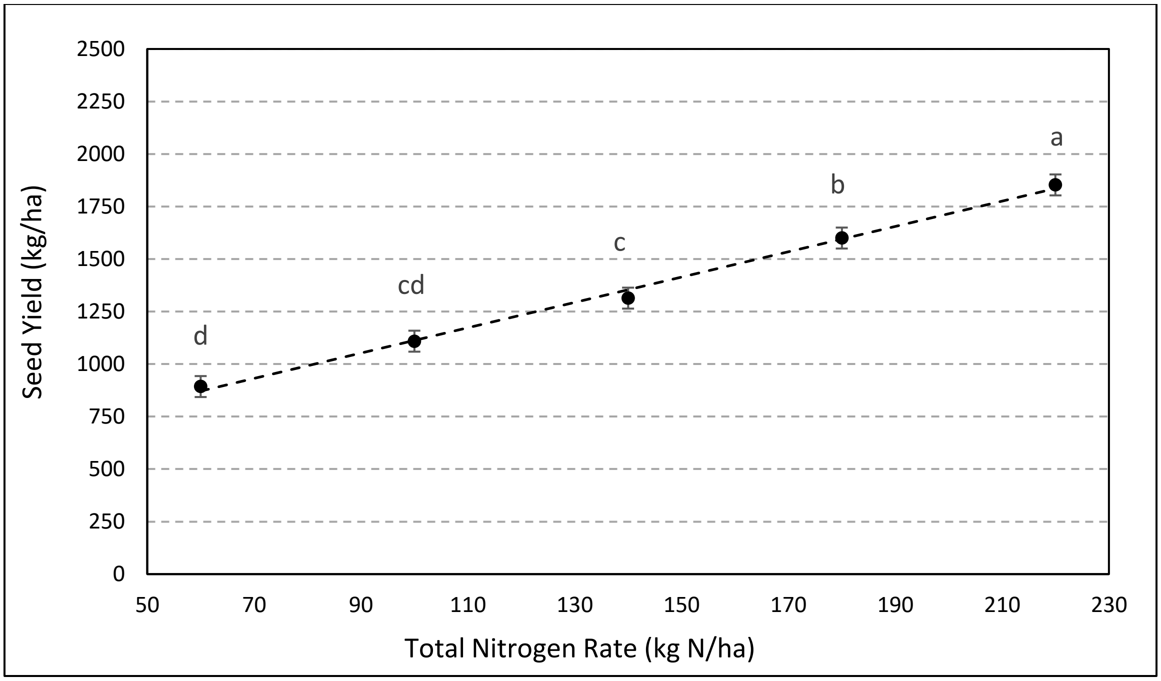

Figure 3. Side-banded nitrogen (N) rate effects on hemp seed yield at Indian Head in 2022.

Quinoa Adaptation and Response to Nitrogen Rate

Detailed results for the quinoa at Indian Head in 2022 are presented in Table 5 of the Appendices and Figs. 4, 5, and 6 below for plant densities, plant height, and seed yield, respectively. While information on minimum plant stands in quinoa is limited, NorQuin recommends a seeding rate of 11 kg/ha and, with good seedbed conditions and substantial precipitation in the days that followed, emergence of this crop was excellent. Although the treatment means were somewhat variable, ranging from 143-180 plants/m^2, no differences between them were significant according the multiple comparisons test and, at P = 0.065, the overall F-test was not quite significant at the desired probability. Furthermore, neither the linear nor quadratic orthogonal contrasts were significant (P = 0.109-0.113), indicating that there were no clear trends associated with N rate for establishment.

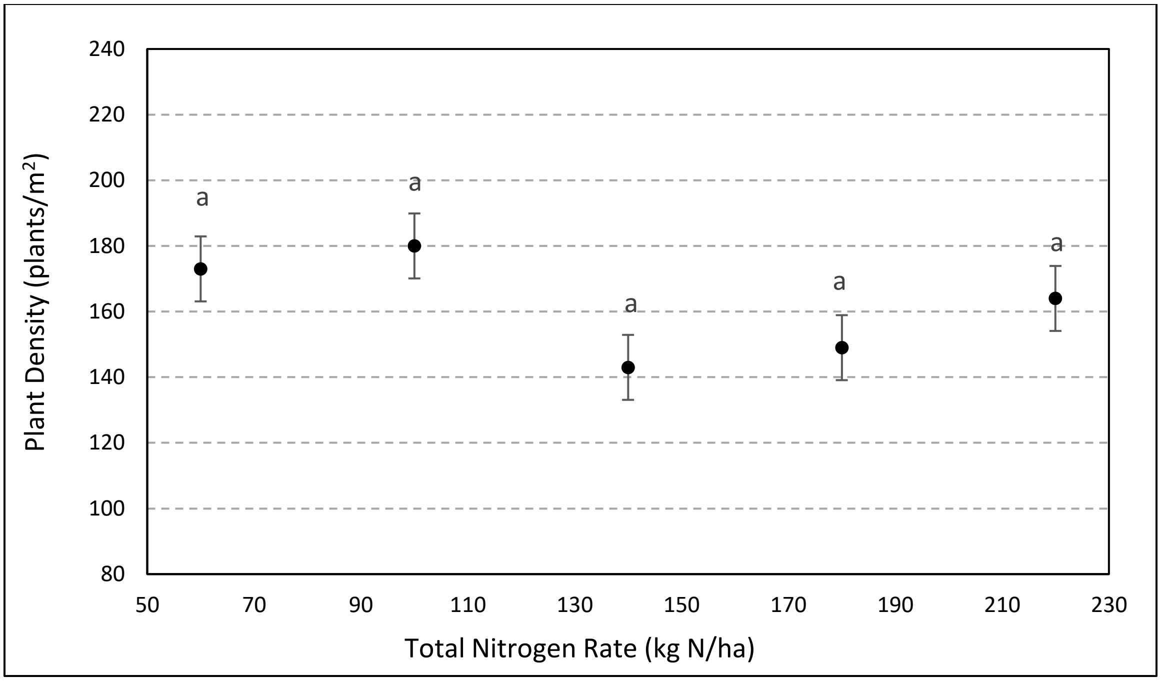

Figure 4. Side-banded nitrogen (N) rate effects on quinoa plant densities at Indian Head in 2022.

The quinoa was quite tall at Indian Head in 2022 and plant height increased quadratically with the amount of N applied (P = 0.005). At the lowest N level, the quinoa height averaged 110 cm while, at 220 kg N/ha, the height was 149 cm. The quadratic response was such that height started to level off at 180 kg N/ha, at which point further increases in N no longer significantly increased the height of the quinoa. While it was not specifically measured, no lodging was observed at any N rates.

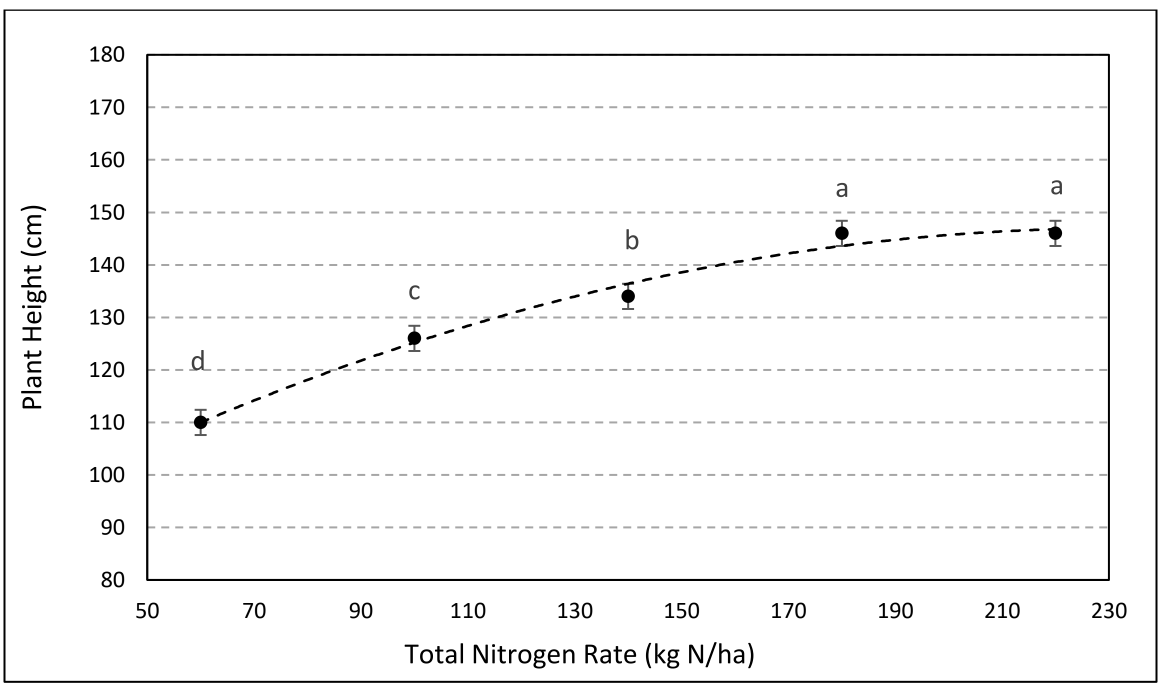

Figure 5. Side-banded nitrogen (N) rate effects on quinoa plant height at Indian Head in 2022.

The quinoa yield response to N was also quadratic (*P* < 0.001); however, yields appeared to start levelling off at slightly lower rates than what was observed for height. The highest yields occurred at 180 kg N/ha (soil plus fertilizer); however, according to the multiple comparisons test, the values at this N rate did not significantly differ from those at either 140 kg N/ha or 220 kg N/ha. Yields ranged from 1233 kg/ha to 2134 kg/ha, an overall increase of 73% at 180 kg N/ha over the yield achieved at 60 kg N/ha. This is consistent with recommendations from NorQuin who suggest N fertilizer rates of 134-168 kg N/ha to achieve maximum yields for this crop.

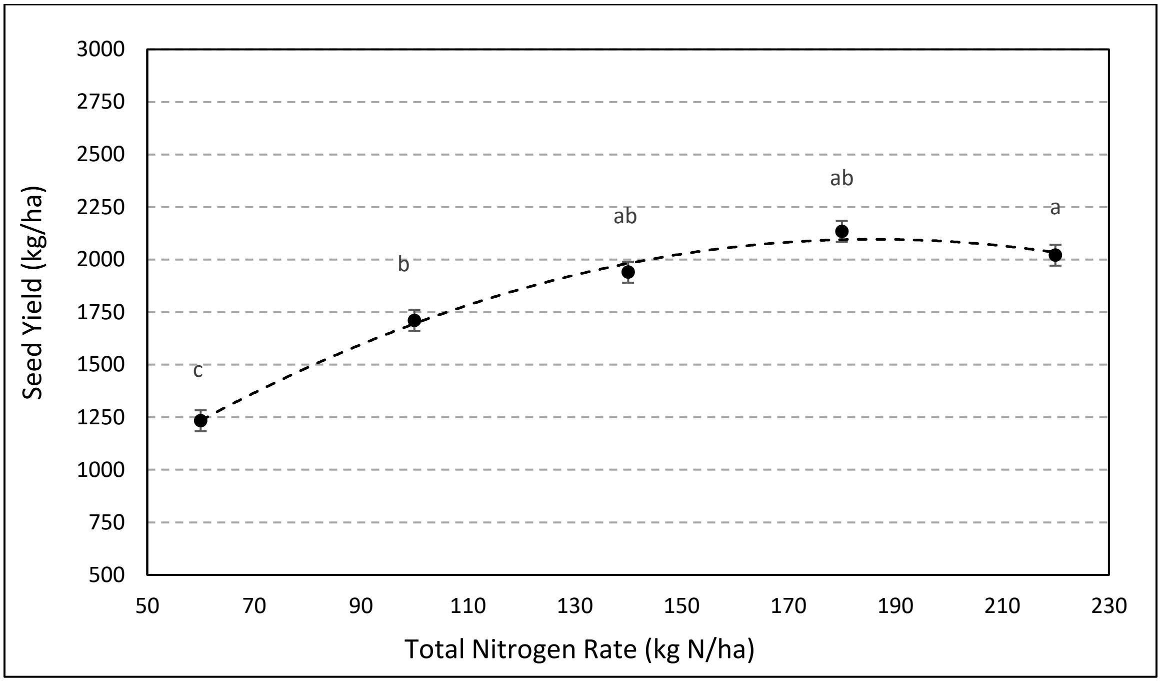

Figure 6. Side-banded nitrogen (N) rate effects on quinoa seed yield at Indian Head in 2022.

Extension Activities

This demonstration could not be shown during the 2022 Indian Head Crop Management Field Day on July 19, but was acknowledged during the indoor event (attended by ~120 people) and visited by multiple farmers and industry representatives throughout the growing season. In addition, the plots were shown and briefly discussed during a Canola Crop Walk which was jointly hosted by IHARF and SaskCanola on August 4 and attended by 40-45 people. This report will be available for download and viewing on the IHARF website (www.iharf.ca) and results will be shared through oral presentations and other means (i.e., fact sheets, popular agriculture press) wherever appropriate opportunities to do arise.

11. Conclusions and Recommendations

This project has demonstrated that both hemp and quinoa can be quite well-adapted to the thin-Black soil zone of Saskatchewan and, provided that other factors are not more limiting to yield, are responsive to relatively high rates of N fertilizer. Growers in this region who are interested in expanding their crop rotations to include special crops are encouraged to consider hemp and quinoa as viable options but should thoroughly research some of the production challenges that they might expect. They should also recognize that the yields observed in the current demonstration may not be consistently achieved in commercial production. Both crops will be better suited for fields that are relatively clean with respect to weeds since herbicide options, particularly for quinoa, are limited. Both crops are quite competitive once they are established and approaching the reproductive growth stages, but much less so early in the growing season. As such, a pre-seed burn-down is essential. For hemp, seeding can be completed quite late, giving ample time to let weeds emerge so that they can be controlled with pre-emergent herbicides. With quinoa, seeding relatively early in May is recommended, so pre-seed herbicide applications may be less effective, but should still be considered essential. Aside from weed control, some of the greatest challenges with production of these crops are likely to be harvest and residue management for hemp and insect control for quinoa. Focussing on N fertility, these results may be considered in conjunction with industry recommendations and past research; however, on their own, their value is limited since the work was only completed for a single growing season. As previously mentioned, similar demonstrations were conducted at Swift Current (Wheatland Conservation Area), Outlook (Irrigation Crop Diversification Corporation), and Melfort (Northeast Agriculture Research Foundation). As such, growers who are in Brown soil zone (dryland or irrigation) of western Saskatchewan or moist Black soil zone of northeast Saskatchewan are encouraged to refer to these reports for more regionally relevant information on the adaption and N response of these crops.

<u>Supporting Information</u>

12. Acknowledgements:

This project was funded through 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. IHARF has a strong working relationship and a memorandum of understanding with Agriculture and Agri-Food Canada which should be acknowledged and IHARF provided the land, equipment, and infrastructure required to complete this project. Quinoa seed and agronomic guidance were provided in-kind by the Northern Quinoa Production Corporation. Hemp seed was sourced by Morgan Cote from the Saskatchewan Ministry of Agriculture. Special thanks are extended to the IHARF staff who worked on the project.

13. Appendices:

Table 3. Selected agronomic information and dates of operations for hemp and quinoa nitrogen fertility demonstrations conducted at Indian Head in 2022.

Factor / Operation	Hemp	Quinoa
Previous Crop	Oat	Oat
Pre-seed Herbicide	894 g glyphosate/ha (May 27)	894 g glyphosate/ha (May 27)
Seeding Date	Jun-1	May-24
Seeding Rate	49 kg/ha (70% germ)	11 kg/ha
kg P_2O_5-K_2O-S/ha	40-20-20	40-20-20
In-Crop Herbicide	89 g clethodim/ha (Jun-20)	89 g clethodim/ha (Jun-20)
Emergence Counts	Jul-6	Jun-17
Plant Height	Aug-19	Aug-2
Harvest Date	Oct-5	Oct-8

Table 4. Treatment means, overall tests of fixed effects, and orthogonal contrast results for nitrogen (N) rate effects on plant density, height, and seed yield for hemp at Indian Head in 2022. Means followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Nitrogen Rate	Final Plant Density	Height	Grain Yield
	--------- plants/m^2 ---------	-------------- cm --------------	------------ kg/ha ------------
60 kg N/ha	68 a	121 c	893 d
100 kg N/ha	70 a	135 b	1109 cd
140 kg N/ha	77 a	140 ab	1314 c
180 kg N/ha	71 a	139 ab	1600 b
220 kg N/ha	75 a	146 a	1853 a
S.E.M.	8.9	2.9	49.9
Pr > F (p-value)	0.930	<0.001	<0.001
	--	p-value	--
NR - linear	0.545	<0.001	<0.001
NR - quadratic	0.747	0.033	0.454

Table 5. Treatment means, overall tests of fixed effects, and orthogonal contrast results for nitrogen rate effects on plant density, height, and seed yield for quinoa at Indian Head in 2022. Means followed by the same letter do not significantly differ (Tukey-Kramer, *P* ≤ 0.05).

Nitrogen Rate	Final Plant Density	Height	Grain Yield
	--------- plants/m^2 ---------	-------------- cm --------------	------------ kg/ha ------------
60 kg N/ha	173 a	110 d	1233 c
100 kg N/ha	180 a	126 c	1711 b
140 kg N/ha	143 a	134 b	1940 ab
180 kg N/ha	149 a	146 a	2134 ab
220 kg N/ha	164 a	149 a	2021 a
S.E.M.	9.9	2.4	77.2
Pr > F (p-value)	0.065	<0.001	<0.001
	--	p-value	--
NR - linear	0.113	<0.001	<0.001
NR - quadratic	0.109	0.005	<0.001

Abstract

14. Abstract/Summary

A demonstration was established near Indian Head in 2022 to demonstrate the adaptation and nitrogen (N) response of hemp and quinoa in the thin-Black soil zone of Saskatchewan. The treatments were five N fertility levels; 60, 100, 140, 180, 220 kg N/ha, including residual soil NO_3-N, arranged in a separate four replicate RCBD for each crop. In addition to residual soil nutrients, data collection included measurements of plant density, plant height, and seed yield. Overall, the 2022 growing season at Indian Head was quite favourable, with relatively high yield potential for both crops. Focussing on hemp, N fertilizer rate had no impact on plant densities; however, stands were poorer than targeted due to wet conditions at seeding followed by an extended period of dry weather. Hemp height increased quadratically from 121 cm at 60 kg N/ha to 146 cm at 220 kg N/ha, but height increases began slowing down at 140 kg N/ha. The yield response to N was somewhat stronger than expected for hemp, increasing linearly right to the highest rate of 220 kg N/ha by a magnitude of 960 kg/ha or 108% over the 60 kg N/ha rate. The maximum yield was 1853 kg/ha, which was likely above the average that could be expected for this region. For quinoa, emergence was excellent with mean plant densities of 143-180 plant/m^2. Despite this range, no differences between treatments were significant and there were no trends in terms of an N rate effect. Quinoa height increased quadratically from 110 cm at 60 kg N/ha to 146-149 cm at 180-220 kg N/ha. The quinoa yields followed a similar trend as height, peaking at 180 kg N/ha but starting to level off at approximately 140 kg N/ha. The top yield was 2134 kg/ha compared to 1233 kg/ha at 60 kg N/ha, an increase of 788 kg/ha or 64%. In conclusion, these results show promise for both crops in the thin-Black soil zone; however, producers should recognize that the yields reported are likely above average for the region and should research potential challenges with these crops prior to committing to growing them on a commercial scale.