Project Identification

Project Title: Regional adaptation & response to nitrogen of Hemp and Quinoa in Saskatchewan

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Objectives and Rationale:

Project objectives: To gain information on the overall productivity and response to increasing rates of nitrogen (N) fertility for hemp (*Cannabis sativa* L.) and quinoa (*Chenopodium quinoa* Willd.) grown across a range of SK environments

Project Rationale:
Hemp (*Cannabis sativa* L.) is an annual crop grown for both seed and fibre. Across the world, the largest producers are France and China (Risula 2017). In 2020, there were approximately 20,243 hectares of hemp cultivated across Canada with the largest proportion of acres found in Saskatchewan (Stephenson 2021). Hemp grown in Saskatchewan is primarily harvested for seed with a small market for fibre (Risula 2017). Seed varieties tend to be shorter in height. The current fertility recommendations for hemp by the Saskatchewan Ministry of Agriculture are similar to growing wheat to supply approximately 100 kg N/ha, 50 kg P_2O_5/ha, 67 kg K_2O/ha, and 17 kg S/ha that includes both soil residual and applied nutrients (Risula 2017). In contrast, modern wheat varieties such as AAC Brandon have shown to demonstrate increases in grain yield at nitrogen rates beyond 125 kg N/ha depending on the moisture conditions (Ens 2020; Hnatowich 2020a; Holzapfel 2020; Loken and Kowalski 2020; Wall 2020; Hnatowich 2021). Under irrigation relative to the 1X rate (150 kg N/ha soil + applied), wheat matured significantly later once a 1.75X rate of N was applied (Hnatowich 2021). Past research at Melfort has shown that hemp is responsive to nitrogen rates greater than 120 kg/ha (Risula 2017). Hemp is sensitive to the placement of many nutrients in the seedrow, therefore N should be placed in either the midrow or side-band with P, K, and S being placed in the side-band (Risula 2017). In hybrid fall rye, increasing nitrogen rates from 0-250 kg N/ha saw plant height increase up to 100 kg N/ha while grain yield increased up to 150 kg N/ha (Hnatowich 2020 b). However, the response of hemp plants to increasing nitrogen rate has not been documented beyond grain yield.

Quinoa is a grain crop that is grown under contract in Saskatchewan. The company that contract's quinoa production within Saskatchewan is known as the Northern Quinoa Production Corporation (NorQuin). Although, quinoa has been successfully produced in the province, there are many production concerns in this growing region, some of which are the lack of agronomic research. NorQuin advises producer's to fertilizer their quinoa crop similarly to canola; however very limited public research is available to support that this is the right practice to optimize yields in quinoa. Because of the limited knowledge of nitrogen response in both quinoa and hemp this demonstration sought to gain information on the overall productivity and response to increasing rates of nitrogen (N) fertility for hemp (*Cannabis sativa* L.) and quinoa (*Chenopodium quinoa* Willd.) grown across a range of SK environments.

Methodology and Results:

Methodology: This report covers one small plot demonstration that was conducted in two crops in 2022 in the RM of Star City 1.6 miles south of Melfort, SK. The demonstration evaluated nitrogen rates in two separate crops, which included hemp and quinoa. Both demonstrations were set up as randomized complete block (RCBD) designs with 4 replications. The manipulated variable in both trials was nitrogen rate (Soil+applied) of which there were five treatments 60 kg N/ha, 100 kg N/ha, 140 kg N/ha, 180 kg N/ha, and 220 kg N/ha (Table 1).

Table 1: Treatments used in Regional adaptation & response to nitrogen of Hemp and Quinoa in Saskatchewan at Melfort, SK 2022.

Treatment Number	Nitrogen Rate (kg N/ha) [a]
1	60
2	100
3	140
4	180
5	220

[a] Nitrogen rate is based on what is supplied by the residual soil N (0-60cm) and applied N

At Melfort, plots were 2-m wide by 7-m long. On May 15th, 2023, the test site was soil sampled for residual nutrient levels (Table 2). Both quinoa and hemp were located in the same area, therefore only one soil analysis was required. Results of the soil test were used to determine rates of N (46-0-0) to be applied. Rates of P (11-52-0), K (0-0-60), and S (21-0-0-24) were supplied at rates based on the Saskatchewan Ministry of Agriculture's recommendation for hemp of 50 kg P_2O_5/ha, 67 kg K_2O/ha, and 17 kg S/ha (Risula 2017). The quinoa was fertilized similarly to canola recommendations and received 34 kg P_2O_5/ha, 34 kg K_2O/ha, and 17 kg S/ha. All fertility sources were placed in the side-band at seeding time in both crops. Plots were seeded with the hemp variety X59 on May 27th and quinoa was seeded with a high yielding variety on June 1st. Both crops were seeded into wheat stubble using a 6-row Fabro plot seeder with 30cm row spacing. Seeding rate for hemp was adjusted for a 70% germination to target 48.6 kg seed/ha, and the seeding rate for quinoa was 11 kg/ha.

Table 2: Residual soil nutrient levels found in Regional adaptation & response to nitrogen of Hemp and Quinoa in Saskatchewan at Melfort, SK 2022.

Depth	NO3-N[z] (kg/ha)	Olsen-P (ppm)	K (ppm)	S (kg/ha)	pH	Organic Matter (%)	Salts (mmho/cm)
0-15cm	19	8	396	18	6.0	8.7	0.27
15-30cm	15			29	6.5		0.27

[z]Residual nitrogen was estimated for 0-60cm for adjusting for treatment N by adding the NO_3-N in 0-15cm and 15-30cm depths and multiplying the amount by 1.5.

The trial area received crop protection products as required. Glyphosate (Roundup Transorb 0.67 L/ac) was applied as a pre-emergent herbicide to both crops on June 3rd. A post-emergent herbicide application of clethodim (Arrow All In 0.15 L/ac, 120 g AI/L) was applied on June 23rd. Plots were also hand-weeded to manage weeds that were not controlled by the post-emergent herbicide. Quinoa received an early season insecticide application (Decis 5EC 40mL/ac) for cutworms on June 16 and a fungicide application (Cotegra 280mL/ac) for downy mildew on July 12. Additionally, quinoa received two late season insecticide applications (Cygon 480 900mL/ha) for stem borer on July 12th and 29th. The quinoa was desiccated (Reglone 0.7L/ac) on September 28th. The hemp did not receive any insecticides, fungicides, or desiccants. Both crops were harvested by collecting five crop rows per plot with a plot combine. Hemp was harvested on September 28th and quinoa on October 5th.

To assess treatment differences, data measurements consisted of plant density, plant height, and grain yield. Plant density (PPMS) was measured by counting the seedlings along four one-meter sections of crop row per plot. The average of all counted rows was then divided by the row spacing to determine the plants per m^{-2}. Plant density was assessed on June 22nd for both crops. Height was determined by

measuring the height of eight plants per plot to the nearest centimeter. Height was then averaged from the eight measurements of each plant to report the average height of each plot. Height was assessed on August 9th for hemp and August 10th for quinoa. Seed yield was determined by weighing each harvested plot sample and converting the grams per plot to a kg/ha and lbs/ac equivalent, while correcting to consistent moisture. Lastly, statistical analysis was completed for each crop separately using randomized complete block in Statistix 10.

Results:

Environmental Conditions

The environmental conditions of 2022 can be divided into two main sections described in Table 3. First, conditions in May and June were cooler and wetter than the long-term average continuing the trend of above average precipitation that was seen during the winter of 2021-2022. This generally resulted in delayed seeding for farmers in Northeast Saskatchewan. The second portion, in July and August was drier and warmer than the long-term average. This resulted in early maturation of most crops at Melfort, which allowed for timely harvesting.

Table 3: Mean temperatures and precipitation collected from the Environment Canada Weather Station at Melfort SK., from May to September 2022.

	May	June	July	August	September	Average/Total
			--- Mean Temperature (°C) ---			
2022	9.9	15.2	18.2	18.7	13.7	15.1
Long-Term [x]	10.7	15.9	17.5	16.8	10.8	14.3
			--- Total Precipitation (mm) ---			
2022	90.8	78.1	34.9	36.5	29.6	269.9
Long-Term [x]	42.9	54.3	76.7	52.4	38.7	265

[x] Long-term climate normal from Environment Canada Weather Station located at Melfort SK., from 1981-2010

Plant Density (PPMS):

Plant density (PPMS) was only significantly affected by nitrogen rate in quinoa ($p=0.0017$) (Table 4). The significant affect of nitrogen rate on quinoa PPMS was that PPMS were significantly reduced from 60 kg/ha (146.6 PPMS) at 180 kg/ha (84.5 PPMS) and 220 kg/ha (59.3 PPMS) of nitrogen. PPMS was numerically lower at 100 kg/ha (106.8 PPMS) and 140 kg/ha (110.1 PPMS); however, the difference was not significant from the 60 kg/ha rate. The effect of nitrogen rate on hemp PPMS was similar as to quinoa, where PPMS was numerically reduced at high rates of N as compared to the 60 kg/ha of N treatment; however, the difference was not significant. PPMS ranged from 154.0-170.6 PPMS in hemp and 59.3-146.6 PPMS in quinoa. Overall, plant stands were high in both crops with an average of 161.7 PPMS for hemp and 101.5 PPMS in quinoa.

Plant Height:

Plant height was significantly affected by nitrogen rate in quinoa ($p<0.0001$) and hemp ($p=0.0011$) (Table 4). Average plant height ranged from 86.1-133.7cm in quinoa, and 103.7-152.0cm in hemp. The significant affect of nitrogen rate in both crops was that plant height increased as nitrogen rate increased. For quinoa, plant height was significantly increased beyond 60 kg/ha of N (86.1cm). Both 100 kg/ha (112.9cm) and 140 kg/ha (115.8cm) had significantly increased height as compared to 60kg/ha. In

comparison, both 180 kg/ha (127.9cm) and 220 kg/ha (133.7cm) were significantly taller than all other nitrogen rates, but were not significantly different from one another. Therefore, in quinoa crop height was not significantly increased beyond 180 kg/ha of nitrogen. For hemp, crop height was only significantly greater than 60 kg/ha (103.7cm) at 140 kg/ha (139.4cm), 180 kg/ha (145.1cm), and 220 kg/ha (139.4cm); however, none of these nitrogen rates were significantly different from one another. Therefore, in hemp crop height was not significantly increased beyond 140 kg/ha of nitrogen.

Grain Yield:

Grain yield was significantly affected by nitrogen rate in quinoa ($p<0.0001$) and hemp ($p<0.0001$) (Table 4). Average yield ranged from 1298.2-3057.5 kg/ha in quinoa and 609.2-871.7 kg/ha in hemp. The significant affect of nitrogen rate in both crops was that grain yield increased as nitrogen rate increased (Figure 1). For quinoa, grain yield was significantly increased beyond 60 kg/ha of N (1458.6 kg/ha) at 100 kg/ha of N (2098.0 kg/ha), 140 kg/ha of N (2708.7 kg/ha), 180 kg/ha of N (3047.2 kg/ha) and 220 kg/ha of N (3435.4 kg/ha). Yield was significantly greater at 140 kg/ha of N and 180 kg/ha of N as compared to 100 kg/ha of N, but 140 kg/ha of N and 180 kg/ha of N were not significantly different from one another. At 220 kg/ha of N yield was significantly greater in quinoa as compared to all other treatments, therefore yields were maximized at the highest nitrogen rate. In hemp, yield was significantly increased beyond 60 kg/ha of N (684.5 kg/ha) for 180 kg/ha of N (955.0 kg/ha) and 220 kg/ha of N (979.5 kg/ha). At 100 kg/ha of N (696.5 kg/ha) and 140 kg/ha of N (815.0 kg/ha) yields were numerically increased as compared to 60 kg/ha of N; however, the difference was not significant. At 220 kg/ha of N yields were greater than at 180 kg/ha of N; however, the difference between treatment was not significant. Therefore, in hemp yields were not significantly increased beyond 180 kg/ha of N.

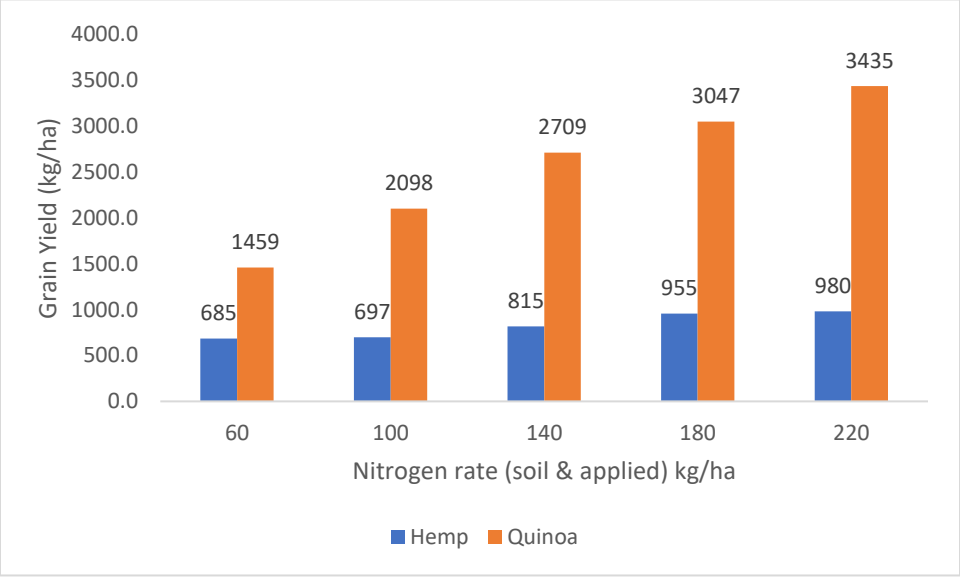

Figure 1: The grain yield of hemp and quinoa at increasing rates of nitrogen for Regional adaptation & response to nitrogen of Hemp in Saskatchewan at Melfort, SK in 2022.

Table 4: The analysis of variance and pairwise comparison of treatments in Regional adaptation & response to nitrogen of Hemp and Quinoa in Saskatchewan at Melfort, SK. in 2022

Hemp[d]								
	PPMS [a]		**Height (cm)**		**Grain Yield (kg/ha)**		**Grain Yield (lbs/ac)**	
p-value[b]	0.2593		0.0011**		<0.001***		<0.0001***	
Grand Mean	161.7		130.4		826.1		735.2	
CV	10.21		10.68		8.09		8.09	
N Rate (kg N/ha) [c]								
60	170.6	A	103.7	C	684.5	C	609.2	C
100	172.7	A	111.8	BC	696.5	C	619.9	C
140	161.8	A	139.4	AB	815.0	BC	725.4	BC
180	149.3	A	145.1	A	955.0	AB	850.0	AB
220	154.0	A	152.0	A	979.5	A	871.7	A
Quinoa[d]								
	PPMS [a]		**Height (cm)**		**Grain Yield (kg/ha)**		**Grain Yield (lbs/ac)**	
p-value[b]	0.0017*		<0.0001***		<0.0001***		<0.0001***	
Grand Mean	101.5		115.3		2549.6		2269.1	
CV	21.94		4.29		6.41		6.41	
N Rate (kg N/ha) [c]								
60	146.6	A	86.1	C	1458.6	D	1298.2	D
100	106.8	ABC	112.9	B	2098.0	C	1867.2	C
140	110.1	AB	115.8	B	2708.7	B	2410.7	B
180	84.5	BC	127.9	A	3047.2	B	2712.0	B
220	59.3	C	133.7	A	3435.4	A	3057.5	A

[a] PPMS Plants per m^2

[b] p-value significance levels * p<0.05, ** p<0.01, *** p<0.001

[c] Nitrogen rate is the sum of soil residual (0-60cm) and applied nitrogen

[d] Letters signify treatments that are significantly different using Tukey's HSD

Conclusions and Recommendations

In this demonstration both hemp and quinoa were very responsive to increasing nitrogen rates. When nitrogen rate was significant it decreased plant stands and increased crop height and seed yields. Quinoa was more seed sensitive to increased nitrogen rates and demonstrated significant declines in plant stands at high rates of 180 and 220 kg/ha of nitrogen. Hemp was less sensitive to increasing nitrogen rate and demonstrated no significant reductions in plant stands as nitrogen rates increased. Both crops had average height increases up to 220 kg/ha of N; however, in quinoa height was not significantly increased beyond 180 kg/ha of N and in hemp height was not significantly increased beyond 140 kg/ha of N. For seed yields, both crops demonstrated a linear increase in yields up to 220 kg/ha of N. In quinoa, yield was significantly increased at up to 220 kg/ha of N, and in hemp yield was significantly increased at up to 180 kg/ha of N. In conclusion, current recommendations for nitrogen in both crops in this demonstration are well below the nitrogen rates used in this demonstration (100 kg/ha in Hemp and 145 kg/ha in quinoa). This demonstration has provided results that suggest nitrogen rates can be increased beyond the current recommendations to maximize yields in both of these crops, under the growing season conditions at Melfort, SK in 2022.

Extension Activities

The results of this project were shared during the Northeast Branch of the Saskatchewan Institute of Agrologist's Ag Update at the Kerry Vickar Center in Melfort, SK on February 2nd, 2023. The demonstration was also acknowledge at NARF's annual field day on July 20th with 37 people in attendance. The final project report will be posted on neag.ca, and results will be shared at winter meetings and on social media whenever possible.

Supporting Information

Acknowledgements

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Abstract

Abstract/Summary

Hemp and quinoa are minor acreage crops in the province of Saskatchewan; however, with growing interest from the agricultural industry to diversify cropping rotations these crops provide alternative options to commonly grown annual grain crops in SK. Although it is known that these crops can be successfully grown in SK, the proper agronomics to grow a high yielding crop with more recent varieties is lacking research. Both crops are known to be responsive to nitrogen, but rates beyond current recommendations have not been widely researched. To determine the responsiveness of both quinoa and hemp to higher than recommended nitrogen rates a small-plot demonstration was conducted at Melfort, SK in the 2022 growing season. The nitrogen rates in the demonstration were 60, 100, 140, 180 and 220 kg/ha of soil and applied nitrogen. To assess treatment differences plant density (plants/m^2), plant height, and seed yield were collected in both crops. Quinoa was the only crop that demonstrated significant reductions in plant density at higher nitrogen rates. Plant stands were significantly reduced in quinoa at 180 and 220 kg/ha of N. Plant height was increased in both crops as nitrogen rate increased. In quinoa plant height was significantly increased up to 180 kg/ha of N and in hemp plant height was significantly increased up to 140 kg/ha of N. Seed yield was also increased in both crops as nitrogen rates increased. In quinoa seed yield was significantly increased up to 220 kg/ha N and for hemp seed yield was significantly increased up to 180 kg/ha of N. Based on current nitrogen recommendations in both crops, both crops were responsive to much higher rates than what is currently recommended in SK based on this one-year demonstration at Melfort.

Finances

Budget Report

See attached excel spreadsheet