2017 Annual Report

for the

SASKATCHEWAN CANOLA DEVELOPMENT COMMISSION
(SASKCANOLA)

PROJECT TITLE:
Enhancing Canola Production with Improved Phosphorus Fertilizer Management

(CARP SCDC ADF Project Number 201502 Brandt)

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Executive Summary:

Most soils in Saskatchewan are deficient in available phosphate (P_2O_5) and this macronutrient typically limits crop yield. Canola has a relatively high phosphate requirement compared with cereals. With ever increasing yield potential of newer canola hybrids, phosphate nutrition of this crop is crucial to ensure that yield potential can be optimized. Fertilizer phosphate (P) is used to augment soil available phosphate to meet crop needs. Because fertilizer phosphate is not highly mobile in the soil and because it can be readily immobilized in the soil, how it is placed can influence how readily the canola crop can utilize it for crop growth. Historically, it was recommended that fertilizer phosphate should be placed in the seed-row to optimize availability. However, the rate that can be safely placed alongside the seed is limited because high rates can result in excessive damage to seed. With high yielding canola hybrids, the safe rates for seed-row placement typically are insufficient to optimize yield. Additionally, safe rates for seed-row placement are not sufficient to offset crop removal, further depleting soil P reserves.

As well, the logistics of seeding equipment sometimes means that the most logical way to place fertilizer sulphur (S) is in the seed row along with fertilizer phosphate. The objective of this study was to evaluate the impact rate and placement (seed-placed versus side-band) of fertilizer phosphate either alone or in combination with fertilizer S has on uptake and yield of canola across a range of soil and climatic conditions in Saskatchewan. The trial was designed as

a two-factor factorial, in a randomized complete block design, with four replicates. The first factor was five fertilizer P_2O_5 rates ranging from 0, 20, 40, 60, and 80 kg/ha. The second factor was placement which compared side-band, seed-placed, and seed-placed with fertilizer S. Trials were established at Melfort, Indian Head, and Scott, Saskatchewan.

Seed-placed fertilizer P reduced plant populations with damage increasing with P rate. Adding S to seed-placed P fertilizer increased damage in an additive manner. There was some evidence of recovery later in the growing season, but it was minimal. Side-banding P did not cause any seed damage, and was effective in increasing plant biomass, P uptake, and canola yield, particularly at high P rates. There was some indication that increased safe rates of seed-placed fertilizer P could be applied above current recommendations. However, where possible it would be preferable to side-band fertilizer P to minimise seed damage and optimize fertility response. This likely is more critical now to protect investments in high priced hybrid seed while taking full advantage of their high yield potential. Where only low rates (less than 28 kg/ha) of fertilizer P are required, placement with seed may still be appropriate.

Background/Introduction:

Approximately 82% of soil samples taken in Saskatchewan tested below critical levels required for optimal crop growth in 2010 (Canadian Fertilizer Institute, 2010). Median soil test P levels for Saskatchewan were 14 ppm compared with 21 for Alberta and 19 for Manitoba. Historically, far less of the P that was removed by cropping was replaced, because fertilizer P application was very limited prior to 1947 (Statistics Canada 1976 and Saskatchewan Agriculture, 1976). Since that time, fertilizer P rates have increased, but even now they fall well short of replacing what is removed by crops. Based on rates of phosphate fertilizer and P from manure applied in Saskatchewan, farmers were only replacing 73% of the P that is removed in the crops harvested in 2010 (Canadian Fertilizer Institute, 2010).

For each metric tonne of canola produced, the crop must take up 26 to 32 kg ha^{-1} of phosphate (Canadian Fertilizer Institute, 1998). Furthermore, with each tonne of crop removed from the field, a canola crop will remove 18 to 22 kg of phosphate (Canadian Fertilizer Institute, 1998). By comparison, wheat takes up 10-15 kg/ha and removes 9-11 kg/ha of phosphate per tonne of grain produced. Historically, canola yield rarely exceeded 1.5 t/ha (about 30 bu/ac), but with the development of high yielding hybrids yields exceeding 3 t/ha are increasingly achieved (Canola Council of Canada, 2017; Canola Variety Performance Trials)

Fertilizer phosphate is regularly used to augment soil available P to meet the needs of a canola crop. Canola is very responsive to fertilizer phosphate where the soil is P deficient, but the Canola Council of Canada suggests that growers should expect responses only about 50% of the time. Canola is effective at exploring and extracting both soil and fertilizer phosphate by acidifying the rhizosphere (Grant and Bailey, 1993). It does this by developing more root hairs when the crop is phosphorus (P) deficient and by growing more roots to where fertilizer P is located (Canola Council of Canada). Canola seeds are small and contain only limited reserves of P. Therefore, the crop needs to access soil or fertilizer P early to avoid yield limiting deficiencies.

Canola is often seeded early into cool soils where soil P is less readily available; due to extremely low mobility and slow mineralization. For these reasons, fertilizer P needs to be placed near the seed to ensure crop access shortly after it emerges. Several studies indicate that seed row placement of fertilizer P is the most efficient way to meet this requirement. When rates of phosphate exceed 28 kg/ha, excessive seed damage can occur. This damage can negate the benefit from added phosphate. Where soils are low or very low in available P, the recommended rate of fertilizer phosphate exceeds the 28 kg/ha seed safe rate.

Several studies have indicated that side-banded fertilizer P was slightly less efficient than seed-placed at low rates of phosphate (Lemke et al, 2009), but more efficient in enhancing yield at rates that exceeded the safe seed placed rate (Slinkard and Henry, 1977; Ukrainetz, 1976). These studies found that as the rate of seed-placed phosphorus was increased, there was a sharp decline in canola plant densities. They found a 40 to 50% reduction in density at 20 kg/ha, which increased to 70 to 80% reductions when fertilizer P was increased to 60 kg/ ha. In these studies seed and fertilizer were placed in a very tight row with a double disc opener. More recent research found a decline in canola plant densities when rates of seed-placed P increased, but the decline was less severe. In these studies plant densities reductions of 10% or less were found at 20 kg ha^{-1} of P_2O_5 and 20 to 30% decline at 60 kg ha^{-1} of P_2O_5 (Grant, 2012; Karamanos et al., 2014; Moir et al., 2013). These studies were conducted with hoe type openers, which place seed and fertilizer in wider bands than double disc type openers. This suggests that damage from seed-placed P is decreased when openers with higher seed bed utilization are used, which is also the case with nitrogen fertilizer (Saskatchewan Ministry of Agriculture 2012). While double disc press drills were widely in the past, hoe type openers equipped to place fertilizer either with seed or in a band near the seed are the most commonly used equipment at present.

Equipment logistics sometimes means that other fertilizers such as ammonium sulphate are applied in combination with P in the seed row. Recent work by Quain et al. (2002), indicated that there were detrimental additive effects of seed placed phosphate plus ammonium sulfate when canola was grown under growth cabinet conditions. Overall, there is relatively little work to establish the safe rates of fertilizer applied in combination with each other using the hoe type openers popular today.

Current canola hybrids can readily yield more than 3500 kg/ha (Canola Council of Canada). This results in the crop removing two or more times the amount of P than is replaced by fertilizer applied at the safe rate for seed placed phosphorus. Recent data indicates that in Saskatchewan farmers replace only 75% of the P that their crops remove on average (Canadian Fertilizer Institute 2010). Over time this strategy will further deplete soil P reserves and reduce soil productivity. Strategies that allow growers to economically and safely replace more of the P that crops remove are crucial to sustainable crop production in the region.

Objectives:

This research will address the following questions:

- Are current P fertilizer recommendations adequate for the high yielding cultivars currently used?

- Does all fertilizer P need to be seed-placed or can all or some be banded below and to the side of the seed row?
- Are the current recommendations regarding safe rates of P and S suitable for typical knife or hoe openers in use today?

Overall, the objective of this project is to provide the basis for updated recommendations for fertilizer P rate and placement for canola production in Saskatchewan.

Materials and Methods:

Small plot field trials were located near Indian Head, Melfort, and Scott, SK. Trials were set up as a 2-factor factorial with 4 replicates in an Randomized Complete Block Design. The first factor was 5 rates of P_2O_5 applied using monoammonium phosphate (11-52-0; MAP). The second factor was placement consisting of side-band (SB), seed-placed (SP), and seed-placed along with fertilizer S as ammonium sulfate (21-0-0-24; S-SP). These two factors combined created a 15-treatment trial (Table 1).

Table 1: Fertilizer P rate and placement methods used to evaluate improved phosphorus management for canola production at Melfort, Indian Head, and Scott, SK. in 2016 and 2017.

Treatment Name	Fertilizer Rate (kg/ha)	Fertilizer Placement
0 P-SB	0 P_2O5	Side-Band
20 P-SB	20 P_2O5	Side-Band
40 P-SB	40 P_2O5	Side-Band
60 P-SB	60 P_2O5	Side-Band
80 P-SB	80 P_2O5	Side-Band
0 P-SP	0 P_2O5	Seed-Placed
20 P-SP	20 P_2O5	Seed-Placed
40 P-SP	40 P_2O5	Seed-Placed
60 P-SP	60 P_2O5	Seed-Placed
80 P-SP	80 P_2O5	Seed-Placed
0 P+15 S-SP	0 P_2O5 & 15 S	Seed-Placed
20 P+15 S-SP	20 P_2O5 & 15 S	Seed-Placed
40 P+15 S-SP	40 P_2O5 & 15 S	Seed-Placed
60 P+15 S-SP	60 P_2O5 & 15 S	Seed-Placed
80 P+15 S-SP	80 P_2O5 & 15 S	Seed-Placed

All six trials were established on cereal stubble. Plot sizes varied depending on seeding equipment, with a minimum of 1.5m by 6m used. The seeding equipment used also differed in row spacing, with Indian Head on 20 cm row spacing, Scott on 25 cm row spacing, and Melfort on 30 cm row spacing. Therefore, seedbed utilization was 6%, 10%, and 8%, respectfully. Seeding was completed in early to mid-May (Appendix A1). The seeding rate of L140P (a Liberty Link canola variety) was adjusted for seed weight and % germination at each location to place 120 seeds m^{-2}. Potassium and additional sulphur fertilizers were applied as required by soil test recommendations (Appendix A2). At each location, the total amount of nitrogen applied was balanced for the N supplied through other fertilizers. All pre-seed and in-crop herbicides, insecticides, fungicides, and desiccants were applied to ensure none were yield limiting (Appendix A3). Harvest was completed during late August to early September with a plot combine, after a dry down period.

Data collection consisted of plant density, biomass, biomass phosphorus content, maturity, yield, green seed, and thousand kernel weight (TKW). Plant densities were assessed by counting all plants in a one meter row at two locations per plot. Each sampling site was marked with pin flags and plant densities counted at 2, 4 and 6 weeks after planting, and again after harvest (post-harvest plant counts were done on separate row lengths for logistical reasons). Canola dry matter accumulation was assessed at GS50 (approximately 6 weeks after planting) by cutting all above ground biomass in a one meter row at two locations per plot. Dry matter samples were analyzed for P concentration by Agvise Laboratories to determine P uptake. The date when the entire plot reached 60% seed colour change was recorded to assess the number of days required for the crop to reach maturity. Yield was determined by cleaning, weighing the entire combined sample, and correcting for 10% moisture content. From the cleaned plot sample, a 100-seed crushed sub-sample was used to determine the number of distinctly green seed. A further sub-sample was collected to determine the 1000 seed weight of each plot.

Results and Discussion:

Statistical Analysis

Phosphorus rate, fertilizer placement, and site-year were all considered fixed effects, while replicate within site-year, phosphorus rate by site-year, and fertilizer placement by site-year were considered random effects. There was a treatment by site-year interaction for each variable analyzed. Therefore, each site-year was analyzed independently. Results were considered significant at the $p<0.05$ level. Differences between treatment means were detected using LSD at 0.05.

Residual Soil Nutrients

The site at Indian Head was located on the Thin Black soil zone, with low to moderate soil organic matter, neutral pH, and non- saline. The Melfort site was on a Thick Black clay loam soil with very high organic matter, slightly acidic, and non-saline. At Scott, the site was located in the Dark Brown soil zone on a low organic matter loam soil that was acidic and non-saline. Available soil P_2O_5 levels were very low (0-10 ppm) at Indian Head, low (10-15 ppm) at Melfort in 2016 and Scott in 2017, moderate (15-20) at Scott in 2016 and high (over 20 ppm) at Melfort in 2017 (Table 2). Available soil nitrogen was low at Melfort in 2016, Indian Head in 2016 and 2017 and Scott in 2017 and high at Melfort in 2017 and Scott in 2016. Potassium was high at all three sites. Available soil sulphur was moderate to low at Scott, moderate at Indian Head in 2016 and high at Melfort and Indian Head in 2017 (Table 2).

Table 2: Soil characteristics at Melfort, Indian Head, and Scott, SK in 2016 & 2017.

	Melfort		Indian Head		Scott	
Soil Zone	Thick Black		Thin Black		Dark Brown	
Soil Texture	Clay Loam		Clay Loam		Loam	
Salinity	Non-saline		Non-saline		Non-saline	
(0 – 6")	2016	2017	2016	2017	2016	2017
Soil PH (0-6")	6.2	6.1	7.9	8.0	5.2	5.6
Organic Matter (%) (0-6")	12.3	11.5	2.7	4.8	4.1	3.5
NO_3-N (lb/ac) (0-6")	12	35	10	11	17	9
NO_3-N (lb/ac) (0-24")	31	73	21	26	68	
P_2O_5 (ppm) (0-6")	11	43	6	7	18	9
K_2O (lb/ac) (0-6")	357	796	>540	701	312	380
SO_4-S (lb/ac) (0-6")	10	40	9	16	8	10
SO_4-S (lb/ac) (0-24")	26	80	28	76	16	

Weather

The long-term normal temperatures over the growing season (May 1 to September 31) tend to be lowest at Scott, intermediate at Melfort and highest at Indian Head (Table 3). In Indian Head and Melfort, 2016 tended to be warmer than average, particularly during the months of May, June and September. During 2017, temperatures at these two sites were more similar to long-term normal. Scott was also warmer than normal during May and June of 2016, but a bit cooler during July to September. During 2017, Scott was slightly warmer than normal throughout the growing season.

The 2016 growing season was marked by above average rainfall, while 2017 was marked by less than half of the normal precipitation. Indian Head received 15.4 mm more precipitation in 2016, while in 2017 less than half of the normal precipitation was received (Table 3). However, timely rains in June 2017 and sub-soil moisture likely mitigated drought-like symptoms. Melfort received slightly more than 115% of the normal precipitation in 2016, while 2017 there was less than 50% of normal over the growing season. Adequate moisture in May and June, along with excess soil moisture from the previous fall, also help to mitigate drought symptoms. Scott received 40.9 mm more than normal growing season precipitation in 2016, while in 2017 was fortunate to receive three quarters of the normal precipitation, with May and August receiving above average rainfall.

Plant Density

Phosphorus placement had a statistically significant effect on plant density 2 weeks after planting at all location years, except at Indian Head in 2017 (Table 4). At 4 weeks after seeding, phosphorus placement only had a significant effect on plant population at 3 location years (Indian Head 2017, Melfort and Scott 2016). However, at 6 weeks after seeding phosphorus placement had a significant effect on plant population at the same 5 location years as at 2 weeks after seeding.

Table 3: Mean temperature and total precipitation at Indian Head, Melfort and Scott, SK during the 2016 and 2017 growing seasons (May 1 to September 31).

	May	June	July	August	Sept	May 1-Sept. 31
			--- Mean Monthly Temperature (°C) ---			
Melfort						
2016	13.6	17.1	18.1	16.3	12.0	15.4
2017	10.8	15.2	18.7	17.2	12.5	14.9
Long-Term[x]	10.7	15.9	17.5	16.8	10.8	14.3
Indian Head						
2016	12.8	16.9	17.6	16.9	12.8	15.4
2017	11.6	15.5	18.4	16.7	11.3	14.7
Long-Term[x]	10.8	15.8	18.2	17.4	11.5	14.7
Scott						
2016	12.4	15.8	17.8	16.1	10.9	14.6
2017	11.5	15.1	18.3	16.6	11.5	14.6
Long-Term[x]	10.8	14.8	17.3	16.3	11.2	14.1
			--- Total Monthly Precipitation (mm) ---			
Melfort						
2016	16.8	53.2	128.7	80.8	41.3	320.8
2017	46.4	44.1	33.3	3.1	13.2	140.1
Long-Term[x]	42.9	54.3	76.7	52.4	38.7	265.0
Indian Head						
2016	74.7	50.2	107.9	21.9	40.5	295.2
2017	10.4	65.6	15.4	25.2	12.4	129.0
Long-Term[x]	51.7	77.4	63.8	51.2	35.3	279.4
Scott						
2016	64.8	20.8	88.1	98.2	22.2	294.1
2017	69.0	34.3	22.4	53.0	18.9	197.6
Long-Term[x]	38.9	69.7	69.4	48.7	26.5	253.2

[x] Long-Term Climate Normal from the closest Environment Canada Weather Station to location calculated from 1981-2010

Phosphorus rate had a statistically significant effect on plant density at 2 weeks after seeding at Indian Head in both years, at Melfort in 2017, and at Scott in 2016. At 4 and 6 weeks after seeding the rate effect was only significant at 3 location years. However, the rate effect was significant at P = 0.1 at Melfort in 2016 at both 4 and 6 weeks after seeding.

Both years at Scott, there were significant interactions between placement and rate on plant density at 2 weeks after seeding. At Indian Head, this interaction was not significant at P=0.05, but was at P=0.10 in both years, suggesting that there was some impact of placement and rate. The interaction effect was significant at P = 0.05 at one location at 4 weeks and at two locations at 6 weeks after seeding. In addition, the interaction effect was significant at P = 0.1 at one location 4 weeks after seeding.

Overall, plant populations varied considerably between locations and years. Populations tended to be quite low at Melfort and Scott in 2016, and high at Indian Head in 2016 and Melfort and Scott in 2017. Generally, plant populations tended to be higher at later assessment times with a couple of exceptions. At Melfort in 2017, plant densities declined sharply between 4 and 6 weeks after seeding. This decline could be caused by control of Roundup Ready volunteer plants or insect damage. The incidence of Roundup Ready volunteers at this site was low, therefore the most probable cause was cutworm damage. A similar but less dramatic effect was noted at Scott in 2017, but it is unclear what the cause might have been.

Table 4: Phosphorus rate and placement effect on canola plant populations at 2, 4 and 6 weeks after at three locations in Saskatchewan in 2016 & 2017.

	Indian Head		Melfort		Scott	
	2016	2017	2016	2017	2016	2017
2 Weeks After Seeding						
Placement (P)	0.296	<0.001**	0.005**	0.031*	<0.001**	<0.001**
Rate (R)	0.046*	0.008**	0.346	0.006**	<0.001**	0.210
P * R	0.077	0.051	0.466	0.7966	0.003**	0.036*
Grand Mean	90.9	59.5	38.6	77.0	27.7	87.3
CV	11.5	21.6	36.5	28.7	29.9	17.6
4 Weeks After Seeding						
Placement (P)	0.779	0.008**	0.001**	0.311	<0.001**	0.132
Rate (R)	0.117	0.006**	0.0931	0.003**	0.001**	0.607
P * R	0.164	0.088	0.4201	0.728	0.034*	0.783
Grand Mean	89.2	66.4	37.4	84.2	40.5	92.0
CV	10.4	18.5	32.0	21.8	26.2	51.3
6 Weeks After Seeding						
Placement (P)	0.359	0.023*	<0.001**	0.040*	<0.001**	<0.001**
Rate (R)	0.005*	0.013*	0.065	0.581	0.001**	0.307
P * R	0.047*	0.268	0.791	0.195	0.254	0.010**
Grand Mean	88.3	67.6	39.5	50.8	44.3	81.9
CV	9.1	20.9	25.5	27.8	26.5	13.6

[x] ** p<0.01; *p<0.05

Two weeks after seeding at Indian Head in 2017 (IH-17) and Scott in 2016 and 2017, plant populations were the greatest with the P-SB treatments; declined with P-SP, and lowest in the P+15S-SP treatments (Figure 1and Appendix B1). At Melfort 2016 (ME-16), the plant population in the P+15S-SP treatment was similar to the other two placements however the P-SP and P-SB treatments were slightly higher and similar to each other. At Melfort 2017 (ME-17), the two P-SP treatments were similar to each other, with the plant population in the P-SB treatment being significantly higher. Overall, initial plant densities were higher when phosphorus was side-banded, while densities were slightly lower with two seed-placed treatments.

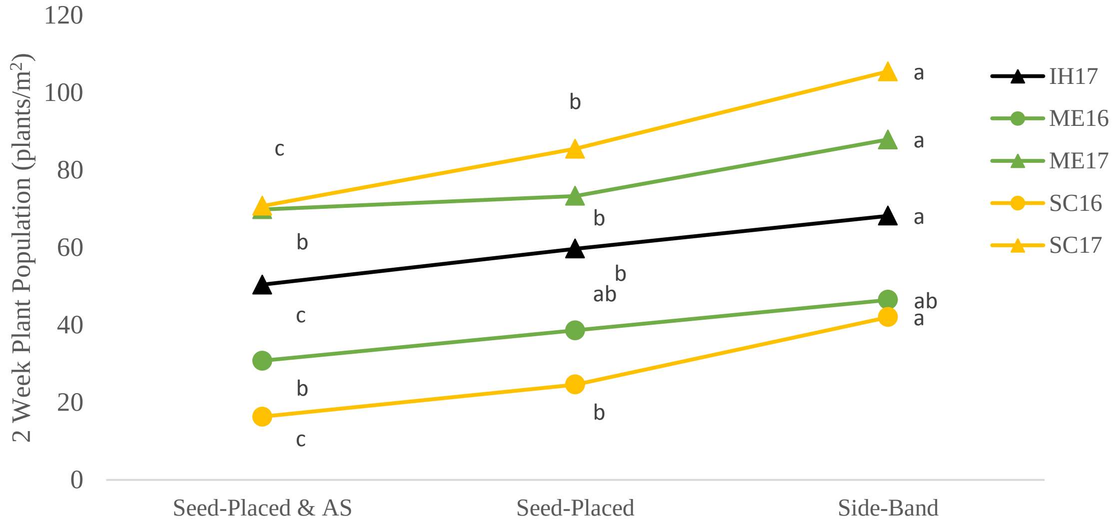

Figure 1: Phosphorus placement effects on plant populations 2 weeks after seeding at 5 site-years in SK during 2016 and 2017.

At 4 weeks after seeding, the P-SB treatments continued to contain the highest plant populations (Figure 2, Appendix B2). At IH-17 and ME-16, the P-SP and P-SB treatments were statistically similar, while the P-SP and P+15S-SP treatments were lower and similar to one another. At SC-16, the lowest plant populations were found in the P+15S-SP treatments, while the highest were in the P-SB treatments.

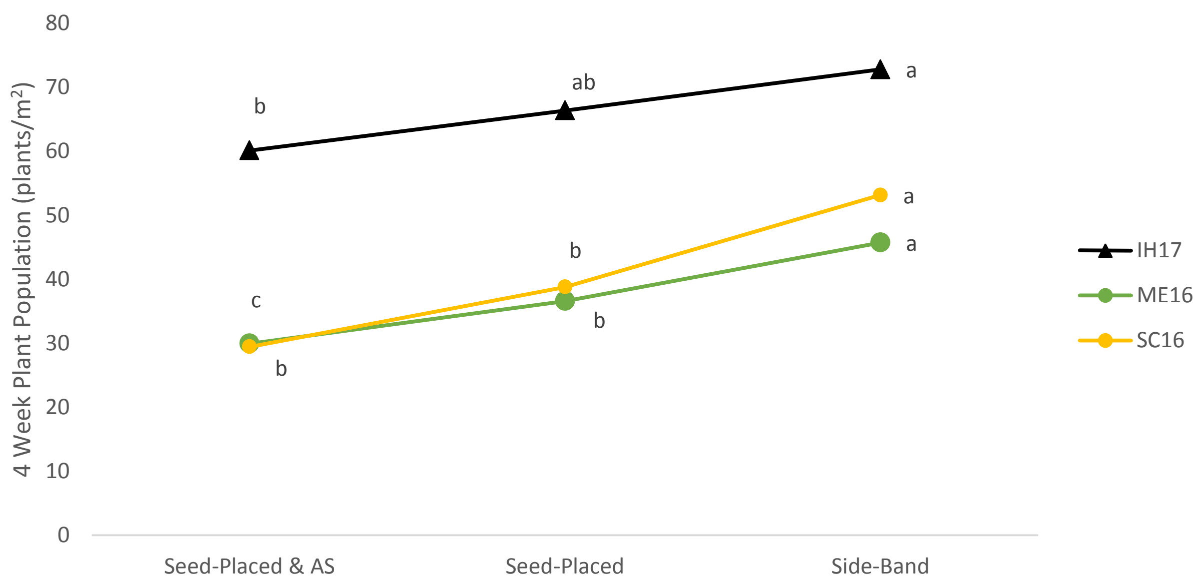

Figure 2: Phosphorus placement effects on canola plant populations 4 weeks after seeding at 3 site- years in SK during 2016 and 2017.

At 6 weeks after seeding, placement effects tended to be similar to earlier assessment dates. The general trend was for P-SB>P-SP>P+15S-SP (Figure 3; Appendix B3). At IH-17, the P-SB treatments were greater than the P+15S-SP treatments, while the P-SP treatments were intermediate and not significantly different than P-SB or P+15S-SP. At ME-16 & -17, and Scott 2017 (SC-17) the P-SP and P+15S-SP treatments were similar and less than P-SB treatments. At SC-16, the P-SP treatments had significantly less plants, while the P-SB treatments were the highest.

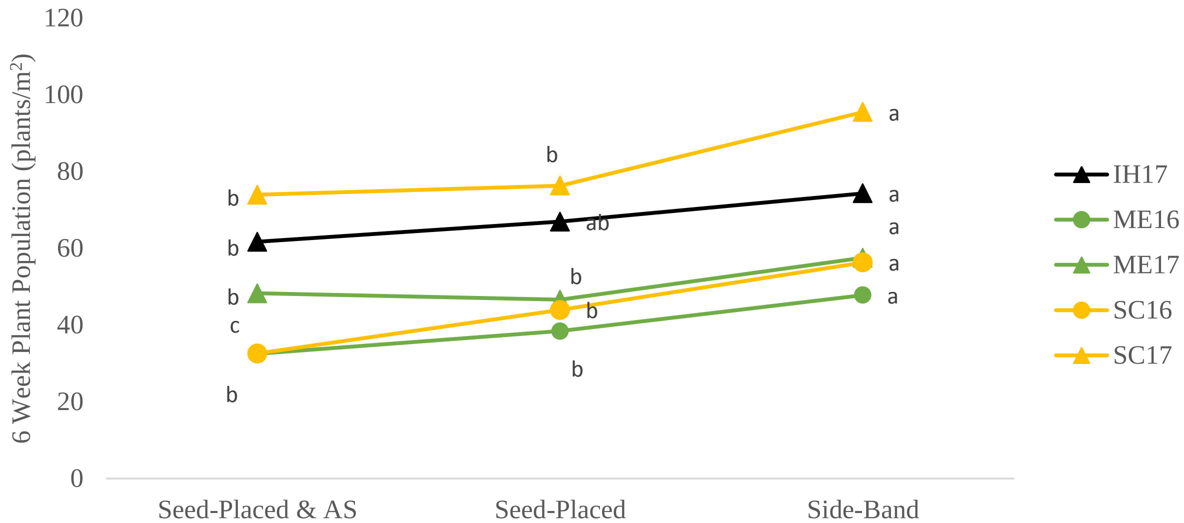

Figure 3: Phosphorus placement effects on canola plant populations 6 weeks after seeding at 5 site- years in SK during 2016 and 2017.

At all locations, plant populations 2 weeks after seeding tended to decline with increasing phosphorus rates (Appendix B1), and the P rate effect was statistically significant at 4 of six location years. These included IH-16, IH-17, ME-17 and SC-16 (Figure 4). Canola plant populations appeared to decrease by a similar amount for each increase in fertilizer P at most location years. When averaged across all placements and locations the decline was about 3% for each 10 kg/ha of fertilizer P_2O_5.

At all locations with significant rate effects plant populations at 4 weeks continued to decline with increasing phosphorus rates (Figure 5, Appendix B2). At IH-17, the significant decline occurred at 40 kg P_2O_5/ha, at ME-17 and SC16 populations declined at 20 kg P_2O_5/ha, and at SC-16.

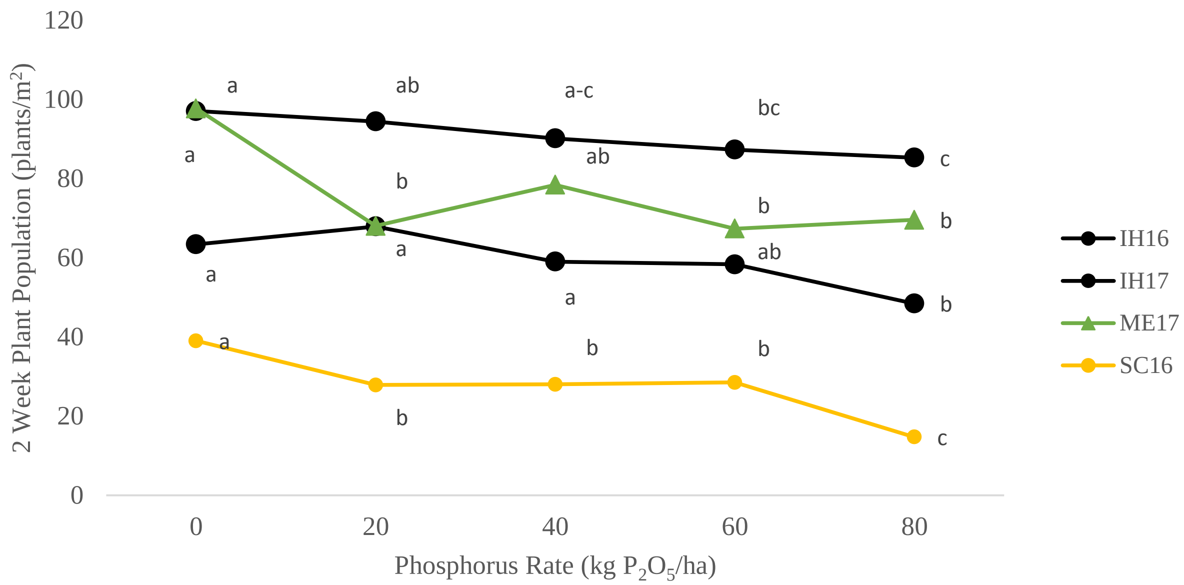

Figure 4: Phosphorus rate effects on canola plant populations 2 weeks after seeding at 4 site-years in Saskatchewan during 2016 and 2017.

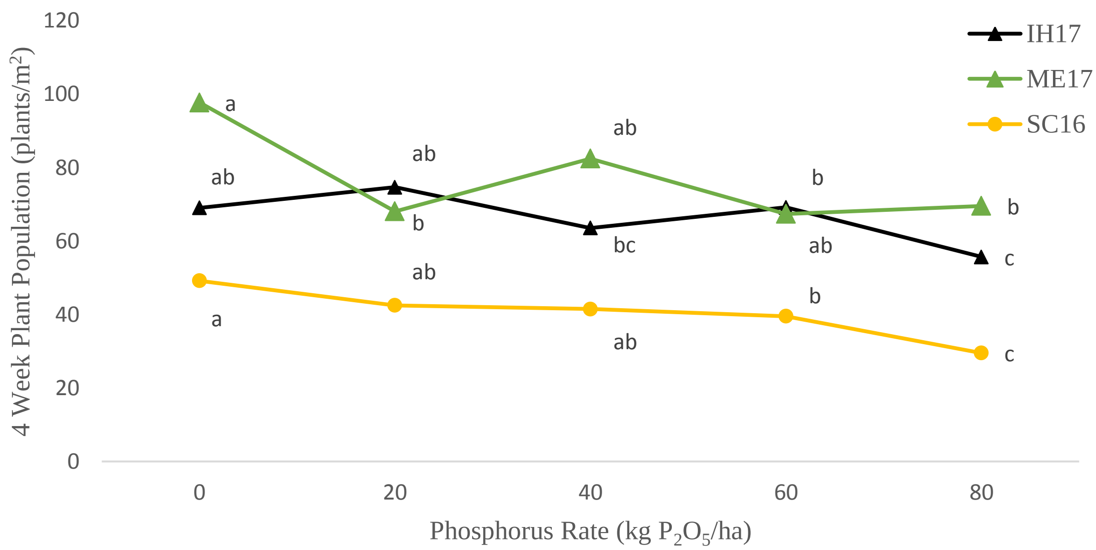

Figure 5: Phosphorus rate effects on canola plant populations 4 weeks after seeding at 3 site-years in Saskatchewan during 2016 and 2017.

At 6 weeks, plant populations continued to decline with increasing phosphorus rate, however, the differences between treatments diminished somewhat (Figure 6, Appendix B3). The rate effect was statistically significant at IH-16, IH-17 and SC-16. At this time, the decline averaged about 2% for each 10 kg/ha od added P_2O_5 fertilizer.

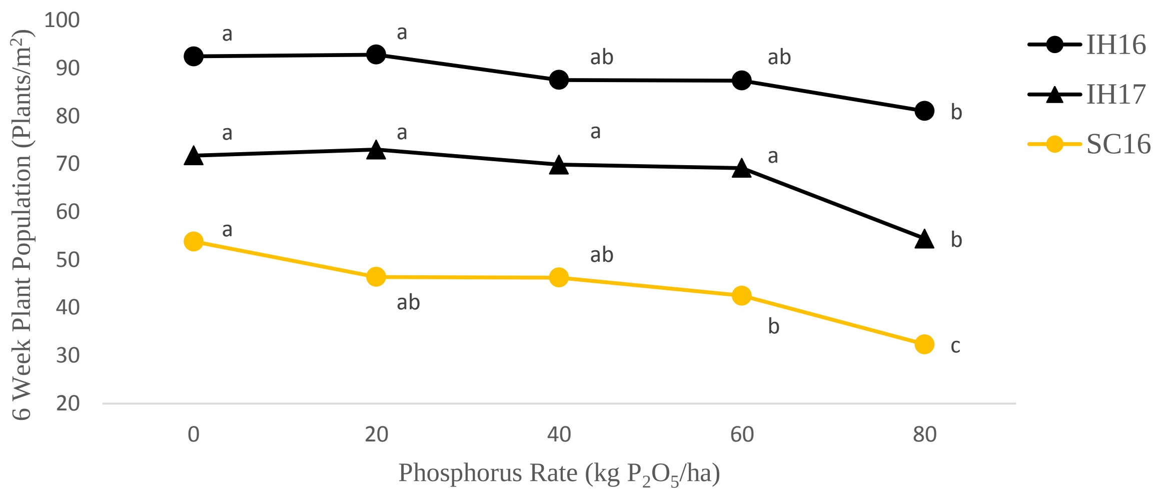

Figure 6: Phosphorus rate effects on plant populations 2 weeks after seeding at 3 site- years in Saskatchewan during 2016 and 2017.

At SC-16 and SC-17 the interaction effect on plant population at 2 weeks after seeding was significant at P=0.05 and at IH-16 and IH-17 it was significant at P=0.10. Overall plant populations declined with increasing fertilizer rates with P-SP and P+15S-SP (Appendix B1). As expected, P-SB plant populations were not affected by P rate at any location year. At 4 weeks after seeding the interaction effect was only statistically significant at SC-17 and at 6 weeks at SC-16 and SC-17. Despite small differences between evaluation timings the same general trend for increased damage with increased P rate with P-SP and P+15S-SP but not with P-SB was maintained. Effects of rate and placement of P on plant populations was greatest at SC-17 at all evaluation timings.

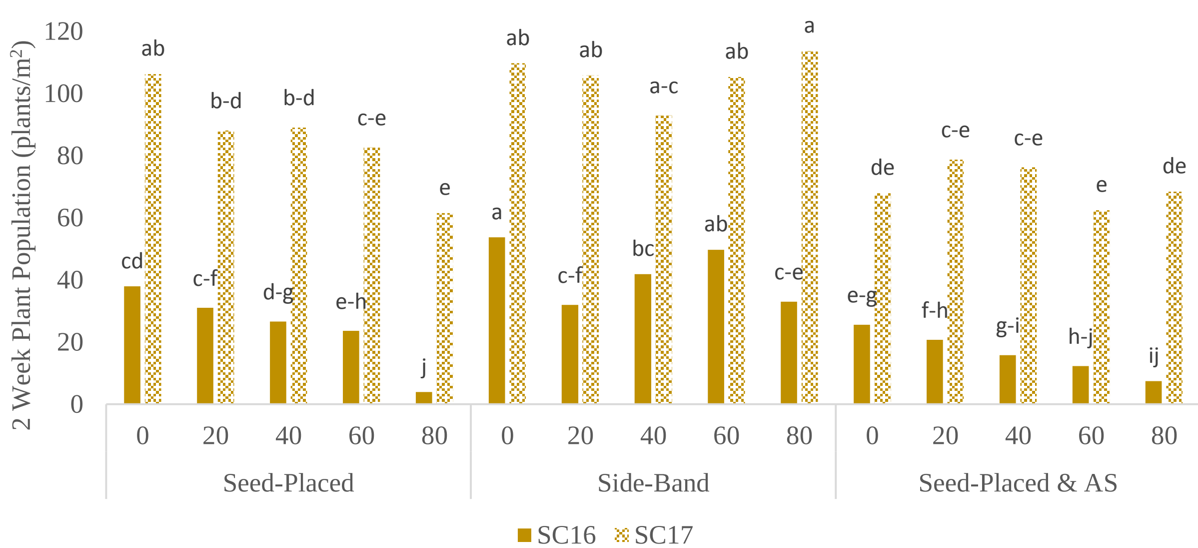

Figure 7: Phosphorus rate and placement effect on plant populations 2 weeks after seeding at Scott in 2016 & 2017.

In general, the same trends at two and four-weeks post seeding were similar at SC-16. Plant populations continued to decline with increasing rate and the side-banded treatments were significantly higher than the two seed-placed treatments (Figure 8). Furthermore, the seed-placed 80 and seed-placed phosphorus with sulphur were the lowest stand treatments overall.

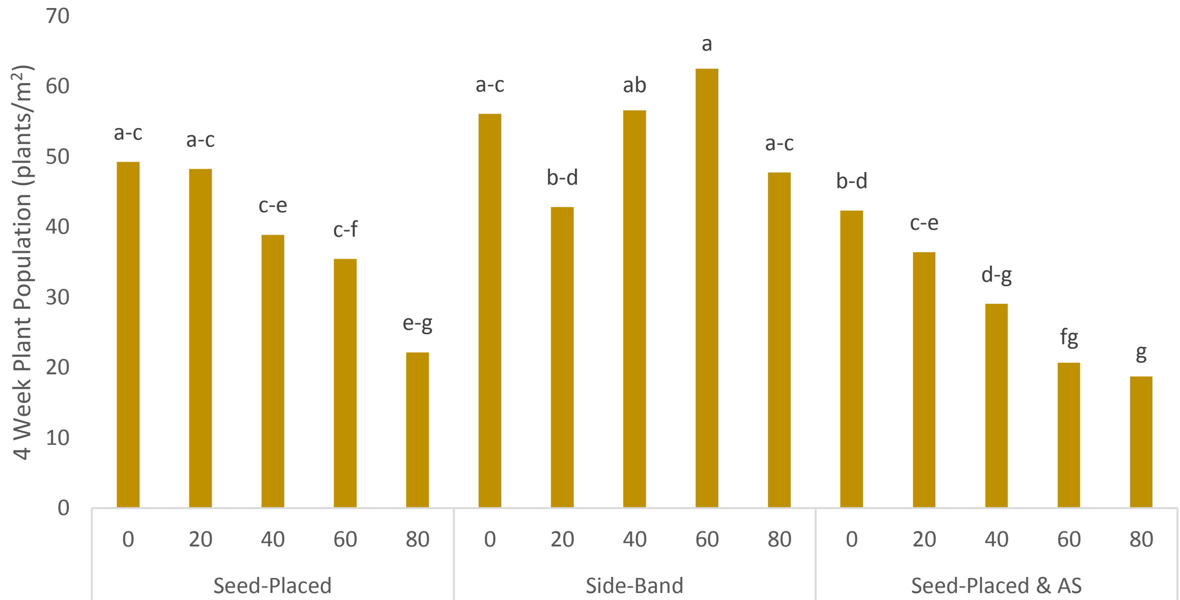

Figure 8: Phosphorus Placement and Rate Effects on Plant Populations 4 Weeks After Seeding in Enhanced Canola Production with Improved Phosphorus Fertilizer Management at Scott 2016.

By six-weeks after seeding, the interaction effects between placement and rate minimized. At this time, the seed-placed phosphorus & sulphur was similar to the seed-placed and side-band treatments. Overall, plant populations were the lowest when 80 kg P_2O_5/ha was seed-placed and at 60 & 80 kg P_2O_5/ha was seed-placed with sulphur.

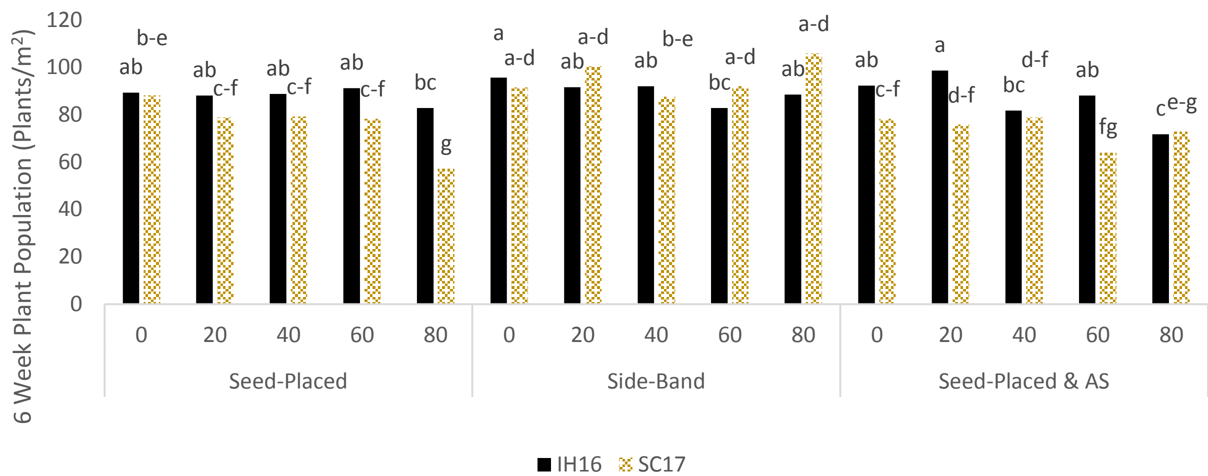

Figure 9: Phosphorus Placement and Rate Effects on Plant Populations 6 Weeks After Seeding in Enhanced Canola Production with Improved Phosphorus Fertilizer Management at two site-years.

Plant Density – POST Harvest

After harvest was completed, canola stems were counted near the previous count locations. Phosphorus placement had a significant effect at Indian Head 2017 and Scott in both years (Table 7). Phosphorus rate was only significant at Indian Head 2017 and Scott 2016. There was no significant treatment interaction affecting plant density after harvest. Plant populations were similar to those at four and six weeks after planting; however, plant density increased at Melfort 2017. This could be due to a new recruitment of volunteer canola.

Table 7: Phosphorus Rate and Placement Effect on Plant Populations After Harvest for Enhanced Canola Production with Improved Phosphorus Fertilizer Management in 2016 & 2017.

	Indian Head		Melfort		Scott	
	2016[x]	2017[x]	2016[x]	2017[x]	2016[x]	2017[x]
Placement (P)	0.936	0.001**	0.426	0.713	<0.001**	<0.001**
Rate (R)	0.328	<0.001**	0.424	0.191	0.005**	0.469
P * R	0.261	0.188	0.189	0.850	0.064	0.103
Grand Mean	78.5	76.6	46.7	76.2	40.1	84.0
CV	11.1	13.2	53.6	26.7	24.5	14.7

[x]; ** p<0.01; *p<0.05

In general, the two seed-placed treatments were similar to each other and had a smaller plant population than the side-band treatment (Figure 10, Appendix 4). However, at SC16 the seed-placed phosphorus and sulphur treatment had a significantly lower plant population than the seed-placed phosphorus only treatments.

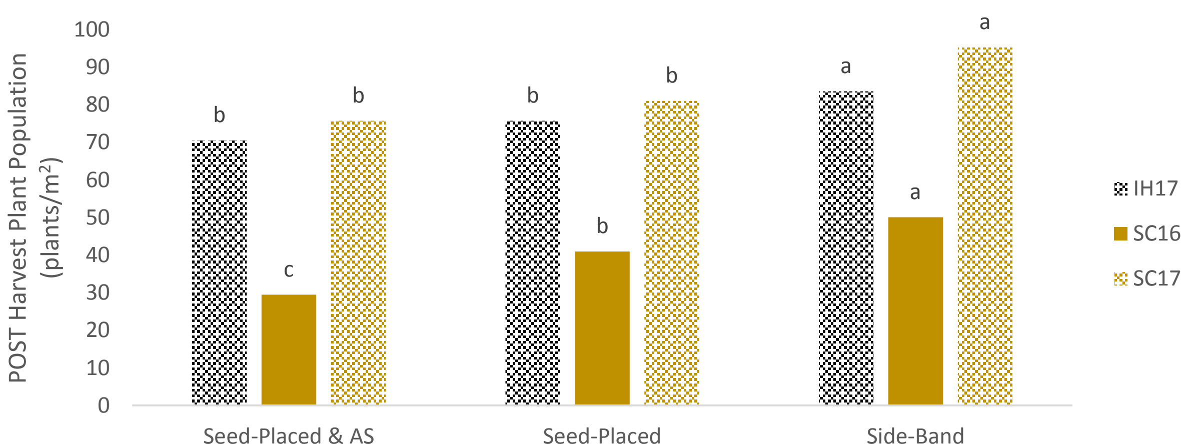

Figure 10: Phosphorus Placement Effects on Plant Populations After Harvest in Enhanced Canola Production with Improved Phosphorus Fertilizer Management at three Site-Years.

Phosphorus rate only had a significant effect on final plant populations at two of six site-years. At IH-17, there was a significant decline after 40 kg P_2O_5/ha was applied, which was similar to the populations as the rate increased (Figure 11). At SC16, plant populations tended to decline with phosphorus application, however, the largest decline occurred at 80 kg P_2O_5/ha.

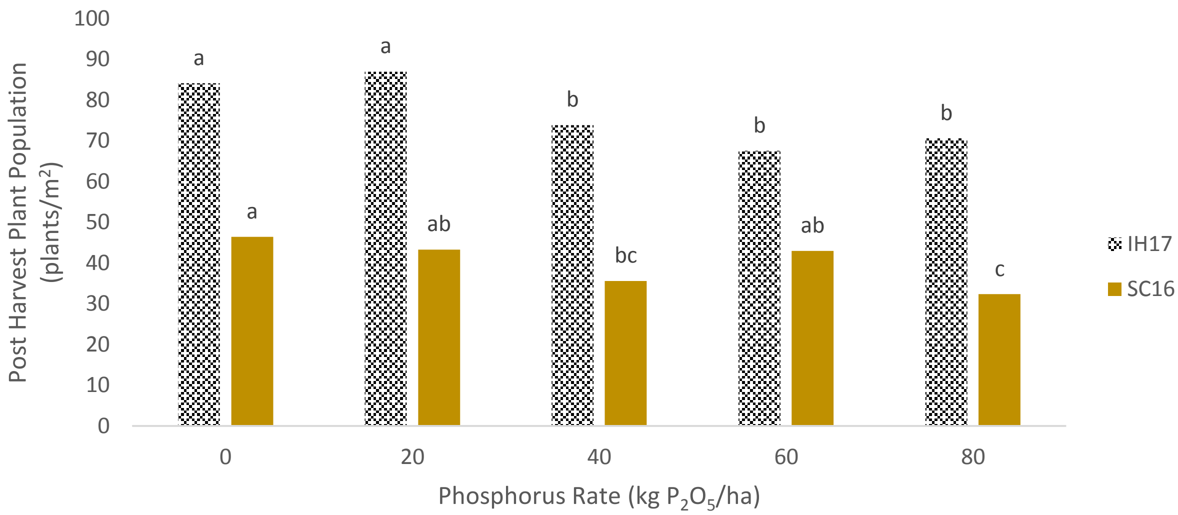

Figure 11: Phosphorus Rate Effects on Canola Plant Populations After Harvest at Two Site-Years.

The interaction of P rate with fertilizer placement on canola plant population was of particular interest because it provides an insight into how placement can minimise damage to seeds and seedlings. To provide some preliminary insight into how rate and placement affect seed and seedling damage, trend-lines of rate effects for each placement method were included from Scott 2016 data (where damage was greatest) and for the all location year means. Figure 12 illustrates these effects for the 4 week and post-harvest sampling times. At 4 weeks after seeding at Scott in 2016, P-SB had no effect on plant density, while P-SP and P+15S-SP showed sharp declines in plant density as P rate increased (Figure 12A). The P+15S-SP had consistently fewer plants than P-SP even at zero P, and the trend- lines for these 2 placements appear parallel. This would tend to indicate 2 things. The ammonium sulfate in the P+15S-SP was detrimental to canola emergence on its own, and the effects of seed placed ammonium sulfate and P are additive at this time. When averaged across all locations at 4 weeks after seeding, the overall trend was quite similar to Scott in 2016 (Table 12 C). The P-SB had no effect at any rate while P-SP and P+15S-SP were more damaging as rates increased. At Scott, the rate of decline in plant population was about 6% for each 10 kg/ha of P2O5 as P-SP, but was only about 3% when averaged across all location years. With P+15S-SP there was an initial plant loss of about 15% at zero P followed by a 6% additional loss for each 10 kg/ha of added P at SC-16. When averaged across all locations the initial plant loss declined to about 10% followed by a 3% additional decline for each 10 kg/ha of added P.

Post-harvest plant densities followed the same general trends as were noted at 4 weeks after seeding with one notable difference. The rate response trend-lines for P-SP and P+15S-SP were no longer parallel. The P rate effect appeared to diminish as P rate increased with P+15S-SP compared with P-SP. A more comprehensive analysis of the data will be required after the 2019 growing season to try to better understand these effects.

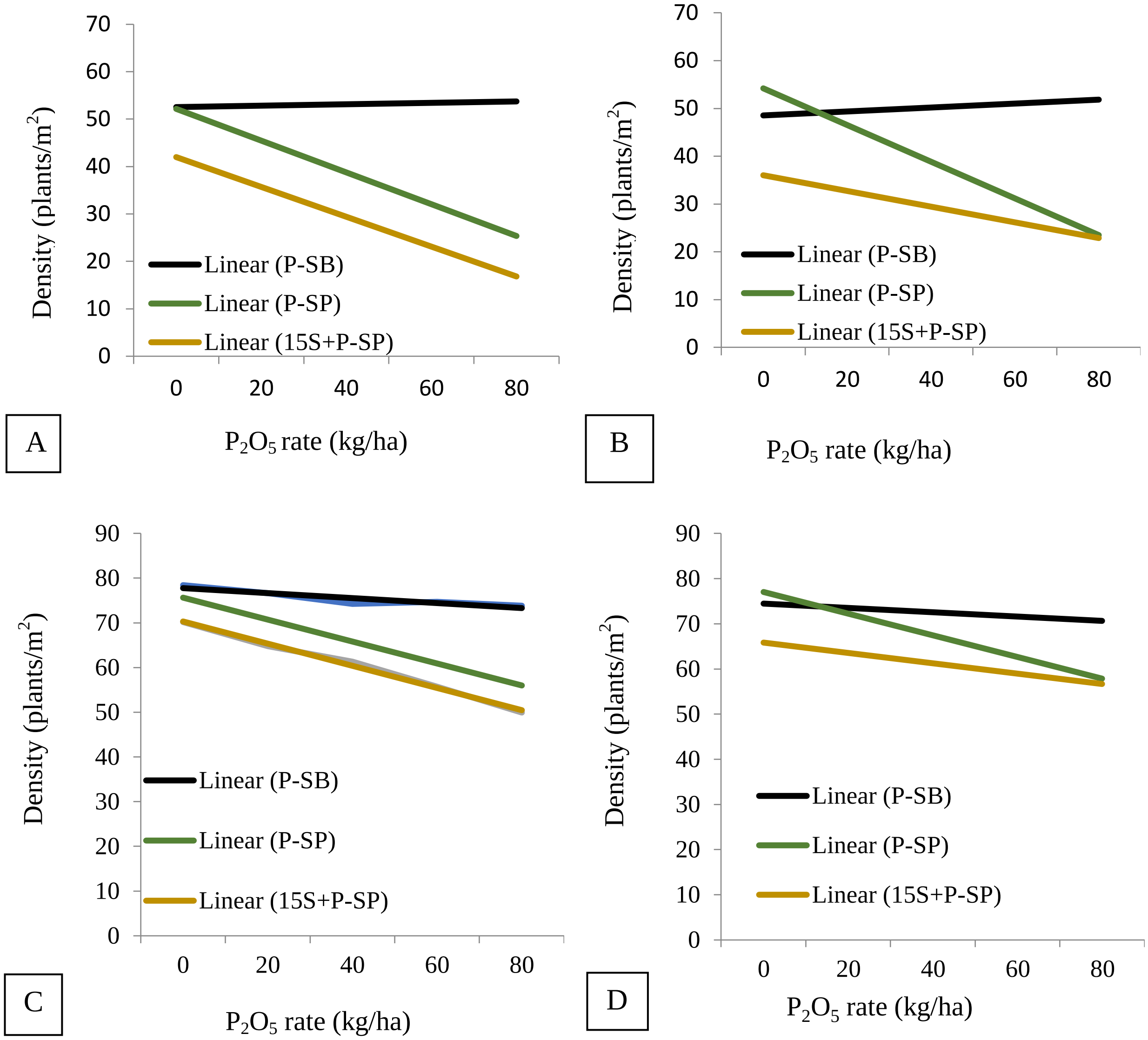

Figure 12: Trend-lines for P rate effects on canola plant density. A: 4 weeks after seeding at Scott 2016 B: post-harvest at Scott in 2016 C: 4 weeks after seeding at all location years and D: post-harvest at all location years.

Biomass and Tissue Phosphorus Levels

Phosphorus rate had a significant effect on plant biomass at three of six site-years which all occurred in 2016 (Table 8, Appendix B5). Both placement and the interaction between rate and placement was only significant at Scott in 2016. At Indian Head, biomass production was significantly higher in both years than in Melfort or Scott. This discrepancy was likely due to a slightly later sampling timing at Indian Head than at the other two locations. At GS50 canola plants undergo rapid growth so any delay in sampling can have a big impact on total biomass. Regardless, treatments effects would be expected to remain proportional. In 2017, biomass totals were about half of 2016 totals in Melfort, while the opposite was true at Scott. Again this could be related to sampling timing. At Scott, where placement was significant, the side-banded treatments had significantly more biomass than seed-placed which was significantly more than seed-placed with sulphur (data not shown). This trend reflects the 6 week and POST harvest plant density trend.

Table 8: Phosphorus Rate and Placement Effect on Biomass Production for Enhanced Canola Production with Improved Phosphorus Fertilizer Management in 2016 & 2017.

	Indian Head		Melfort		Scott	
	2016[x]	2017[x]	2016[x]	2017[x]	2016[x]	2017[x]
Placement (P)	0.068	0.483	0.180	0.740	<0.001**	0.116
Rate (R)	0.002**	0.161	0.001**	0.706	0.002**	0.551
P * R	0.562	0.755	0.221	0.982	0.039*	0.393
Grand Mean	151.7	224.7	74.9	39.0	46.1	81.2
CV	12.9	31.1	36.2	35.5	23.3	26.7

[x] ** p<0.01; *p<0.05

At Indian Head and Melfort, there was a significant increase in biomass with phosphorus application regardless of the rate applied (Figure 13). However, at Scott, biomass production was similar to the control between 20, 40, and 60 kg P_2O_5/ha and significantly decreased at 80 kg P_2O_5/ha. Most of this decline could be attributed to seedling damage with SP phosphorus at this high rate which more than offset any nutrient benefit.

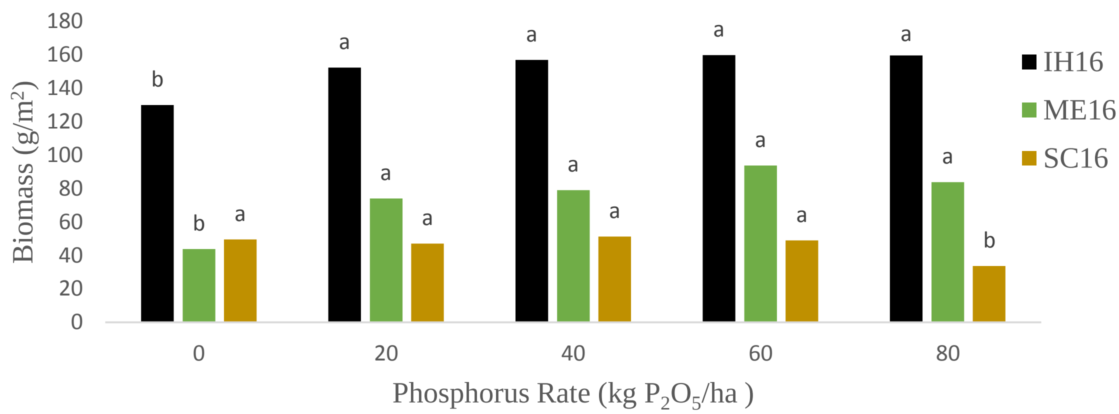

Figure 13: Phosphorus Rate Effects on Biomass Production (g/m^2) at 3 Location Years in 2016.

At Scott, the P-SB treatments had more biomass than the P-SP or P+15S-SP treatments (Figure 14). The 40 P-SB and 60 P-SB treatments produced the largest amounts of biomass, while 80 P-SB produced the least.

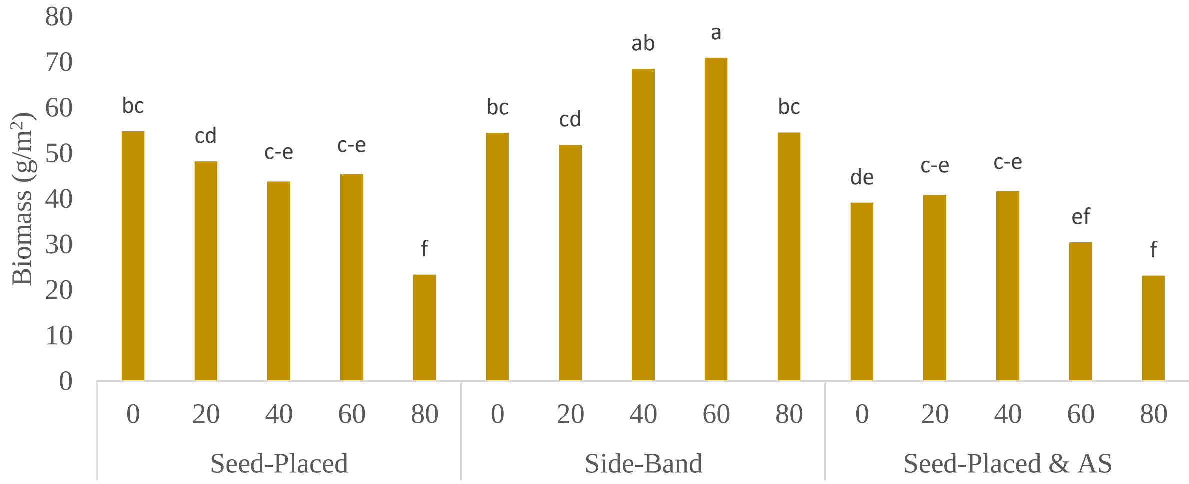

Figure 14: Phosphorus Placement and Rate Effects on Biomass Production (g/m^2) at Scott 2016.

Phosphorus rate had a significant effect on tissue phosphorus levels at 5 of 6 site-years, as expected (Table 9). Placement only had a significant effect at Scott in 2017 and there was no significant interaction between the two treatment variables. Between years and locations, tissue levels were very similar. At Scott, the phosphorus levels were highest in the two seed-placed treatments (0.47 and 0.46 ppm) and lowest in the side-band treatment (0.44 ppm).

Table 9: Phosphorus Rate and Placement Effect on Tissue Phosphorus Levels in 2016 & 2017.

	Indian Head		Melfort		Scott	
	2016^x	2017^x	2016^x	2017^x	2016^x	2017^x
Placement (P)	0.292	0.572	0.106	0.425	0.180	0.022*
Rate (R)	<0.001**	0.006**	<0.001**	0.321	<0.001**	<0.001**
P * R	0.455	0.882	0.408	0.666	0.443	0.819
Grand Mean	0.40	0.61	0.39	0.41	0.42	0.46
CV	10.5	8.4	14.3	8.0	6.1	5.9

^{x} ** $p<0.01$; *$p<0.05$

Much like the biomass levels, rate had a significant effect at all locations in 2016; however, it was also significant at two 2017 locations. At all locations where rate had a significant effect, biomass P content increased with P rate, with the highest levels noted at the highest rate (Figure 15).

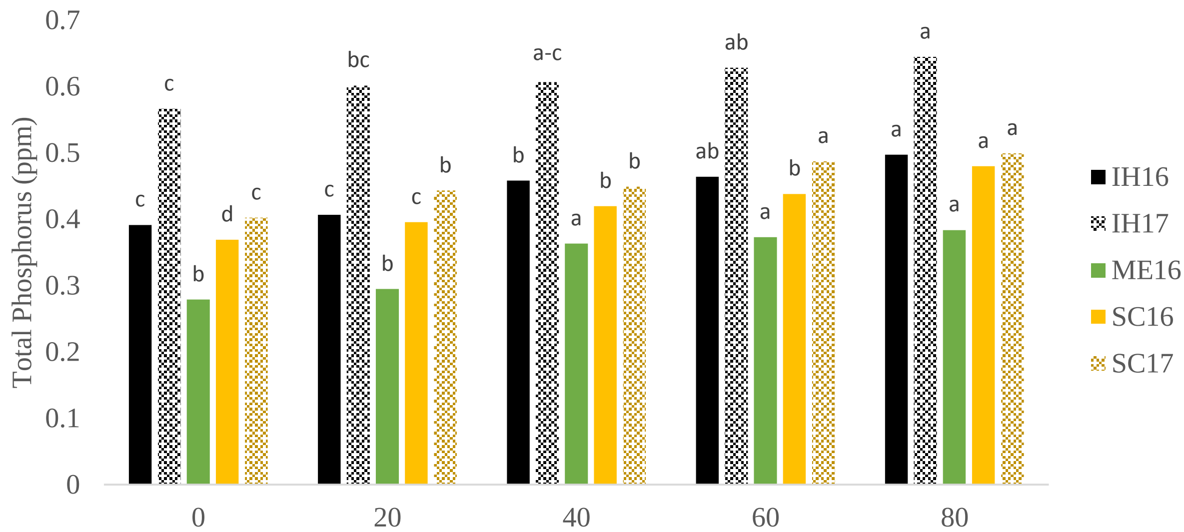

Figure 15: Phosphorus Rate Effects on Biomass Production (g/m^2) at 5 site-years.

Days to Maturity

At Melfort maturity differences between treatments were not noted, therefore analysis of data from these location years was not done. At each of the other site-years placement had a significant effect, while rate was significant at each site-year except for Indian Head 2016 (Table 10). In 2017, there was a significant treatment interaction on days to maturity. Overall, maturity was very similar between years at each location, except at Melfort. At Melfort, the average date of maturity was 11 days sooner in 2017 than it was in 2016. Canola maturity was roughly three days earlier than at Indian Head.

Table 10: Phosphorus Rate and Placement Effect on Days to Maturity for Enhanced Canola Production with Improved Phosphorus Fertilizer Management in 2016 & 2017.

	Indian Head		Melfort		Scott	
	2016^x	2017^x	2016^x	2017^x	2016^x	2017^x
Placement (P)	0.008**	<0.001**	NA	NA	0.002**	0.029*
Rate (R)	0.438	0.0017**	NA	NA	0.003**	0.035*
P * R	0.631	0.004**	NA	NA	0.207	0.021*
Grand Mean	97.4	98.0	103.0	92.0	101.6	100.1
CV	0.4	0.5	NA	NA	1.9	1.3

^{x} ** p<0.01; *p<0.05

There was a tendency for the P-SP and P+15S-SP treatment to mature earlier than the P-SB treatments, however results were inconsistent between locations (Figure 15, Appendix B8). At three of the 4 location years P-SB tended to mature slightly earlier than P+15S-SP while P-SP was intermediate. At the fourth location year (SC-16) P-SB matured slightly later than P-SP, but earlier than P+15S-SP.

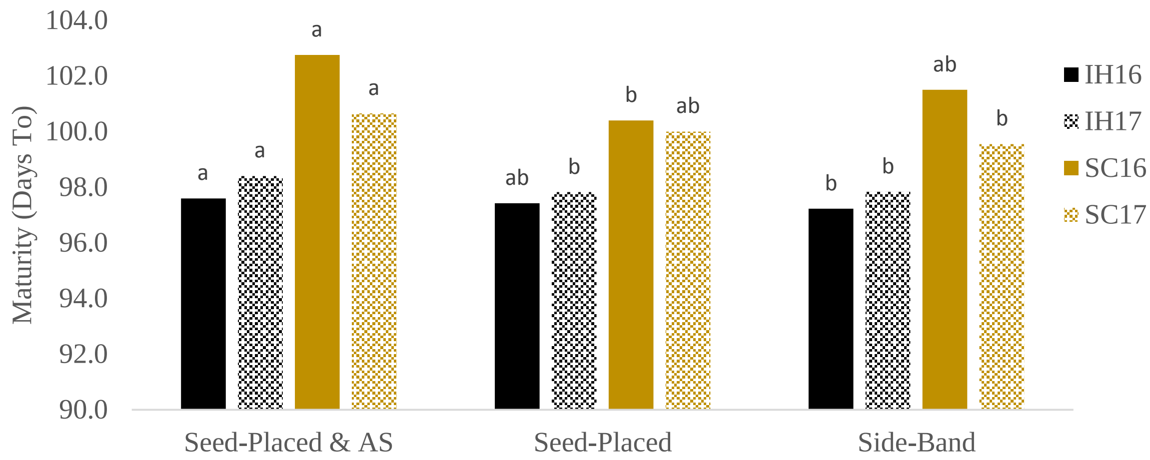

Figure 16: Phosphorus Placement Effects on Days to Maturity at 4 site-years in 2016 and 2017.

At Indian Head, phosphorus application above 60 kg P_2O_5/ha, delayed maturity, with 80 kg P_2O_5/ha maturity being similar to the untreated control (Figure 17). At Scott 2016, 60 and 80 kg P_2O_5/ha significantly delayed maturity in comparison to the 0, 20, and 40 kg P_2O_5/ha rates. At SC17, when 20, 60, and 80 kg P_2O_5/ha was applied, maturity was delayed by one day. Overall treatment effects on maturity were very small and may not be of much practical significance.

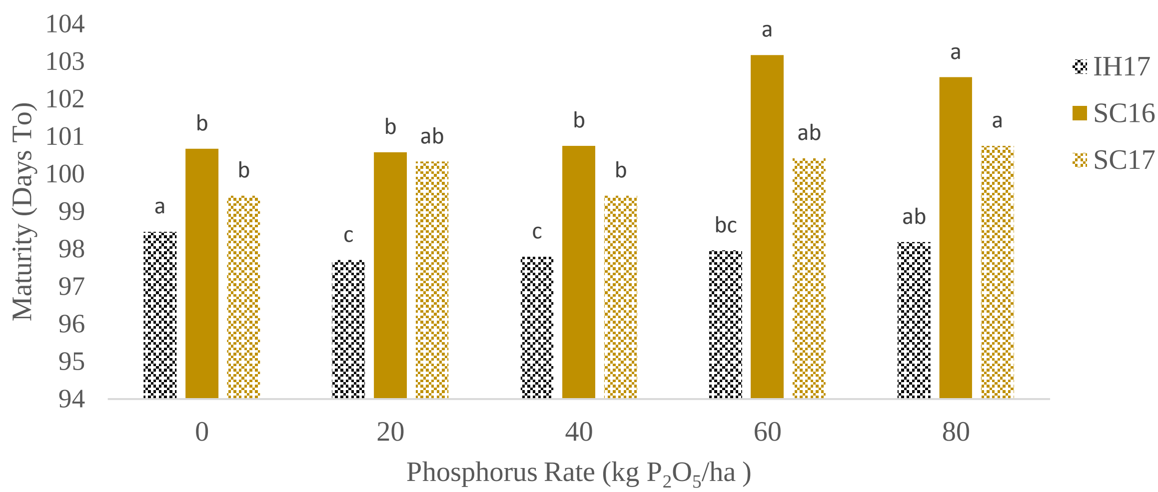

Figure 17: Phosphorus Rate Effects on Days to Maturity of Canola at 3 site-years.

At Indian Head, no phosphorus applied was associated with a 1 day delay in maturity and was similar to all P+15S-SP treatments (Figure 18). Low rates of phosphorus seed applied were very similar to when phosphorus was applied in a side-band and occurred in 97 days. At Scott, results were very variable. Yet, there was a trend for the no phosphorus applied treatments to mature 1 to 2 days sooner than other treatments.

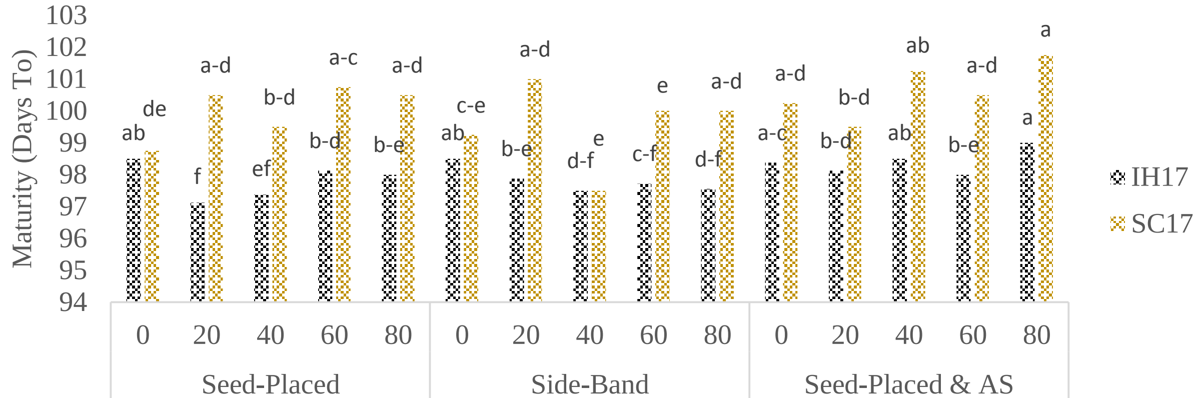

Figure 18: Phosphorus Placement and Rate Effects on Maturity (days to) in Enhanced Canola Production with Improved Phosphorus Fertilizer Management in 2017.

Yield

Phosphorus placement significantly affected yield at Scott 2016, while rate was significant at three site-years (Table 11). Furthermore, the phosphorus rate and placement interaction was only significant at Scott 2016. The lack of response at Melfort in 2017 was not unexpected since soil available P tested 53 ppm. With this much available soil P a response to fertilizer P would be very unusual. At Indian Head, soil test P was 6 ppm in 2016 and 7 ppm in 2017. At these low levels we would expect to see relatively large responses to fertilizer P. The lack of response combined with high yield without fertilizer P is troubling. It suggests that soil tests are not providing an adequate estimate of available P from the soil. This site deserves more comprehensive evaluation to determine what the real soil P supply is.

Table 11: Phosphorus Rate and Placement Effect on Canola Yield in 2016 & 2017.

	Indian Head		Melfort		Scott	
	2016[x]	2017[x]	2016[x]	2017[x]	2016[x]	2017[x]
Placement (P)	0.164	0.367	0.079	0.507	<0.001***	0.940
Rate (R)	0.330	<0.001**	<0.001***	0.781	0.122	0.024*
P * R	0.702	0.996	0.791	0.109	0.006**	0.470
Grand Mean	3624	3303	3206	2680	3784	3726
CV	3.2	3.0	13.2	16.4	4.1	5.1

[x] ** p<0.01; *p<0.05

The three sites that responded to fertilizer P showed some similar responses despite the fact that only one site showed a significant effect of the interaction of rate with placement. At Melfort in 2016, all three placements showed a good response to fertilizer P at rates of 20 or 40 kg/ha (Table 19A). However the P-SB placement responded well at rates of 60 and 80 kg/ha. The P-SP placement showed little response to rates above 40 kg/ha and the P+15S-SP treatments tended to provide the poorest responses.

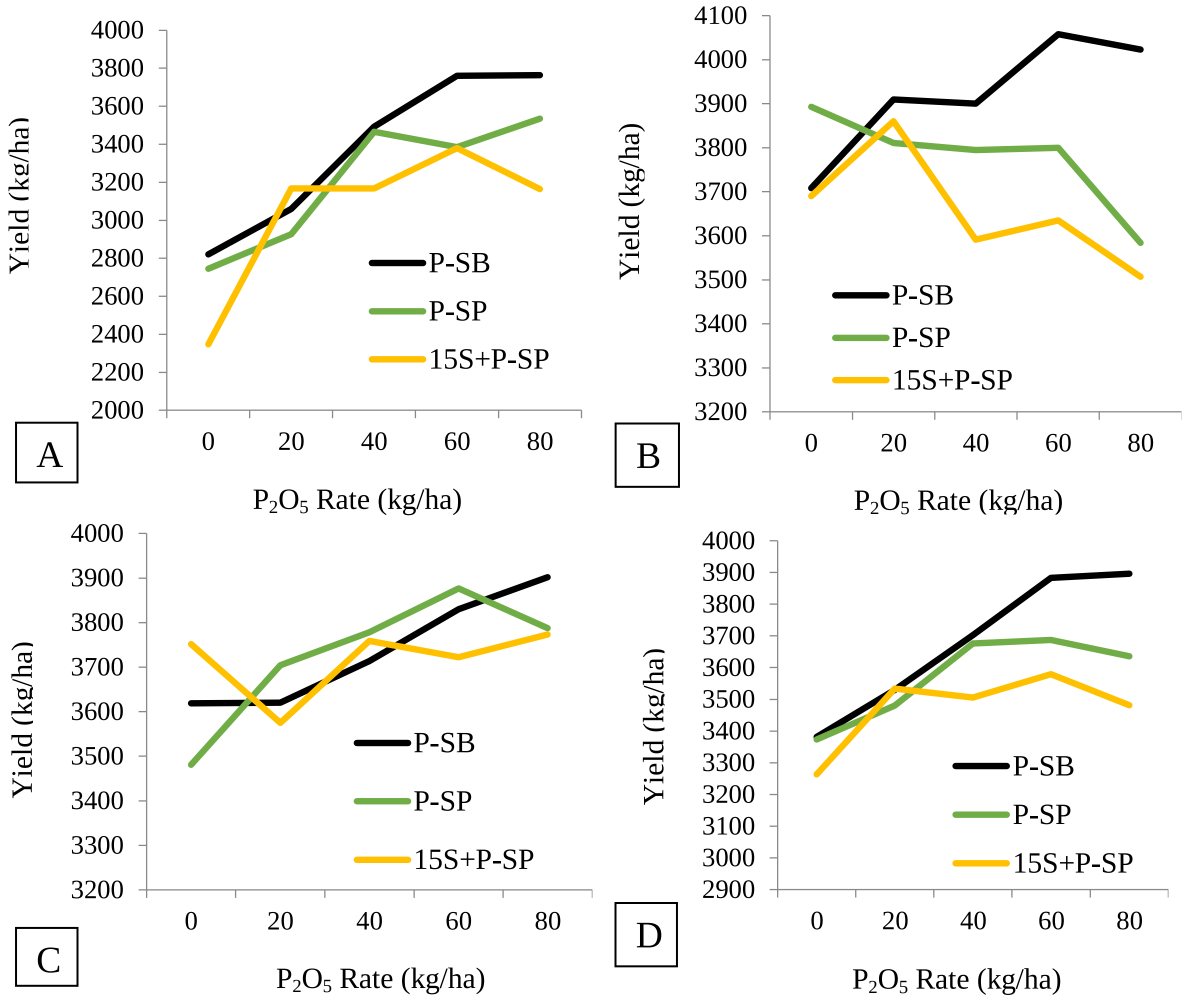

Figure 19: Yield (kg/ha) Response of Canola to Rate and Placement of P Fertilizer. A: Melfort 2016; B: Scott 2016; C: Scott 2017; and D: Average of 3 Responsive Locations.

At Scott in 2016, where the interaction of rate with placement was significant, the P-SB placement tended to respond at rates up to 60 kg/ha before tapering off (Figure 19B). By contrast, the P-SP placement showed declining yield as rates increased. With P+15S-SP there was a positive response to 20 kg/ha but as rates increased further, yield declined rather sharply.

At Scott in 2017, all placements tended to enhance yield as rate increased (Table 19C). The P-SB treatments were usually very similar to P-SP and generally better than P+15S-SP treatments at the same P rates.

Averaged across the three responsive sites, the three placements were very similar at rates up to 20 kg/ha (Table 19D). As rates increased above 20 kg/ha, the P+15S-SP placement stopped responding. The P-SP treatment responded similarly to P-SB up to 40 kg/ha, but at rates of 60 and 80 kg/ha the P-SB placement tended to yield more than P-SP.

At all three site-years, 80 kg P_2O_5/ha produced the largest yields (Figure 20). This treatment resulted in yield increases between 204 and 820 kg/ha. At IH-17 yields increased with phosphorus application and maximized at 60 kg P_2O_5/ha, which resulted in a 102 kg/ha yield increase. At Melfort, yields also increase with phosphorus application and occurred at 40 kg P_2O_5/ha. This increase was the largest at any location at resulted in a 739 kg/ha increase between 0 and 40 kg P_2O_5/ha. At Scott, yields were not significantly different from the no phosphorus applied treatment until 80 kg P_2O_5/ha, however, yields were similar to the 80 kg P_2O_5/ha treatment starting at 40 kg P_2O_5/ha. Phosphorus application at 40 kg P_2O_5/ha resulted in a 133 kg/ha increase in comparison to the untreated control.

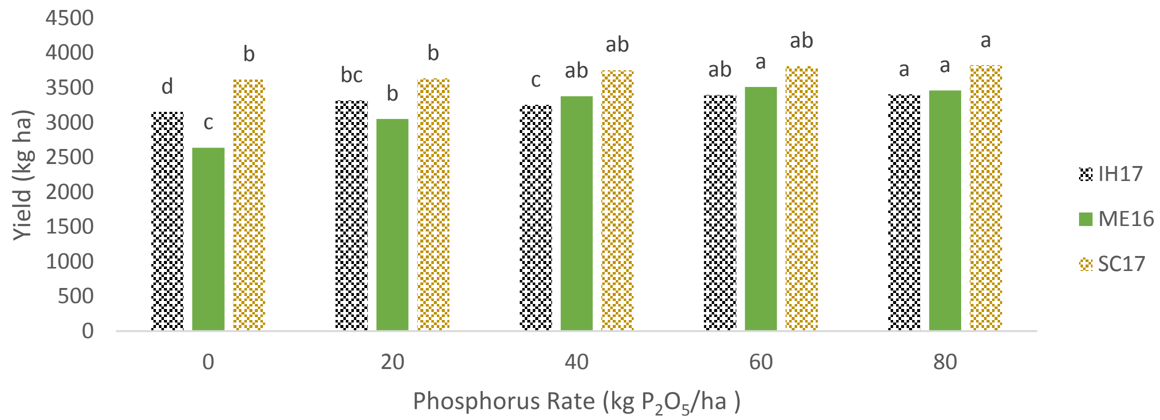

Figure 20: Phosphorus Rate Effects on Yield (kg/ha) in Enhanced Canola Production with Improved Phosphorus Fertilizer Management at three site-years.

Quality

Thousand kernel weight or seed weight, was largely unaffected by the applied treatments. However, placement was significant at IH-16 and rate was significant at IH17 and ME16, with no significant interaction being detected (Table 12). Overall, seed weights were as expected ranging between 3.0 and 3.4 mg/ seed. When placement was significant, seed weight increased by 0.02g/1000 seeds when side-banded, with seed-placed P alone being similar. Seed weight also tended to increase with phosphorus application and was the greatest at or after 40 kg P_2O_5/ha. The largest seed weight increases averaged between 0.10g and 0.25 mg.

Table 12: Phosphorus Rate and Placement Effect on Seed Weight for Enhanced Canola Production with Improved Phosphorus Fertilizer Management in 2016 & 2017.

	Indian Head		Melfort		Scott	
	2016[x]	2017[x]	2016[x]	2017[x]	2016[x]	2017[x]
Placement (P)	0.013*	0.635	0.074	0.673	0.527	0.764
Rate (R)	0.280	0.032*	0.032*	0.845	0.309	0.880
P * R	0.807	0.446	0.377	0.870	0.568	0.439
Grand Mean	3.0	3.1	3.0	3.4	3.0	3.1
CV	2.0	2.4	7.1	4.6	2.7	2.4

[x] ** p<0.01; *p<0.05

Green seed values were affected by placement and rate at ME-16 and placement, rate, and placement by rate at SC-16 (Table 13). As expected, there was considerable variability between treatment means. At Indian Head, an average of 10% green seed was found in 2016, while in 2017 there was none. In Melfort, 4 and 1% green seed were found in 2016 and 2017, respectfully. At Scott, the green seed values were significantly higher in 2017 (47%) than in 2016 (5%). Overall green seed was very low at all trials so treatment effects may be of little practical significance.

Table 13: Phosphorus Rate and Placement Effect on Green Seed for Enhanced Canola Production with Improved Phosphorus Fertilizer Management in 2016 & 2017.

	Indian Head		Melfort		Scott	
	2016[x]	2017[x]	2016[x]	2017[x]	2016[x]	2017[x]
Placement (P)	0.157	0.603	0.001**	0.079	<0.001***	0.869
Rate (R)	0.128	0.690	0.001**	0.364	0.001**	0.535
P * R	0.630	0.722	0.742	0.959	0.003**	0.310
Grand Mean	0.10	0.00	0.04	0.01	0.05	0.47
CV	160.7	715.8	57	121	42.3	64.3

[x] ** p<0.01; *p<0.05

At ME16, green seed doubled between the P-SP and P+15S-SP treatments. At SC16, green seed did double between the P+15S-SP treatment and P-SB, but only increased by 1% between the P+15S-SP and P-SP treatment. At Melfort, phosphorus application decreased green seed counts by half (6 vs 3%), whereas at Scott, they were increased with P application up to 4% (3 vs 7%). In Scott, where there was a significant interaction, there tended to be less % green seed in the lower phosphorus rate treatments and when p was side-banded.

Summary and Conclusions:

Plant populations declined significantly as P rates increased with the P-SP and the P+15S-SP treatments but not with the P-SB placement. The level of the damage from P-SP and P+15S-SP varied across location years, from rather extensive damage at Scott in 2016 to limited or no damage at some other locations. Damage from these two placement methods was evident at 2, 4, and 6 weeks after seeding as well as post-harvest. There was some indication that damage diminished at later evaluation timing, particularly with the P+15S-SP placement at high rates of P. It was also apparent that the damaging effects of seed placed P and S were additive. Results to date also suggest that damage in these trials from seed placed P alone may not be as great as in initial studies used to establish safe seed placed rates. This may reflect the greater seedbed utilization with the hoe type openers used in these trials compared with disc type openers used in earlier trials.

Biomass production increased with phosphorus fertilizer application rates and was greatest when applied in a side-band. There also was an indication that biomass production may decrease at high rates when seed-placed alone or with sulfur. There was also a trend for the biomass values to reflect the final in-crop plant population assessment.

In general, tissue P levels increased with fertilizer P application rates, as expected. Tissue phosphorus concentrations tended to be higher in the seed-placed treatments than in the side-band placements. This may be a reflection of lower plant densities with seed placed treatments meaning that more P was available to each plant.

In general, maturity data was very variable between the treatments and no really clear trends emerged. In most cases, treatment effects on maturity were less than one day. At some locations phosphate rates of 40 and 60 kg/ha resulted in maturity delays of 2 to 3 days. It is likely that nutrient effects of fertilizer P or S are confounded with plant density effects resulting from seed damage. At this point it is difficult to know if they are any practical significance.

Yield was largely unaffected by placement and significantly impacted by phosphorus rate. Side-banded phosphorus fertilizer resulted in yield increases of up to 263 kg/ha. Canola grain yields often increased with phosphorus application and optimal yields were often achieved between 40 and 60 kg/ha, depending on location. Therefore, if high rates of phosphorus are required, fertilizer P should be side-banded to maintain maximum yields without seed damage. This was the most consistent and beneficial application method. Quality parameters (TKW and Green Seed) were largely unaffected by treatment application however, % green seed tended to increase while TKW decreased with Seed-Placed P & AS. Higher rates of phosphorus tended to increased % green seed and mean seed weight.

Overall, it appears that the optimal phosphorus management may be changing for growing canola in Saskatchewan. After two-years it appears that phosphorus fertilizer should be side-banded, especially when high rates are required. Furthermore, the effects of applying sulphur in the seed row appear to be detrimental to crop establishment and are additive to damage caused by seed row phosphorus.

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This project was featured as a part of the 2017 Joint Annual Field Day at the Melfort Research Farm and was presented by Jessica Weber. Jessica Weber also presented this trial at the 2016 Soils and Crops Conference at Saskatoon in March and at the 2017 Agri-ARM update at the Western Canadian Crop Production Show in January.

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Table A1: Seeding and harvest dates at Melfort, Indian Head, and Scott, SK for Enhanced Canola Production with Improved Phosphorus Fertilizer Management in 2016 & 2017.

Location	Seeded		Harvested	
	2016	2017	2016	2017
Indian Head	May 17	May 13	September 13	September 3
Melfort	May 18	May 30	September 20	September 18
Scott	May 11	May 11	September 1	August 30

Table A2: Fertilizer Rates, Products, and Placement for Enhanced Canola Production with Improved Phosphorus Fertilizer Management in 2016 & 2017.

Location	Nitrogen			Potassium			Sulphur		
	Rate (kg/ha)	Product	Placement	Rate (kg/ha)	Product	Placement	Rate (kg/ha)	Product	Placement
				--- 2016 ---					
Indian Head	135	46-0-0	Side-band	49	0-0-53-18	Broadcast	17	0-0-53-18	Broadcast
Melfort	146	46-0-0	Side-band	56	0-0-50-17	Broadcast	19	0-0-50-17	Broadcast
Scott	NA	NA	NA	NA	NA	NA	NA	NA	NA
				--- 2017 ---					
Indian Head	135	46-0-0	Side-band	55	0-0-53-18	Broadcast	19	0-0-53-18	Broadcast
Melfort	153	46-0-0	Side-band	0	NA	NA	15	21-0-0-24	Broadcast
Scott	188	46-0-0	Side-band	165	0-0-50-17	Midrow	NA	NA	NA

Table A3: Herbicide and Desiccant Applications for Enhanced Canola Production with Improved Phosphorus Fertilizer Management in 2016 & 2017.

Location	Pre-Emerge Herbicide			In-Crop Herbicide			Desiccant		
	Product	Rate	Date	Product	Rate	Date	Product	Rate	Date
--- 2016 ---									
Indian Head	Roundup Transorb HC	0.67 L/ac	May 15	Liberty Centurion & Amigo	1.6 L 50 mL & 10 gal/ac	June 15 June 15	Roundup Transorb HC	0.67 L/ac	August 25
Melfort	NA			Liberty	1.6 L/ac	NA	Reglone	0.7 L/ac	NA
Scott	Roundup RT540	0.75 L/ac	NA	Liberty Centurion & Amigo	1.08 L/ac 25.5 mL/ac & 0.5 L	June 13 June 13	Reglone	0.69 L/ac	August 24
--- 2017 ---									
Indian Head	StartUp	0.67 L/ac	May 10	Lontrel 360 Liberty Centurion	225 mL/ac 1.6 L/ac 78 mL/ac	June 6 June 18 June 18	Startup	0.67 L/ac	August 20
Melfort	NA			Liberty Centurion & Amigo	1.35 L/ac 77 mL/ac & 0.5 L	July 5	Roundup Transorb	0.67 L/ac	September 6
Scott	Roundup RT540 Bromoxynil	0.75 L/ac 0.4 L/ac	May 6 May 6	Liberty Liberty Centurion & Amigo	0.81 L/ac 0.61 L/ac 75 mL/ac & 0.5 L	June 7 June 20 June 20	Reglone	0.83 L/ac	August 23

Table A4: Fungicide and Insecticide Applications for Enhanced Canola Production with Improved Phosphorus Fertilizer Management in 2016.

Location	Insecticide			Fungicide		
	Product	Rate	Date	Product	Rate	Date
			--- 2016 ---			
Indian Head	NA			Lance	142 g/ac	July 5
Melfort	NA			Lance	140 g/ac	July 5
Scott	Matador	34 ml/ac	June 23	Priaxor	120 mL/ac	June 29
			--- 2017 ---			
Indian Head	NA			Lance Headline 250 EC	140 g/ac 0.13 L/ac	July 5
Melfort	NA			Acapella	350 mL/ac	July 18
Scott	Decis Decis	40 ml/ac 40 ml/ac	May 29 August 7	Priaxor	180 mL/ac	July 8

APPENDIX B

Table B1. Influence of Fertilizer P Rate and Placement on Canola Plant Densities (number per M2) at 2 weeks after seeding at Melfort, Indian Head and Scott in 2016 and 2017.

	Melfort		**Indian Head**		**Scott**		**All**
Treatment	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**Years**
0P-SB	44.7	101.3	96.8	70.5	53.6	109.7	79.4
20P-SB	46.3	74.6	90.0	63.6	32.0	105.8	68.7
40P-SB	43.9	93.5	102.3	69.7	41.8	93.0	74.0
60P-SB	47.2	87.8	85.3	70.5	49.7	105.3	74.3
80P-SB	52.5	82.4	92.7	61.9	33	113.7	72.7
0P-SP	34.0	91.0	97.0	63.2	37.9	106.3	71.6
20P-SP	49.6	72.6	92.7	75.9	31.0	88.1	68.3
40P-SP	41.0	72.2	88.4	65.2	26.6	89.1	63.8
60P-SP	45.5	60.7	89.0	48.0	23.6	82.7	58.3
80P-SP	23.0	70.1	88.0	46.3	3.9	61.5	48.8
15S+0P-SP	36.9	100.9	97.6	56.6	25.6	67.9	64.3
15S+20P-SP	36.5	57.0	100.7	64.4	20.7	78.7	59.7
15S+40P-SP	34.0	81.6	79.8	42.2	15.7	76.3	54.9
15S+60P-SP	25.0	53.7	87.8	56.6	12.3	62.5	49.7
15S+80P-SP	21.3	56.2	75.3	32.4	7.4	68.4	43.5
All P-SB	***46.6***	***87.9***	***93.4***	***67.2***	***42.0***	***105.5***	***73.8***
All P-SP	***38.6***	***73.3***	***91.0***	***58.7***	***24.6***	***85.5***	***62.0***
All 15S+P-SP	***30.8***	***69.9***	***88.2***	***50.4***	***16.3***	***70.8***	***54.4***
All 0P	***38.5***	***97.7***	***97.1***	***63.4***	***39.0***	***94.6***	***71.8***
All 20P	***44.1***	***68.1***	***94.5***	***68.0***	***27.9***	***90.9***	***65.6***
All 40P	***39.6***	***82.4***	***90.2***	***59.0***	***28.0***	***86.1***	***64.2***
All 60P	***39.2***	***67.4***	***87.4***	***58.4***	***28.5***	***83.5***	***60.7***
All 80P	***32.3***	***69.6***	***85.3***	***46.9***	***14.8***	***81.2***	***55.0***

Table B2. Influence of Fertilizer P Rate and Placement on Canola Plant Densities (number per M2) at 4 weeks after seeding at Melfort, Indian Head and Scott in 2016 and 2017.

	Melfort		Indian Head		Scott		All
Treatment	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**Years**
0P-SB	45.9	101.7	93.7	74.6	56.1	98.4	78.4
20P-SB	49.6	90.2	89.0	70.9	42.8	115.2	76.3
40P-SB	41.8	87.8	94.5	69.3	56.6	95.0	74.2
60P-SB	46.3	78.3	83.7	80.4	62.5	96.9	74.7
80P-SB	45.4	86.9	90.8	65.6	47.7	106.3	73.8
0P-SP	37.3	106.2	90.4	68.5	49.2	92.5	74.0
20P-SP	43.5	87.4	88.2	79.6	48.2	82.7	71.6
40P-SP	38.5	70.5	89.0	70.1	38.9	94.5	66.9
60P-SP	41.4	77.1	91.5	57.0	35.4	74.3	62.8
80P-SP	22.1	77.1	84.5	56.6	22.1	60.4	53.8
15S+0P-SP	42.2	104.2	94.3	64.0	42.3	74.3	70.2
15S+20P-SP	32.4	70.9	100.3	73.4	36.4	75.3	64.8
15S+40P-SP	33.2	87.8	85.1	51.3	29.0	81.2	61.3
15S+60P-SP	21.7	68.1	85.9	70.1	20.7	67.9	55.7
15S+80P-SP	20.1	69.3	76.5	41.8	18.7	72.8	49.9
All P-SB	***45.8***	***89.0***	***90.3***	***72.2***	***53.1***	***102.4***	***75.5***
All P-SP	***36.6***	***83.7***	***88.7***	***66.4***	***38.8***	***80.9***	***65.9***
All 15S+P-SP	***29.9***	***80.1***	***88.4***	***60.1***	***29.4***	***74.3***	***60.4***
All 0P	***41.8***	***104.0***	***92.8***	***69.0***	***49.2***	***88.4***	***74.2***
All 20P	***41.8***	***82.8***	***92.5***	***74.6***	***42.5***	***91.1***	***70.9***
All 40P	***37.8***	***82.0***	***89.5***	***63.6***	***41.5***	***90.2***	***67.5***
All 60P	***36.5***	***74.5***	***87.0***	***69.2***	***39.5***	***79.7***	***64.4***
All 80P	***29.2***	***77.8***	***83.9***	***54.7***	***29.5***	***79.8***	***59.2***

Table B3. Influence of Fertilizer P Rate and Placement on Canola Plant Densities (number per M2) at 6 weeks after seeding at Melfort, Indian Head and Scott in 2016 and 2017.

	Melfort		Indian Head		Scott		All
Treatment	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**Years**
0P-SB	52.5	54.5	95.8	77.1	61.5	**91.5**	72.2
20P-SB	50.4	55.0	91.7	69.7	43.8	100.4	68.5
40P-SB	46.3	59.9	92.1	77.1	61.5	87.6	70.8
60P-SB	47.2	59.5	82.8	81.6	62.0	92	70.9
80P-SB	42.7	58.6	88.6	61.1	52.7	105.8	68.2
0P-SP	40.6	41.8	89.4	66.0	54.1	88.1	63.3
20P-SP	40.2	46.3	88.2	79.6	58.1	78.7	65.2
40P-SP	38.6	47.6	88.8	74.2	45.3	79.2	62.3
60P-SP	43.5	47.6	91.2	58.6	40.4	78.2	59.9
80P-SP	29.1	49.6	82.8	56.2	21.7	57.1	49.4
15S+0P-SP	38.5	68.9	92.3	72.2	45.8	78.2	66.0
15S+20P-SP	32.8	39.0	98.6	69.7	37.4	75.8	58.9
15S+40P-SP	40.2	52.9	81.8	58.2	32.0	78.7	57.3
15S+60P-SP	27.5	38.1	88.2	67.3	25.1	64	51.7
15S+80P-SP	23.4	42.2	71.8	41	22.6	72.8	45.6
All P-SB	***48.1***	***57.5***	***90.2***	***73.3***	***65.3***	***95.5***	***71.7***
All P-SP	***38.4***	***46.6***	***88.1***	***66.9***	***43.9***	***76.3***	***60.0***
All 15S+P-SP	***32.5***	***48.2***	***86.5***	***61.7***	***32.6***	***73.9***	***55.9***
All 0P	***43.9***	***55.1***	***92.5***	***71.8***	***53.8***	***85.9***	***67.2***
All 20P	***41.1***	***46.8***	***92.8***	***73.0***	***46.4***	***85.0***	***64.2***
All 40P	***41.7***	***53.5***	***87.6***	***69.8***	***35.6***	***81.8***	***61.7***
All 60P	***39.4***	***48.4***	***87.4***	***69.2***	***43.0***	***78.1***	***60.9***
All 80P	***31.7***	***50.1***	***81.1***	***52.8***	***32.3***	***78.6***	***54.4***

Table B4. Influence of Fertilizer P Rate and Placement on Post Harvest Canola Plant Densities (number per M2) at Melfort, Indian Head and Scott in 2016 and 2017.

	Melfort		**Indian Head**		**Scott**		**All**
Treatment	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**Years**
0P-SB	51.3	82.4	77.9	84.5	48.2	96.9	73.5
20P-SB	58.6	88.6	75.0	93.9	45.8	98.4	76.7
40P-SB	41.8	80.0	88.2	78.7	47.7	89.6	71.0
60P-SB	45.1	72.2	75.5	73	59.1	90.6	69.3
80P-SB	54.1	60.3	77.5	92.7	49.2	100.4	72.4
0P-SP	43.1	82.4	80.0	87.8	54.6	90.1	73.0
20P-SP	46.3	82.0	83.9	83.7	51.2	82.2	71.6
40P-SP	90.6	90.6	77.3	76.3	33.5	86.6	75.8
60P-SP	32.8	77.9	80.4	69.7	38.4	84.2	63.9
80P-SP	35.3	59.9	72.2	61.1	27.1	62	52.9
15S+0P-SP	41.8	77.5	77.7	80.0	36.4	73.3	64.5
15S+20P-SP	43.5	68.5	86.5	83.3	33.0	82.7	66.3
15S+40P-SP	40.6	72.2	75.5	66.4	25.6	76.3	59.4
15S+60P-SP	46.3	78.7	75	59.9	31.5	68.4	60.0
15S+80P-SP	30.8	69.7	74.8	63.2	20.7	77.8	56.2
All P-SB	***50.0***	***76.7***	***78.8***	***84.6***	***50.0***	***85.2***	***70.9***
All P-SP	***49.6***	***78.6***	***78.7***	***75.7***	***40.9***	***81.0***	***67.4***
All 15S+P-SP	***40.6***	***73.3***	***79.9***	***70.5***	***29.4***	***75.7***	***61.6***
All 0P	***45.4***	***80.8***	***78.5***	***84.1***	***46.4***	***86.8***	***70.3***
All 20P	***49.5***	***79.7***	***81.8***	***87.0***	***43.3***	***87.8***	***71.5***
All 40P	***57.7***	***80.9***	***80.3***	***73.8***	***35.6***	***84.2***	***68.8***
All 60P	***41.4***	***76.3***	***77.0***	***67.5***	***43.0***	***81.1***	***64.4***
All 80P	***40.1***	***63.3***	***74.8***	***72.3***	***32.3***	***80.1***	***60.5***

Table B5. Influence of Fertilizer P Rate and Placement on Canola Plant biomass (kg/ha) at Melfort, Indian Head and Scott in 2016 and 2017.

	Melfort		**Indian Head**		**Scott**		**All**
Treatment	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**Years**
0P-SB	43.3	32.4	122.4	228.6	54.5	75.9	92.9
20P-SB	72.1	44.4	134.3	221.5	51.8	78.3	100.4
40P-SB	72.1	41.8	161.4	200.2	68.5	103.7	108.0
60P-SB	98.5	37.5	151.3	276.4	71.0	92.9	121.3
80P-SB	121.7	44.6	157.1	236.3	54.6	97.3	118.6
0P-SP	49.8	34.1	136.5	193.9	54.9	84.1	92.2
20P-SP	73.2	38.6	165.9	269.9	48.3	74.7	111.8
40P-SP	83.3	39.3	168.9	267.3	43.8	80.2	113.8
60P-SP	111.9	33.6	166.8	251.5	45.5	77.5	114.5
80P-SP	71.8	39.5	161.0	189.5	23.4	67.0	92.0
15S+0P-SP	38.4	40.8	130.8	206.2	39.2	63.9	86.6
15S+20P-SP	76.9	34.8	156.7	240.8	40.9	95.0	107.5
15S+40P-SP	81.7	40.8	140.4	191.5	41.7	84.7	96.8
15S+60P-SP	71.1	38.3	161.7	245.1	30.5	69.2	102.7
15S+80P-SP	60.2	44.5	160.9	163.5	23.2	73.6	87.7
All P-SB	***79.4***	***40.1***	***145.3***	***232.6***	***60.1***	***89.6***	***107.9***
All P-SP	***78.0***	***37.0***	***159.8***	***234.4***	***43.2***	***76.7***	***104.9***
All 15S+P-SP	***65.7***	***39.8***	***150.1***	***209.4***	***35.1***	***77.2***	***96.2***
All 0P	***43.8***	***35.8***	***129.9***	***209.6***	***49.5***	***74.6***	***90.5***
All 20P	***74.1***	***39.3***	***152.3***	***244.1***	***47.0***	***82.7***	***106.6***
All 40P	***79.0***	***40.6***	***156.9***	***219.7***	***51.3***	***89.5***	***106.2***
All 60P	***93.8***	***36.5***	***159.9***	***257.7***	***49.0***	***79.9***	***112.8***
All 80P	***84.6***	***42.9***	***159.7***	***196.4***	***33.7***	***79.3***	***99.4***

Table B6. Influence of Fertilizer P Rate and Placement on Canola Plant Biomass P Concentration (%) at Melfort, Indian Head and Scott in 2016 and 2017.

Treatment	**Melfort**		**Indian Head**		**Scott**		**All**
	2016	**2017**	**2016**	**2017**	**2016**	**2017**	**Years**
0P-SB	0.275	0.410	0.375	0.548	0.368	0.398	0.396
20P-SB	0.313	0.403	0.403	0.613	0.403	0.443	0.430
40P-SB	0.383	0.388	0.458	0.595	0.415	0.433	0.445
60P-SB	0.408	0.413	0.448	0.608	0.440	0.470	0.465
80P-SB	0.410	0.413	0.473	0.668	0.455	0.475	0.482
0P-SP	0.275	0.383	0.403	0.578	0.355	0.398	0.399
20P-SP	0.275	0.425	0.435	0.578	0.385	0.443	0.424
40P-SP	0.383	0.398	0.430	0.628	0.418	0.455	0.452
60P-SP	0.348	0.410	0.473	0.645	0.428	0.483	0.465
80P-SP	0.340	0.380	0.490	0.658	0.498	0.510	0.479
15S+0P-SP	0.288	0.395	0.398	0.575	0.385	0.413	0.409
15S+20P-SP	0.298	0.423	0.383	0.615	0.400	0.445	0.427
15S+40P-SP	0.325	0.398	0.488	0.598	0.428	0.460	0.450
15S+60P-SP	0.365	0.420	0.473	0.633	0.448	0.510	0.475
15S+80P-SP	0.403	0.428	0.530	0.638	0.488	0.513	0.500
All P-SB	***0.355***	***0.405***	***.431***	***0.606***	***0.416***	***0.444***	***0.443***
All P-SP	***0.324***	***0.399***	***.446***	***0.617***	***0.417***	***0.458***	***0.444***
All 15S+P-SP	***0.336***	***0.413***	***0.454***	***0.612***	***0.430***	***0.468***	***0.452***
All 0P	***0.279***	***0.396***	***0.392***	***0.567***	***0.369***	***0.403***	***0.401***
All 20P	***0.295***	***0.417***	***0.407***	***0.602***	***0.396***	***0.444***	***0.427***
All 40P	***0.364***	***0.395***	***0.459***	***0.607***	***0.420***	***0.449***	***0.449***
All 60P	***0.374***	***0.414***	***0.465***	***0.629***	***0.439***	***0.488***	***0.468***
All 80P	***0.384***	***0.407***	***0.498***	***0.655***	***0.480***	***0.499***	***0.487***

Table B7. Influence of Fertilizer P Rate and Placement on Canola Plant P uptake (kg/ha of P) at Melfort, Indian Head and Scott in 2016 and 2017.

Treatment	Melfort		Indian Head		Scott		All
	2016	2017	2016	2017	2016	2017	Years
0P-SB	0.119	0.133	0.459	1.253	0.201	0.302	0.367
20P-SB	0.226	0.179	0.541	1.358	0.209	0.347	0.431
40P-SB	0.276	0.162	0.739	1.191	0.284	0.449	0.481
60P-SB	0.402	0.155	0.678	1.681	0.312	0.437	0.563
80P-SB	0.499	0.184	0.743	1.578	0.248	0.462	0.572
0P-SP	0.137	0.131	0.550	1.121	0.195	0.335	0.368
20P-SP	0.201	0.164	0.722	1.560	0.186	0.331	0.473
40P-SP	0.319	0.156	0.726	1.679	0.183	0.365	0.514
60P-SP	0.389	0.138	0.789	1.622	0.195	0.374	0.532
80P-SP	0.244	0.150	0.789	1.247	0.117	0.342	0.441
15S+0P-SP	0.111	0.161	0.521	1.186	0.151	0.264	0.354
15S+20P-SP	0.229	0.147	0.600	1.481	0.164	0.423	0.459
15S+40P-SP	0.266	0.162	0.685	1.145	0.178	0.390	0.435
15S+60P-SP	0.260	0.161	0.765	1.551	0.137	0.353	0.487
15S+80P-SP	0.243	0.190	0.853	1.043	0.113	0.378	0.438
All P-SB	***0.282***	***0.162***	***0.626***	***1.410***	***0.250***	***0.398***	***0.478***
All P-SP	***0.253***	***0.148***	***0.713***	***1.446***	***0.180***	***0.351***	***0.465***
All 15S+P-SP	***0.221***	***0.164***	***0.681***	***1.282***	***0.151***	***0.361***	***0.435***
All 0P	***0.122***	***0.142***	***0.509***	***1.188***	***0.183***	***0.301***	***0.363***
All 20P	***0.219***	***0.164***	***0.620***	***1.469***	***0.186***	***0.367***	***0.455***
All 40P	***0.287***	***0.160***	***0.720***	***1.333***	***0.216***	***0.402***	***0.477***
All 60P	***0.351***	***0.151***	***0.743***	***1.620***	***0.215***	***0.389***	***0.528***
All 80P	***0.325***	***0.174***	***0.795***	***1.286***	***0.162***	***0.396***	***0.484***

Table B8. Influence of Fertilizer P Rate and Placement on Days to Mature of Canola at Melfort, Indian Head and Scott in 2016 and 2017.

Treatment	Melfort		Indian Head		Scott		All
	2016	2017	2016	2017	2016	2017	Years
0P-SB	103.0	92.0	97.4	98.5	101.3	99.3	98.6
20P-SB	103.0	92.0	97.1	97.9	100.8	101	98.6
40P-SB	103.0	92.0	97.1	97.5	100.3	97.5	97.9
60P-SB	103.0	92.0	97.1	97.8	103.8	100	99.0
80P-SB	103.0	92.0	97.4	97.6	101.5	100	98.6
0P-SP	103.0	92.0	97.4	98.5	98.5	98.8	98.0
20P-SP	103.0	92.0	97.3	97.1	99.5	100.5	98.2
40P-SP	103.0	92.0	97.4	97.4	98.5	99.5	98.0
60P-SP	103.0	92.0	97.8	98.1	102.8	100.8	99.1
80P-SP	103.0	92.0	97.4	98	102.8	100.5	99.0
15S+0P-SP	103.0	92.0	97.4	98.4	102.3	100.3	98.9
15S+20P-SP	103.0	92.0	97.5	98.1	101.5	99.5	98.6
15S+40P-SP	103.0	92.0	97.6	98.5	103.5	101.3	99.3
15S+60P-SP	103.0	92.0	97.8	98	103	100.5	99.1
15S+80P-SP	103.0	92.0	97.8	99	103.5	101.8	99.5
All P-SB	***103.0***	***92.0***	***97.2***	***97.9***	***101.5***	***99.6***	***98.5***
All P-SP	***103.0***	***92.0***	***97.4***	***97.8***	***100.4***	***100***	***98.4***
All 15S+P-SP	***103.0***	***92.0***	***97.6***	***98.4***	***102.8***	***100.7***	***99.1***
All 0P	***103.0***	***92.0***	***97.4***	***98.5***	***100.7***	***99.5***	***98.5***
All 20P	***103.0***	***92.0***	***97.3***	***97.7***	***100.6***	***100.3***	***98.5***
All 40P	***103.0***	***92.0***	***97.4***	***97.8***	***100.8***	***99.4***	***98.4***
All 60P	***103.0***	***92.0***	***97.6***	***98.0***	***103.2***	***100.4***	***99.0***
All 80P	***103.0***	***92.0***	***97.5***	***98.2***	***102.6***	***100.8***	***99.0***

Table B9. Influence of Fertilizer P Rate and Placement on Canola Grain yield (kg/ha) at Melfort, Indian Head and Scott in 2016 and 2017.

	Melfort		Indian Head		Scott		All
Treatment	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**Years**
0P-SB	2820	2562	3588	3107	3708	3619	3234
20P-SB	3060	2411	3586	3309	3910	3620	3316
40P-SB	3493	2846	3592	3215	3900	3714	3460
60P-SB	3760	2424	3608	3363	4058	3830	3507
80P-SB	3763	2770	3627	3324	4023	3902	3568
0P-SP	2745	2740	3642	3191	3893	3481	3282
20P-SP	2926	2857	3528	3318	3811	3704	3357
40P-SP	3466	2921	3660	3265	3795	3778	3481
60P-SP	3385	3064	3549	3392	3800	3877	3511
80P-SP	3535	2244	3655	3402	3584	3788	3368
15S+0P-SP	2347	2580	3676	3151	3690	3752	3199
15S+20P-SP	3167	2483	3675	3320	3860	3575	3347
15S+40P-SP	3168	2454	3591	3276	3591	3759	3307
15S+60P-SP	3380	2879	3621	3425	3635	3722	3444
15S+80P-SP	3164	2958	3765	3414	3507	3773	3430
All P-SB	***3359***	***2603***	***3600***	***3264***	***3920***	***3737***	***3414***
All P-SP	***3211***	***2765***	***3607***	***3314***	***3776***	***3726***	***3400***
All 15S+P-SP	***3045***	***2671***	***3666***	***3317***	***3656***	***3716***	***3345***
All 0P	***2637***	***2627***	***3635***	***3150***	***3764***	***3617***	***3238***
All 20P	***3051***	***2584***	***3596***	***3316***	***3860***	***3633***	***3340***
All 40P	***3376***	***2740***	***3614***	***3252***	***3762***	***3750***	***3416***
All 60P	***3508***	***2789***	***3593***	***3393***	***3831***	***3810***	***3487***
All 80P	***3487***	***2657***	***3682***	***3380***	***3705***	***3821***	***3455***

Table B10. Influence of Fertilizer P Rate and Placement on Canola Seed Weight (mg) at Melfort, Indian Head and Scott in 2016 and 2017.

	Melfort		Indian Head		Scott		All
Treatment	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**Years**
0P-SB	2.85	3.45	3.04	3.04	2.99	3.11	3.08
20P-SB	2.9	3.47	3.03	3.06	2.96	3.08	3.08
40P-SB	3.1	3.39	3.07	3.2	3.01	3.11	3.15
60P-SB	3.1	3.46	3.09	3.12	3.02	3.1	3.15
80P-SB	3.2	3.48	3.07	3.16	2.96	3.16	3.17
0P-SP	2.9	3.52	3.06	3.17	3.04	3.07	3.13
20P-SP	3	3.36	2.98	3.07	3	3.11	3.09
40P-SP	3.35	3.44	3.06	3.15	2.94	3.12	3.18
60P-SP	3.15	3.35	3.06	3.12	2.99	3.12	3.13
80P-SP	3.1	3.45	3.06	3.13	2.95	3.08	3.13
15S+0P-SP	2.8	3.45	3.02	3.09	2.98	3.15	3.08
15S+20P-SP	3.05	3.41	2.99	3.08	3.02	3.1	3.11
15S+40P-SP	2.85	3.53	2.97	3.14	2.88	3.07	3.07
15S+60P-SP	3	3.46	3.01	3.13	2.96	3.04	3.10
15S+80P-SP	3	3.48	3.02	3.18	2.96	3.11	3.13
All P-SB	***3.02***	***3.45***	***3.06***	***3.12***	***2.99***	***3.11***	***3.13***
All P-SP	***3.10***	***3.42***	***3.04***	***3.13***	***2.98***	***3.10***	***3.13***
All 15S+P-SP	***2.94***	***3.47***	***3.00***	***3.12***	***2.96***	***3.09***	***3.10***
All 0P	***2.85***	***3.47***	***3.04***	***3.10***	***3.00***	***3.11***	***3.10***
All 20P	***2.98***	***3.41***	***3.00***	***3.07***	***2.99***	***3.10***	***3.09***
All 40P	***3.10***	***3.45***	***3.03***	***3.16***	***2.94***	***3.10***	***3.13***
All 60P	***3.08***	***3.42***	***3.05***	***3.12***	***2.99***	***3.09***	***3.13***
All 80P	***3.10***	***3.47***	***3.05***	***3.16***	***2.96***	***3.12***	***3.14***

Table B11. Influence of Fertilizer P Rate and Placement on Green Seed (%) of canola at Melfort, Indian Head and Scott in 2016 and 2017.

	Melfort		Indian Head		Scott		All
Treatment	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**Years**
0P-SB	0.045	0.015	0.15	0.002	0.034	0.15	0.066
20P-SB	0.015	0.018	0.05	0.001	0.034	0.7	0.136
40P-SB	0.028	0.013	0.05	0.001	0.04	0.4	0.089
60P-SB	0.018	0.005	0	0	0.023	0.5	0.091
80P-SB	0.030	0.018	0.2	0.002	0.02	0.6	0.145
0P-SP	0.05	0.005	0.1	0.002	0.033	0.45	0.107
20P-SP	0.028	0.008	0.05	0.001	0.03	0.5	0.103
40P-SP	0.018	0.003	0.05	0.004	0.049	0.65	0.129
60P-SP	0.025	0.003	0.05	0.002	0.05	0.3	0.072
80P-SP	0.015	0.008	0.05	0.001	0.07	0.55	0.116
allP-SP	0.027	0.005	0.06	0.002	0.046	0.49	0.105
15S+0P-SP	0.09	0.005	0.05	0.001	0.038	0.4	0.097
15S+20P-SP	0.053	0.013	0	0	0.05	0.35	0.078
15S+40P-SP	0.05	0.01	0.05	0.002	0.075	0.5	0.115
15S+60P-SP	0.053	0.01	0	0.001	0.046	0.6	0.118
15S+80P-SP	0.035	0.02	0.05	0.001	0.114	0.35	0.095
All P-SB	***0.027***	***0.014***	***0.09***	***0.001***	***0.03***	***0.47***	***0.105***
All P-SP	***0.027***	***0.005***	***0.06***	***0.002***	***0.046***	***0.49***	***0.105***
All 15S+P-SP	***0.056***	***0.012***	***0.03***	***0.001***	***0.065***	***0.44***	***0.101***
All 0P	***0.062***	***0.008***	***0.100***	***0.002***	***0.035***	***0.333***	***0.090***
All 20P	***0.032***	***0.013***	***0.033***	***0.001***	***0.038***	***0.517***	***0.106***
All 40P	***0.032***	***0.009***	***0.050***	***0.002***	***0.055***	***0.517***	***0.111***
All 60P	***0.032***	***0.006***	***0.017***	***0.001***	***0.040***	***0.467***	***0.094***
All 80P	***0.027***	***0.015***	***0.100***	***0.001***	***0.068***	***0.500***	***0.119***