2017 Interim Report

for the

Saskatchewan Ministry of Agriculture (ADF Program), Saskatchewan Flax Development Commission (SFDC) & Western Grains Development Commission (WGRF)

Project Title: Flax Response to a Wide Range of Nitrogen & Phosphorus Fertilizer Rates in Western Canada

(Project #20150105)

Principal Applicant: Chris Holzapfel[Z]

Collaborators: Jeff Schoenau[Y], Stewart Brandt[X], Michael Hall[V], Ramona Mohr[T], Bryan Nybo[S], Lana Shaw[R], Jan Slaski[Q] and Jessica Weber[U]

[Z]Indian Head Agricultural Research Foundation, Box 156, Indian Head, SK, S0G 2K0; [Y]University of Saskatchewan, Dept. of Soil Science, Saskatoon, SK; [X]Northeast Agricultural Research Foundation, Melfort, SK; [V]East Central Research Foundation, Yorkton, SK; [U]Western Applied Research Corporation, Scott, SK; [T]Agriculture & Agri-Food Canada, Brandon, MB; [S]Wheatland Conservation Area, Inc., Swift Current, SK, [R]Southeast Research Farm, Redvers, SK; [Q]InnoTech Alberta, Vegreville, AB

Correspondence: cholzapfel@iharf.ca

1. Project Information

a. **Title:** Flax (*Linum usitatissimum)* response to a wide range of nitrogen and phosphorus fertilizer rates in western Canada
b. **ADF File Number:** 20150105
c. **Reporting Period:** February 15, 2016 to February 15, 2018

2. Special Project Activities Undertaken During this Reporting Period

a. **Methodology:** Following consultations with the Saskatchewan Flax Development Commission (SFDC), an extensive field study to revaluate flax (*Linum usitatissimum*) fertility requirements was conceived and designed in 2015. The project aimed to investigate flax response to nitrogen (N) and phosphorus (P) fertilizer applications under a broad range of western Canadian environments and using modern varieties and seeding equipment. Field trials for the three-year project were initiated in 2016 with eight locations including six in Saskatchewan (Indian Head, Melfort, Redvers, Scott, Swift Current and Yorkton), one in Alberta (Vegreville) and one in Manitoba (Brandon). The treatments were a factorial combination of four N rates (13, 50, 100 and 150 kg N/ha) and four P rates (0, 20, 40 and 60 kg P_2O_5/ha) arranged in Randomized Complete Block Design (RCBD) with four replicates. While certain aspects of the specific seeding equipment varied (i.e. row spacing, opener type) plots at all locations except Vegreville were direct-seeded into cereal stubble and all fertilizer was side-banded during seeding. At Vegreville, the plots were tilled prior to seeding and fertilizer was mid-row banded. The fertilizer products utilized in the treatments were commercial grade urea (46-0-0) and monoammonium phosphate (11-52-0).

Selected agronomic information for each location is provided for 2016 and 2017 in Tables 1 and 2 of the Appendices. Specific management practices and decisions were largely left to individual site managers and tailored to regional practices, available equipment and pests encountered; however, all controllable factors other than fertility were intended to be non-limiting. Seeding dates ranged from May 5 to June 7 and, except at Melfort in 2017 where plots were hand-weeded throughout the season, weeds were managed using registered pre-emergent and in-crop herbicides. Foliar fungicide applications were utilized at most sites to minimize the potential for disease (pasmo) and insecticides were applied only if considered necessary. If considered necessary or desirable by the site managers, pre-harvest herbicides or desiccants were applied at or after the latest maturing plots reached physiological maturity. All plots were harvested when fit to do so and, wherever possible, outside rows were excluded to minimize edge effects. Due to heavy and widespread snowfall in early October and extremely wet conditions through that entire month, the 2016 harvest was delayed late into the fall at Melfort, Swift Current and Vegreville. The prolonged exposure to severe environmental conditions led to reduced yields and seed quality (test weight) while increasing variability at the affected sites. Data from some locations in this year, Melfort in particular, will likely have to be discarded prior to the final, combined analyses. In 2017, the plots at Swift Current were affected by drought and then badly damaged by deer prior to harvest. Yield data from this site-year will be excluded from combined analyses. At Vegreville in 2017, emergence was initially very poor so the plots were sprayed out and then re-seeded in early June with no fertilizer applied at the second date. It will likely be appropriate to exclude data from this site-year from the final, combined analyses as well.

A composite soil sample (targeted depth intervals of 0-15 cm and 15-60 cm) was collected from each trial location in the late fall or early spring and submitted to AgVise laboratories for various analyses. There was some variation in the specific sampling depths and analyses requested amongst sites (Table 3). The crop response data collected included plant density, days to maturity, seed yield and test weight. Plant density was measured by counting the number of emerged plants in two separate 1 m sections of crop row per plot and calculating average plants/m^2 for each plot. These counts were targeted for approximately 3-4 weeks after planting but the specific dates varied amongst individual sites (Table 1 and 2). Physiological maturity, defined as when approximately 75% of the bolls had turned brown, was recorded for each plot with values expressed as days from planting to maturity. Days to maturity was not recorded at Melfort or Redvers in 2016. At Melfort and Swift Current in 2017 there was no variation in maturity recorded across treatments or replicates therefore this data was not statistically analyzed or discussed. Seed yield was determined from the harvested grain samples and is corrected for dockage and to a uniform moisture content of 10%. Test weights were measured at each location except Swift Current in 2017 and, with the exception of Vegreville, determined from clean sub-samples using standard methodology (Canadian Grain Commission 2016). At Vegreville, test weights were determined using the HarvestMaster weighing system (uncleaned samples) and therefore will be excluded from any combined analyses. At Swift Current in 2017, the harvest samples were too small to measure test weight. Mean monthly temperatures and precipitation amounts were estimated from the nearest weather station for each site.

For the purposes of interim reporting and initial data evaluation, all response data accumulated to date have been statistically analysed on an individual site basis using the Mixed procedure of SAS. The effects of N and P fertilizer rates and the N × P interaction were considered fixed while replicate effects were treated as random. Orthogonal contrasts were used to determine whether the observed responses to N and P were insignificant, linear or quadratic (curvilinear). At this stage, the orthogonal contrasts were completed for both the main effects and for each N × P combination individually, regardless of whether the interactions were significant. All treatment effects and differences between means were considered significant at $P \leq 0.05$.

b. Research Accomplishments:

In 2016, growing season temperatures and, especially, precipitation amounts were above-average at all 8 sites, therefore, the flax was never limited by lack of moisture in any cases this season. In contrast, 2017 was much drier with drought limiting yields to a varying extent across locations but a good range of overall yield environments. Mean monthly temperatures and precipitation amounts for the 2016 and 2017 growing seasons are presented for all locations along with the long-term averages in Tables 3 and 4 of the Appendices. Not necessarily unexpected with such a large number of site-years (n=16), data quality was negatively impacted by weather, wildlife, and equipment issues in a few cases. Excess moisture resulted in high variability and yield loss in one replicate at Vegreville in 2016 therefore it was discarded prior to any statistical analyses. Furthermore, at Melfort, Swift Current, and Vegreville in 2016 the plots were not yet harvested when wet, snowy weather occurred in early October and the flax at these locations was exposed to prolonged severe weather subsequently resulting in lodging, yield loss, lower test weights and increased variability. In addition to drought stress at Swift Current in 2017, the plots were badly damaged by deer feeding as they approached maturity. Staff at that location did their best to salvage the yields by harvesting early, adjusting the harvest area and rating the damage; however, yield data from this site-year will have to be excluded from final analyses. At Vegreville in 2017, equipment issues with seeding in mid-May resulted in poor initial emergence and the crop was terminated and re-seeded over the same plots in early June with no fertilizer. This compromised placement of the fertilizer, which can be a concern for P in particular, and the delayed seeding likely reduced yields; therefore, data from this site-year will likely be excluded from combined analyses. It has yet to be finalized whether yield data from Swift Current and Vegreville in 2016 will be excluded from the final combined analyses.

Soil test results for all locations are presented in Table 4 of the Appendices. Overall, there was a wide range of soil properties with textures ranging from coarse loam to heavy clay, pH values ranging from 4.9-7.9, and soil organic matter levels ranging from 2.3-9.5%. Total NO_3-N ranged from 25-104 kg N/ha and extractable P (Olsen) ranged from 4-24 ppm. Generally, soil test levels of less than approximately 15 ppm are considered low in P while values below 10 ppm are very low.

Objectives: *To evaluate the response of flax to varying rates and combinations of nitrogen (N) and phosphorus (P) fertilizer, including higher N and P rates than are typically recommended or utilized.*

Overall F-test results for plant density are presented in Tables 6-7. Nitrogen rate significantly affected emergence at 11/16 site-years and, in all cases, emergence declined with increasing N rates (Tables 8-9). The exceptions were Indian Head, Melfort and Redvers under the wetter conditions of 2016 (emergence was affected by N at all of these locations in 2017) and Vegreville where the fertilizer was mid-row banded and therefore farther away from the seed than at the other locations. In addition to the tables, these results are also presented graphically in Fig. 1. Phosphorus fertilizer rate only affected emergence at 1/16 site-years (Table 6-7) with a slight linear increase in populations detected with P fertilization at Brandon in 2016 (Table 8). There were never any interactions between N and P rate for emergence indicating that the responses to these two fertilizer products were independent of each other; however, individual treatment means are still provided in Tables 10-11 and orthogonal contrast results for the interactions are in Tables 12-13.

Maturity was measured at all locations except Melfort and Redvers in 2016; however, no variation was recorded at Melfort or Swift Current in 2017 so data from those locations was not analyzed or presented. A significant delay in maturity with N fertilization was detected at 10/12 site-years where data was analyzed with an observed range from <1 to approximately 5 days between the lowest and highest N rates. Phosphorus fertilizer only affected maturity at Scott in 2017 where the flax matured about 1 day later in the unfertilized control. At Brandon in 2017, the N × P interaction for maturity was significant but the effects were variable and no clear trends were identified (Table 19). While delays in maturity are not particularly desirable, they tend to coincide with higher yield and the observed differences would not pose any agronomic challenges under most conditions.

Overall F-tests for N and P effects on seed yield are presented in Table 22-23 of the Appendices. Nitrogen rate affected yield at 13/16 site-years and 12/13 of those which will tentatively be included in the final combined analysis. At Melfort in 2017, the lack of a significant N response can be attributed to high residual N levels (56 kg NO_3-N/ha at 0-30 cm depth), organic matter (9%) and subsequent mineralization, and overall variability. The observed yield increases at N responsive site-years ranged from 192-1229 kg/ha or 13-115% over the lowest, 13 kg N/ha, rate (Fig. 2). In the vast majority of individual cases the responses were quadratic with yields levelling off at 80-125 kg N/ha.

Averaged across all 13 site-years where data will tentatively be combined, the observed increased was 683 kg/ha, or 46% with no further yield increases past 100 kg N/ha (Fig. 3). Yield responses to P were less frequent and smaller in magnitude with evidence of a P response detected (through either overall F-tests or orthogonal contrasts) at 6/13 site-years. Amongst the responsive sites, the yield increase with P fertilization ranged from 3-19% and, in most (not all) cases where the response was not statistically significant, the highest yields still tended to be observed where P fertilizer was applied. Averaged across all thirteen site-years, regardless of significance, yields were approximately 10% higher with P fertilization. For individual sites the responses were generally linear (Fig. 4); however, when data from all sites were averaged the preliminary combined response appeared to be more quadratic with much of the yield increase being realized with the first 20 kg P_2O_5/ha and diminishing returns associated with further increases. Interactions between N and P were rare, significant only at Indian Head and Scott in 2016. At Indian Head in 2016 the interaction was such that the yield response to P became larger at the higher N rates with little or no P effect detected at 13-50 kg N/ha. At Scott the interaction was less consistent with no patterns identified aside from P responses occurring at 13 and 100 kg N/ha but not at 50 or 150 kg N/ha.

Overall F-test results for N and P effects on test weight are provided in Tables 30-31 and showed that test weight was affected by N rates at 12/14 site-years while P only affected this parameter in one case, Indian Head 2016. The N effect was mostly consistent across site-years with the lowest values observed at the lowest N rates and no significant increases beyond rates of 50-100 kg N/ha depending on the specific site-year. In general, test weights began to level off at lower or similar N rates as seed yield. The key exception was Swift Current where there was a slight decline in test weight with increasing N rate. In this case, results may have been affected by the facts that the crop was seeded relatively late and harvest was delayed by wet snowy weather. Regarding the P effect at Indian Head (2016), test weights were significantly higher at 60 kg P_2O_5/ha compared to the lower rates and the linear orthogonal contrast was significant. Despite the lack of a significant F-test, the linear responses to P were also significant at Scott in 2016 and Melfort in 2017 but, in contrast, the effect was negative with the highest tests observed in the control at these site-years.

c. **Discussion:** Overall preliminary results showed reasonably consistent and strong responses to N fertilizer but P responses were smaller and less frequent. At 11/14 sites where N was side-banded, plant populations declined linearly as N rate was increased with the greatest reductions at Swift Current, the site with the coarsest textured soil and lowest organic matter. At Indian Head and Redvers, there was no impact when the crop was seeded into the wetter, warmer soils of 2016 but a small yet significant negative effect under the drier conditions of 2017. This reaffirms that, under certain soil conditions and/or when seed/fertilizer separation is inadequate, flax is quite susceptible to injury from high rates of N. Interestingly, high rates of P appear to be of little concern with no negative impacts on emergence detected at any site-years. When side-banding high rates of N, care should be taken to ensure the best seed/fertilizer separation possible and growers should ensure that seeding rates are sufficiently higher to allow for increased mortality.

Maturity was affected by N rate at 10/12 locations where it was measured and analyzed with a delay of less than <1-5 days (depending on location) with N fertilization. The overall average number of days from planting to maturity ranged from 101-111 days in 2016 and 91-107 days in 2017. Phosphorus only affected maturity in 1/12 possible cases where maturity was delayed by approximately 1 day when no P was applied. While maturity in flax can be an important consideration since this crop requires a relatively long growing season, the observed delays coincided with higher yields and were, in themselves, were unlikely to result in agronomic challenges especially with early seeding and normal fall weather.

Focussing on yield, the N response was significant at 13/16 site-years in total and 12/13 of those which will tentatively be included in the final combined analysis. The exception was Melfort in 2017 where overall high variability, residual NO_3-N and organic matter presumably reduced the response and our ability it to detect it. The optimum N rate appeared to range from approximately 80-120 kg N/ha based on the response curves and, averaged across 13 site-years, yields did not increase with N rates beyond 100 kg N/ha. Phosphorus responses were less frequent and smaller in magnitude; however, they did occur to at least some extent 46% of the time and yields were approximately 10% higher with P fertilization when averaged across 13 site-years. A significant N × P interaction at Indian Head suggested that P became increasingly limiting as the N rate and yield potential increased with the greatest responses detected at 100-150 kg N/ha. While the N × P interaction was also significant at Scott, it was inconsistent and difficult to explain. In general, flax response to P can be inconsistent as this crop is considered a good scavenger of soil P and is also dependant on relationships with arbuscular mycorrhizal (AM) fungi for nutrient uptake. Soil test P levels alone were not particularly effective for predicting P response as the responsive sites varied in residual fertility and there were cases of very low residual P levels and no response. The observed response likely depends on a combination of residual P levels, overall yield potential and other potentially limiting factors.

Nitrogen rate effects on flax test weight were significant at 10/13 sites but somewhat inconsistent with higher test weights with N at nine locations and a reduction at one. At Swift Current, the location where the negative response occurred, results may have been affected by the facts that the crop was seeded relatively late and harvest was delayed by wet snowy weather.

Overall our results to date are consistent with previous western Canadian research, albeit with responses to slightly higher rates of N than many previous studies have reported in a few cases. That said, many studies (i.e. Nuttall and Malhi 1991, Lafond 1992, Grant et al. 1999 and Vera et al. 2014) did not utilize rates exceeding 100 kg N/ha. Of several that did (i.e. Malhi et al. 2007, Lafond et al. 2008 and May et al. 2010), only May et al. (2010) showed a response to N rates higher than 100 kg N/ha. In this case, maximum yields were achieved at 169 kg N/ha; however, the maximum economic rate only exceeded 110 kg N/ha when grain prices were high and N fertilizer prices were low. The negative impacts of side-banded urea on emergence have also been previously documented with flax. For example, Grant et al. (2016) saw lower plant densities with N fertilizer 50% of time with the greatest effects with side-banded urea; however, the authors noted that reductions were unlikely to be of economic importance unless base populations were already marginal.

Regarding phosphorus, our results are, again, generally consistent with previous research. In early trials with low P soils, Bailey and Grant (1989) showed strong yield responses to P provided that the fertilizer was banded either below and to the side or directly below the seed-row. With in-furrow placement, they observed significant crop injury which offset any potential yield benefits. Under high residual P conditions in Manitoba, Grant et al. (1999) only saw a yield response to applied P at 1/9 site-years, presumably due to dry conditions early on in the season at that location. Lafond et al.

(2003) only detected a P yield response at 3/12 site-years and also noted that soil test P levels were not good predictors of whether a yield response to fertilizer was likely (residual P ranged from 24-51 kg/ha at responsive sites). Grant et al. (2009) detected a small but significant flax response to applied phosphorus at 1/6 site-years and also looked at residual P effects (from previous year applications of 0, 25 or 50 kg P_2O_5/ha) but did not detect any benefits to higher rates of P from the previous year. That being said, Bailey et al. (1977) showed that flax does, in fact, benefit from high residual phosphorus over longer periods of time so strategies that ensure long-term soil fertility are important. For this reason, with flax and any other crop, annual P fertilizer applications are generally recommended regardless of the expected yield response.

d. Interim Conclusions:

Results of this project to date have shown consistent, and in some cases strong yield responses to relatively high rates of N fertilizer (i.e. > 100 kg N/ha) while responses to P fertilizer were less frequent (occurring <50% of the time) and, when they did occur, smaller. All factors considered, the results are largely consistent with previous research and it should be noted that the optimum economic N rate will generally be slightly lower than that where maximum yield is achieved. The lack of a P yield response at many sites does not suggest that P fertilizer should not be applied to flax, but rather that, in any given year, current P fertilization practices are not likely major limiting factors to yields of this crop in western Canada. The lack of response to P fertilization at many sites may be explained by contributions of residual inorganic P and organic P mineralization in addition to the strong AM fungi relationships that flax can develop to assist with P uptake. The significant reductions in plant density frequently detected with high rates of side-banded N suggest that care must be taken to ensure adequate seed/fertilizer separation during planting and/or that seeding rates must be sufficient to account for potentially reduced emergence. The extent of seedling loss associated with N at the affected sites ranged from 14-51%; however, high rates of P fertilizer did not negatively affect emergence in any cases. Nitrogen fertilizer delayed maturity by <1-5 days but this delay coincided with higher yields and, in itself, was unlikely to result in any agronomic challenges, particularly when combined with early seeding. Phosphorus rate only affected maturity in one case where maturity was delayed by approximately one day in the unfertilized control. This response occurred at a site where a relatively strong yield response to P was also observed. In the majority of cases, test weight was either not affected by or increased slightly with N fertilizer while P effects on test weight were very rare and somewhat inconsistent. These conclusions should all be considered preliminary and interpreted cautiously as 2018 is the final year of a three-year study.

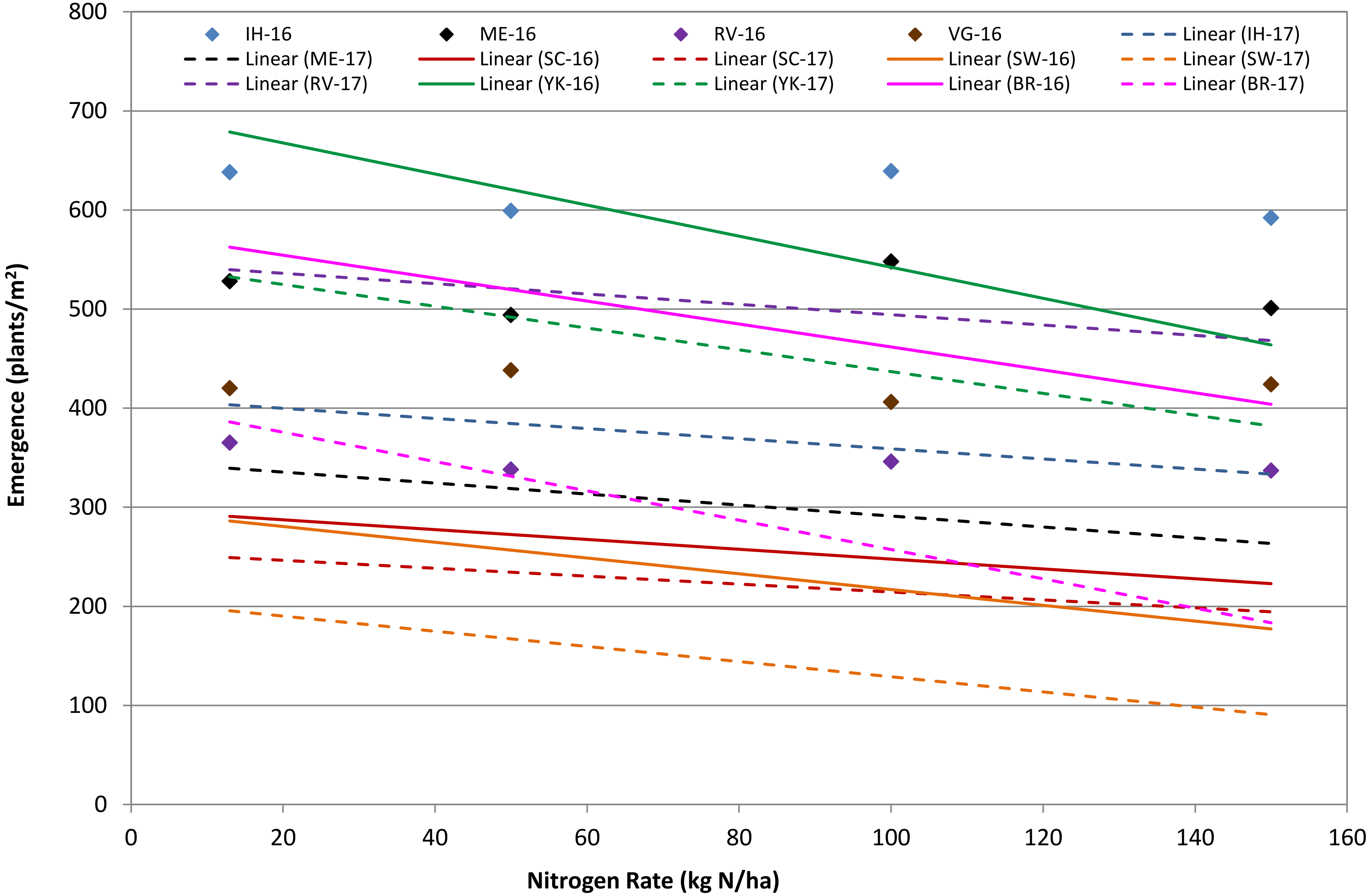

Figure 1. Flax emergence response to side-banded nitrogen (N) fertilizer rate at sixteen site-years in western Canada (2016-17). BR – Brandon, MB; IH – Indian Head, SK; ME – Melfort, SK; RV – Redvers, SK; SC – Scott, SK; SW – Swift Current, SK; VG – Vegreville, AB; YK – Yorkton, SK

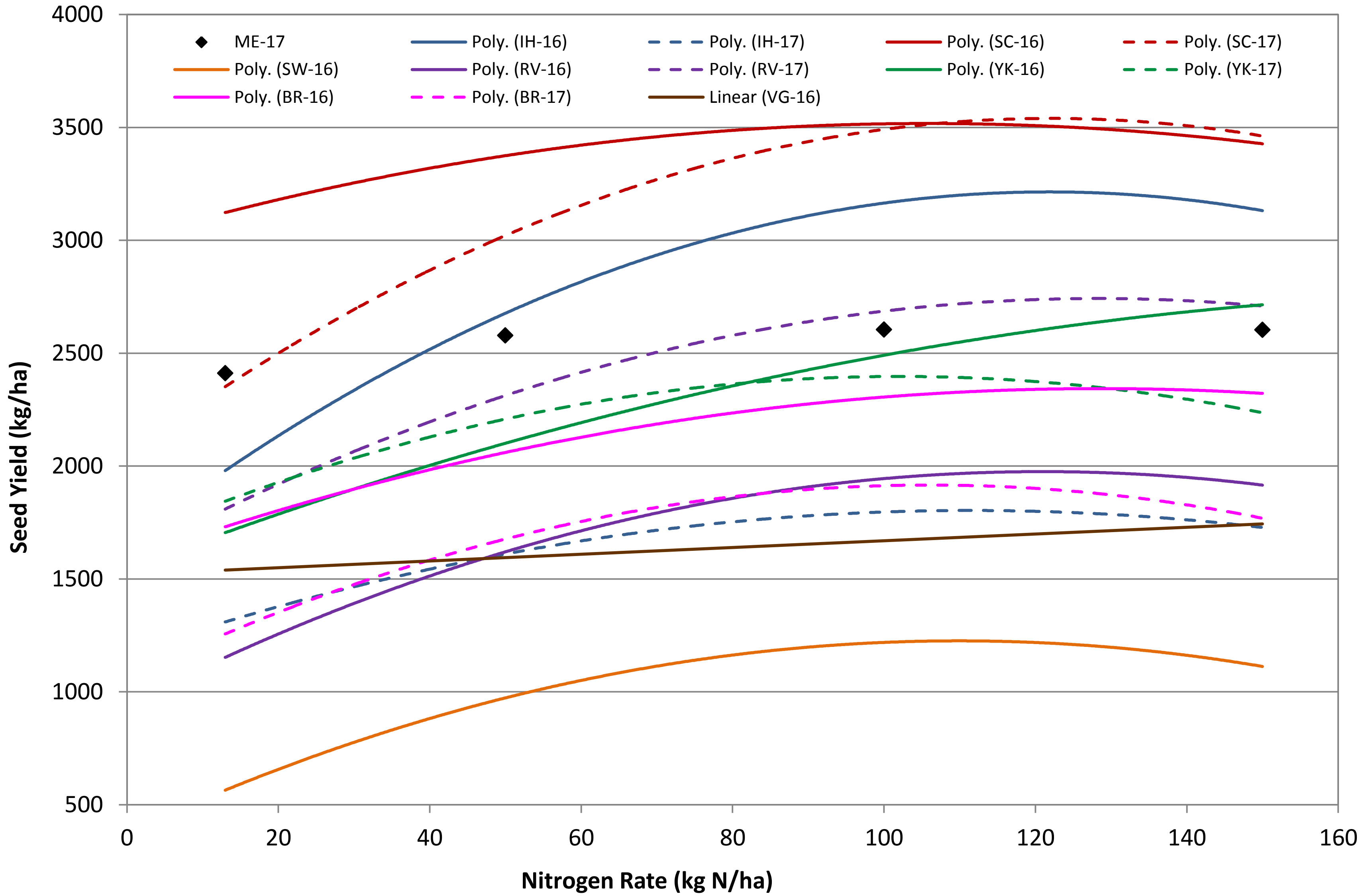

Figure 2. Flax seed yield response to nitrogen (N) fertilizer rate at thirteen site-years in western Canada (2016-17). BR – Brandon, MB; IH – Indian Head, SK; ME – Melfort, SK; RV – Redvers, SK; SC – Scott, SK; SW – Swift Current, SK; VG – Vegreville, AB; YK – Yorkton, SK

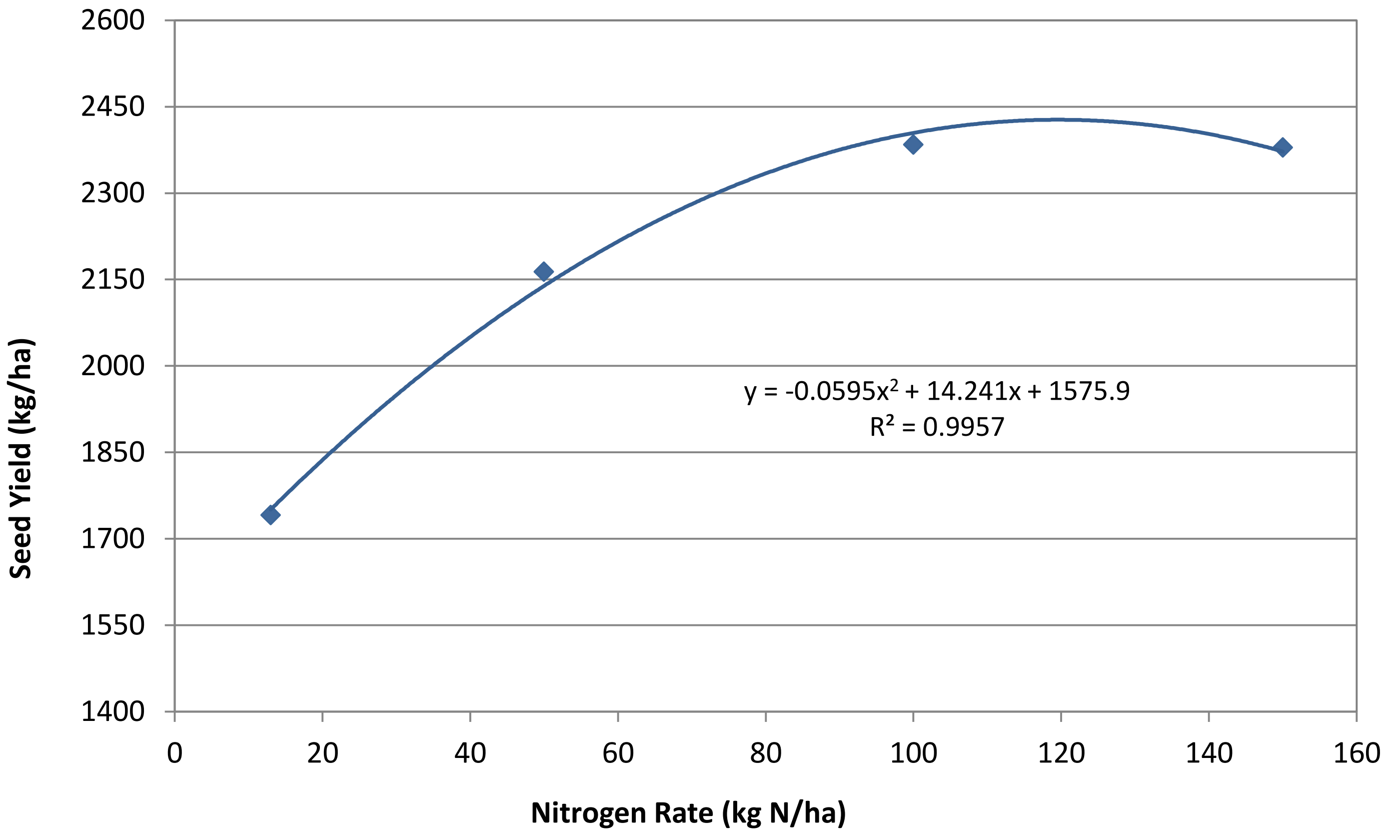

Figure 3. Overall flax seed yield response to nitrogen (N) fertilizer rate averaged across thirteen site-years in western Canada (2016-17).

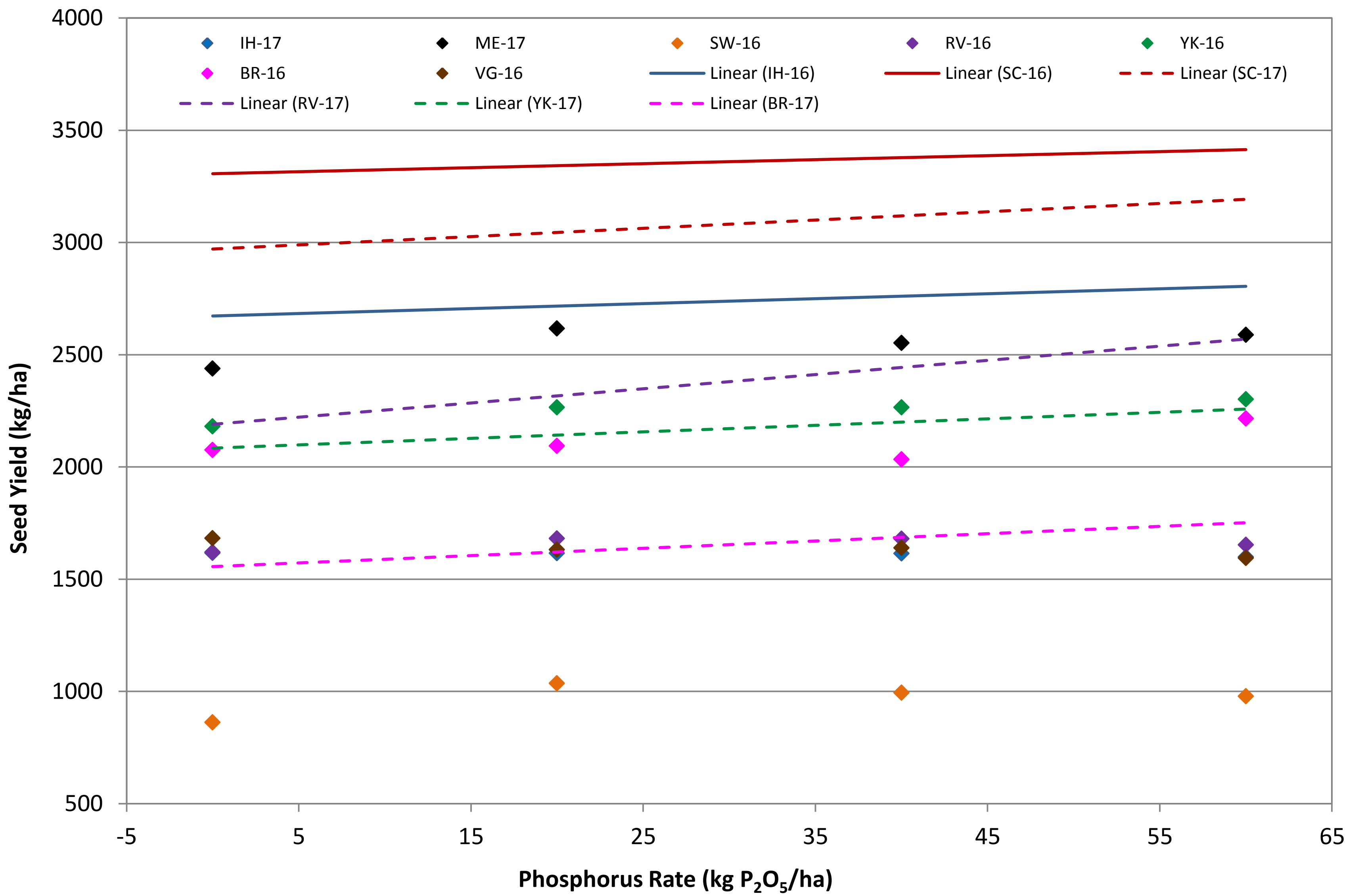

Figure 4. Flax seed yield response to phosphorus fertilizer rate at thirteen site-years in western Canada (2016-17). BR – Brandon, MB; IH – Indian Head, SK; ME – Melfort, SK; RV – Redvers, SK; SC – Scott, SK; SW – Swift Current, SK; VG – Vegreville, AB; YK – Yorkton, SK

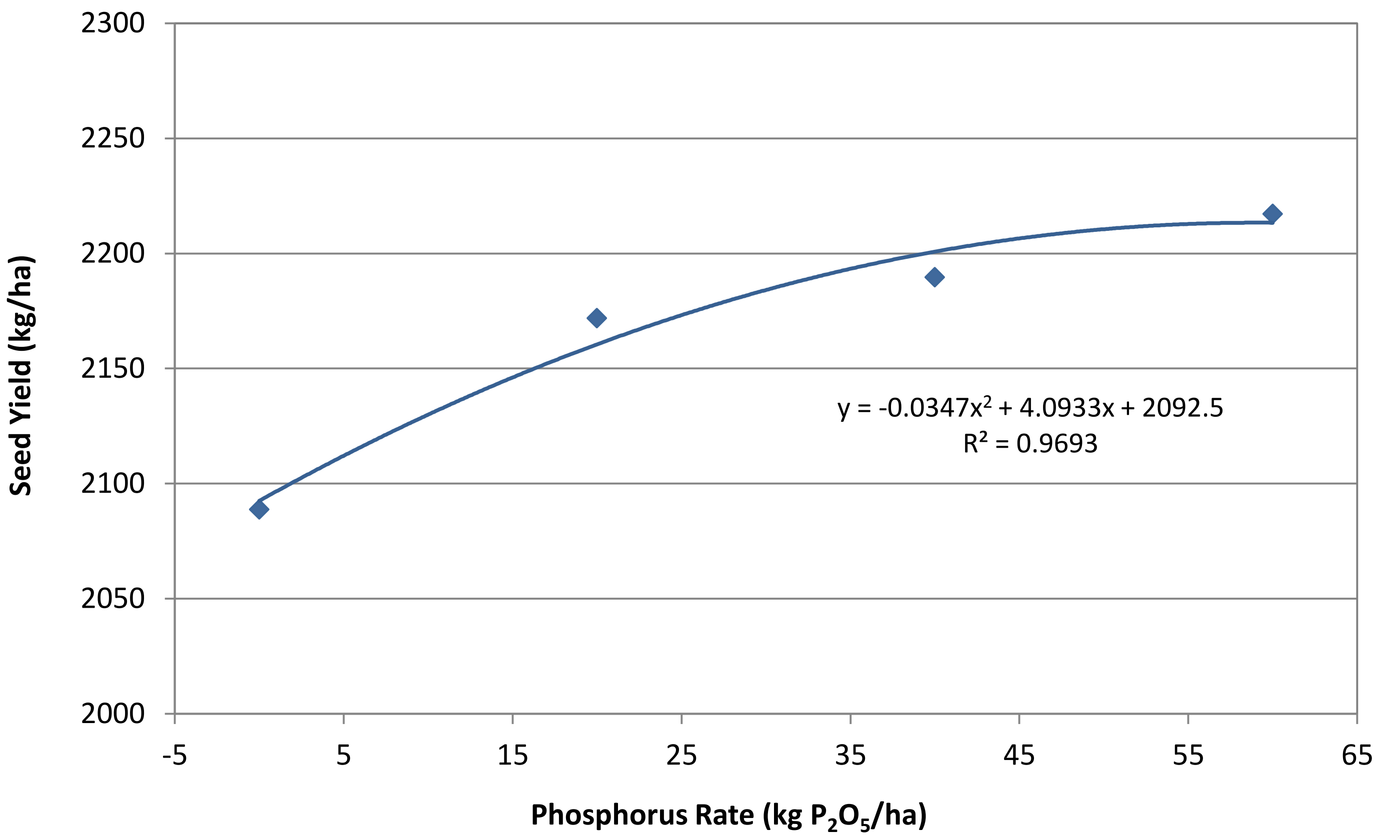

Figure 5. Overall flax seed yield response to phosphorus fertilizer rate averaged across thirteen site-years in western Canada (2016-17).

3. Technology Transfer Activities in Relation to the Project

a. 15-02-2016 to 15-02-2017:

At Indian Head, this trial was not featured at the Indian Head Crop Management Field Day for logistic reasons; however, it was shown during two other tours to 15-20 Australian producers (Seed Hawk Inc. June 16, 2016) and 33 agronomists (Richardson Pioneer July 27, 2016) in addition to several informal site visits.

At Redvers, the trial was showcased at the Southeast Research Farm Summer Field Day on July 20th where approximately 70 guests were in attendance.

At Scott, the trial was highlighted as part of a flax agronomy presentation by Rachel Evans during the Western Applied Research Corporation (WARC) Field Day on July 13, 2016 to approximately 200 guests.

At Swift Current, while this trial was not shown during the Crop Diagnostic School or WCA Annual Field Day, it was shown during 5 separate smaller tours where the number of guests on any given date ranged from 4-18.

At Yorkton, the trial was highlighted during the ECRF Summer Field Day which was held on July 21, 2016 and attended by approximately 60 guests.

At Vegreville, the trial was featured at four tours during the 2016 season. These included the Organic Alberta Tour (July 27, 40 guests), Field Day of Alberta Innovates – Technology Futures (July 28, 100 guests), Agricultural Financial Services Corporation Tour (August 17, 20 people) and the Heilongjiang Academy of Science (China) Tour (August 26, 8 people).

During the winter months, the project was introduced as part of a flax agronomy presentation at the Saskatchewan Oilseed Producer Meetings at Weyburn (40 guests), Humbolt (60 guests), Prince Albert (30 guests), Rosetown (70 guests), and Swift Current (100 guests) on November 14-18, 2016. The presenters at these meetings were Chris Holzapfel, Jessica Pratchler and Stewart Brandt and the total number of people who attended these meetings is not known. Jan Slaski introduced the study in Alberta during his talk entitled ‘Flax Facts’ at the Farming Smarter Conference at Medicine Hat (December 6, 260 guests). The trial was also introduced during a flax agronomy session at Crop Sphere at Saskatoon (January 10, approximately 50 guests) by Rachel Evans (Flax Council of Canada).

b. 15-02-2017 to 15-02-2018:

At Indian Head in 2017, the project was shown to approximately 200 guests at the Indian Head Crop Management Field Day (July 18) with discussions on flax fertility led by Chris Holzapfel (IHARF) and Rachel Evans (WARC) and the project was also shown at smaller industry tours at this site (approximately 100 guests in total).

At the Melfort Research Farm Field Day (July 26, 2017), Chris Holzapfel (IHARF) presented preliminary results on the project to approximately 80 guests.

At Swift Current, the trial was highlighted on the June 27, 2017 "Walk the Plots" segment on Golden West radio with Bryan Nybo (WCA) and also shown on numerous smaller tours for WCA directors and local crop consultants.

At Redvers in 2017, the plots were shown to approximately 70 guests at the July 19 SERF Field Day. Presentations on flax fertility and agronomy were led by Matthew Bernard (SK Ministry of Agriculture) and Rachel Evans (Flax Council of Canada).

At Yorkton, the trial was shown during the ECRF Field Day on July 13, 2017 with a presentation by Mike Hall (Parkland College / ECRF). Mr. Hall also posted on online video showing preliminary results from the trial on the ECRF website. Online [Available}: http://www.ecrf.ca/?page=flaxresponsetonandp2016

At Vegreville, the trial was shown on a July 20, 2017 field day with a presentation on flax fertility and agronomy by Jan Slaski (Innotech Alberta) and the trial was also visited by Flax Council of Canada staff on June 16.

During the winter months, preliminary results from this project were presented to approximately 70 attendees by Jan Slaski (Innotech Alberta) at CropSphere 2018 in a presentation entitled "Factors affecting the agronomic performance of flax on the Prairies." Jessica Pratchler (NARF) and Jessica Weber (WARC) provided updates on this work and other pertinent flax research and developments at the Top Notch Farming meetings at Humboldt (February 14, 2018) and Davidson (February 15, 2018).

Finally, the full technical report from the 2016 field season has been available for download on the IHARF website. Online [Available]: http://iharf.ca/wp-content/uploads/2017/04/Flax-Response-to-a-Wide-Range-of-Nitrogen-Phosphorus-Fertilizer-Rates-in-Western-Canada-interim-report.pdf

4. Changes Expected to Industry Contributions, In-Kind Support, Collaborations, Etc.

a. 15-02-2015 to 15-02-2018:

No changes to industry contributions or in-kind support occurred and none are expected going into the third year of the study. With regard to collaboration, the original site proposed at Roblin (Parkland Crop Diversification Foundation) was dropped prior to the first year of field trials due to staffing issues. This location was replaced with a site at Brandon under the supervision of Ramona Mohr (Agriculture and Agri-Food Canada) and this did have any impacts on budget or the deliverables of the project.

5. Appendices

a. Acknowledgements

Financial support for this project was provided Saskatchewan Ministry of Agriculture and the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement, the Saskatchewan Flax Development Commission, and the Western Grains Research Foundation. Initial project input was provided by the SaskFlax Board of Directors and scientific guidance and oversight is being provided in-kind by Dr. Jeff Schoneau of the University of Saskatchewan's Department of Soil Science. The field trials were carried out by the staff and using the facilities, land and equipment of the Indian Head Agricultural Research Foundation, Northeast Agricultural Research Foundation, Western Applied Research Corporation, Southeast Applied Research Farm, East Central Research Foundation, Wheatland Conservation Area Inc., InnoTech Alberta, and Agriculture and Agri-Food Canada. The many contributions of the technical and professional staff at each location is greatly appreciated.

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Table 1. Selected agronomic information for flax nitrogen and phosphorus response trials at seven Western Canadian locations in 2016.

	Location (2016)							
Factor / Operation	**Indian Head**	**Melfort**	**Scott**	**Swift Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville** [X]
Previous Crop	Wheat	Canola	Wheat	Durum	Barley	Wheat	Wheat	Barley
Variety	CDC Bethune	CDC Bethune	CDC Glas	CDC Sorrel	CDC Bethune	AAC Bravo	CDC Bethune	CDC Bethune
Pre-emergent Herbicide	May-7 to May-15	May-19	May-1	May-30	May-10	May-4	May-7	May-2
Seeding Date	May-5	May-17	May-6	Jun-2	May-9	May-15	May-9	May-26
Seeding Rate	53 kg/ha	182 kg/ha [Z]	32 kg/ha	63 kg/ha	45 kg/ha	67 kg/ha	55 kg/ha	40 kg/ha
Row spacing	30 cm	30 cm	25 cm	23 cm	25 cm	25 cm	20 cm	20 cm
Emergence Counts	May-30	Jun-23	Jun-3	Jun-28	Jun-20	Jun-16	June 7	Jun-23
In-crop Herbicide	Jun-7 to Jun-18	Jun-21 to Jun-28	Jun-14	Jun-24	Jun-13	Jun-16	Jun-14	Jun-10 to Jun-24
Fungicide	Jul-3	Jul-12	Jul-5	n/a	Jul-21	Jul-16	Jul-5	Aug-4
Insecticide	n/a	n/a	Jun-23	n/a	n/a	n/a	n/a	n/a
Pre-harvest herbicide	Aug-25	n/a	Sep-1	Sep-26	n/a	Aug-30	n/a	n/a
Harvest date	Sep-16	Nov-8	Sep-14	Oct-31	Oct-9	Sep-13	Aug-29	Nov-10

[Z] Error during seeding, unintended high rate [Y] Tillage used prior to seeding at Vegreville

Table 2. Selected agronomic information for flax nitrogen and phosphorus response trials at seven Western Canadian locations in 2017.

	Location (2017)							
Factor / Operation	**Indian Head**	**Melfort**	**Scott**	**Swift Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville** [Z]
Previous Crop	Wheat	Wheat	Wheat	Wheat	Barley	Wheat	Wheat	Barley
Variety	CDC Bethune	CDC Sorrel	CDC Glas	CDC Sorrel	CDC Bethune	AC Prairie Thunder	CDC Bethune	CDC Bethune
Pre-emergent Herbicide	May-10 and May-15	None	May-6	May-11	May-8	May-12	May-5	May 22 and Jun-5
Seeding Date	May 11	May-19	May-16	May-17	May-10	May-10	May-11	Jun-7
Seeding Rate	50 kg/ha	49 kg/ha	32 kg/ha	63 kg/ha	45 kg/ha	67 kg/ha	53 kg/ha	55 kg/ha
Row spacing	30 cm	30 cm	25 cm	23 cm	25 cm	25 cm?	20 cm	20 cm
Emergence Counts	Jun-5	Jun-16	Jun-13	Jul-6	Jun-5	May-31	Jun-8	Jun-28
In-crop Herbicide	Jun-6 and Jun-16	None	Jun-12 and Jun-23	Jun-20	Jun-7 and Jun-20	Jun-6 and Jun-7	Jun-6	Jun-20 and Jul-5
Fungicide	Jul-10	Jul-18	July-13	Jul-14	n/a	Jul-9	Jul-13	n/a
Insecticide	n/a	n/a	Jun-29	n/a	n/a	n/a	n/a	n/a
Pre-harvest herbicide	Aug-20	Sep-6	Aug-29	n/a	Sep-2	Aug-25	Sep=8	Sep-25
Harvest date	Sep-5	Sep-18	Sep-18	Aug-8	Sep-11	Sep-1	Sep-13	Oct-6

[Z] Tillage used prior to seeding at Vegreville

Table 3. Soil test results for flax N and P trial at 8 locations in western Canada (2016-2018).

		Soil Test Parameter						
Location	**Year**	**pH (0-15 cm)**	**SOM**	**CEC**	**NO_3-N (0-60 cm)**	**Olsen-P (0-15 cm)**	**K (0-15 cm)**	**S (0-60 cm)**
		–	%	Meq	kg/ha	ppm	ppm	kg/ha
Indian Head	2016	7.6	4.0	43.7	25	10	566	7
	2017	7.7	5.3	45.4	25	10	864	56
	2018	–	–	–	–	–	–	–
Melfort	2016	7.1	9.5	n/a	55^{Z}	22	483	99^{Z}
	2017	6.1	9.0	n/a	56^{Z}	16	425	28^{Z}
	2018	–	–	–	–	–	–	–
Scott	2016	4.9	4.1	9.5	37	24	263	25
	2017	5.9	4.7	13.9	29	19	390	52
	2018	–	–	–	–	–	–	–
Swift Current	2016	7.4	2.7	–	46	7	350	> 227
	2017	7.1	2.3	18.2	31	3	282	49
	2018	–	–	–	–	–	–	–
Redvers	2016	7.7	–	–	104^{Y}	4	162	–
	2017	7.0	3.2	–	28^{Y}	4	319	63
	2018	–	–	–	–	–	–	–
Yorkton	2016	7.8	5.7	35.3	36	6	280	419
	2017	6.5	6.3	23.2	43	11	327	123
	2018	–	–	–	–	–	–	–
Brandon	2016	7.9	5.1	26.6	37	6	202	16
	2017	7.9	5.0	26.6	55	7	271	18
	2018	–	–	–	–	–	–	–
Vegreville	2016	7.5	8.2	35.7	26	11	202	> 227
	2017	6.6	6.3	–	34	14	380	22
	2018	–	–	–	–	–	–	–

^{Z} 0-30 cm sample depth ^{Y} 0-46 cm sample depth

Table 4. Mean monthly temperatures for the 2016-17 growing seasons relative to the long-term averages (1981-2010) at 8 locations in western Canada.

Location	Year	Mean Monthly Temperature				
		May	June	July	August	Average
		°C				
Indian Head	2016	14.0	17.5	18.5	17.2	16.8
	2017	11.6	15.5	18.4	16.7	15.6
	2018	–	–	–	–	–
	LT	10.8	15.8	18.2	17.4	15.6
Melfort	2016	13.6	17.1	18.1	16.3	16.3
	2017	10.8	15.2	18.7	17.2	15.5
	2018	–	–	–	–	–
	LT	10.7	15.9	17.5	16.8	15.2
Scott	2016	12.4	15.8	17.8	16.1	15.5
	2017	11.5	15.1	18.3	16.6	15.4
	2018	–	–	–	–	–
	LT	10.8	15.3	17.1	16.5	14.9
Swift Current	2016	12.4	16.6	17.8	16.7	15.9
	2017	12.1	15.2	20.4	18.2	16.5
	2018	–	–	–	–	–
	LT	10.9	15.4	18.5	18.2	15.8
Redvers [Y]	2016	13.5	17.8	19.6	19.2	17.5
	2017	12.2	15.5	19.6	17.4	16.1
	2018	–	–	–	–	–
	LT	11.1	16.2	18.7	18.0	16.0
Yorkton	2016	13.5	17.2	18.5	17.0	16.6
	2017	11.1	15.5	19	17.4	15.8
	2018	–	–	–	–	–
	LT	10.4	15.5	17.9	17.1	15.2
Brandon	2016	13.1	17.2	18.9	17.5	16.7
	2017	11.4	16.3	19.3	17.5	16.1
	2018	–	–	–	–	–
	LT	11.4	16.6	19.2	18.2	16.4
Vegreville	2016	12.0	16.8	18.1	16.8	15.9
	2017	12.9	16.0	17.9	16.6	15.9
	2018	–	–	–	–	–
	LT	10.3	14.4	16.6	15.6	14.2

[Z] LT- Long-Term average (1981-2010); [Y] Data for Redvers is from Melita, MB

Table 5. Monthly precipitation amounts for the 2016-17 growing season relative to the long-term averages (1981-2010) at 8 locations in western Canada.

Location	Year	Total Monthly Precipitation				
		May	June	July	August	Average
		---------- ºC ----------				
Indian Head	2016	72.6	63.0	112.8	29.8	278
	2017	10.4	65.6	15.4	25.2	117
	2018	–	–	–	–	–
	LT [Z]	51.8	77.4	63.8	51.2	244
Melfort	2016	16.8	53.2	128.7	80.8	280
	2017	46.4	44.1	33.3	3.1	127
	2018	–	–	–	–	–
	LT	42.9	54.3	76.7	52.4	226
Scott	2016	64.8	20.8	88.1	98.2	272
	2017	69.0	34.3	22.4	53.0	179
	2018	–	–	–	–	–
	LT	36.3	61.8	72.1	45.7	216
Swift Current	2016	129.7	80.4	119.0	45.9	375
	2017	16.4	31.1	7.5	24.8	80
	2018	–	–	–	–	–
	LT	48.5	72.8	52.6	41.5	215
Redvers	2016	96.1	72.4	77.9	32.1	279
	2017	41.1	61.5	17.5	33.3	153
	2018	–	–	–	–	–
	LT	60.0	95.2	65.5	46.6	267
Yorkton	2016	74.9	62.8	141.7	59.1	338.5
	2017	12.5	53.9	59.1	32.5	158
	2018	–	–	–	–	–
	LT	51.3	80.1	78.2	62.2	272
Brandon	2016	67.1	67.4	60.6	43.1	238
	2017	15.9	61.1	31.3	30.1	138
	2018	–	–	–	–	–
	LT	56.5	79.6	68.2	65.5	270
Vegreville	2016	109.2	65.4	94.7	50.8	320
	2017	61.5	90.5	46.3	26.6	225
	2018	–	–	–	–	–
	LT	37.1	60.6	76.3	51.8	226

[Z] LT- Long-Term average (1981-2010); [Y] Data for Redvers is from Melita, MB

Years analyzed individually

Table 6. Side-banded nitrogen and phosphorus fertilizer effects on flax plant density at multiple locations in 2016.

	Plant density							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville [X]**
Effect	p-values [Z]							
N Rate (N)	0.192	0.970	**< 0.001**	**< 0.001**	0.649	**< 0.001**	**< 0.001**	0.292
P_2O_5 Rate (P)	0.429	0.509	0.798	0.456	0.744	0.895	**0.044**	0.915
N × P	0.247	0.993	0.179	0.583	0.101	0.494	0.273	0.270
AICC [Y]	577.8	723.5	514.8	524.1	569.9	627.9	564.2	353.5

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability; [Y] Measure of overall model fit, smaller is better
[X] Only three replicates, rep 1 discarded due to excess moisture, poor establishment and low, variable yields

Table 7. Side-banded nitrogen and phosphorus fertilizer effects on flax plant density at multiple locations in 2017.

	Plant density							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
Effect	p-values [Z]							
N Rate (N)	**0.029**	**< 0.001**	**< 0.001**	**< 0.001**	**0.019**	**< 0.001**	**< 0.001**	0.655
P_2O_5 Rate (P)	0.119	0.537	0.726	0.867	0.822	0.520	0.206	0.799
N × P	0.705	0.690	0.341	0.544	0.490	0.530	0.798	0.215
AICC [Y]	569.1	532.3	488.1	502.4	568.2	598.8	576.7	582.8

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability; [Y] Measure of overall model fit, smaller is better

Table 8. Least squares means for main effects of N and P fertilizer rates on flax plant density at multiple locations in 2016. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, *P* ≤ 0.05).

Main effect	Plant Density							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N Rate	------- plants m^{-2} -------							
13 kg/ha	638 a	528 a	289 a	299 a	365 a	671 a	547 a	420 a
50 kg/ha	599 a	494 a	269 a	246 b	338 a	628 ab	534 a	438 a
100 kg/ha	639 a	548 a	260 a	203 c	346 a	548 b	476 c	406 a
150 kg/ha	592 a	501 a	216 b	189 c	337 a	458 c	391 c	424 a
S.E.M.	19.3	88.1	10.0	11.0	17.9	32.0	16.8	18.7
L.S.D.	55.0	251.0	28.5	31.5	49.1	90.5	47.8	33.7
P_2O_5 Rate								
0 kg/ha	613 a	415 a	265 a	233 a	352 a	593 a	470 b	418 a
20 kg/ha	632 a	510 a	252 a	246 a	330 a	558 a	482 ab	418 a
40 kg/ha	631 a	546 a	260 a	221 a	352 a	575 a	467 b	425 a
60 kg/ha	592 a	600 a	256 a	236 a	353 a	578 a	529 a	427 a
S.E.M.	19.3	88.1	10.0	11.0	17.9	32.0	16.8	18.7
L.S.D.	55.0	251.0	28.5	31.5	49.1	90.5	47.8	33.7
Contrast	------- p-values [Y] -------							
N – linear	0.279	0.950	**< 0.001**	**< 0.001**	0.359	**< 0.001**	**< 0.001**	0.631
N – quadratic	0.741	0.907	0.302	0.030	0.608	0.669	0.095	0.816
P – linear	0.465	0.140	0.686	0.731	0.764	0.832	**0.036**	0.896
P – quadratic	0.142	0.817	0.651	0.945	0.504	0.558	0.147	0.487

Table 9. Least squares means for main effects of N and P fertilizer rates on flax plant density at multiple locations in 2017. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, $P \leq 0.05$).

Main effect	**Plant Density**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N Rate	---------- plants m^{-2} ----------							
13 kg/ha	408 a	342 a	247 a	186 a	540 a	544 a	413 a	837 a
50 kg/ha	381 ab	317 ab	235 ab	181 a	514 a	466 b	302 b	804 a
100 kg/ha	353 b	288 bc	220 b	127 b	507 ab	457 b	242 c	818 a
150 kg/ha	338 b	266 c	191 c	88 c	462 b	376 c	201 c	812 a
S.E.M.	17.9	12.6	7.6	8.8	18.4	30.1	23.1	23.4
L.S.D.	48.6	32.9	21.6	25.1	47.9	64.0	59.7	54.8
P_2O_5 Rate								
0 kg/ha	354 a	295 a	222 a	145 a	502	443 a	311 a	818 a
20 kg/ha	393 a	295 a	231 a	140 a	517	488 a	272 a	804 a
40 kg/ha	344 a	307 a	220 a	149 a	496	460 a	262 a	831 a
60 kg/ha	388 a	315 a	221 a	149 a	508	451 a	313 a	816 a
S.E.M.	18.2	12.6	7.6	8.8	18.4	30.1	23.7	23.4
L.S.D.	48.6	32.9	21.6	25.1	47.9	64.0	59.7	54.8
Contrast	---------- p-values [Y] ----------							
N – linear	**0.003**	**< 0.001**	**< 0.001**	**< 0.001**	**0.003**	**< 0. 001**	**< 0.001**	0.520
N – quadratic	0.550	0.684	0.402	0.228	0.655	0.914	**0.047**	0.507
P – linear	0.475	0.162	0.701	0.581	0.973	0.951	0.971	0.808
P – quadratic	0.899	0.690	0.595	0.746	0.933	0.233	**0.036**	0.976

Table 10. Least squares means for N by P fertilizer rate interactions on flax plant density at multiple locations in 2016. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, $P \leq 0.05$).

Main effect	**Plant Density**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N × P Rate	plants m^{-2}							
13N – 0P	657 ab	331 a	305 a	321 a	412 a	719 a	521 b-e	439 a
13N – 20P	661 ab	509 a	258 abc	303 a	352 a	712 a	565 abc	457 a
13N – 40P	612 b	618 a	302 a	282 abc	339 a	573 a-e	532 bcd	367 a
13N – 60P	623 b	656 a	289 a	291 ab	357 a	679 ab	570 ab	418 a
50N – 0P	638 ab	308 a	268 ab	231 b-e	267 a	633 ab	474 c-g	449 a
50N – 20P	597 b	532 a	271 ab	233 b-e	338 a	637 a-d	525 b-e	411 a
50N – 40P	609 b	526 a	272 ab	259 a-d	397 a	575 a-d	508 b-f	442 a
50N – 60P	553 b	609 a	264 ab	261 a-d	351 a	666 abc	629 a	451 a
100N – 0P	593 b	502 a	283 a	201 de	358 a	551 a-f	465 d-g	394 a
100N – 20P	629 ab	544 a	274 a	224 cde	299 a	495 c-f	459 d-g	396 a
100N – 40P	734 a	587 a	217 bc	173 e	386 a	624 a-d	500 b-f	418 a
100N – 60P	598 b	557 a	267 ab	213 de	339 a	524 b-f	482 b-f	416 a
150N – 0P	565 b	518 a	204 c	180 e	370 a	524 def	420 fgh	419 a
150N – 20P	641 ab	454 a	203 c	226 cde	331 a	470 f	379 gh	408 a
150N – 40P	568 b	452 a	251 abc	171 e	285 a	528 b-f	330 h	445 a
150N – 60P	595 b	579 a	204 c	178 e	363 a	442 ef	434 efg	424 a
S.E.M.	38.6	176.3	20.0	22.1	34.8	63.7	33.5	27.5
L.S.D.	110.0	502.1	57.1	62.9	98.15	181.0	95.5	67.4

Table 11. Least squares means for N by P fertilizer rate interactions on flax plant density at multiple locations in 2017. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, *P* ≤ 0.05).

Main effect	**Plant Density**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N × P Rate	plants m^{-2}							
13N – 0P	337 bcd	342 ab	267 a	212 a	506 abc	593 a	421 ab	842 a
13N – 20P	462 a	322 a-e	256 ab	170 a-d	572 a	560 ab	420 ab	803 a
13N – 40P	402 abc	375 a	250 abc	176 abc	541 ab	550 ab	356 abc	914 a
13N – 60P	433 ab	327 a-d	215 b-g	186 ab	540 ab	474 a-f	455 a	789 a
50N – 0P	379 a-d	313 a-e	239 a-d	168 a-d	541 ab	404 c-f	314 bcd	820 a
50N – 20P	406 abc	310 a-e	237 a-e	173 a-d	555 ab	482 a-e	309 bcd	810 a
50N – 40P	352 bcd	310 a-e	229 a-f	200 a	466 bc	479 a-f	308 bcd	826 a
50N – 60P	385 a-d	335 abc	237 a-e	184 ab	496 abc	497 a-d	276 c-f	759 a
100N – 0P	358 bcd	264 def	205 d-g	112 efg	489 abc	413 c-f	284 c-f	811 a
100N – 20P	376 a-d	279 b-f	223 b-f	129 c-f	479 abc	523 abc	186 ef	795 a
100N – 40P	303 d	298 b-f	217 b-g	145 b-e	540 ab	459 b-f	205 def	824 a
100N – 60P	374 a-d	312 a-e	238 a-e	123 d-g	518 abc	432 b-f	293 cde	841 a
150N – 0P	342 bcd	260 ef	176 g	87 fg	472 bc	364 ef	224 def	800 a
150N – 20P	330 cd	272 c-f	209 c-g	89 fg	463 bc	388 def	172 f	810 a
150N – 40P	320 cd	243 f	186 fg	73 g	436 c	352 f	177 ef	762 a
150N – 60P	362 bcd	288 b-f	196 e-g	104 efg	479 abc	399 c-f	229 def	876 a
S.E.M.	34.6	23.6	15.2	17.6	34.5	49.2	43.0	40.7
L.S.D.	97.2	65.7	43.2	50.2	95.9	128.0	119.5	109.6

Table 12. Orthogonal contrast results for N by P fertilizer rate interactions on flax plant density at multiple locations in 2016. Values greater than 0.05 are not considered significant.

Main effect	**Plant Density**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
Contrast	p-values [Y]							
N (0P) – lin	0.069	0.334	**0.002**	< **0.001**	0.980	**0.006**	**0.045**	0.266
N (0P) – quad	0.993	0.997	0.309	0.085	**0.046**	0.840	0.923	0.601
N (20P) – lin	0.942	0.835	0.065	**0.026**	0.539	< **0.001**	< **0.001**	0.153
N (20P) – quad	0.367	0.752	**0.046**	0.097	0.446	0.970	0.746	0.194
N (40P) – lin	0.911	0.587	**0.030**	< **0.001**	0.212	0.736	< **0.001**	0.070
N (40P) – quad	**0.023**	0.890	0.067	0.396	**0.029**	0.417	**0.048**	0.339
N (60P) – lin	0.886	0.731	**0.007**	< **0.001**	0.954	**0.004**	< **0.001**	0.803
N (60P) – quad	0.445	0.822	0.380	0.864	0.647	0.778	0.255	0.680
P (13N) – lin	0.391	0.176	0.973	0.272	0.254	0.369	0.457	0.159
P (13N) – quad	0.937	0.692	0.394	0.531	0.255	0.382	0.920	0.487
P (50N) – lin	0.170	0.262	0.899	0.238	**0.050**	0.903	**0.004**	0.725
P (50N) – quad	0.841	0.690	0.795	0.999	0.097	0.497	0.298	0.318
P (100N) – lin	0.497	0.792	0.244	0.869	0.848	0.870	0.541	0.397
P (100N) – quad	0.031	0.839	0.146	0.712	0.854	0.732	0.870	0.938
P (150N) – lin	0.919	0.818	0.601	0.545	0.659	0.848	0.974	0.624
P (150N) – quad	0.524	0.592	0.250	0.391	0.095	0.966	**0.036**	0.816

Table 13. Orthogonal contrast results for N by P fertilizer rate interactions on flax plant density at multiple locations in 2017. Values greater than 0.05 are not considered significant.

Main effect	**Plant Density**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
Contrast	p-values [Y]							
N (0P) – lin	0.925	**0.006**	**< 0.001**	**< 0.001**	0.281	**0.002**	**0.002**	0.442
N (0P) – quad	0.433	0.442	0.795	0.351	0.525	0.114	0.490	0.851
N (20P) – lin	**0.008**	0.088	**0.027**	**0.001**	**0.010**	**0.022**	**< 0.001**	0.979
N (20P) – quad	0.784	0.800	0.764	0.358	0.791	0.522	0.138	0.894
N (40P) – lin	0.066	**< 0.001**	**0.004**	**< 0.001**	0.125	**0.004**	**0.003**	**0.012**
N (40P) – quad	0.266	0.725	0.855	**0.024**	0.567	0.777	0.626	0.694
N (60P) – lin	0.161	0.170	0.344	**< 0.001**	0.303	0.142	**0.001**	**0.044**
N (60P) – quad	0.556	0.574	**0.044**	0.904	0.960	0.644	0.165	0.538
P (13N) – lin	0.139	0.947	**0.021**	0.365	0.629	0.076	0.851	0.776
P (13N) – quad	0.174	0.555	0.433	0.143	0.323	0.631	0.233	0.271
P (50N) – lin	0.822	0.520	0.818	0.350	0.139	0.177	0.538	0.340
P (50N) – quad	0.943	0.543	0.737	0.580	0.812	0.506	0.751	0.463
P (100N) – lin	0.868	0.124	0.184	0.518	0.329	0.982	0.802	0.491
P (100N) – quad	0.446	0.979	0.909	0.270	0.862	0.135	0.030	0.670
P (150N) – lin	0.746	0.580	0.611	0.669	0.971	0.730	0.916	0.301
P (150N) – quad	0.428	0.481	0.467	0.407	0.448	0.797	0.239	0.179

Table 14. Side-banded nitrogen and phosphorus fertilizer effects on flax maturity at multiple locations in 2016.

	Days to Maturity							
	Indian Head	**Melfort** [X]	**Scott**	**S. Current**	**Redvers** [X]	**Yorkton**	**Brandon**	**Vegreville**
Effect	-------	-------	-------	p-values [Z]	-------	-------	-------	-------
N Rate (N)	**< 0.001**	–	0.113	**< 0.001**	–	**< 0.001**	**< 0.001**	**< 0.001**
P_2O_5 Rate (P)	0.212	–	0.681	0.283	–	0.862	0.695	0.296
N × P	**0.029**	–	0.895	0.806	–	0.302	0.961	0.924
AICC [Y]	111.7	–	265.0	212.5	–	149.8	149.0	100.2

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability; [Y] Measure of overall model fit, smaller is better
[X] Data not collected / statistically analyzed

Table 15. Side-banded nitrogen and phosphorus fertilizer effects on flax maturity at multiple locations in 2017.

	Days to Maturity							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
Effect	-------	-------	-------	p-values [Z]	-------	-------	-------	-------
N Rate (N)	**< 0.001**	–	**0.010**	–	0.068	**< 0.001**	**< 0.001**	**< 0.001**
P_2O_5 Rate (P)	0.288	–	**0.001**	–	0.243	0.203	0.978	0.367
N × P	0.467	–	0.184	–	0.089	0.621	**0.010**	0.112
AICC [Y]	100.4	–	138.5	–	216.6	196,8	197.0	62.6

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability; [Y] Measure of overall model fit, smaller is better
[X] Data not collected / statistically analyzed

Table 16. Least squares means for main effects of N and P fertilizer rates on flax maturity at multiple locations in 2016. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, $P \leq 0.05$).

Main effect	Days to Maturity							
	Indian Head	**Melfort** [X]	**Scott**	**S. Current**	**Redvers** [X]	**Yorkton**	**Brandon**	**Vegreville**
<u>N Rate</u>	---------- days ----------							
13 kg/ha	102.0 d	–	106.8 b	108.6 b	–	105.1 bc	99.4 b	105.8 c
50 kg/ha	103.5 c	–	106.9 b	108.8 b	–	104.7 c	99.8 b	106.8 b
100 kg/ha	104.1 b	–	107.8 ab	113.0 a	–	105.5 b	101.9 a	107.4 ab
150 kg/ha	105.2 a	–	108.9 a	114.1 a	–	107.0 a	102.0 a	108.0 a
S.E.M.	0.16	–	1.23	0.47	–	0.22	0.24	0.26
L.S.D.	0.41	–	1.92	1.17	–	0.62	0.60	0.67
<u>P_2O_5 Rate</u>								
0 kg/ha	103.9 a	–	108.3 a	110.6 a	–	105.7 a	100.9 a	106.7 a
20 kg/ha	103.7 a	–	107.4 a	111.0 a	–	105.5 a	100.9 a	107.2 a
40 kg/ha	103.5 a	–	107.5 a	111.1 a	–	105.7 a	100.8 a	106.9 a
60 kg/ha	103.7 a	–	107.3 a	111.8 a	–	105.5 a	100.6 a	107.3 a
S.E.M.	0.16	–	1.23	0.47	–	0.22	0.24	0.26
L.S.D.	0.41	–	1.92	1.17	–	0.62	0.60	0.67
<u>Contrast</u>	---------- p-values [Y] ----------							
NR – linear	**< 0.001**	–	**0.019**	**< 0.001**	–	**< 0.001**	**< 0.001**	**< 0.001**
NR – quadratic	0.084	–	0.533	0.916	–	**< 0.001**	0.085	0.277
PR – linear	0.252	–	0.316	0.067	–	0.701	0.473	0.159
PR – quadratic	0.090	–	0.613	0.705	–	1.000	0.661	0.722

[X] Data not collected

Table 17. Least squares means for main effects of N and P fertilizer rates on flax maturity at multiple locations in 2017. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, *P* ≤ 0.05).

Main effect	**Days to Maturity**							
	Indian Head	**Melfort** [X]	**Scott**	**S. Current**	**Redvers** [X]	**Yorkton**	**Brandon**	**Vegreville**
N Rate				------- days -------				
13 kg/ha	96.8 d	–	99.3 ab	–	90.4 a	97.6 b	106.4 b	103.5 c
50 kg/ha	97.6 c	–	98.9 b	–	90.0 a	97.6 b	106.3 b	104.0 b
100 kg/ha	98.2 b	–	99.5 a	–	90.8 a	98.2 b	108.3 a	104.1 b
150 kg/ha	98.8 a	–	99.8 a	–	91.6 a	100.4 a	108.8 a	104.4 a
S.E.M.	0.19	–	0.31	–	0.56	0.37	0.37	0.09
L.S.D.	0.35	–	0.52	–	1.19	1.00	1.04	0.26
P_2O_5 Rate								
0 kg/ha	98.0 a	–	100.0 a	–	90.3 a	98.6 a	107.5	103.9 a
20 kg/ha	97.7 a	–	99.0 b	–	90.3 a	99.0 a	107.4	103.9 a
40 kg/ha	97.8 a	–	99.3 b	–	91.3 a	97.9 a	107.6	104.1 a
60 kg/ha	97.8 a	–	99.1 b	–	90.9 a	98.3 a	107.4	103.9 a
S.E.M.	0.19	–	0.31	–	0.56	0.372	0.37	0.09
L.S.D.	0.35	–	0.52	–	1.19	1.00	1.04	0.26
Contrast				------- p-values [Y] -------				
NR – linear	< **0.001**	–	**0.008**	–	**0.021**	< **0.001**	< **0.001**	< **0.001**
NR – quadratic	0.142	–	0.179	–	0.234	**0.005**	0.847	0.220
PR – linear	0.613	–	**0.005**	–	0.109	0.257	0.909	0.644
PR – quadratic	0.171	–	**0.020**	–	0.711	0.930	0.932	0.304

[X] Data not collected

Table 18. Least squares means for N by P fertilizer rate interactions on flax maturity at multiple locations in 2016. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, $P \leq 0.05$).

Main effect	**Days to Maturity**							
	Indian Head	**Melfort** [X]	**Scott**	**S. Current**	**Redvers** [X]	**Yorkton**	**Brandon**	**Vegreville**
N × P Rate	---------- days ----------							
13N – 0P	102.0 f	–	107.8 ab	107.5 c	–	105.3 de	99.8 b	105.3 e
13N – 20P	101.9 f	–	107.8 ab	108.5 bc	–	104.5 ef	99.8 b	106.3 b-e
13N – 40P	102.1 f	–	106.5 ab	109.0 bc	–	105.5 cde	99.0 b	105.7 de
13N – 60P	102.1 f	–	105.3 b	109.3 bc	–	105.0 def	99.0 b	106.0 cde
50N – 0P	103.4 de	–	107.3 ab	108.8 bc	–	105.0 def	99.8 b	106.3 b-e
50N – 20P	103.3 de	–	107.3 ab	109.0 bc	–	104.0 f	99.8 b	107.0 a-d
50N – 40P	103.0 e	–	107.0 ab	107.5 c	–	105.1 def	99.8 b	106.3 b-e
50N – 60P	104.3 bc	–	106.3 b	110.0 b	–	104.8 def	100.0 b	107.3 abc
100N – 0P	104.5 bc	–	108.0 ab	112.8 a	–	105.1 def	102.0 a	107.0 a-d
100N – 20P	104.0 cd	–	106.5 ab	112.5 a	–	105.9 bcd	102.0 a	107.3 abc
100N – 40P	103.8 cde	–	107.8 ab	113.3 a	–	105.5 cde	101.5 a	107.7 ab
100N – 60P	104.0 cd	–	108.8 ab	113.5 a	–	105.4 cde	102.0 a	107.7 ab
150N – 0P	105.8 a	–	110.3 a	113.5 a	–	107.3 a	102.0 a	108.0 a
150N – 20P	105.5 a	–	108.0 ab	114.0 a	–	107.5 a	102.0 a	108.0 a
150N – 40P	105.0 ab	–	108.8 ab	114.5 a	–	106.5 abc	102.0 a	108.0 a
150N – 60P	104.5 bc	–	108.8 ab	114.3 a	–	106.8 ab	102.0 a	108.0 a
S.E.M.	0.30	–	1.70	0.85	–	0.44	0.44	0.48
L.S.D.	0.82	–	3.84	2.33	–	1.24	1.21	1.34

[X] Data not collected

Table 19. Least squares means for N by P fertilizer rate interactions on flax maturity at multiple locations in 2017. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, $P \leq 0.05$).

Main effect	**Days to Maturity**							
	Indian Head	**Melfort** [X]	**Scott**	**S. Current** [X]	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N × P Rate	-----------	-----------	-----------	days	-----------	-----------	-----------	-----------
13N – 0P	96.8 g	–	100.0 ab	–	89.8 a	98.5 b-e	104.8 e	103.8 cd
13N – 20P	96.8 g	–	99.0 bc	–	89.8 a	98.3 b-e	107.3 abc	103.3 d
13N – 40P	96.9 g	–	99.0 bc	–	90.5 a	96.8 e	108.3 a	103.8 cd
13N – 60P	96.9 g	–	99.0 bc	–	91.5 a	97.0 de	105.5 cde	103.3 d
50N – 0P	97.8 def	–	99.5 abc	–	89.5 a	97.3 de	107.3 abc	104.0 bc
50N – 20P	97.6 ef	–	99.0 bc	–	90.8 a	99.0 a-d	106.0 b-e	104.0 bc
50N – 40P	97.9 c-f	–	98.5 c	–	90.5 a	97.0 de	105.0 de	104.0 bc
50N – 60P	97.3 fg	–	98.5 c	–	89.3 a	97.0 de	107.0 a-d	104.0 bc
100N – 0P	98.4 bcd	–	100.5 a	–	91.8 a	97.8 de	109.0 a	104.0 bc
100N – 20P	97.9 c-f	–	99.0 bc	–	90.3 a	98.5 b-e	107.3 ab	104.0 bc
100N – 40P	98.1 cde	–	99.0 bc	–	91.3 a	98.0 cde	109.0 a	104.0 bc
100N – 60P	98.3 cde	–	99.5 abc	–	89.8 a	98.5 b-e	108.0 ab	104.3 abc
150N – 0P	99.1 a	–	100.0 ab	–	90.0 a	100.8 a	109.0 a	104.0 bc
150N – 20P	98.4 bcd	–	99.0 bc	–	90.3 a	100.3 ab	109.0 a	104.5 ab
150N – 40P	98.5 abc	–	100.5 a	–	92.8 a	100.0 abc	108.0 ab	104.8 a
150N – 60P	99.0 ab	–	99.5 abc	–	93.3 a	100.8 a	109.0 a	104.3 abc
S.E.M.	0.28	–	0.44	–	0.91	0.72	0.73	0.18
L.S.D.	0.704	–	1.04	–	2.39	2.01	2.08	0.51

[X] Data not statistically analyzed

Table 20. Orthogonal contrast results for N by P fertilizer rate interactions on flax maturity at multiple locations in 2016. Values greater than 0.05 are not considered significant.

Main effect	**Days to Maturity**							
	Indian Head	**Melfort** [X]	**Scott**	**S. Current**	**Redvers** [X]	**Yorkton**	**Brandon**	**Vegreville**
Contrast	p-values [Y]							
N (0P) – lin	**< 0.001**	–	0.161	**< 0.001**	–	**0.002**	**< 0.001**	**< 0.001**
N (0P) – quad	0.455	–	0.355	0.407	–	**0.012**	0.593	0.832
N (20P) – lin	**< 0.001**	–	0.972	**< 0.001**	–	**<.0001**	**< 0.001**	**0.016**
N (20P) – quad	0.838	–	0.439	0.895	–	0.058	0.593	0.907
N (40P) – lin	**< 0.001**	–	0.217	**< 0.001**	–	0.073	**< 0.001**	**< 0.001**
N (40P) – quad	0.793	–	0.913	0.344	–	0.151	0.453	0.500
N (60P) – lin	**< 0.001**	–	**0.038**	**< 0.001**	–	**0.003**	**< 0.001**	**0.006**
N (60P) – quad	**0.007**	–	0.573	0.646	–	0.102	0.099	0.240
P (13N) – lin	0.631	–	0.154	0.124	–	0.898	0.121	0.525
P (13N) – quad	0.830	–	0.646	0.649	–	0.775	1.000	0.478
P (50N) – lin	0.073	–	0.593	0.542	–	0.848	0.695	0.270
P (50N) – quad	**0.022**	–	0.782	0.177	–	0.476	0.770	0.722
P (100N) – lin	0.183	–	0.565	0.417	–	0.848	0.794	0.270
P (100N) – quad	0.201	–	0.359	0.762	–	0.319	0.559	0.722
P (150N) – lin	**0.002**	–	0.538	0.457	–	0.205	1.000	1.000
P (150N) – quad	0.667	–	0.409	0.649	–	1.000	1.000	1.000

Table 21. Orthogonal contrast results for N by P fertilizer rate interactions on flax maturity at multiple locations in 2017. Values greater than 0.05 are not considered significant.

Main effect	**Days to Maturity**							
	Indian Head	**Melfort** [X]	**Scott**	**S. Current**	**Redvers** [X]	**Yorkton**	**Brandon**	**Vegreville**
Contrast	----------	----------	----------	----------	p-values [Y]	----------	----------	----------
N (0P) – lin	< **0.001**	–	0.509	–	0.433	**0.017**	< **0.001**	0.386
N (0P) – quad	0.389	–	0.814	–	0.267	**0.006**	**0.052**	0.482
N (20P) – lin	< **0.001**	–	1.000	–	0.832	0.087	**0.039**	< **0.001**
N (20P) – quad	0.351	–	1.000	–	0.585	0.475	0.071	0.430
N (40P) – lin	< **0.001**	–	**0.002**	–	**0.046**	**0.001**	0.239	**0.001**
N (40P) – quad	0.155	–	**0.014**	–	0.446	0.306	0.294	0.204
N (60P) – lin	< **0.001**	–	0.112	–	0.088	< **0.001**	**0.001**	< **0.001**
N (60P) – quad	0.788	–	0.674	–	**0.002**	0.195	0.598	**0.028**
P (13N) – lin	0.653	–	0.072	–	0.116	0.064	0.326	0.222
P (13N) – quad	1.000	–	0.176	–	0.554	0.725	**0.001**	1.000
P (50N) – lin	0.264	–	**0.037**	–	0.791	0.388	0.595	1.000
P (50N) – quad	0.317	–	0.495	–	0.143	0.221	**0.031**	1.000
P (100N) – lin	0.910	–	0.072	–	0.189	0.582	0.704	0.358
P (100N) – quad	0.213	–	**0.009**	–	1.000	0.860	0.611	0.492
P (150N) – lin	0.822	–	1.000	–	**0.002**	0.937	0.761	0.222
P (150N) – quad	0.015	–	1.000	–	0.882	0.380	0.498	**0.008**

Table 22. Side-banded nitrogen and phosphorus fertilizer effects on flax seed yield at multiple locations in 2016.

	Seed Yield							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
Effect	p-values [Z]							
N Rate (N)	**< 0.001**	0.933	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**0.037**
P_2O_5 Rate (P)	**< 0.001**	0.542	0.185	0.325	0.915	0.645	0.224	0.768
N × P	**< 0.001**	0.915	**0.014**	0.609	0.811	0.681	0.183	0.253
AICC [Y]	600.7	718.4	651.1	704.8	703.6	705.4	685.8	450.3

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability
[Y] Measure of overall model fit, smaller is better

Table 23. Side-banded nitrogen and phosphorus fertilizer effects on flax seed yield at multiple locations in 2017.

	Seed Yield							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
Effect	p-values [Z]							
N Rate (N)	**< 0.001**	0.316	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	0.636
P_2O_5 Rate (P)	0.905	0.482	**0.025**	0.968	**0.001**	0.180	0.147	0.062
N × P	0.624	0.849	0.353	0.705	0.917	0.984	0.405	0.588
AICC [Y]	590.1	630.0	689.6	593.5	713.0	703.6	689.1	705.5

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability
[Y] Measure of overall model fit, smaller is better

Table 24. Least squares means for main effects of N and P fertilizer rates on flax seed yield at multiple locations in 2016. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, *P* ≤ 0.05).

Main effect	**Seed Yield**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N Rate	kg/ha							
13 kg/ha	1933 d	923 a	3129 c	586 c	1170 c	1678 d	1716 a	1530 c
50 kg/ha	2790 c	926 a	3361 b	923 b	1580 b	2166 c	2097 ab	1568 bc
100 kg/ha	3069 b	986 a	3528 a	1262 a	1979 a	2436 b	2275 b	1748 a
150 kg/ha	3162 a	962 a	3424 ab	1099 ab	1905 a	2732 a	2332 c	1701 ab
S.E.M.	50.5	92.8	72..8	84.1	74.7	90.3	101.0	58.4
L.S.D.	63.2	226.2	106.7	195.0	196.0	194.6	180.8	168.6
P_2O_5 Rate								
0 kg/ha	2685 c	900 a	3321 a	862 a	1620 a	2181 a	2076 a	1682 a
20 kg/ha	2702 bc	889 a	3326 a	1036 a	1681 a	2265 a	2094 a	1631 a
40 kg/ha	2752 b	1033 a	3370 a	994 a	1680 a	2265 a	2034 a	1640 a
60 kg/ha	2816 a	976 a	3425 a	979 a	1653 a	2301 a	2216 a	1594 a
S.E.M.	50.5	92.8	72.8	84.1	74.7	90.3	101.0	58.4
L.S.D.	63.2	226.2	106.7	195.0	196.0	194.6	180.8	168.6
Contrast	p-values [Y]							
NR – linear	**< 0.001**	0.621	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**0.013**
NR – quadratic	**< 0.001**	0.818	**< 0.001**	**< 0.001**	**< 0.001**	**0.054**	**0.006**	0.309
PR – linear	**< 0.001**	0.302	**0.038**	0.321	0.756	0.348	0.212	0.338
PR – quadratic	0.298	0.774	0.511	0.173	0.528	0.385	0.206	0.974

Table 25. Least squares means for main effects of N and P fertilizer rates on flax seed yield at multiple locations in 2017. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, $P \leq 0.05$).

Main effect	**Seed Yield**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N Rate	---------- kg/ha ----------							
13 kg/ha	1279 c	2411 a	2346 c	246 c	1796 c	1834 b	1221 b	1572 a
50 kg/ha	1685 b	2578 a	3036 b	331 b	2346 b	2233 a	1762 a	1553 a
100 kg/ha	1734 ab	2604 a	3479 a	370 ab	2658 a	2376 a	1841 a	1640 a
150 kg/ha	1748 a	2603 a	3466 a	397 a	2718 a	2243 a	1792 a	1665 a
S.E.M.	50.7	101.5	100.1	29.4	106.1	103.4	85.3	75.2
L.S.D.	55.3	238.0	160.6	60.3	208.6	187.7	193.8	200.6
P_2O_5 Rate								
0 kg/ha	1617 a	2438 a	2931 b	342 a	2153 c	2044	1544 a	1768 a
20 kg/ha	1616 a	2617 a	3092 a	340 a	2311 bc	2199	1663 a	1531 a
40 kg/ha	1615 a	2552 a	3146 a	331 a	2565 a	2209	1642 a	1609 a
60 kg/ha	1599 a	2589 a	3158 a	330 a	2490 ab	2234	1768 a	1521 a
S.E.M.	50.7	101.6	100.1	29.4	106.1	103.4	85.3	75.2
L.S.D.	55.3	238.4	160.6	60.3	208.6	187.7	193.8	200.6
Contrast	---------- p-values [Y] ----------							
NR – linear	**< 0.001**	0.138	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	0.240
NR – quadratic	**< 0.001**	0.239	**< 0.001**	0.109	**< 0.001**	**< 0.001**	**< 0.001**	0.857
PR – linear	0.533	0.314	**0.006**	0.983	< **0.001**	0.056	**0.036**	**0.041**
PR – quadratic	0.714	0.399	0.191	0.619	0.120	0.329	0.958	0.299

Table 26. Least squares means for N by P fertilizer rate interactions on flax seed yield at multiple locations in 2016. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, $P \leq 0.05$).

Main effect	**Seed Yield**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N × P Rate	kg/ha							
13N – 0P	2023 e	807 a	3004 de	482 d	1191 ef	1649 g	1829 d	1481 bcd
13N – 20P	1855 f	897 a	3070 bc	639 cd	1084 f	1852 fg	1789 de	1354 d
13N – 40P	1960 ef	885 a	3346 b	700 cd	1110 f	1643 g	1416 e	1753 ab
13N – 60P	1895 f	1105 a	3098 cd	525 d	1296 def	1566 g	1831 d	1532 a-d
50N – 0P	2659 d	855 a	3395 bc	694 cd	1529 cde	2114 ef	1924 cd	1704 abc
50N – 20P	2714 d	915 a	3452 b	1205 ab	1673 a-d	2071 ef	2180 bcd	1696 abc
50N – 40P	2697 d	1047 a	3224 cd	827 bcd	1586 bcd	2285 cde	2119 bcd	1478 bcd
50N – 60P	3090 bc	885 a	3374 bc	966 abc	1531 cde	2193 def	2163 bcd	1392 cd
100N – 0P	2974 c	940 a	3501 b	1246 a	1887 abc	2287 cde	2258 abc	1842 a
100N – 20P	3114 b	809 a	3409 bc	1150 ab	2029 a	2331 b-e	2273 abc	1712 abc
100N – 40P	3109 b	1154 a	3475 b	1319 a	1961 ab	2512 a-d	2316 ab	1662 a-d
100N – 60P	3080 bc	1039 a	3726 a	1333 a	2037 a	2614 abc	2252 bc	1776 ab
150N – 0P	3084 bc	998 a	3384 bc	1026 abc	1875 abc	2673 abc	2294 ab	1698 abc
150N – 20P	3126 ab	934 a	3372 bc	1152 ab	1935 ab	2804 a	2132 bcd	1763 ab
150N – 40P	3242 a	1043 a	3437 bc	1128 ab	2062 a	2763 a	2286 ab	1667 a-d
150N – 60P	3197 ab	874 a	3503 b	1091 ab	1746 abc	2687 ab	2618 a	1675 a-d
S.E.M.	63.2	165.9	97.5	145.4	140.7	148.8	150.1	116.8
L.S.D.	124.6	452.3	213.4	389.9	392.1	389.1	361.7	337.2

Table 27. Least squares means for N by P fertilizer rate interactions on flax seed yield at multiple locations in 2017. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, $P \leq 0.05$).

Main effect	**Seed Yield**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N × P Rate	----------	----------	----------	---------- kg/ha	----------	----------	----------	----------
13N – 0P	1332 c	2283 a	2129 g	224 ef	1675 g	1653 f	1197 d	1720 a
13N – 20P	1279 c	2641 a	2303 fg	221 f	1718 fg	1963 c-f	1216 d	1478 a
13N – 40P	1233 c	2359 a	2493 f	254 def	2001 efg	1816 ef	1209 d	1704 a
13N – 60P	1272 c	2362 a	2458 f	284 c-f	1791 fg	1905 def	1263 d	1386 a
50N – 0P	1686 ab	2519 a	3073 de	344 a-e	2104 def	2153 a-e	1765 abc	1679 a
50N – 20P	1722 ab	2641 a	3091 de	358 a-d	2304 cde	2240 a-d	1895 ab	1487 a
50N – 40P	1701 ab	2462 a	2911 e	320 a-f	2516 a-d	2267 a-d	1549 bcd	1663 a
50N – 60P	1630 b	2691 a	3068 de	301 b-f	2461 bcd	2270 a-d	1841 abc	1384 a
100N – 0P	1723 ab	2355 a	3206 cde	353 a-d	2293 cde	2322 abc	1747 abc	1815 a
100N – 20P	1722 ab	2646 a	3468 abc	369 a-d	2683 abc	2330 abc	1792 abc	1523 a
100N – 40P	1748 a	2750 a	3590 ab	355 a-d	2876 ab	2440 a	1867 ab	1439 a
100N – 60P	1744 a	2666 a	3654 a	405 abc	2781 ab	2411 ab	1959 a	1782 a
150N – 0P	1727 ab	2596 a	3316 bcd	399 abc	2539 abc	2048 b-e	1465 cd	1857 a
150N – 20P	1738 ab	2540 a	3506 abc	421 ab	2538 abc	2264 a-d	1751 abc	1638 a
150N – 40P	1776 a	2639 a	3592 ab	432 a	2865 ab	2312 abc	1942 a	1631 a
150N – 60P	1750 a	2636 a	3451 abc	336 a-f	2928 a	2349 ab	2011 a	1532 a
S.E.M.	60.8	176.2	139.8	47.0	165.3	154.0	145.4	143.3
L.S.D.	110.6	476.3	321.3	120.6	417.1	375.5	387.4	401.3

Table 28. Orthogonal contrast results for N by P fertilizer rate interactions on flax seed yield at multiple locations in 2016. Values greater than 0.05 are not considered significant.

Main effect	**Seed Yield**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
Contrast	----------	----------	----------	---------- p-values [Y]	----------	----------	----------	----------
N (0P) – lin	**< 0.001**	0.358	**0.001**	**0.001**	**< 0.001**	**< 0.001**	**0.004**	0.166
N (0P) – quad	**< 0.001**	0.974	**0.001**	0.055	0.125	0.609	0.609	0.101
N (20P) – lin	**< 0.001**	0.989	**0.023**	**0.029**	**< 0.001**	**< 0.001**	0.092	**0.030**
N (20P) – quad	**< 0.001**	0.701	**0.008**	**0.044**	0.008	0.523	**0.042**	0.201
N (40P) – lin	**< 0.001**	0.445	0.105	**0.006**	**< 0.001**	**< 0.001**	**< 0.001**	0.978
N (40P) – quad	**< 0.001**	0.358	0.807	0.137	0.097	0.098	**0.003**	0.295
N (60P) – lin	**< 0.001**	0.477	**< 0.001**	**0.002**	**0.005**	**< 0.001**	**< 0.001**	0.116
N (60P) – quad	**< 0.001**	0.912	**< 0.001**	**0.008**	**0.029**	**0.020**	0.979	0.894
P (13N) – lin	0.163	0.221	0.102	0.758	0.580	0.458	0.526	0.298
P (13N) – quad	0.245	0.686	**0.042**	0.232	0.293	0.310	0.092	0.694
P (50N) – lin	**< 0.001**	0.755	0.389	0.479	0.895	0.464	0.254	**0.035**
P (50N) – quad	**< 0.001**	0.488	0.539	0.180	0.470	0.856	0.406	0.739
P (100N) – lin	0.116	0.371	**0.032**	0.484	0.536	0.064	0.965	0.637
P (100N) – quad	0.060	0.964	**0.027**	0.691	0.810	0.835	0.759	0.304
P (150N) – lin	**0.025**	0.713	0.213	0.781	0.675	0.995	0.054	0.754
P (150N) – quad	0.326	0.742	0.606	0.556	0.179	0.454	0.058	0.809

Table 29. Orthogonal contrast results for N by P fertilizer rate interactions on flax seed yield at multiple locations in 2017. Values greater than 0.05 are not considered significant.

Main effect	Seed Yield							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
Contrast	p-values [Y]							
N (0P) – lin	< **0.001**	0.358	< **0.001**	**0.009**	< **0.001**	**0.040**	0.282	0.374
N (0P) – quad	0.389	0.948	< **0.001**	0.349	0.413	**0.004**	**0.003**	0.844
N (20P) – lin	< **0.001**	0.681	< **0.001**	**0.003**	< **0.001**	0.117	**0.040**	0.406
N (20P) – quad	0.351	0.757	< **0.001**	0.282	**0.008**	0.173	**0.014**	0.743
N (40P) – lin	< **0.001**	0.151	< **0.001**	**0.005**	< **0.001**	**0.010**	< **0.001**	0.504
N (40P) – quad	0.155	0.411	**0.016**	0.992	**0.043**	**0.023**	0.213	0.338
N (60P) – lin	< **0.001**	0.309	< **0.001**	0.186	< **0.001**	**0.021**	**0.001**	0.195
N (60P) – quad	0.788	0.271	< **0.001**	0.228	**0.043**	0.087	**0.041**	0.263
P (13N) – lin	0.653	0.954	**0.024**	0.266	0.341	0.309	0.752	0.223
P (13N) – quad	1.000	0.303	0.359	0.700	0.392	0.407	0.895	0.790
P (50N) – lin	0.264	0.677	0.698	0.376	0.057	0.525	0.844	0.266
P (50N) – quad	0.317	0.752	0.540	0.700	0.389	0.753	0.548	0.758
P (100N) – lin	0.910	0.148	**0.006**	0.457	**0.015**	0.526	0.245	0.771
P (100N) – quad	0.213	0.240	0.387	0.700	0.105	0.888	0.863	0.029
P (150N) – lin	0.822	0.776	0.336	0.353	**0.027**	0.114	**0.004**	0.125
P (150N) – quad	0.015	0.876	0.149	0.172	0.828	0.502	0.444	0.673

Table 30. Side-banded nitrogen and phosphorus fertilizer effects on flax test weight at multiple locations in 2016.

	Test Weight							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville [X]**
Effect	p-values [Z]							
N Rate (N)	**< 0.001**	0.482	**0.006**	**0.017**	**< 0.001**	0.753	0.093	**0.010**
P_2O_5 Rate (P)	**0.028**	0.371	0.162	0.402	0.893	0.348	0.723	0.990
N × P	0.163	0.693	0.158	0.523	0.094	0.760	0.460	0.084
AICC [Y]	258.1	363.3	218.7	333.4	400.1	226.4	225.8	303.8

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability; [Y] Measure of overall model fit, smaller is better
[X] Test weight completed on uncleaned samples using combine weighing system – will not be utilized in combined analyses

Table 31. Side-banded nitrogen and phosphorus fertilizer effects on flax test weight at multiple locations in 2017.

	Test Weight							
	Indian Head	**Melfort**	**Scott**	**S. Current [X]**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
Effect	p-values [Z]							
N Rate (N)	**< 0.001**	**0.049**	**< 0.001**	–	**0.013**	**< 0.001**	**< 0.001**	0.057
P_2O_5 Rate (P)	0.938	0.093	0.923	–	0.778	0.134	0.377	0.185
N × P	0.472	0.992	0.787	–	0.132	0.664	0.521	0.192
AICC [Y]	311.0	199.4	214.5	–	284.0	264.3	261.5	214.7

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability; [Y] Measure of overall model fit, smaller is better
[X] Samples too small to measure test weight

Table 32. Least squares means for main effects of N and P fertilizer rates on flax test weight at multiple locations in 2016. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, $P \leq 0.05$).

Main effect	**Test Weight**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N Rate	-- g 0.5/l --							
13 kg/ha	327.4 c	233.1 a	347.5 b	332.4 a	263.2 b	343.7 a	341.3 a	278.2 a
50 kg/ha	328.3 c	232.2 a	347.5 b	331.6 ab	263.1 b	344.0 a	340.9 a	259.5 b
100 kg/ha	330.0 b	228.7 a	349.4 a	328.1 bc	278.4 a	344.2 a	342.2 a	251.2 b
150 kg/ha	331.9 a	232.1 a	348.6 ab	326.3 c	280.8 a	343.6 a	342.4 a	251.9 b
S.E.M.	2.01	2.08	0.58	1.56	3.87	0.54	0.53	5.91
L.S.D.	1.71	5.93	1.22	4.16	9.06	1.35	1.34	17.1
P_2O_5 Rate								
0 kg/ha	328.6 b	231.4 a	348.8 a	331.7 a	269.8 a	343.8 a	342.0 a	261.3 a
20 kg/ha	328.7 b	230.6 a	348.6 a	328.8 a	271.9 a	343.4 a	341.6 a	258.6 a
40 kg/ha	329.2 b	234.5 a	347.9 a	329.3 a	271.0 a	344.6 a	341.3 a	260.7 a
60 kg/ha	331.0 a	229.5 a	347.6 a	328.5 a	272.8 a	343.7 a	341.9 a	260.2 a
S.E.M.	2.01	2.08	0.58	1.56	3.87	0.54	0.54	5.91
L.S.D.	1.71	5.93	1.22	4.16	9.06	1.35	1.37	17.1
Contrast	--- p-values [Y] ---							
NR – linear	**< 0.001**	0.523	**0.008**	**0.002**	**< 0.001**	0.946	**0.028**	**0.003**
NR – quadratic	0.640	0.255	0.227	0.954	0.884	0.303	0.717	0.078
PR – linear	**0.007**	0.840	**0.028**	0.170	0.524	0.699	0.818	0.956
PR – quadratic	0.167	0.319	0.873	0.469	0.965	0.704	0.307	0.853

[Z] Test weight completed on uncleaned samples using combine weighing system – will not be utilized in combined analyses

Table 33. Least squares means for main effects of N and P fertilizer rates on flax test weight at multiple locations in 2017. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, $P \leq 0.05$).

Main effect	**Test Weight**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N Rate	---------- g 0.5/l ----------							
13 kg/ha	304.8 b	350.7 b	347.3 b	–	351.4 b	337.3 b	322.2 c	341.7 a
50 kg/ha	311.9 a	351.4 ab	346.6 b	–	352.9 b	340.4 a	323.7 bc	342.0 a
100 kg/ha	314.4 a	351.8 a	348.8 a	–	353.6 ab	341.1 a	325.0 ab	342.9 a
150 kg/ha	313.5 a	351.9 a	348.5 a	–	355.4 a	342.3 a	326.6 a	343.3 a
S.E.M.	1.33	0.95	0.55	–	1.39	0.74	1.02	0.44
L.S.D.	3.25	0.94	1.17	–	2.36	2.10	1.88	1.25
P_2O_5 Rate								
0 kg/ha	310.6 a	352.0 a	348.0 a	–	353.2 a	339.3 a	324.4 a	342.9 a
20 kg/ha	311.3 a	351.7 a	347.7 a	–	352.8 a	340.1 a	323.7 a	341.7 a
40 kg/ha	311.6 a	351.1 a	347.7 a	–	353.5 a	339.9 a	324.2 a	342.8 a
60 kg/ha	311.2 a	351.0 a	347.8 a	–	353.9 a	341.7 a	325.3 a	342.4 a
S.E.M.	1.33	0.95	0.55	–	1.39	0.74	1.02	0.44
L.S.D.	3.25	0.94	1.17	–	2.36	2.10	1.88	1.25
Contrast	---------- p-values [Y] ----------							
NR – linear	**< 0.001**	**0.009**	**0.001**	–	**0.001**	**< 0.001**	**< 0.001**	**0.007**
NR – quadratic	**< 0.001**	0.299	0.995	–	0.934	0.136	0.830	0.984
PR – linear	0.666	**0.014**	0.697	–	0.422	**0.037**	0.281	0.818
PR – quadratic	0.641	0.873	0.592	–	0.600	0.534	0.169	0.364

[Z] Test weight completed on uncleaned samples using combine weighing system – will not be utilized in combined analyses

Table 34. Least squares means for N by P fertilizer rate interactions on flax test weight at multiple locations in 2016. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, $P \leq 0.05$).

Main effect	**Test Weight**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N × P Rate	---------- g 0.5/l ----------							
13N – 0P	327.9 d-h	233.8 a	348.0 a-e	332.1 abc	251.8 d	344.5 a	342.0 a	281.4 a
13N – 20P	326.8 gh	233.7 a	348.3 a-d	332.8 abc	262.8 cd	343.0 a	341.5 a	275.4 ab
13N – 40P	327.7 e-h	230.8 a	347.4 b-e	335.5 a	273.3 abc	344.3 a	339.6 a	273.5 ab
13N – 60P	327.2 fgh	233.9 a	346.4 cde	329.1 abcd	265.0 bcd	342.9 a	342.2 a	282.3 a
50N – 0P	325.9 h	234.7 a	349.1 ab	335.0 ab	269.3 abc	344.1 a	340.5 a	235.7 c
50N – 20P	327.5 e-h	228.2 a	349.0 ab	327.9 a-d	261.0 cd	343.2 a	341.0 a	271.6 ab
50N – 40P	328.6 c-h	233.5 a	345.9 de	330.0 a-d	252.3 d	345.5 a	340.1 a	250.1 abc
50N – 60P	331.2 a-d	232.4 a	345.8 e	333.4 ab	270.0 abc	343.2 a	342.2 a	280.5 a
100N – 0P	327.7 e-h	226.1 a	349.6 ab	329.2 a-d	275.0 abc	344.0 a	342.9 a	265.2 abc
100N – 20P	330.6 a-f	228.3 a	348.4 abc	327.1 bcd	283.8 a	344.1 a	341.9 a	233.5 c
100N – 40P	329.8 b-g	236.3 a	350.2 ab	329.4 a-d	274.8 abc	343.9 a	342.2 a	262.1 abc
100N – 60P	331.9 abc	224.3 a	349.4 ab	326.8 bcd	280.3 ab	345.0 a	341.7 a	243.9 bc
150N – 0P	333.0 ab	231.2 a	348.6 abc	330.7 abc	283.3 a	342.8 a	342.6 a	263.0 abc
150N – 20P	330.0 b-g	232.3 a	348.9 ab	327.5 a-d	280.0 ab	343.2 a	342.2 a	253.9 abc
150N – 40P	330.7 a-e	237.5 a	348.3 abcd	322.4 d	283.8 a	344.5 a	343.4 a	256.9 abc
150N – 60P	333.7 a	227.4	348.9 ab	324.9 cd	276.0 abc	343.9 a	341.6 a	233.8 c
S.E.M.	2.26	4.17	0.94	2.97	6.25	0.98	0.97	11.82
L.S.D.	3.42	11.9	2.44	8.31	16.11	2.70	2.69	34.6

Table 35. Least squares means for N by P fertilizer rate interactions on flax test weight at multiple locations in 2017. Means within a column followed by the same letter do not significantly differ (Fisher's Protected LSD test, *P* ≤ 0.05).

Main effect	**Test Weight**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
N × P Rate	----------	----------	----------	---------- g 0.5/l	----------	----------	----------	----------
13N – 0P	305.8 def	351.4 a-d	347.0 bcd	–	351.0 de	336.5 de	323.0 cde	342.3 a
13N – 20P	307.1 c-f	351.1 a-d	347.1 bcd	–	351.8 cde	336.0 e	322.2 de	340.9 a
13N – 40P	302.3 f	350.4 cd	348.0 a-d	–	351.5 cde	337.7 cde	320.5 e	342.9 a
13N – 60P	304.0 ef	350.0 d	347.1 a-d	–	351.5 cde	338.9 cde	323.2 cde	340.9 a
50N – 0P	311.2 a-d	351.8 a-d	347.5 a-d	–	350.3 e	340.3 a-d	323.4 b-e	342.7 a
50N – 20P	308.9 b-e	351.8 a-d	346.6 cd	–	352.5 b-e	340.0 b-e	323.9 a-e	340.0 a
50N – 40P	313.3 abc	350.8 bcd	345.8 d	–	355.3 a-d	340.9 abc	323.1 cde	341.9 a
50N – 60P	314.2 ab	351.2 a-d	346.5 cd	–	353.8 a-e	340.4 a-d	324.4 a-d	343.4 a
100N – 0P	313.4 abc	352.7 a	349.1 ab	–	356.5 ab	338.5 cde	323.8 a-e	343.0 a
100N – 20P	313.9 ab	352.0 abc	348.3 abc	–	353.3 a-e	341.3 abc	322.8 cde	342.8 a
100N – 40P	314.9 ab	351.8 a-d	349.4 a	–	350.0 e	340.3 a-d	327.0 ab	342.2 a
100N – 60P	315.4 a	350.9 a-d	348.5 abc	–	354.5 a-e	344.3 a	326.5 abc	343.5 a
150N – 0P	311.9 a-d	352.3 ab	348.6 abc	–	355.0 a-d	341.8 abc	327.4 a	343.9 a
150N – 20P	315.3 ab	352.0 abc	348.8 abc	–	353.5 a-e	343.3 ab	325.9 a-d	343.1 a
150N – 40P	315.7 a	351.7 a-d	347.7 a-d	–	357.3 a	340.9 abc	326.1 abc	344.4 a
150N – 60P	311.3 a-d	351.7 a-d	349.1 ab	–	356.0 abc	343.2 ab	327.2 ab	341.8 a
S.E.M.	2.38	1.11	0.90	–	2.00	1.48	1.53	0.88
L.S.D.	6.49	1.88	2.34	–	4.72	4.20	3.76	2.51

Table 36. Orthogonal contrast results for N by P fertilizer rate interactions on flax seed yield at multiple locations in 2016. Values greater than 0.05 are not considered significant.

Main effect	**Test Weight**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
Contrast	p-values [Y]							
N (0P) – lin	**0.002**	0.382	0.627	0.429	**< 0.001**	0.213	0.292	0.756
N (0P) – quad	**0.007**	0.493	0.208	0.951	0.329	0.707	0.736	0.112
N (20P) – lin	**0.023**	0.879	0.798	0.230	**0.005**	0.753	0.445	0.065
N (20P) – quad	0.452	0.263	0.904	0.346	0.572	0.501	0.787	0.195
N (40P) – lin	0.065	0.229	0.068	**0.004**	**0.023**	0.791	0.002	0.529
N (40P) – quad	0.910	0.798	0.502	0.858	**0.029**	0.890	0.914	0.489
N (60P) – lin	**< 0.001**	0.148	**0.006**	0.120	0.101	0.287	0.604	**0.002**
N (60P) – quad	0.308	0.465	0.711	0.412	0.324	0.381	0.991	0.987
P (13N) – lin	0.793	0.889	0.140	0.643	**0.053**	0.417	0.791	0.988
P (13N) – quad	0.821	0.705	0.469	0.230	0.096	0.969	0.105	0.536
P (50N) – lin	**0.003**	0.938	**0.002**	0.843	0.798	0.897	0.348	**0.041**
P (50N) – quad	0.683	0.516	1.000	0.080	**0.026**	0.481	0.387	0.820
P (100N) – lin	**0.035**	0.889	0.775	0.701	0.791	0.524	0.445	0.511
P (100N) – quad	0.741	0.095	0.816	0.925	0.775	0.647	0.792	0.573
P (150N) – lin	0.603	0.744	0.948	0.089	0.480	0.284	0.711	0.120
P (150N) – quad	**0.016**	0.187	0.862	0.332	0.693	0.583	0.470	0.558

Table 37. Orthogonal contrast results for N by P fertilizer rate interactions on flax seed yield at multiple locations in 2017. Values greater than 0.05 are not considered significant.

Main effect	**Test Weight**							
	Indian Head	**Melfort**	**Scott**	**S. Current**	**Redvers**	**Yorkton**	**Brandon**	**Vegreville**
Contrast	---	---	---	p-values [Y]	---	---	---	---
N (0P) – lin	0.061	0.234	0.081	–	**0.016**	**0.042**	**0.023**	0.194
N (0P) – quad	0.112	0.472	0.430	–	0.560	0.891	0.283	0.822
N (20P) – lin	**0.006**	0.342	0.060	–	0.428	**0.001**	0.099	**0.018**
N (20P) – quad	0.726	0.570	0.713	–	0.838	0.389	0.575	0.719
N (40P) – lin	< **0.001**	0.105	0.400	–	0.116	0.214	**0.001**	0.211
N (40P) – quad	**0.022**	0.620	0.917	–	0.212	0.387	0.101	0.089
N (60P) – lin	**0.045**	0.113	**0.030**	–	0.064	**0.015**	**0.021**	0.572
N (60P) – quad	**0.002**	0.761	0.607	–	0.761	0.253	0.685	**0.022**
P (13N) – lin	0.321	0.107	0.715	–	0.867	0.182	0.837	0.609
P (13N) – quad	0.944	0.940	0.566	–	0.822	0.567	0.195	0.703
P (50N) – lin	0.195	0.360	0.310	–	0.080	0.859	0.708	0.303
P (50N) – quad	0.490	0.777	0.343	–	0.264	0.953	0.756	**0.021**
P (100N) – lin	0.483	0.069	0.834	–	0.218	0.017	**0.043**	0.805
P (100N) – quad	0.997	0.910	0.940	–	**0.024**	0.674	0.843	0.422
P (150N) – lin	0.884	0.501	0.930	–	0.367	0.778	0.946	0.222
P (150N) – quad	0.096	0.821	0.442	–	0.940	0.755	0.339	0.332