2024 Project Report

for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Regional Adaptation of Quinoa and Response to Nitrogen and Phosphorus Fertilizer Applications

(Project #20230540)

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Agriculture Demonstration of Practices and Technologies (ADOPT)

Project Final Report

The final project report should be made available electronically (MS Word). Additional data tables and or graphs may be submitted in spreadsheet format. Due to formatting, printing and distribution requirements, final reports will not be accepted as PDF documents. Completed reports must be returned by email to Evaluation.Coordinator@gov.sk.ca.

Project Title: Regional Adaptation of Quinoa and Response to Nitrogen and Phosphorus Fertilizer Applications

Project Number: 2023054

Producer Group Sponsoring the Project: Indian Head Agricultural Research Foundation
Northeast Agriculture Research Foundation
Irrigation Saskatchewan
Swift Current

Project Location(s): *Provide the name or number of the rural municipality, nearest town or legal land location if possible. Provide the name of any cooperating landowner(s).* Indian Head, Saskatchewan (R.M. #156); Melfort, Saskatchewan (R.M. #428); Outlook, Saskatchewan (R.M. #284); Swift Current, Saskatchewan (R.M. #137).

Project start date *(month & year):* 4/1/2024

Project end date *(month & year):* 3/31/2025

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Abstract *(maximum 200 words)*

Detail key elements from the project objectives, methodology, results and conclusions to provide a short concise summary of the project. List extension activities such as field days or workshops and include the number of people who visited the project.

Field trials with quinoa (*Chenopodium quinoa*) were established at four Saskatchewan locations which were Indian Head (thin Black soil), Melfort (moist Black soil), Outlook (irrigated Brown soil), and Swift Current (dry Brown soil). The treatments were nitrogen (N) rates ranging from 60-220 kg N/ha and phosphorus (P) rates ranging from 0-60 kg P_2O_5/ha. The N rates were tested with P non-limiting while P rates were tested with N non-limiting. In addition to soil and weather information, data collection included emergence, height, yield, and protein. Although the season started cool and wet, heat and drought were the biggest limiting factors at most sites. We saw occasional, but minor, increases in seedling mortality and consistent height increases with N. Yields at Indian Head were low and not responsive to the

treatments; however, reasonably strong yield responses to N occurred at Melfort and Outlook. There was no yield at Swift Current, due to drought. Protein increased reasonably reliably with N. Benefits to P fertilization were less consistent. To conclude, N rates of about 140 kg N/ha, including soil nitrate, and 20-40 kg P_2O_5/ha will be appropriate under most circumstances with the lower P rate often being sufficient unless yield potential is high or the goal is to increase soil fertility.

Project Objectives

Provide a short statement outlining the project objectives. Identify the key concept this project was designed to demonstrate. For example, you might use a statement such as *"This project was intended to demonstrate and compare the benefits of……" or "The objective of this project was to demonstrate the impact of…."*

The main objectives of this project were to 1) gain experience with quinoa production and gather information on the overall productivity and adaptation of this crop across a range of Saskatchewan soil-climatic zones, 2) demonstrate quinoa response to nitrogen (N) fertilizer rates, and 3) demonstrate quinoa response to phosphorus (P) fertilizer rates.

Project Rationale

Briefly describe why this project is of interest to local producers. Why is it important to have this project? What are the potential beneficial outcomes? What is the perceived need?

While the seeded area of quinoa is relatively small, this crop has proven to be reasonably well adapted for production in Saskatchewan and can be quite profitable. Most 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, or NorQuin) is based in Saskatoon and much of the value adding and distribution of this crop occurs in Saskatchewan. Published research on quinoa response to nitrogen (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. An 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 2022, multiple Agri-ARM sites conducted a basic N fertility demonstration and yields at Indian Head peaked at 2134 kg/ha with an optimum total N rate (soil NO_3-N plus fertilizer N) of 140-180 kg N/ha (Holzapfel 2023). 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. As expected, information on quinoa response to phosphorus (P) is even more limited than it is for N; however, most crops have potential to respond to applications of this nutrient, particularly in low P soils. In Morocco, Bouras et al. (2022) increased yields by as much as 51% with P fertilization when salinity and other nutrients were not limiting to yield.

While specialty crops such as quinoa are unlikely to be a fit for all Saskatchewan grain farmers, many are receptive to alternative cropping options and seeking to diversify their rotations. The current demonstration was initiated with the intent of increasing exposure of quinoa to farmers and agronomists throughout the province, while also generating basic, regionally relevant, yield and N/P response data. The N response data will build upon results from 2022 while the P fertility component is new and more exploratory. Gaining first-hand experience with quinoa will better enable the collaborating Agri-ARM groups and those who work closely with them to provide insights and basic agronomic advice regarding the production of this crop. Nitrogen fertility has been identified as one of the most important and expensive inputs for quinoa production. With limited acres, and, as such, relatively few opportunities for private or producer led research funding, demonstrations with this crop are a good fit for government administered programs such as ADOPT.

Literature Cited

Bouras H, Choukr-Allah R, Amouaouch Y, Bouaziz A, Devkota KP, El Mouttaqi A, Bouazzama B, Hirich A. 2022. How Does Quinoa (Chenopodium quinoa Willd.) respond to phosphorus fertilization and Irrigation Water Salinity? Plants. 11:

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Biswas, P. K., Fatema, K., and Rahman, A. 2021. Influence of planting method and nitrogen dose on growth and yield of quinoa (Chenopodium quinoa). Bangladesh Agron. J. 24: 83-92.

Holzapfel, C., 2023. Regional Adaptation and Response to Nitrogen of Hemp and Quinoa in Saskatchewan. Online [Available]: https://iharf.ca/document/regional-adaptation-and-response-to-nitrogen-of-hemp-and-quinoa-in-saskatchewan/ (March 3, 2025)

Kansomjet, P., Thobunluepop, P., Lertmongkol, S., Sarobol, E., Kaewsuwan, P., Junhaeng, P., Pipattanawong, N., and Ivan, M. T. 2017. Response of physiological characteristics, seed yield, and seed quality of quinoa under difference of nitrogen fertilizer management. Am. J. Plant Physiol. 12: 20-27.

Methodology

Fully describe how the project was set up and run. You should provide enough information so that any reader can understand what you did, and where and when you did it. From that they can determine if your report has any relevance to their own operation. For example, your description should include all relevant items such as 1) the number and size of any field plots, 2) what was seeded, 3) what treatments were applied to the plots, 4) the schedule or timing of any relevant activities such as seeding, treatment application or harvest, and 5) what was measured to evaluate the success of any treatment. If your project dealt with animals, you should be sure to include 1) the number of animals in each trial group, 2) the treatment or procedure applied to each group, and 3) what was measured to evaluate the success of each treatment.

Field trials with quinoa were established at four locations: Indian Head (thin Black soil zone), Melfort (moist Black soil zone), Outlook (irrigated Brown soil zone), and Swift Current (dry Brown soil zone). The locations were selected to represent a variety of Saskatchewan environments. The treatments, summarized in Table 1, included five nitrogen (N) fertilizer rates (60, 100, 140, 180, and 220 kg N/ha, including residual soil NO_3-N) and four phosphorus (P) fertilizer rates (0, 20, 40, and 60 kg P_2O_5/ha). To keep costs down, the treatments were not a factorial combination and N rates were evaluated at 40 kg P_2O_5/ha while P rates evaluated at 180 kg total N/ha. The primary N and P sources were urea (46-0-0) and monoammonium phosphate (MAP; 11-52-0) and the placement method for both was side banding.

Table 1. Nitrogen (N) and phosphorous (P) rate treatments for the 2024 ADOPT quinoa fertility demonstrations.

#	N Rate [Z]	P Rate
1 [Y]	60 kg N/ha	40 kg P_2O_5/ha
2 [Y]	100 kg N/ha	40 kg P_2O_5/ha
3 [Y]	140 kg N/ha	40 kg P_2O_5/ha
4 [XY]	180 kg N/ha	40 kg P_2O_5/ha
5 [Y]	220 kg N/ha	40 kg P_2O_5/ha
6 [X]	180 kg N/ha	0 kg P_2O_5/ha
7 [X]	180 kg N/ha	20 kg P_2O_5/ha
8 [X]	180 kg N/ha	60 kg P_2O_5/ha

[Z] N rates include residual NO_3-N (0-60 cm)
[Y] Treatment used to evaluate N rate response
[X] Treatment used to evaluate P rate response

All controllable factors other than N and P fertilizer were intended to be non-limiting. The variety NQ Red was seeded at 11 kg/ha and the seed was treated with Insure Pulse (60 ml/100 kg seed) and Stress Shield (100 ml/100 kg seed) to reduce the potential impact of root disease and/or early season insect feeding. Where required, potassium and sulfur were supplied as either side-banded (Swift Current) or pre-seed broadcast (Indian Head) potassium sulfate or side-banded ammonium sulfate (Melfort). Weeds were managed using a combination of pre-seed herbicides, in-crop herbicides, and hand weeding. Foliar insecticides were required by protocol due to the high susceptibility of this crop and difficulties in scouting. Foliar fungicides and pre-harvest herbicides/desiccants were utilized at the discretion of site managers. The centre rows of each plot were straight combined as early as possible after the crop was ready. Selected agronomic information and dates of field operations/data collection activities are provided in Table 5 of the Appendices.

Various data were collected for explanatory purposes and to evaluate treatment performance. While fall, whole site composite soil samples were permitted for N fertilizer rate determination, the specific trial areas were sampled in the spring for determination of residual nutrients and basic chemical/physical properties. Establishment was measured after emergence was complete by counting a minimum of 2 x 1 m sections of crop row and converting the averaged values to plants/m^2. After the plants had finished elongating, the overall height for each plot was estimated by measuring 6-8 plants per plot to the nearest 1 cm and averaging their heights. Yields were determined for each plot by cleaning and weighing the harvested grain samples and converting the values to kg/ha. Where possible, yields were adjusted to 12% seed moisture content but, regardless, we air dried the samples and allowed sufficient time for moisture to equilibrate prior to weighing. Cleaned seed sub-samples were forwarded to NorQuin for protein determination using an NIR analyzer and custom quinoa protein curve. Growing season weather temperatures and precipitation amounts were recorded using the nearest Environment and Climate Change Canada weather stations.

All available response data for each site were analyzed using the general linear model (GLM) procedure of SAS Studio. Individual treatment means were separated using Fisher's protected LSD test and orthogonal contrasts were used to test whether responses to N and P rate were linear, quadratic (curvilinear), or not significant. All treatment effects and differences between means were considered significant at $P \leq 0.05$

Results *(you must provide the following information)*

Present and discuss any project results, including any data or measurements taken to evaluate the demonstration. Include things that didn't appear to work. These results are just as important to share. List extension activities such as field days or workshops. List the activity, the date it occurred, and the number of people who attended.

Soil Test Results and Growing Season Weather

Again, while the soil test results used to determine fertilizer rates sometimes differed, all the specific trial areas were sampled in the spring and selected results are presented in Table 2. Indian Head and Swift Current had higher than ideal residual N levels; however, any discrepancies between the fall (whole site) and spring (trial specific) were within a reasonable margin of error. At Indian Head, the higher soil NO_3-N levels observed in the spring were likely at least partly attributable to mineralization and denitrification that occurred in the early spring since the fall samples were collected during a period of extended and severe drought. Soil pH, C.E.C., and organic matter levels ranged widely, but were generally considered representative of the agroclimatic regions within which they were located. Detailed soil test results for Outlook were not available; however, residual N at this location was relatively low with an estimated 30 kg NO_3-N/ha in the 0-60 cm soil profile. Residual P levels (Olsen) were low at Indian Head and Outlook (3-7 ppm) and more moderate at Melfort and Swift Current (10-13 ppm).

Table 2. Selected soil test analyses for ADOPT quinoa N and P response demonstration conducted at Indian Head (IH), Melfort (ME), Outlook (OL), and Swift Current (SW) in 2024. Unless otherwise indicated, all measurements are representative of the 0-15 cm soil profile.

Parameter	IH-24	ME-24	OL-24	SW-24
pH	8.0	6.3	7.9	6.9
Organic Matter (%)	3.9	8.6	3.1	2.4
CEC (meq)	47.2	33.8	20.4	16.9
NO_3-N (kg/ha) [Z]	50	35	36	72
Olsen-P (ppm)	3	13	7	10
K (ppm)	422	407	351	275
kg S/ha (kg/ha) [Z]	27	27	111	27

[Z] Values for residual NO_3-N and S are for the 0-60 cm soil profile

[Y] The residual NO_3-N levels used to calculated fertilizer rates at IH-24 and SW-24 was 29 kg/ha and 60 kg N/ha, respectively

Mean monthly temperatures and precipitation totals for the four-month (May through August) growing season are presented in Tables 3 and 4, respectively. For all locations, temperatures were slightly below average in May and particularly cool in June, followed by a remarkably hot July and about average to well-above average temperatures in August. The precipitation patterns were such that cumulative rainfall in May and June were above average at all locations but well below average in July. August participation varied with conditions continuing to be quite dry at all locations except Indian Head where frequent thunderstorms resulted in nearly 140% of average precipitation for the month. The wet August weather was largely detrimental at Indian Head with the crop being past the point of benefitting much from the extra moisture, but extreme winds and heavy rains increasing harvest losses due to stem breakage and seed shatter. For all locations, it was a season of extremes characterized by both cool periods with excess moisture followed by prolonged heat and drought during the reproductive phases. The Outlook site received an estimated 256 mm of supplemental irrigation.

Table 3. Mean monthly temperatures along with long-term (LT; 1981-2010) averages for the 2024 growing season at Indian Head (IH), Melfort (ME), Outlook (OL), and Swift Current (SW), Saskatchewan.

Year	May	June	July	August	May-Aug
	--	Mean Temperature (°C)	--		
IH-24	10.6	13.6	19.5	17.9	15.4 (-0.2)
IH-LT	10.8	15.8	18.2	17.4	15.6
ME-24	10.1	13.2	19.4	17.4	15.0 (-0.2)
ME-LT	10.7	15.9	17.5	16.8	15.2
OL-24	11.2	14.2	20.4	18.1	16.0 (-0.1)
OL-LT	11.5	16.1	18.9	18.0	16.1
SW-24	10.6	14.3	21.3	19.4	16.4 (+0.6)
SW-LT	11.0	15.7	18.4	17.9	15.8

Table 4. Total monthly precipitation amounts along with long-term (LT; 1981-2010) averages for the 2024 growing season at Indian Head (IH), Melfort (ME), Outlook (OL), and Swift Current (SW), Saskatchewan.

Year	May	June	July	August	May-Aug
	--	Total Precipitation (mm)	--		
IH-24	63.7	74.9	37.4	71.2	248 (102%)
IH-LT	51.7	77.4	63.8	51.2	244
ME-24	73.0	84.0	36.1	16.9	210 (93%)
ME-LT	42.9	54.3	76.7	52.4	226
OL-24	65.7	122.0 (75)	19.1 (106)	3.8 (75)	211 (103%)
OL-LT	42.6	63.9	56.1	42.8	205
SW-24	73.6	52.1	18.6	18.2	163 (87%)
SW-LT	42.1	66.1	44.0	35.4	188

Indian Head

Detailed results for Indian Head are presented in Table 6 of the Appendices. Establishment was excellent with an average of 135 established plants/m^2. The overall F test for emergence was significant (P = 0.013), with the main response being a linear decline (P < 0.001) in plant densities, from 157 to ~127 plants/m^2 as the N rate was increased from 60 to 220 kg N/ha (soil plus fertilizer; Fig. 1). Although the quadratic response was not significant (P = 0.155), the greatest reduction occurred going from 100 to 140 kg total N/ha, or 136 to 223 kg urea/ha (after soil N and N from MAP were accounted for) and subsequent increases in N rate had little effect on plant densities. Phosphorus rate did not affect establishment. Plant heights also varied with fertilizer treatment (P = 0.003) and the response showed a linear (P < 0.001) increase from 103 to 119 cm as the total N rate increased from 60 to 220 kg N/ha (Fig. 2). According to the orthogonal contrasts, P rate did not affect quinoa height (*P* = 0.117-0.430). Yields were extremely low at Indian Head, averaging only 343 kg/ha, and not affected by treatment. A marginally significant quadratic response to N (*P* = 0.091) suggested that yields peaked with 100-140 kg N/ha; however, the lack of any significant F test (*P* = 0.430) means that this trend was too small and/or inconsistent to have confidence in. There was no evidence of any yield response to P fertility in the corresponding orthogonal contrast results (*P* = 0.394-0.521) The reason for such low yields is not entirely clear, but is likely attributable to the combination of hot, dry conditions through flowering/seed development and environmental losses resulting from extreme winds and heavy rains in August and September. Despite the lack of any effects on yield, the overall F-test for protein was highly significant (*P* < 0.001) and the orthogonal contrasts detected a linear increase in protein (*P* < 0.001), from ~13.7% at 60 kg N/ha to 16.8% at 220 kg N/ha with N rate with a significant overall F-test (*P* < 0.001). Although the quadratic orthogonal contrast was only marginally significant (*P* = 0.081), it did appear to fit the data best and would describe a typical protein response if the yield potential (prior to any environmental losses) was initially increasing with N before levelling off at 100-140 kg N/ha.

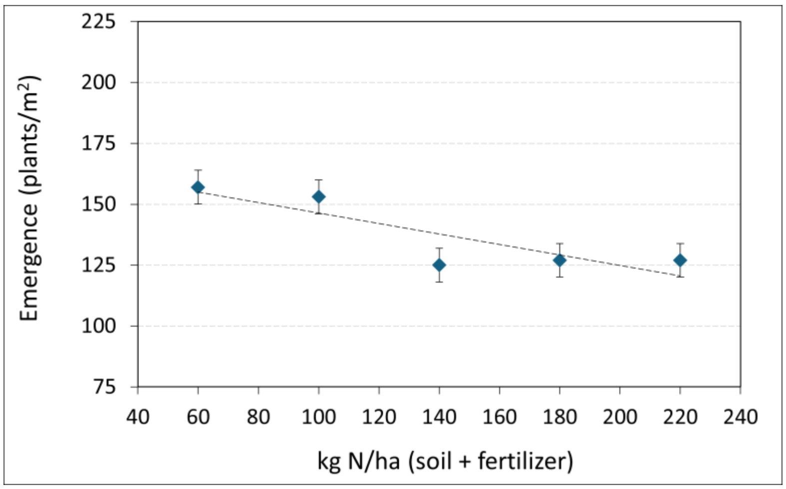

Figure 1. Nitrogen rate effects on quinoa establishment at Indian Head, 2024. The primary N source was side-banded urea. The overall F-test (*P* = 0.013) and the linear orthogonal contrast (*P* < 0.001) were significant.

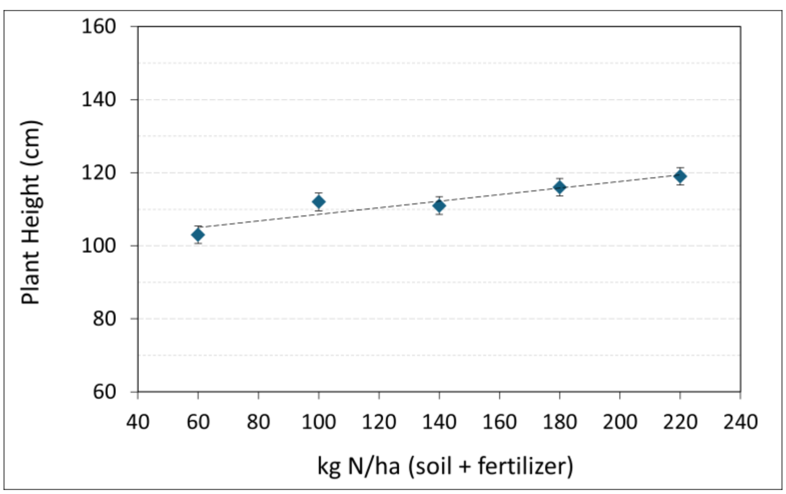

Figure 2. Nitrogen rate effects on quinoa height at Indian Head, 2024. The primary N source was side-banded urea. The overall F-test (*P* = 0.003) and the linear orthogonal contrast (*P* < 0.001) were significant.

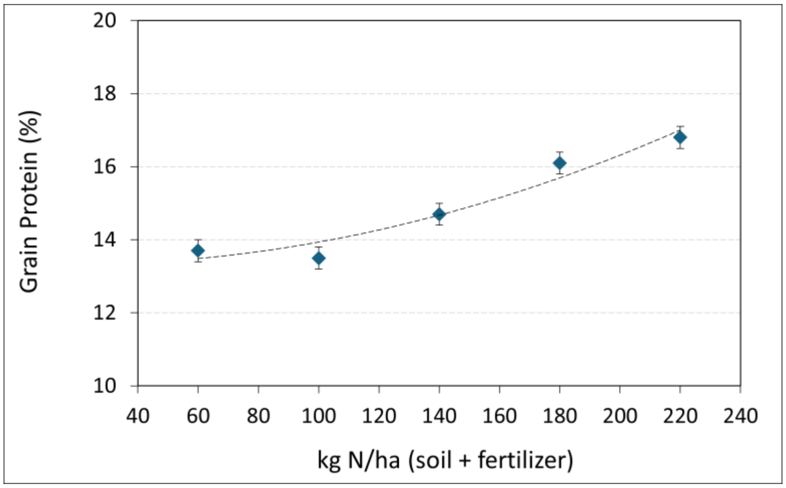

Figure 3. Nitrogen rate effects on quinoa grain protein at Indian Head, 2024. The primary N source was side-banded urea. The overall F-test (*P* < 0.001) and the linear orthogonal contrast (*P* < 0.001) were significant. The quadratic orthogonal contrast was marginally significant (*P* = 0.081).

Melfort

Detailed results for Melfort are presented in Table 7 of the Appendices. Like Indian Head, the overall F-test for emergence at Melfort was significant (*P* = 0.019), along with both the linear and quadratic orthogonal contrasts for N rate (*P* = 0.013-0.039). The quadratic nature of the response was such that plant densities declined going from 60 to 140 kg N/ha but were relatively unaffected by subsequent increases (Fig. 4). The orthogonal contrasts for P rate indicated that side-banded MAP did not affect emergence (*P* = 0.127-0.935). The overall F-test for plant height at Melfort was highly significant (*P* < 0.001), with values increasing quadratically (*P* = 0.029) from 71 to 111 cm as the N rate was increased from 60 to 220 kg N/ha. The quadratic nature of the response was due to the greatest increases occurring going from 60 to 140 kg N/ha (Fig. 5). Although the overall F-test was not significant (*P* = 0.197) due to high variability relative to the absolute yields, the orthogonal contrasts (*P* = 0.034-0.062) did suggest some yield benefit to N at Melfort. Despite the higher p-value, the data appear to fit the quadratic equation best, with greatest increase going from 60 to 100 kg N/ha and diminishing returns with subsequent additions of N (Fig. 6). For protein, no potential responses were significant (*P* = 0.065-0.110) at the desired probability level, and at best, there was a weak trend for higher protein at the highest N rate and lowest P rate (14.3-14.4%) relative to the other fertility treatments (13.4-13.7%).

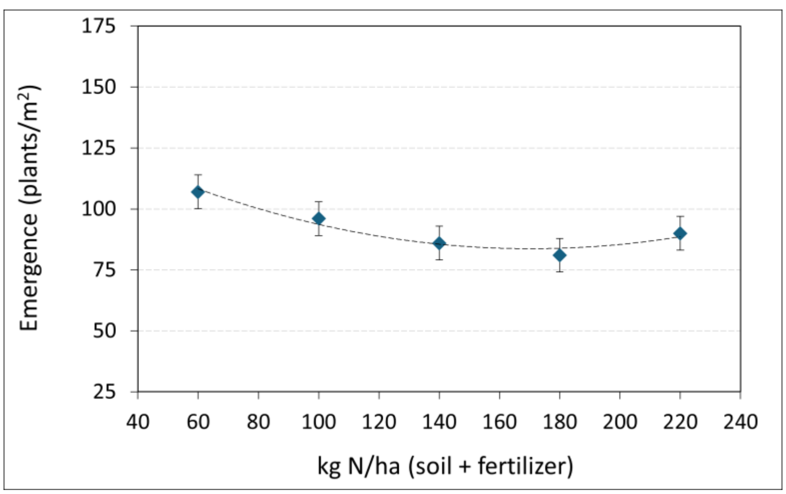

Figure 4. Nitrogen rate effects on quinoa emergence at Melfort, 2024. The primary N source was side-banded urea. The overall F-test (*P* = 0.019) and both the linear and quadratic orthogonal contrasts were significant (*P* = 0.013-0.039).

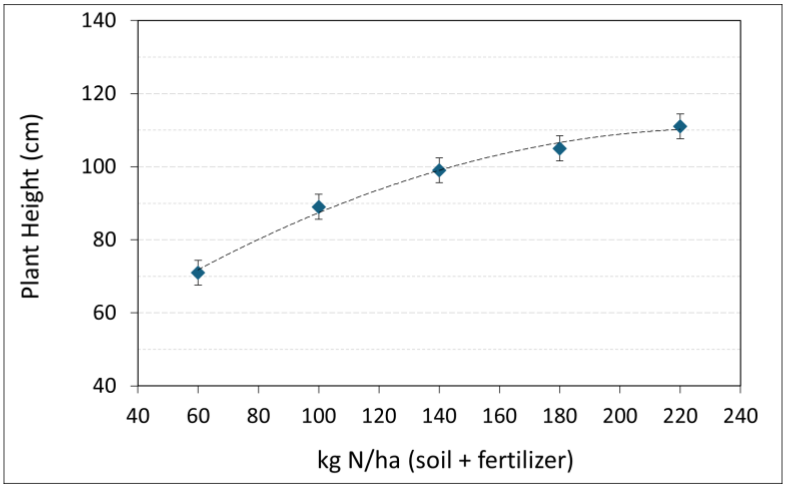

Figure 5. Nitrogen rate effects on quinoa plant height at Melfort, 2024. The primary N source was side-banded urea. The overall F-test (*P* < 0.001) and both the linear and quadratic orthogonal contrasts were significant (*P* < 0.001-0.029).

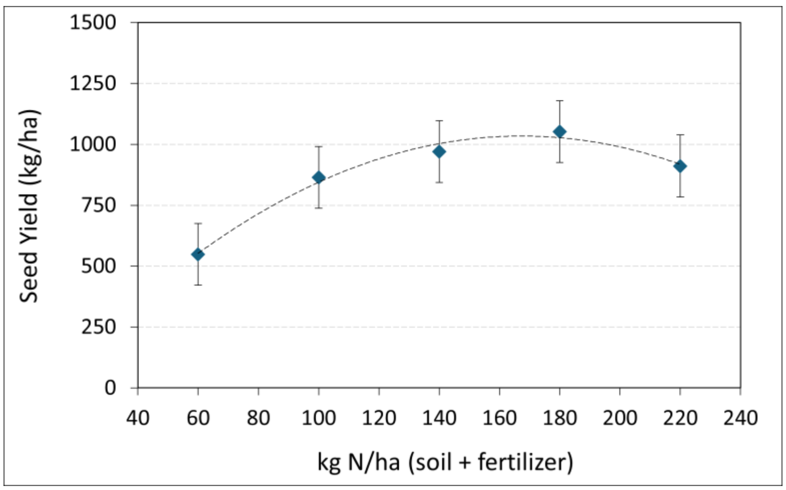

Figure 6. Nitrogen rate effects on quinoa grain yield at Melfort, 2024. The primary N source was side-banded urea. The overall F-test was not significant (*P* = 0.197) due to high variability; however, the linear and quadratic orthogonal contrasts suggested some yield benefit to N fertilizer (*P* = 0.034-0.062).

Outlook

Detailed results for Outlook are provided in Table 8 of the Appendices. The overall F-test for emergence was highly significant (*P* < 0.001) but, unlike the previously discussed sites, the only clear effect was that plant populations were much higher when no P fertilizer was applied (128 plants/m^2) than for any other treatments (57-78 plants/m^2), thus resulting in significant linear and quadratic orthogonal contrasts for P rate (*P* <0.001-0.015) but not N rate (*P* = 0.444-0.790). While it appeared to be genuine, this P response (Fig. 7) was unexpected with side-band placement where the previously discussed sites and past experience have generally shown that high rates of side-banded urea have greater potential to negatively impact sensitive crops than high rates of side-banded MAP. If there was an error regarding P fertilizer placement, it was not specifically detected or documented. With supplemental irrigation, the quinoa was notably taller at Outlook than for the other sites, averaging 168 cm across treatments. The overall F-test was highly significant (*P* = 0.001) and the orthogonal contrasts indicated height significant responses for both nutrients. The N rate effect was strictly linear (*P* < 0.001; Fig. 8) while, for P rate, the response was more quadratic (*P* = 0.002; Fig. 9) with shorter plants in the control but similar heights for P rates of 20-60 kg P_2O_5/ha. With good yield potential, low residual N levels, and a significant overall F-test (*P* = 0.031) despite relatively high variability, Outlook was the most N responsive site for grain yield. Yield increased quadratically (*P* = 0.005), peaking at 140-180 kg N/ha but dropping off substantially at the highest N rate (Fig. 10). There was no evidence in the orthogonal contrast results of a yield response to P (*P* = 0.141-0.144). Fertility effects on quinoa protein were more subtle with the overall F-test being only marginally significant (*P* =

0.080), but the linear orthogonal contrasting showing increasing protein as more N fertilizer was applied (Fig. 11).

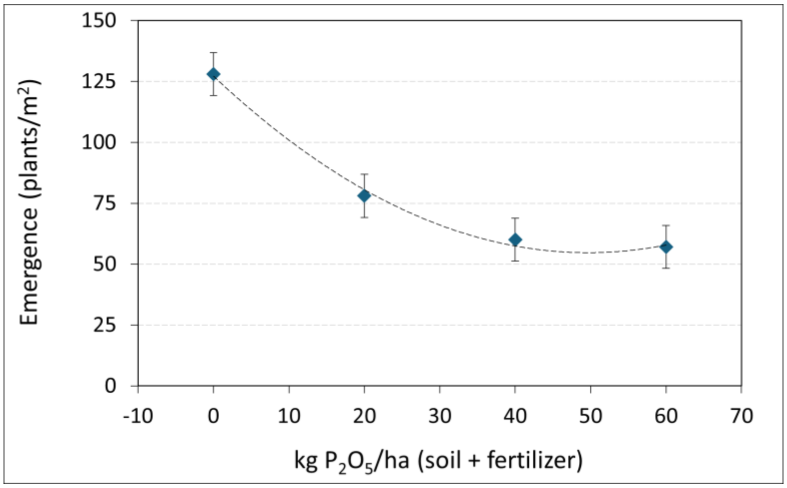

Figure 7. Phosphorus fertilizer rate effects on quinoa emergence at Outlook, 2024. The P fertilizer source was side-banded monoammonium phosphate. The overall F-test (*P* < 0.001) and both the linear and quadratic orthogonal contrasts were significant (*P* < 0.001-0.015).

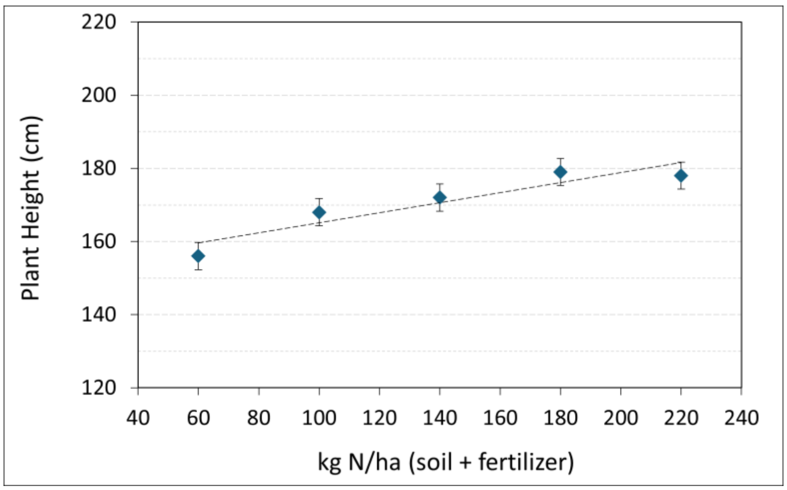

Figure 8. Nitrogen rate effects on quinoa plant height at Outlook, 2024. The primary N source was side-banded urea. The overall F-test (*P* = 0.001) and linear orthogonal contrast (*P* < 0.001) results were significant.

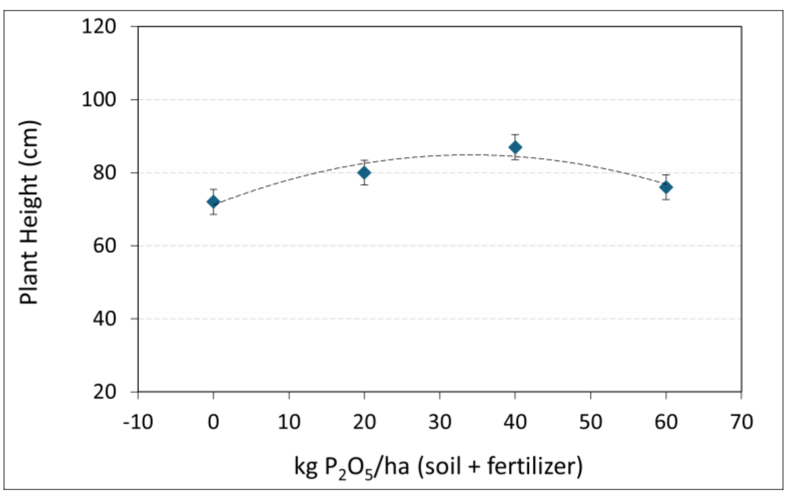

Figure 9. Phosphorus rate effects on quinoa plant height at Outlook, 2024. The P fertilizer source was side-banded monoammonium phosphate. The overall F-test (*P* = 0.001) and both linear and quadratic orthogonal contrasts (*P* < 0.001-0.009) results were significant.

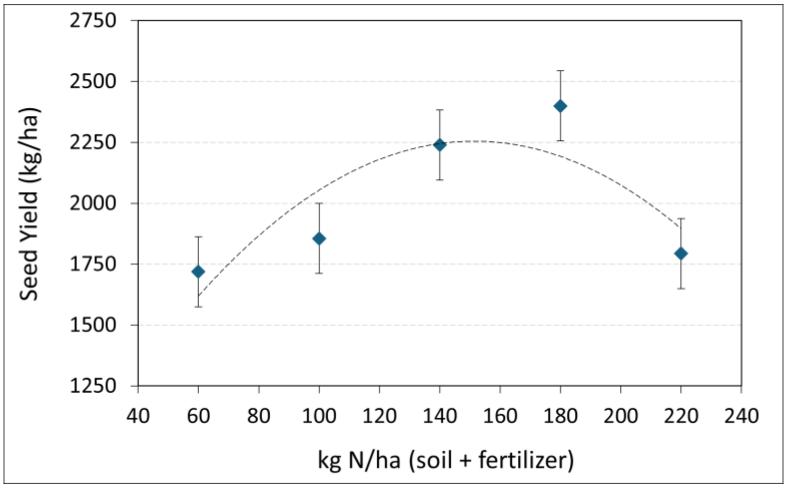

Figure 10. Nitrogen rate effects on quinoa grain yield at Outlook, 2024. The primary N source was side-banded urea. The overall F-test (P = 0.031) and quadratic orthogonal contrast (P = 0.005) results were significant.

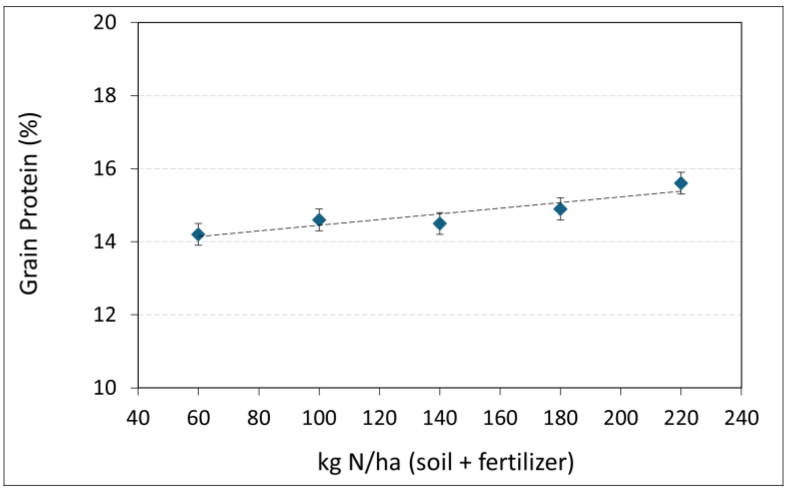

Figure 11. Nitrogen rate effects on quinoa grain protein at Outlook, 2024. The primary N source was side-banded urea. The overall F-test was only marginally significant (P = 0.080), but the orthogonal contrasts suggested a linear response to N (P = 0.005).

Swift Current

Detailed results for the Swift Current site are provided in Table 9 of the Appendices. Overall plant densities were amongst the lowest at this location, averaging 60 plants/m^2 overall; however, establishment was unaffected by fertility treatment with no significant overall F-test or orthogonal contrast results (P = 0.359-0.793). Due to the drier environment, the plants were also relatively short at Swift Current, averaging 76 cm. The overall F-test result (P = 0.017) and orthogonal contrast results showed a linear increase in height with N rate (P = 0.002; Fig. 12) and a quadratic response to P (P = 0.011; Fig. 13). The maximum height was 87 cm at 180 kg N/ha relative to 68 cm at 60 kg N/ha, while the quadrate P response showed values peaking at 40 kg P_2O_5/ha (87 cm) and being more intermediate at 20 and 60 kg P_2O_5/ha 76-80 cm) relative to the control (72 cm). Unfortunately, and presumably due to drought, yields were essentially zero at Swift Current with only 2-10 g of grain recovered from each plot. Consequently, neither grain yield nor protein data were available to analyze for this site.

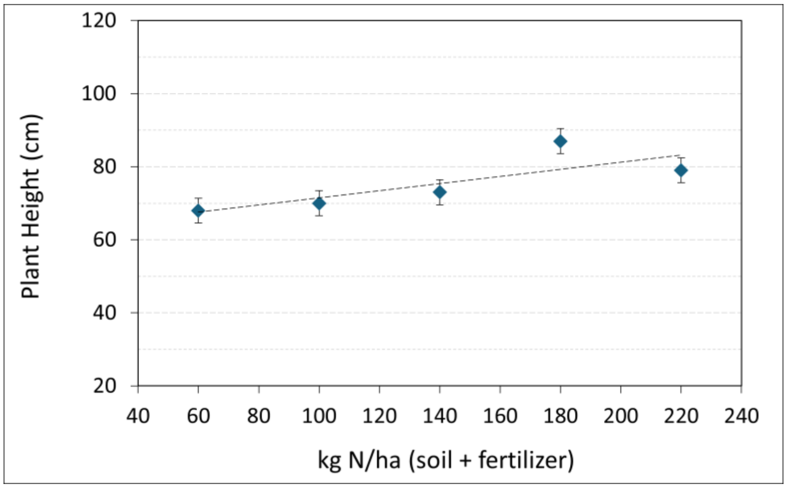

Figure 12. Nitrogen rate effects on quinoa plant height at Swift Current, 2024. The primary N source was side-banded urea. The overall F-test (*P* = 0.017) and linear orthogonal contrast (*P* = 0.002) results were significant.

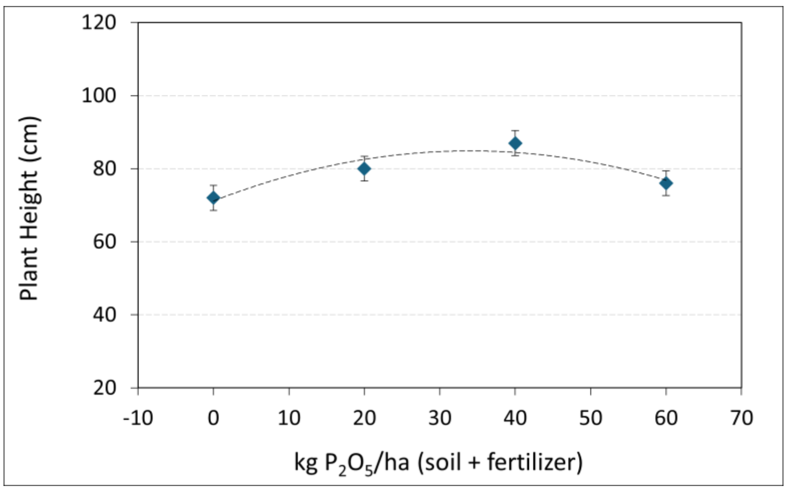

Figure 13. Phosphorus rate effects on quinoa plant height at Swift Current, 2024. The P fertilizer source was side-banded monoammonium phosphate. The overall F-test (*P* = 0.017) and quadratic orthogonal contrast (*P* = 0.011) results were significant.

Extension

The plots were visited on a few occasions during the growing season. At Indian Head, this trial was toured by attendees from a University of Saskatchewan International Farm Management Conference on July 2nd, 2024. There were 28 attendees in total, comprised of farmers and farm managers from Canada, US, South America, Europe, and Australia. The plots were also visited by several farmers and industry representatives throughout the season but could not be shown during the Indian Head Crop Management Field Day. At Swift Current, the plots were shown during a Saskatchewan Ministry of Agriculture tour on July 3 and during the annual field day on July 18 (83 participants in total). At Melfort, the plots were visited during informal tours and had sponsor signs in place for the joint AAFC/NARF annual field day but was not a formal part of the main tour at this location. No extension was reported for the Outlook site. This technical report will be publicly available on the IHARF website (https://iharf.ca/library/) and results may be incorporated into future extension materials, where deemed appropriate.

Conclusions and Recommendations

Describe what was learned from the demonstration. Highlight any significant conclusions and provide recommendations for the application and adoption of the project results. Be sure that you have presented the relevant data to support your conclusions. Identify any further research, development and communication needs, if applicable.

Overall, the project demonstrated that quinoa can be somewhat sensitive to high rates of side-banded urea compared to cereal crops, much like flax and canola. While side-banding is considered a safe and efficient placement option overall, farmers should pay attention to seeding conditions and drill settings while ensuring that seeding rates are high enough to offset potential mortality. Except for a substantial, and somewhat unexpected, reduction in emergence with monoammonium phosphate at Outlook, any impacts on establishment were considered minor. The observed height responses showed relatively strong responses to nitrogen (N), often increasing right up to the highest rate, while phosphorus (P) effects on height were less consistent, but still significant at Outlook and Swift Current. Grain yields were relatively low and, perhaps, less responsive to N and P fertility under the growing conditions encountered. Yields at Indian Head were extremely low (343 kg/ha on average), presumably due to a combination of drought and heat stress during the reproductive growth stages combined with environmental losses due to heavy rains and extreme winds late in the season. At Melfort, yields peaked at approximately 1000 kg/ha with N rates of 140-180 kg N/ha, including soil nitrate; however, there was no response to P fertilizer. Under irrigation at Outlook, yields were variable but relatively high and responsive to N, peaking at approximately 2200-2400 kg/ha at 140-180 kg total N/ha, but with a substantial decline at the highest rate. Like Melfort, there was no yield response to P fertilization at Outlook. At Swift Current, where the heat and drought stress were most severe, yields were essentially zero. Often marketed for its nutritional benefits, high protein is important with quinoa, and this should also be considered when determining N fertilizer requirements for this crop. Despite the low yields at Indian Head, we saw a classic protein response to N with values being similar for N rates of 60-100 kg total N/ha (13.5-13.7%) but increasing rapidly to as high as 16.8% with further increases in N rate. At Melfort, the protein response was weak and only marginally significant at best; however, there were indications of an N benefit with values ranging from as low as 13.4% to 14.3% at the highest N rate. This was similar to Outlook where the response was not as pronounced as at Indian Head but showed protein increasing from 14.2% at the lowest N rate to 15.6% at the highest rate. Phosphorus rates did not affect protein content in any cases.

In conclusion, our results show that quinoa yields can be quite variable depending on environmental conditions; however, relatively high N rates are required to achieve high yields when the potential exists. Including residual soil N, rates of approximately 140 kg N/ha are likely appropriate for growers who have reasonable confidence in their ability to grow this crop. Perhaps this could be reduced slightly for growers who are less confident and/or hesitant to commit to the higher input costs; however, this could result in yield and quality loss. In addition to the higher input costs, excessive N rates could have negative effects such as poorer establishment and increased potential for lodging. For phosphorus, rates of 20-40 kg P_2O_5/ha are likely sufficient to ensure that yields are not limited, and soil fertility is not depleted. While specific information is not available, farmers should assume that this crop is sensitive to seed-placed fertilizer and, if relying on in-furrow P placement for any reason, the amount should likely be limited to 20 kg P_2O_5, or less.

Sustainable Canadian Agricultural Partnership (Sustainable CAP) Performance Indicators

a) List of performance indicators

Sustainable CAP Indicator	Total Number
Scientific publications from this project (List the publications under section b)	
• Published	None
• Accepted for publication	None
Highly Qualified Personnel (HQPs) trained during this project	

• Master's students	None
• PhD students	None
• Post docs	None
Knowledge transfer products developed based on this project (presentations, brochures, factsheets, flyers, guides, extension articles, podcasts, videos)[1]. List the knowledge transfer products under section (c)	4+

[1] Please only include the number of unique knowledge transfer products.

b) List of scientific journal articles published/accepted for publication from this project. Please ensure that each line includes the following: **Title, Author(s), Journal, Date Published or Accepted for Publication and Link to Article (if available).** *Add additional lines as needed*.

1. Not Applicable – no scientific articles associated with this project have been submitted for peer-review or publication.

c) List of knowledge transfer products/activities developed from this project.

Knowledge Transfer Product or Activity	Event/Location Where Knowledge Transfer Was Conducted	Estimated Number of Participants	Link (if available)
D. Petty (IHARF), plot site tour	U of SK International Farm Management Conference Tour (Jul-2-2024, Indian Head, SK)	28	n/a
A. Wall (WCA) plot site tour	SK Ag Research Branch Tour (Jul-3-2024, Swift Current, SK)	8	n/a
A. Wall (WCA), plot site tour	Swift Current Field Day (Jul-18-2024, Swift Current, SK)	75	https://wheatlandconservation.ca/annual-field-day-swift-current-sk/
C. Holzapfel (IHARF), Final Project Report	Online, IHARF Website	unknown	https://iharf.ca/library/

Acknowledgements

Include actions taken to acknowledge support by the Ministry of Agriculture, the Canadian Agriculture Partnership (for projects approved between 2017 and 2023) and the Sustainable Canadian Agriculture Partnership (for projects approved between 2023 and 2028).

Financial support for this demonstration was provided under the Sustainable Canadian Agricultural Partnership, a federal-provincial-territorial initiative. Signs were in-place for any plot tours to acknowledge the funding sources and appropriate acknowledgements will be made in all written communications, oral presentations, or other printed materials pertaining to the project. Seed and grain protein analyses, along with basic agronomic support, were provided in-kind by the Northern Quinoa Production Company (NorQuin). We would like to acknowledge the Boards of Directors for the participating organizations in addition to the many technical and support staff who worked on the project. IHARF, NARF, ISask, and WCA all have strong working relationships and memorandum of understanding with Agriculture and Agri-Food Canada and all participating organizations have received funding for infrastructure and basic operating expenses from the Saskatchewan Ministry of Agriculture and several other producer/commodity groups, all of which has helped to make work like this possible.

Appendices

Identify any changes expected to industry contributions, in-kind support, collaborations or other resources.

Table 5. Selected agronomic information and dates of operations for the 2024 quinoa nitrogen (N) and phosphorus (P) response demonstration (ADOPT #20230540) conducted at Indian Head (IH), Melfort (ME), Outlook (OL), and Swift Current (SW), Saskatchewan.

Activity	IH-24	ME-24	OL-24	SW-23
Previous Crop	Canaryseed	Wheat	Field Peas	Wheat
Pre-Emergent Herbicide	May-14-2024 (glyphosate)	May 14-2024 (glyphosate)	nil	May-2-2024 (glyphosate + AIM)
Seeding Date	May-15-2024	May-29-2024	May-22-2024	May-15-2024
Row Spacing	30 cm	30 cm	20 cm	21 cm
kg N-P_2O_5-K_2O-S/ha [Z]	0-0-136-46[Y]	15-0-0-17	0-0-0-0	0-0-49-17
Emergence Counts	Jun-18-2024	Jun-24-2024	Jun-17-2024	Jun-12-2024
In-crop Herbicide	Jun-20-2024 (Poast Ultra)	Jun-21-2024 (Centurion)	Jun-24-2024 (Centurion)	Jun-18-2024 (Centurion)
Foliar Fungicide	Jul-8-2024 (Dyax)	nil	Jul-5-2024 (Dyax)	nil
Foliar Insecticide 1	Jul-5-2024 (Cygon 480)	Jul-22-2024 (Cygon 480)	Jul-24-2024 (Matador)	Jul-23-2024 (Voliam Xpress)
Foliar Insecticide 2	Jul-19-2024 (Cygon 480)	Aug-10-2024 (Cygon 480)	Aug-8-2024 (Matador)	nil
Plant Height	Aug-2-2024	Aug-21-2024	Aug-9-2024	Aug-29-2024
Pre-harvest Herbicide / Desiccant	Sep-20-2024 (glyphosate)	nil	nil	Oct-8-2024 (glyphosate)
Harvest Date	Oct-7-2024	Oct-8-2024	Oct-17-2024	Oct-31-2024

[Z] Fertility information only includes nutrients provided by potassium, and/or sulfur products applied.
[Y] The high rates of potassium sulphate were due to a Valmar calibration error which has since been corrected

Table 6. Treatment means and results of the multiple comparisons tests, overall F-tests, and orthogonal contracts for selected response variables in quinoa nitrogen (N) and phosphorus (P) response demonstrations conducted at Indian Head in 2024. For each response variable, values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

	Indian Head 2024			
N / P Rate	**Plant Density**	**Plant Height**	**Seed Yield**	**Seed Protein**
	plants/m²	(cm)	kg/ha	%
60 N / 40 P [Z]	157 a	103 c	333 a	13.7 c
100 N / 40 P [Z]	153 ab	112 b	407 a	13.5 c
140 N / 40 P [Z]	125 c	111 b	400 a	14.7 b
180 N / 40 P [ZY]	127 c	116 ab	318 a	16.1 a
220 N / 40 P [Z]	127 c	119 a	286 a	16.8 a
180 N / 0 P [Y]	128 c	111 b	317 a	16.4 a
180 N / 20 P [Y]	125 c	116 ab	313 a	16.6 a
180 N / 60 P [Y]	135 bc	117 ab	371 a	16.0 a
S.E.M.	6.9	2.4	43.5	0.30
	Pr > F (p-value)			
Overall F-test	0.013	0.003	0.430	<0.001
N Rate – linear	<0.001	<0.001	0.194	<0.001
N Rate - quadratic	0.155	0.486	0.091	0.081
P Rate – linear	0.475	0.117	0.394	0.168
P Rate - quadratic	0.433	0.430	0.521	0.677

[Z] Treatment used to demonstrate N rate response (kg N/ha; soil NO_3-N plus fertilizer)

[Y] Treatment use to demonstrate P rate response (kg P_2O_5/ha; fertilizer)

Table 7. Treatment means and results of the multiple comparisons tests, overall F-tests, and orthogonal contracts for selected response variables in quinoa nitrogen (N) and phosphorus (P) response demonstrations conducted at Melfort in 2024. For each response variable, values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

	Melfort 2024			
N / P Rate	**Plant Density**	**Plant Height**	**Seed Yield**	**Seed Protein**
	plants/m²	(cm)	kg/ha	%
60 N / 40 P [Z]	107 a	71 d	548 a	13.6 a
100 N / 40 P [Z]	96 ab	89 c	864 a	13.4 a
140 N / 40 P [Z]	86 bc	99 b	970 a	13.6 a
180 N / 40 P [ZY]	81 bc	105 ab	1052 a	13.6 a
220 N / 40 P [Z]	90 bc	111 a	911 a	14.3 a
180 N / 0 P [Y]	77 c	104 ab	970 a	14.4 a
180 N / 20 P [Y]	96 ab	102 ab	991 a	13.5 a
180 N / 60 P [Y]	83 bc	108 ab	1017 a	13.7 a
S.E.M.	5.5	3.4	127.0	0.27
	Pr > F (p-value)			
Overall F-test	0.019	<0.001	0.197	0.097
N Rate – linear	0.013	<0.001	0.034	0.065
N Rate - quadratic	0.039	0.029	0.062	0.096
P Rate – linear	0.935	0.352	0.726	0.110
P Rate - quadratic	0.127	0.456	0.830	0.070

[Z] Treatment used to demonstrate N rate response (kg N/ha; soil NO_3-N plus fertilizer)

[Y] Treatment use to demonstrate P rate response (kg P_2O_5/ha; fertilizer)

Table 8. Treatment means and results of the multiple comparisons tests, overall F-tests, and orthogonal contracts for selected response variables in quinoa nitrogen (N) and phosphorus (P) response demonstrations conducted at Outlook in 2024. For each response variable, values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

	Outlook 2024			
N / P Rate	Plant Density	Plant Height	Seed Yield	Seed Protein
	plants/m²	(cm)	kg/ha	%
60 N / 40 P [Z]	74 b	156 b	1719 c	14.2 a
100 N / 40 P [Z]	70 b	168 a	1855 bc	14.6 a
140 N / 40 P [Z]	74 b	172 a	2239 ab	14.5 a
180 N / 40 P [ZY]	60 b	179 a	2399 a	14.9 a
220 N / 40 P [Z]	68 b	178 a	1793 c	15.6 a
180 N / 0 P [Y]	128 a	155 b	1821 bc	15.0 a
180 N / 20 P [Y]	78 b	170 a	1814 c	15.3 a
180 N / 60 P [Y]	57 b	168 a	1951 bc	14.6 a
S.E.M.	8.8	3.7	143.8	0.30
	Pr > F (p-value)			
Overall F-test	<0.001	0.001	0.031	0.080
N Rate – linear	0.444	<0.001	0.142	0.005
N Rate - quadratic	0.790	0.107	0.005	0.400
P Rate – linear	<0.001	0.009	0.144	0.241
P Rate - quadratic	0.015	0.002	0.141	0.303

[Z] Treatment used to demonstrate N rate response (kg N/ha; soil NO_3-N plus fertilizer)

[Y] Treatment use to demonstrate P rate response (kg P_2O_5/ha; fertilizer)

Table 9. Treatment means and results of the multiple comparisons tests, overall F-tests, and orthogonal contracts for selected response variables in quinoa nitrogen (N) and phosphorus (P) response demonstrations conducted at Swift Current in 2024. For each response variable, values within a column followed by the same letter do not significantly differ (Fisher's protected LSD test, *P* ≤ 0.05).

	Swift Current 2024			
N / P Rate	Plant Density	Plant Height	Seed Yield	Seed Protein
	plants/m²	(cm)	kg/ha	%
60 N / 40 P [Z]	61 a	68 c	—	—
100 N / 40 P [Z]	74 a	70 bc	—	—
140 N / 40 P [Z]	61 a	73 bc	—	—
180 N / 40 P [ZY]	57 a	87 a	—	—
220 N / 40 P [Z]	60 a	79 ab	—	—
180 N / 0 P [Y]	61 a	72 bc	—	—
180 N / 20 P [Y]	57 a	80 ab	—	—
180 N / 40 P [Y]	48 a	76 bc	—	—
S.E.M.	9.8	3.4	—	—
	Pr > F (p-value)			
Overall F-test	0.793	0.017	—	—
N Rate – linear	0.570	0.002	—	—
N Rate - quadratic	0.749	0.566	—	—
P Rate – linear	0.359	0.274	—	—
P Rate - quadratic	0.789	0.011	—	—

[Z] Treatment used to demonstrate N rate response (kg N/ha; soil NO_3-N plus fertilizer)

[Y] Treatment use to demonstrate P rate response (kg P_2O_5/ha; fertilizer)

Expenditure Statement

Sustainable Canadian Agricultural Partnership
Saskatchewan
Canada

You must provide an expenditure statement showing how ADOPT funds were used. Expenditures must be reported using the budget categories shown in Appendix B of your contract. We recommend that you report your expenditures using the Excel spreadsheet we have developed for this purpose (ADOPT Expenditure Statement.xls). That spreadsheet is available from the research branch project manager or the evaluation coordinator.

Note that the ADOPT contract requires you to retain all receipts and financial records relating to the project for at least six years after the project is completed.

Provided in a separate Excel workbook and available upon request.