2022 Final Report

from the

East Central Research Foundation

Project Title: Flax Yield Response to Added Phosphorus Depends on Stubble Type and Cultivation

ADOPT # 20200492

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Project Identification

1. **Project Number:** 20200492
2. **Producer Group Sponsoring the Project:**
3. **Project Location(s):** Yorkton, SK
4. **Project start and end dates (month & year):** April 2021 to February 2023
5. **Project contact person & contact details:**

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Objectives and Rationale

6. **Project objectives:**
The first objective is to demonstrate practices that reduce mycorrhizal root associations in flax and in turn reduce phosphorus uptake and yield. Practices that disturb mycorrhizal populations include fall tillage or growing canola, a non-mycorrhizal crop, the year prior to seeding flax. Any additive detrimental effects of previous crop and tillage will also be determined.

The second objective is to demonstrate that these detrimental effects on mycorrhizal populations and flax yield may not be corrected in-crop with increasing rates of side-banded phosphorus as the crop relies heavily on mycorrhizal exploration of the soil for P.

7. **Project Rationale:**
Flax relies heavily on myccorhizal associations to explore the entire soil volume around it for phosphorus. This may be part of the reason flax is relatively unresponsive to in-season applications of P. Anything that disturbs myccorhizal populations such as tillage or growing a preceding non-myccorhizal crop, are likely to cause a P deficiency for flax, which may not be compensated for by higher rates of in-season P. All producers should be aware of this before including flax in their operations.

8. **Methodology:**

The trial will be established as a split-split plot with 4 replications. In the spring of 2021, canola and wheat were seeded into the main plots to establish the two stubble types in which flax was seeded into in 2022 (Figure 1). Wheat was fertilized with 30 lb P_2O_5/ac and 85 lb N/ac. Canola was fertilized with 30 lb P_2O_5/ac, 15 lb S/ac and 90 lb N/ac. Rates of applied N were relatively low as residual soil N was high due to the 2020 drought. After harvest, cultivation was applied to the split-plots to establish the comparison between tilled soil and standing stubble. The split-split factor comparing different rates of side-banded P was applied at the time of seeding flax in the spring of 2022. Rates compared were 0, 25 and 50 lb P_2O_5/ac. A list of completed treatment combinations are found in Table 1. Each individual plot was 11 by 30 ft and seeded with a 10 ft Seedmaster drill on 12 inch row spacing. All treatments received only 40 lb N/ac as residual levels of soil N were quite high due to 2 years of consecutive drought. In 2021, the canola and wheat only yielded 20 and 30 bu/ac, respectively. In 2022, Flax yield was taken from the middle 4 rows of each plot using a Wintersteiger plot combine in order to avoid edge effects. A list of completed operations are found in Table 2.

Figure 1. Wheat and Canola Main Plots established in 2021 under drought conditions.

Table 1. Treatment List for "Flax Yield Response to Added Phosphorus Depends on Stubble Type and Cultivation" trial			
Trt #	**Stubble Type (preceding crop to flax)**	**Fall Cultivation 2021**	**Lb P_2O_5/ac side-banded in Flax (2022)**
1	wheat	Yes	0
2	wheat	Yes	25
3	wheat	Yes	50
4	wheat	No, standing stubble	0
5	wheat	No, standing stubble	25
6	wheat	No, standing stubble	50
7	canola	Yes	0
8	canola	Yes	25
9	canola	Yes	50
10	canola	No, standing stubble	0
11	canola	No, standing stubble	25
12	canola	No, standing stubble	50

Table 2. Dates of operations for the "Flax Yield Response to Added Phosphorus Depends on Stubble Type and Cultivation" trial.

2021	
Pre-seed Herbicide Application	None
Seeding Date	May 17 (Wheat) May 18 (Canola)
Emergence Counts	June 11 (Wheat) June 8 (Canola
In-crop Herbicide	June 8 (Prestige on wheat) June 22 (Axial on wheat) June 17 (Roundup Transorb on canola)
In-crop Fungicide	None
Harvest	Aug 26 (canola) Aug 30 (wheat)
Cultivated trt # 1-3 and 7-9	Sept 17
2022	
Seeding Date	May 24
Emergence Counts	June 3
Crop Vigour	June 3
In-crop Herbicide	Curtail M (June 13) Centurion (June 20)
In-crop Fungicide	Dyax-July 15
Maturity	Ratings on Sept 2
Desiccant	Reglone- September 19
Harvest	September 28

9. Results:

Growing Season Weather

Mean monthly temperatures and precipitation amounts for Yorkton in 2021 and 2022 are listed in Table 3. Monthly temperatures were above the long-term average in 2021. Precipitation was well below the long-term average and soil moisture reserves were depleted in 2021. Growing conditions were much better in 2022. Rainfall in May was well above the long-term average which helped to replenish soil reserves. It was cooler in 2022 compared to 2021but season was still warmer than historical average.

Table 3. Mean monthly temperatures and precipitation amounts for 2021 and 2022 along with long-term normals (1981-2010) for Yorkton in Saskatchewan.

Location	Year	May	June	July	August	Avg. / Total
		-------------------------*Mean Temperature (°C)*				------------------
Yorkton	2021	8.9	19.1	21.0	17.3	16.5
	2022	10.6	15.7	18.6	18.9	15.95
	Long-term	***10.4***	***15.5***	***17.9***	***17.1***	***15.2***
		---------------------------- *Precipitation (mm)*				-------------------
Yorkton	2021	24.6	18.1	35.2	69.7	147.6
	2022	137.9	57.9	38.4	90.8	325
	Long-term	***51***	***80***	***78***	***62***	***272***

The canola and wheat established well in 2021 (Figure 1), averaging 103 and 160.5 plants/m^2, respectively. Yield data from the canola and wheat was not taken directly but yields would have been low due to drought. Yields from neighboring canola trials were 20 bu/ac and wheat may have averaged 30 bu/ac. Background levels of soil N were high in 2022 due to 2 years of back-to-back drought and low yields. In the spring of 2022, a soil test from the field found 104 lb N/ac in top 24 inches of soil. Thus, only 40 lb N/ac was applied to the flax.

In 2022, the flax emerged well, averaging 302 plants/m^2 across the trial. Crop emergence did not significantly differ between stubble type, cultivation system, or rate of side-banded P (Table 4). Thus the flax in all treatments had a similar start. Based on visual assessments on June 23, the flax growth was more vigorous on wheat stubble compared to canola stubble and on standing stubble compared to fall cultivation (Table 4). Rate of phosphorus did not appear to affect crop vigor. However, the most vigorous flax, receiving an average vigor rating of 7.9 out of 10 was on standing wheat stubble. The least vigorous flax, receiving an average vigor rating of 6.1 out of 10 was on cultivated canola stubble. Figure 1 shows this difference for flax which received 50 lb/ac of side-banded P_2O_5 (trt 6 vs 9).

Figure 2. The 4 replicates of flax fertilized with 50 lb P_2O_5/ac on standing wheat stubble vs cultivated canola stubble (June 23, 2022)

Standing Wheat Stubble 50 lb P_2O_5/ac

Cultivated Canola Stubble 50 lb P_2O_5/ac

While no statistically significant differences could be detected between any of the main effects on yield (Table 4), numerical yield differences still mirrored the vigor ratings. On average, flax yield was 10% higher yielding on wheat stubble and 6% higher yielding on standing stubble. Like the vigor ratings, flax yield was highest at 2456 kg/ha on standing wheat stubble compared 2100 kg/ha for flax grown on cultivated canola stubble (Table 4). Statistically, there were no main effect differences or interactions with the rates of side-banded P_2O_5 for either the vigor ratings or yield data. However, there was a numerical trend for increasing vigor and yield as P_2O_5 was increased from 0 to 50 lb/ac for flax sown on wheat stubble. When averaged over fall cultivation system, the vigor rating increased with increasing P_2O_5 from 7.6 to 8.3 and in turn yield increased from 2207 to 2421 kg/ha. If this trend is true, perhaps the flax was better able to utilize the added phosphorus when grown on wheat stubble due to better mycorrhizal root associations. The lower yield potential of flax growing on cultivated canola stubble could not be compensated for by increasing the rate of phosphorus. For example, side-banding 50 lb P_2O_5/ac produced a flax yield of 2119 kg/ha when grown on cultivated canola stubble which was lower than 2351 kg/ha for flax receiving no added P when seeded on standing wheat stubble (Table 7). In fact, flax yield on standing wheat stubble was increased further to 2540 kg/ha in response to 50 lb/ac of added P_2O_5. This trend was also observed with the vigor data. Flax grown on cultivated canola stubble with 50 lb P_2O_5/ac had a vigor rating of only 6.3 whereas flax grown on standing wheat stubble with no applied P had a better vigor rating on 7.8 (Table 7). All the data discussed so far supports the concept that flax grows better on standing wheat stubble compared to cultivated canola stubble due to better mycorrhizal root associations aiding the uptake of phosphorus. While this is likely true, the maturity data suggests there were other factors associated with the wheat stubble that improved yield.

In contrast to N, a P deficiency will delay maturity. So any factor that decreases mycorrhizal uptake of P such as tillage or seeding on the stubble of a non-mycorrhizal crop like canola should delay maturity. While not statistically significant, cultivation did delay flax maturity as indicated by percent "brown boll" ratings on September 2 (Table 4). The greater the percent of brown bolls the more mature the crop. However, the percent "brown bolls" were significantly higher for flax grown on canola stubble compared to wheat stubble. Delayed maturity of flax on wheat stubble is the opposite expectation. This result suggests there is something more than improved P uptake that was increasing flax yield on wheat stubble. Perhaps the better yield of flax grown on wheat stubble was due to other factors that would also delay maturity such as higher residual N, more soil moisture or less disease. The differences in stubble type and tillage practice can bring in a number of confounding factors which can not be controlled.

There were also two significant interactions with the maturity data. One was between stubble type and P rate and the other was between cultivation system and P rate (Table 4). When averaged across cultivation system, increasing rate of P significantly hastened maturity (increased % brown bolls) for flax sown on wheat stubble but not canola stubble (Table 5). Added Phosphorus should hasten maturity. Perhaps it was only evident for flax on wheat stubble because it was more immature than the flax on the canola stubble. It is also possible that the better mycorrhizal root associations with the wheat stubble facilitated better up-take of the applied P. Added phosphorus was also found to hasten maturity but only with the high rate on standing stubble (Table 6). Again, this may suggest better use of applied phosphorus due to better mycorrhizal root associations when stubble is left standing.

10. Conclusions and Recommendations

Since flax is highly depended on mycorrhizal root association for P uptake, it was anticipated that flax would perform more poorly when seeded on the stubble of a non-mycorrhizal crop like canola compared to wheat and when seeded on land where mycorrhizal populations have been disturbed by cultivation. This was the case in this demonstration. Vigor and yield of flax were lower when grown on canola stubble and lower still if the land was fall tilled. At the extremes, flax grown on tilled canola stubble had a vigor rating of 6.1 and a yield of 2100 kg/ha, whereas flax sown on standing wheat stubble had a higher vigor rating of 7.9 and a higher yield of 2456 kg/ha (a 17% increase). Increasing the rate of side-banded P was expected to increase crop vigor, increase yield and hasten maturity. This was observed in this study, but only for flax seeded on wheat stubble. Perhaps better mycorrhizal root associations with wheat stubble improved the uptake of applied phosphorus. However, it is also possible that maturity differences were just more apparent on the wheat stubble because the flax grown on wheat stubble was generally more immature that flax on canola stubble. Increasing rate of side-banded phosphorus was not expected to fully compensate for phosphorus limitations resulting from seeding flax on canola stubble, particularly if the stubble was cultivated. This was also observed in this demonstration, as the high rate of phosphorus on cultivated canola stubble couldn't produce a flax crop equal in yield to flax grown on standing wheat stubble with no added P. This trend was also observed in the vigor data. This study demonstrated many of results that were anticipated except one. While flax maturity was hastened numerically when grown on standing stubble as expected, flax maturity was significantly delayed when grown on wheat stubble. This was not anticipated as P availability should have been better on wheat stubble which would hasten maturity, not delay it. This implies that there was something more than better P availability that was improving flax yield on the wheat stubble. When dealing with differences in stubble type and cultivation, other influences on crop vigor and yield can come into play, such as differences in available N, soil moisture, disease and seed bed quality to name just a few. In conclusion, the study successfully demonstrated that flax grows better on standing wheat stubble and the worst on cultivated canola stubble. However, factors in addition to better phosphorus uptake were likely involved in creating this difference.

Supporting Information

11. Acknowledgements:

This project was funded by Agricultural Demonstration of Practices and Technologies (ADOPT)

12. Appendices

Table 4. Main Treatment Effects on Emergence, Vigor, Maturity and Yield of Flax.				
Treatments	**Emergence (plants/m2)**	**Vigour (June 23) (0-10)**	**Maturity (Sept 2) (% brown boll)**	**Yield (kg/ha)**
Stubble Type (S)				
Wheat	288.1 a	7.8 a	49.2 b	2334.3 a
Canola	316.3 a	6.5 b	63.8 a	2113.5 a
P-values[z]	NS	0.036	0.029	NS
LSD	NA	1.06	11.8	NA
Cultivation System (C)				
Fall Cultivated	296.2 a	6.8 b	53.8 a	2156.0 a
Standing Stubble	308.2 a	7.5 a	59.2 a	2291.8 a
P-values[z]	NS	0.05	NS	NS
LSD	NA	0.63	NA	NA
Lb P2O5/ac side-banded in Flax (P)				
0	307.5 a	7.2 a	53.4 a	2182.3 a
25	300.5 a	6.9 a	54.7 a	2226.6 a
50	298.6 a	7.4 a	61.3 a	2262.8 a
P-values[z]	NS	NS	NS	NS
LSD	NA	NA	NA	NA
S x P	NS	NS	0.0011	NS
C x P	NS	NS	0.011	NS
S x C x P	NS	NS	NS	NS
[z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability				

Table 5. Stubble Type by Phosphorus Rate Interaction on Flax Maturity.

		Maturity (Sept 2) (% brown boll)
Stubble Type (S)	Lb P2O5/ac side-banded in Flax (P)	
Wheat	0	42.5 b
Wheat	25	41.3 b
Wheat	50	63.8 a
Canola	0	64.4 a
Canola	25	68.1 a
Canola	50	58.8 a
P-values[z]	NS	0.0005
LSD	NA	12.3

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability

Table 6. Fall Cultivation by Phosphorus Rate Interaction on Flax Maturity.

		Maturity (Sept 2) (% brown boll)
Stubble Type (S)	Lb P2O5/ac side-banded in Flax (P)	
Cultivated	0	52.5 b
Cultivated	25	57.5 b
Cultivated	50	51.25 b
Standing Stubble	0	54.4 b
Standing Stubble	25	51.9 b
Standing Stubble	50	71.3 a
P-values[z]	NS	0.008
LSD	NA	12.3

[Z] p-values ≤ 0.05 indicate that a treatment effect was significant and not due to random variability

Table 7. Individual Treatment Means for Emergence, Vigor, Maturity and Yield of Flax.

Stubble Type (S)	Cultivation System (C)	Lb P2O5/ac side-banded in Flax (P)	Emergence (plants/m2)	Vigour (June 23) (0-10)	Maturity (Sept 2) (% brown boll)	Yield (kg/ha)
Wheat	Fall Cultivated	0	290	7.3	37.5	2062
		25	238	7.3	42.5	2275
		50	309	8.3	60.0	2301
	Standing Stubble	0	282	7.8	47.5	2352
		25	306	7.8	40.0	2477
		50	304	8.3	67.5	2541
Canola	Fall Cultivated	0	327	6.5	67.5	2108
		25	328	5.5	72.5	2072
		50	287	6.3	42.5	2119
	Standing Stubble	0	331	7.3	61.3	2208
		25	331	7.0	63.8	2083
		50	296	6.8	75.0	2092
		LSD	NS	1.45	23.4	830

Abstract

13. Abstract/Summary:

In 2021, a trial was initiated to demonstrate impact of preceding crop type (canola vs wheat) and tillage system (fall cultivated vs no-till) on phosphorus (P) uptake and yield of flax. Since flax is highly dependent on mycorrhizal root associations to maximize P uptake, flax growth was anticipated to be poorer when seeded on canola (a non-mycorrhizal crop) and on cultivated stubble, as cultivation disturbs mycorrhizal populations. It was also anticipated that increasing the rate of side-banded P would not compensate for flax yield losses caused by poor mycorrhizal root associations. To test these hypotheses, the trial was designed as a split-split-plot. The main plot factor was crop type (canola vs wheat), the subplot factor was cultivation system (fall cultivated vs standing stubble) and the sub-subplot factor was increasing rate of side-banded phosphorus when seeding the flax the following year (2022). Rates of side-banded P evaluated were 0, 25 and 50 lb P_2O_5/ac. Vigor (assessed on June 23) and yield of flax was poorer on cultivated land and canola stubble. At the extremes, flax grown on tilled canola stubble had a vigor rating of 6.1 out of 10 and a yield of 2100 kg/ha, whereas flax sown on standing wheat stubble had a higher vigor rating of 7.9 out of 10 and a higher yield of 2456 kg/ha (a 17% increase). Increasing the rate of side-banded P was expected to increase crop vigor, increase yield and hasten maturity. This was observed in this study, but only for flax seeded on wheat stubble. Perhaps better mycorrhizal root associations with wheat stubble improved the uptake of applied phosphorus. Increasing rate of side-banded phosphorus was not expected to fully compensate for phosphorus limitations resulting from seeding flax on canola stubble, particularly if the stubble was cultivated. This was also observed in this demonstration, as the high rate of phosphorus on cultivated canola stubble couldn't produce a flax crop equal in yield to flax grown on standing wheat stubble with no added P. This trend was also observed in the vigor data. Unexpectedly, the maturity of flax was hastened when grown on wheat stubble. Better P uptake of flax seeded on wheat stubble should have hastened maturity and not delayed it. This suggests that something in addition to better P uptake was increasing flax yield. Higher soil N, more soil moisture or less disease associated with wheat stubble may have also increased flax yields and delayed maturity. Despite these confounding factors, the results of this study do support the hypothesis that flax grows best on standing wheat stubble and poorest on cultivated canola stubble.