PROJECT DETAILS

- **Funders:** Alberta Canola and Manitoba Canola Growers
- **Research program:** Canola Agronomic Research Program
- **Principal investigator:** Ken Coles
- **Collaborators/additional investigators:** Lewis Baarda and Michael Gretzinger
- **Year completed:** 2019

Final report

Study background and objectives

Despite the availability of high-quality (> 90% germination) seeds for Canola, the initial crop establishment in the field has often been found to be variable and low. Under field conditions, only 40-60% of Canola seeds emerge to form seedlings (Harker et al 2003; 2012). The seedling emergence and survival may be even lower under poor agronomic conditions such as draught, low temperatures, high seed depth (exceeding 2.5 cm), or low seed vigor. Since the canola seed is a substantial input cost for the producers, reliable improvements in crop establishment can result in significant savings for the producers. Precision planters (row crop planters) are increasingly being used to seed canola, particularly in the regions where they have already been used for seeding corn soybeans drybeans and sugarbeets. Precision planters provide superior depth control and seed placement at precise distances along the row compared to the conventional seeders, and thus have the potential to improve the proportion, uniformity and rapidity of canola emergence.

Earlier crop emergence combined with a regular planting arrangement can lead to an increase in the seed yield of Canola (Yang et al 2014). Rapid emergence of a uniform canola stand with optimum plant density also promotes earlier flowering and maturity, which can increase potential yield, reduce the risk of fall frost, and reduce green seed (Harker et al., 2012). Optimal plant establishment also increases crop competitiveness to weeds and reduces the requirement for herbicide application (Harker et al., 2012). Precision planters also have the ability to reduce the amount of crop residues present on the seed row. This may reduce the risk of spring frost damage due to higher temperatures in the vicinity of the seedling and reduced frost bridging between seedlings and crop residues. Reduced risk of spring frost may also enable earlier emergence of seedlings, which leads to improvement in yield potential, particularly in the regions where high temperatures typically develop during the flowering period.

In order to determine the efficiency of precision planter compared to conventional seeder for seeding canola, Farming Smarter conducted field experiments at three locations across southern Alberta from 2016 to 2019 to determine the influence of precision planters (12" and 20" rows) and conventional air drill on crop establishment and yield in canola at five different seeding rates (20, 40, 60, 80 and 160 seed/m2).

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The objectives of the study were the following -

1. Determine the effect of precision planter at two seeding-row widths (12" and 20") compared to the conventional seeder on canola emergence, growth and yield.

2. Determine the optimum seeding rate for seeding canola using precision planters (12" and 20") and conventional air drill

3. Determine the optimum seed-safe rate of in-row liquid P application to canola when using precision planter

Methodology

Farming Smarter conducted field experiments in southern Alberta under dryland conditions at Lethbridge (LB) and Medicine Hat (MH), and under irrigated conditions at Lethbridge (IR) from 2016 to 2019 for a total of 12 site-years. Lethbridge is located in the Dark Brown soil zone, while Medicine Hat is located in the Brown soil zone. The choice of these locations enabled the inclusion of a wide range of the soil moisture conditions experienced on the Canadian prairies.

Two separate field experiments were conducted at each site for each year. For the first experiment, precision planters with 12" and 20" row spacing and a conventional air drill with 12" row spacing (9.5" row spacing for 2016) were used to seed canola at five different seeding rates (20, 40, 60, 80 and 160 seed/m2). This experiment was designed as a 3x5 factorial randomised complete block design (RCBD) with a total of 15 treatments, each replicated four times in a split-plot design to reduce the impact of spatial variability on treatments of most interest. For the second experiment, precision planters (12" and 20") and air drill were used to seed canola with the in-row liquid ammonium phosphate (10-34-0) application at six different application rates (0, 5, 10, 20, 40, 60 kg/ha P). For year 2016, only five application rates of P were used, including 0, 5, 10, 20, and 40 kg/ha. For this experiment, a total of 15 treatments were again replicated four times in a completely randomized block design.

Crop emergence was determined by conducting plant counts in two 1-m rows at representative locations in each plot (front and back). These plant counts were then divided into the initial seeding rate for each treatment to determine the percent emergence for each plot. A visual evaluation of the uniformity of emergence was conducted at the 4-leaf stage for each trial. This qualitative measure rated each plot as either uniform or non-uniform based on observed uniformity of crop stage across each plot. Plant density was determined by counting plants in two, 1-m rows at two representative places (front and back) in each plot. Canopy closure was estimated using three measures - visual canopy rating, normalized difference vegetation index (NDVI) and fractional green canopy cover (FGCC). Visual canopy ratings were taken by estimating the row width vs bare ground between rows. (For example, a row where the canola was approx. 10 inches wide, with 10 inches of bar ground was 50% closure. 20 inches wide where the canola was just touching the other rows was 100%). NDVI was measured using a NTech Greenseeker. Plots were sampled at or near solar noon, in a diagonal direction across the plot. FGCC measurements were taken by using a smartphone mounted to a tripod

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using the Canapeo Android App (Patrignani and Ochsner, 2015). We also isolated plots using UAV photos and batch processed through the Canapeo software. Both methods were comparable. Visual canopy rating was less reliable compared to the NDVI and FGCC metrics and was obtained for only 5 out 12 site years. Hence the visual canopy ratings have not been discussed in the report, however, the data associated with it has been included in Appendix I. NDVI measurements were obtained for years 2016 and 2018. FGCC measurements using the Canopeo app were obtained for the years 2017-2019. Additionally, the number of days to the start and end of flowering and days to canola maturity were recorded. Canola yield was determined with plot combine harvestMaster system. The data were analyzed using the linear mixed model in SAS and R programs.

Results

Various crop establishment, growth and production metrics were obtained for Canola sown by air drill and precision planters (12" and 20"). These metrics included crop emergence (%), plant stand density, canopy closure, crop yield, and seed quality parameters etc. and are discussed in the following paragraphs.

Crop Establishment

Degree of crop emergence (%), uniformity of emergence and plant stand density were measured. Crop emergence (%) declined with increasing seeding rates (Figure 1a). This is an expected trend, since the competition for resources among the emerging seedlings increases with an increase in seeding rates, thus leading to higher seedling mortality. Crop emergence also varied notably between different planters. Emergence (%) for the precision planter (12") was 1.2-1.5 times higher compared to the air drill and 20" planter for seeding rates between 40 to 180 seeds/m2 (Figure 1). While the difference between the 12" planter and air drill was not significant at 20 seeds/m2 rate, there may have been inaccuracies in recording the number of seeds planted by the air drill and the planters at this low rate. The planters also led to more uniformity in crop staging after seedling emergence compared to the air drill. Both the planters (12" and 20") led to uniform emergence in 83% of plots across all locations. The air drill had uniform emergence in only 58% of the plots (Table 1). This trend was consistent at both the irrigated and rainfed locations. The air drill was prone to uneven emergence largely due to variable seeding depth. Differences in seeding depth led to variability in crop developmental stages, such that seeds sown at shallow depth reached the 4-leaf stage while deeper-sown seeds were still at the 2-leaf or cotyledon stage.

Plant density, which measures the number of plants/m² upon crop establishment, also varied between different planters. The three planters did not show any statistically significant difference at the lowest seed rate (20 seeds/m²), but the 12" planter led to a greater increase in plant density compared to other planters at higher seed rates (Figure 1b). Plant stand density for the 12” planter exceeded the other seeders by about 5 plants/m² at 40 and 60 seeds/m², approx.10 plants/m² at 80 seeds/m², and 15-20 plants/m² at 160 seeds/m² rate. The trends were similar across irrigated and rainfed locations, with the precision planter (12") leading to higher crop emergence and plant density compared to air drill and precision planter (20") (Figure 2). These data indicate that 12” planter provides a distinct advantage for canola emergence and plant density. While the competition between plants is low at 20 seeds/m2 rate, the inter-plant competition increases at higher seeding

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rates. Thus, at higher seeding rates, uniform seed placement and superior depth control provided by the 12" planter leads to higher emergence and plant stand establishment. The 20" planter, on the other hand, does not differ significantly from the air drill in terms of plant emergence and density. This is likely because of the larger inter-row width for 20" planter; more seeds have to be placed in each row to obtain the same seed density as other planters. Thus, higher number of seeds are placed in each row, which increases the competition between plants and is detrimental to early season canola performance.

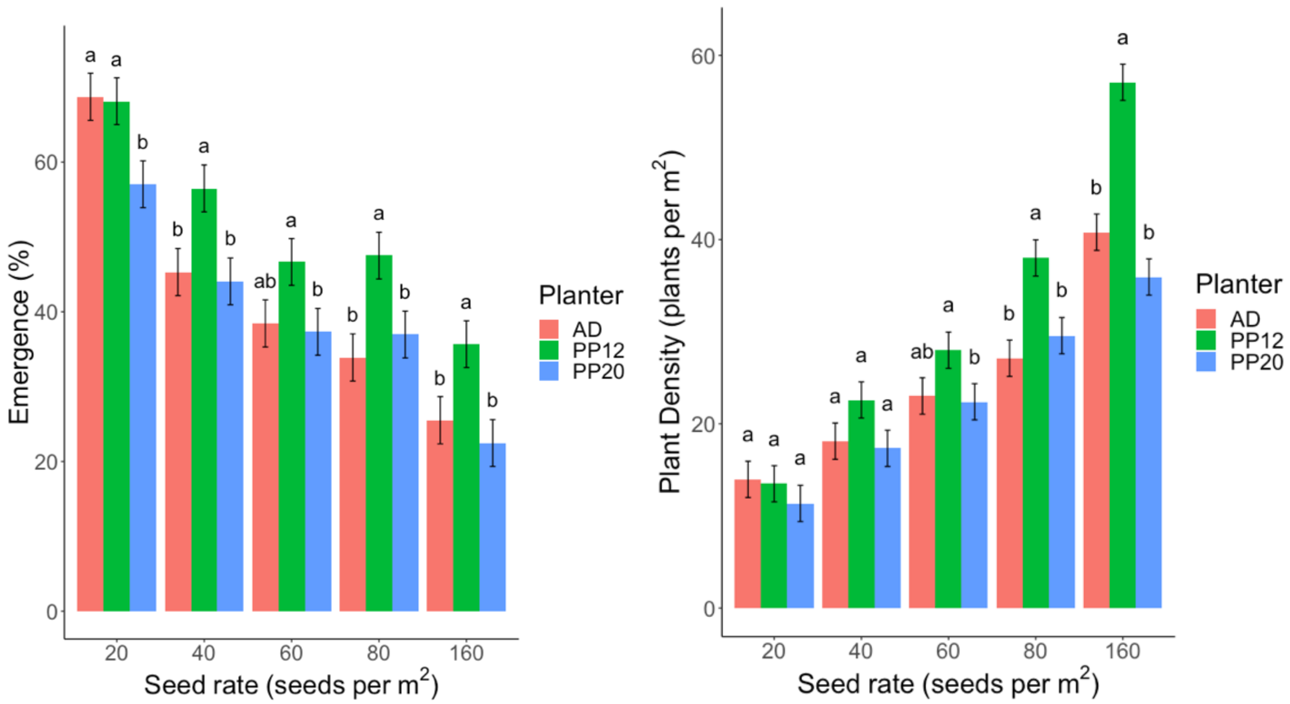

Figure 1: a) Plant emergence (%) and b) stand density (plants/m2) for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) at five different seeding rates averaged across locations (LB irrigated, LB dryland, MH) and years (2016-2019)

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Table 1. Percentage of plots with uniform emergence for the air drill and precision planters (12" & 20") at the three experiment locations.

Study locations	Air Drill	Precision Planter 12"	Precision Planter 20"
Lethbridge dryland	50%	75%	75%
Lethbridge irrigated	75%	100%	100%
Medicine Hat dryland	50%	75%	75%
Average	58%	83%	83%

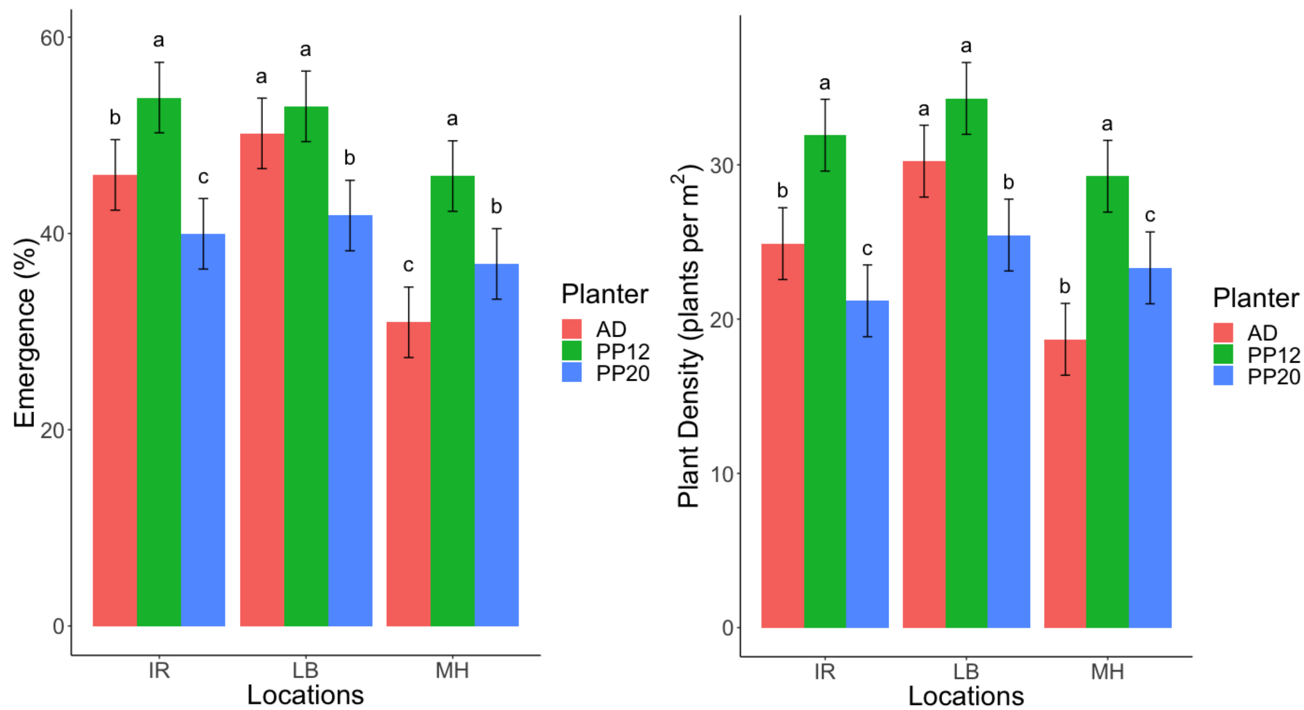

Figure 2: a) Plant emergence (%) and b) stand density (plants/m2) for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) at three locations (IR - Lethbridge irrigated, LB - Lethbridge dryland, MH - Medicine Hat) averaged across different seeding rates and study years (2016-2019)

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Growth and maturity

The effect of different planters on the canopy closure obtained by the crop was of particular interest, since the wider 12" and 20" seed rows are expected to impact the canopy closure obtained by the crop. Canopy closure was estimated using the NDVI and FGCC measurements. NDVI measurements provide a reliable proxy measurement for the photosynthetic activity of the plants. However, extraneous factors such as growth stage of the crop, weed abundance and density, and soil fertility etc. were expected to confound this measurement.

Hence, NDVI measurements were collected for only the years 2016, and 2018; and FGCC measurements were obtained in the years 2017-2019. FGCC was higher for the air drill at lower seeding rates (20 and 40 seeds/m2), while the 12" planter led to higher FGCC compared to the air drill for higher seed rates (80 and 160 seeds/m2; Figure 3a). The 20" planter led to lower FGCC at all seeding rates. Similarly, air drill and 12" planter led to higher NDVI measurements compared to 20" planter although the differences were not statistically significant (Figure 3b).

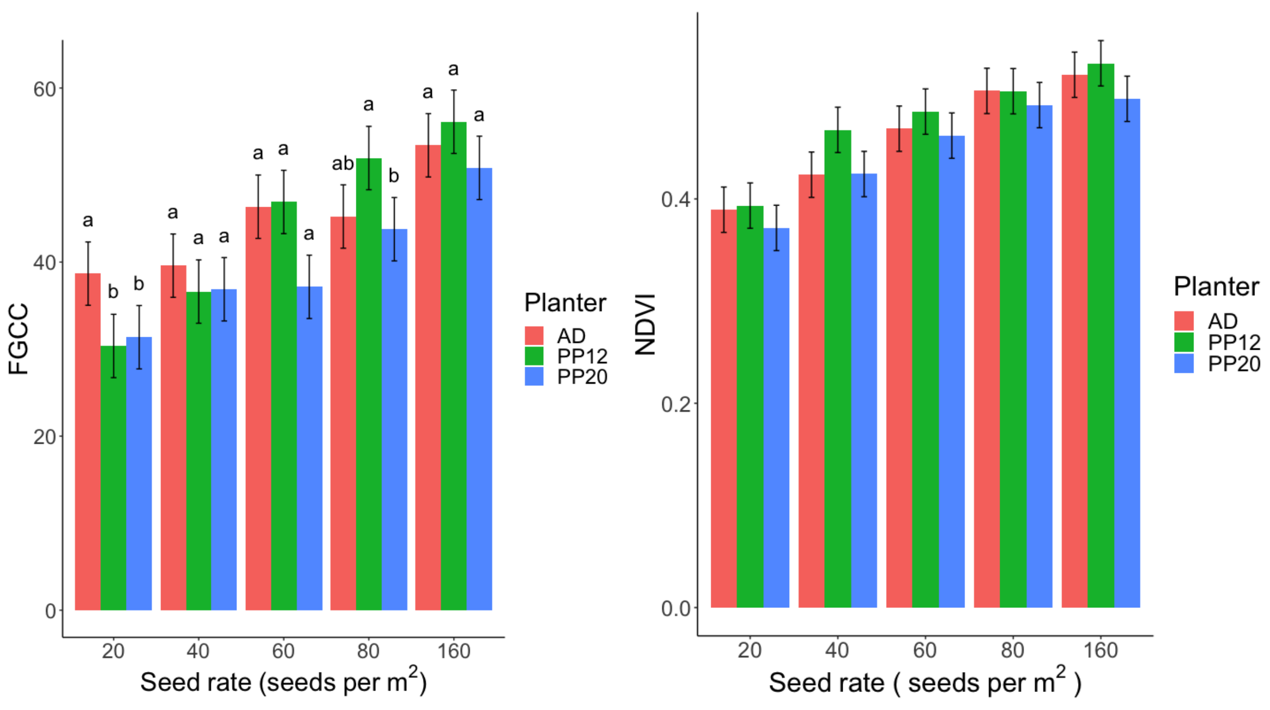

Figure 3: a) Fractional green canopy closure (FGCC) and b) normalized difference vegetation index (NDVI) for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) at five different seeding rates averaged across locations (LB irrigated, LB dryland, MH) and years (2016-2019)

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Other metrics tied to plant growth, including days to flowering and maturity and ratings for plant vigor were estimated. Days to flowering and maturity did not show a statistically significant difference between different planters (Table 1, Appendix 1). Plant vigor ratings were only collected for the site-years when there was a visible difference in plant vigor. In some years, differences in plant vigor were not evident due to poor crop growth caused by extraneous factors such as less precipitation etc. The differences in plant vigor ratings for different seed rates were not significant, however, the trends were similar to canopy closure matrices (Figure 4). Plant vigor was higher for the air drill at lower seed rates (20 and 40 seeds/m2), while precision planter (12") led to higher plant vigor for higher seed rates (60, 80 and 160 seeds/m2).

At lower seeding rates, the less precise spatial placement of seed increases the ground coverage of the air drill seeded plants, leading to an increase in canopy cover. At higher seeding rates, however, the precise seed placement by the 12" planter reduces the competition for resources between plants, thus enabling better crop growth which leads to a better canopy cover. The 12" planter also led to higher canopy closure at the irrigated plot in Lethbridge, while the canopy closure at the rainfed plot in Lethbridge was higher for the air drill, thus indicating that that the 12" planter leads to a better canopy cover in increased crop growth conditions (Figure 5).

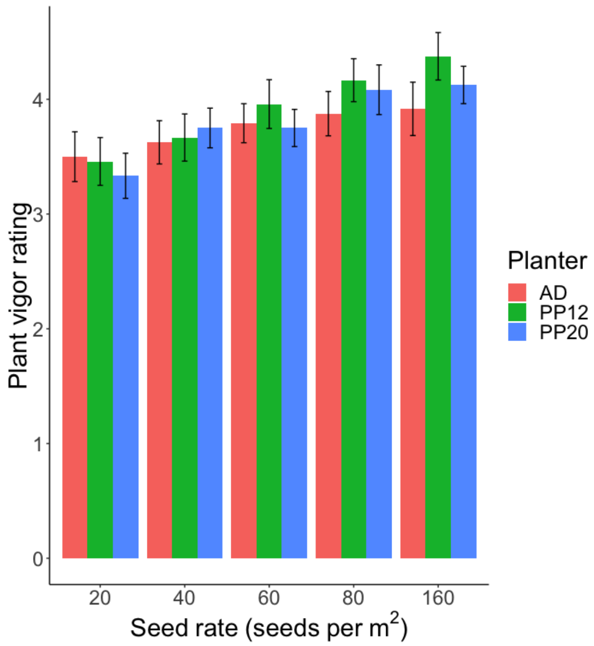

Figure 4: Plant vigor ratings (1 = poor, 5 = excellent) for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) at five different seeding rates averaged across locations (LB irrigated, LB dryland, MH) and years (2016-2019).

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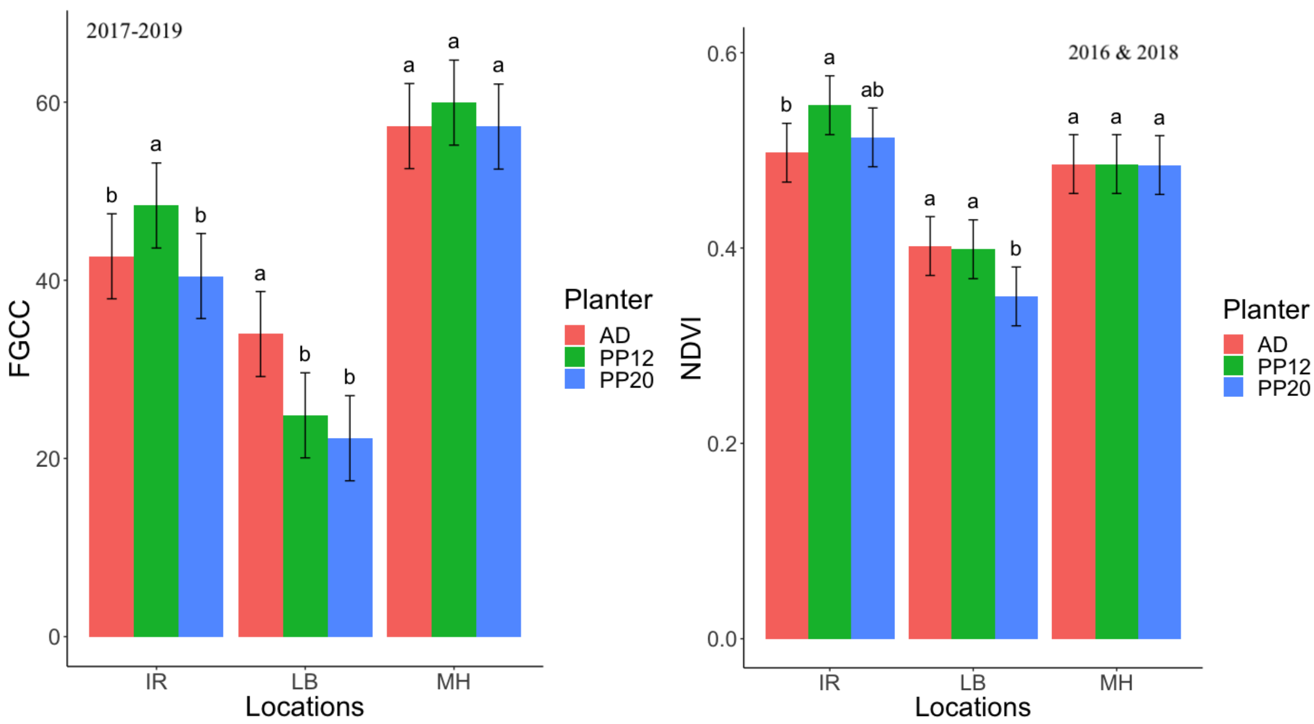

Figure 5: a) Fractional green canopy closure (FGCC) and b) normalized difference vegetation index (NDVI) for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) at three locations (IR - Lethbridge irrigated, LB - Lethbridge dryland, MH - Medicine Hat) averaged across different seeding rates and study years.

Yield

Canola yield was higher at the irrigated location compared to the dryland locations (Figure 6). Across all locations, yield increased with increasing seed rate. However, the increase in yield with higher seed rates was not statistically significant beyond 80 seeds/m2 at Lethbridge dryland and irrigates sites, and beyond 60 seeds/m2 at Medicine Hat (Figure 6). The 12" planter and air drill led to higher yield compared to the 20" planter (Figure 7). Across all seed rates, the 20” planter had an average yield of 2114 kg/ha. The air drill and 12" planter by comparison led to an average yield of 2812 and 2972 kg/ha, respectively. Canola yield for the 20" planter was 20-28% less compared to the air drill for different seed rates (Figure 7). The wider rows on the 20" planter led to increased interplant competition throughout the growing season. Furthermore, the wider rows delay canopy closure and limit access to resources such as water, sunlight, and nutrients between the rows.

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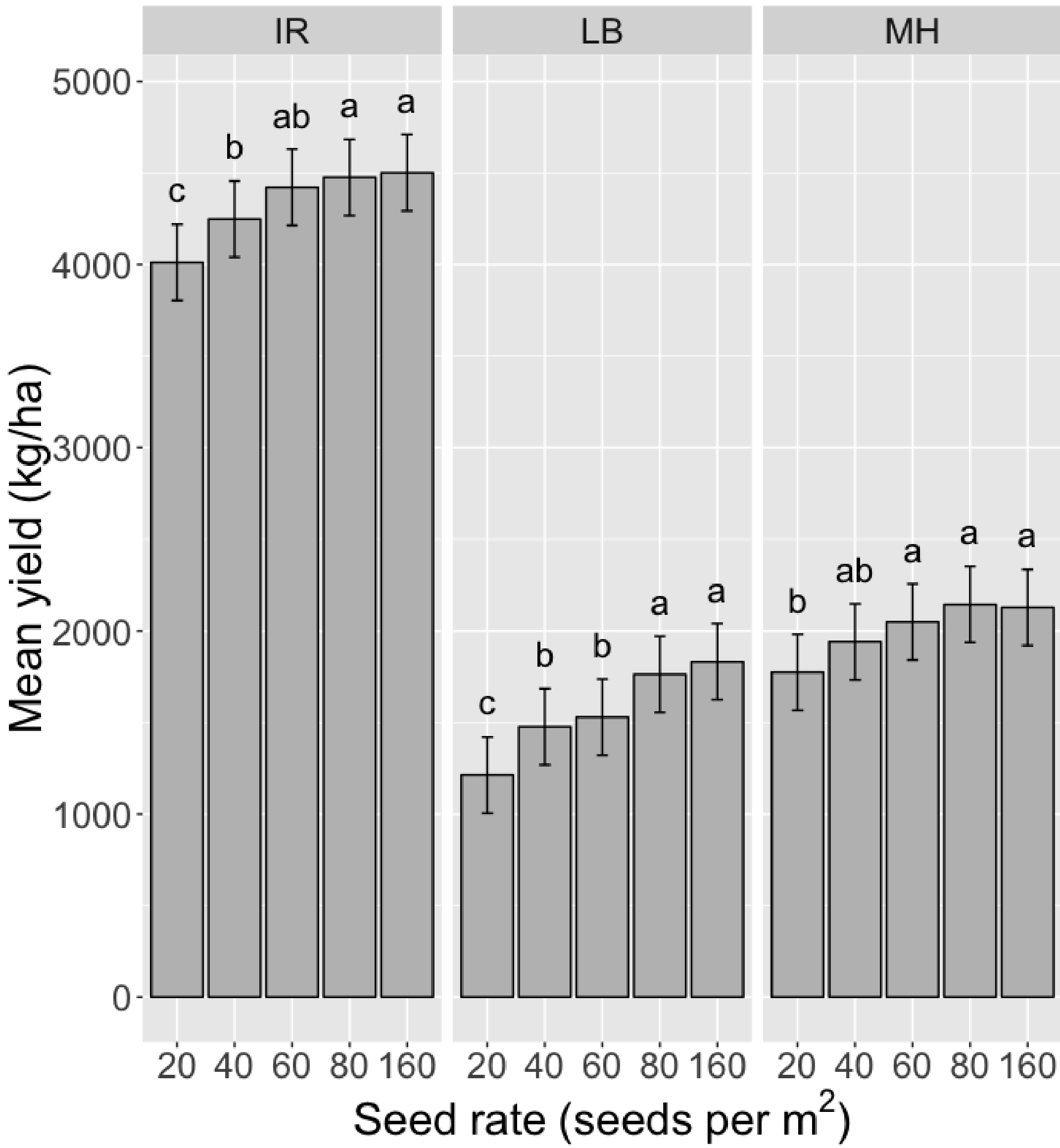

Figure 6: Average canola yield (kg/ha) at three locations (IR - Lethbridge irrigated, LB - Lethbridge dryland, MH - Medicine Hat) averaged across the study years (2016-2019)

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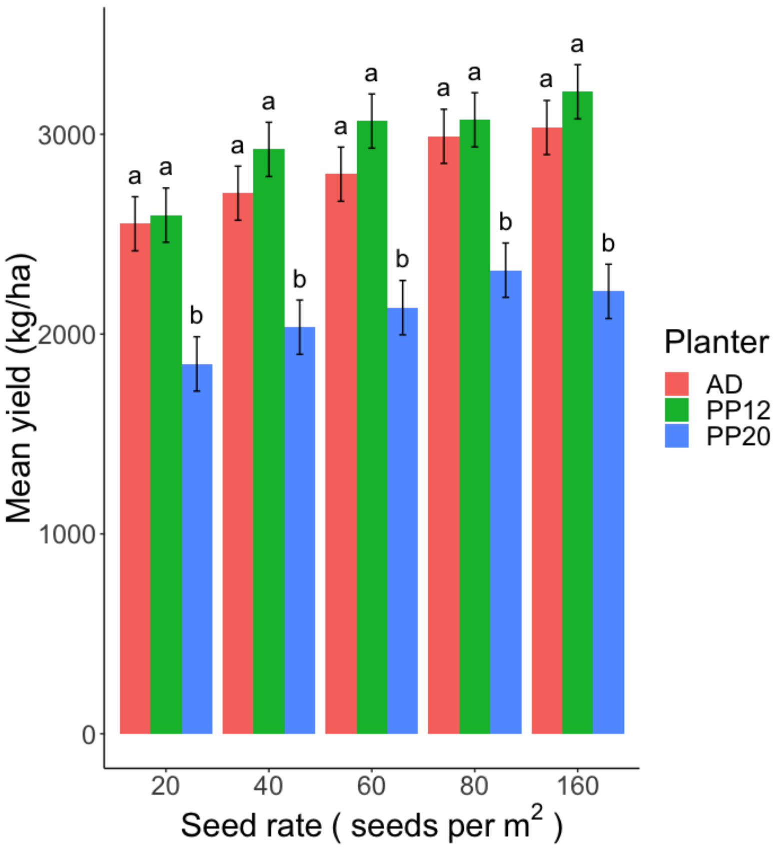

Figure 7: Average canola yield (kg/ha) for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) at five different seeding rates averaged across locations (LB irrigated, LB dryland, MH) and years (2016-2019)

While the differences in yield between the air drill and 12" planter were statistically non-significant, the 12" planter consistently led to a 2-10 % increase in yield compared to the air drill at all seeding rates (Figure 7). The 12" planter led to an average increase of 160 kg/ha of canola yield, which although small in magnitude, may lead to significant increase in profit across the millions of acres of canola production for the industry. More importantly, there was a significant difference in the performance of air drill and 12" planter when observed across different cropping conditions. At the irrigated Lethbridge location, the average yield for all planters was higher compared to the rainfed Lethbridge and Medicine hat locations (Figure 8). However, 12" planter led to a significantly higher yield compared to air drill and 20" planter at the irrigated location, with an increase in average canola yield of 463 kg/ha compared to the air drill and 1584 kg/ha compared to the 20" planter (Figure 8). At the rainfed locations, the difference in yields between the air drill and 12" planter was not statistically significant, while the 20" planter had a significantly less yield. Similar trends were observed when the canola

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yield for different planters was observed across the years. During 2016 and 2017, the 12" planter showed a trend of higher yield compared to the air drill for all seed rates (Figure 9). These years had a high cumulative precipitation, with an annual precipitation of 420 and 303 mm at Medicine Hat, and 369 and 278 mm at Lethbridge during 2016 and 2017, respectively (Figure 1, Appendix 1). Conversely, the yields were higher for air drill compared to the planters during 2018, when the annual precipitation was low, with an average annual precipitation of 199.6 mm at Medicine Hat, and 261 mm at Lethbridge. These trends indicate that the 12" planter performs better in the conditions that favor increased crop production, which may be attributed to the precise control of 12" planters on seed placement which helps to reduce interplant competition, thus enabling higher crop production. However, the performance of air drill is comparable to the 12" planter in growth-limited conditions, since the inter-plant competition is reduced by limited crop production.

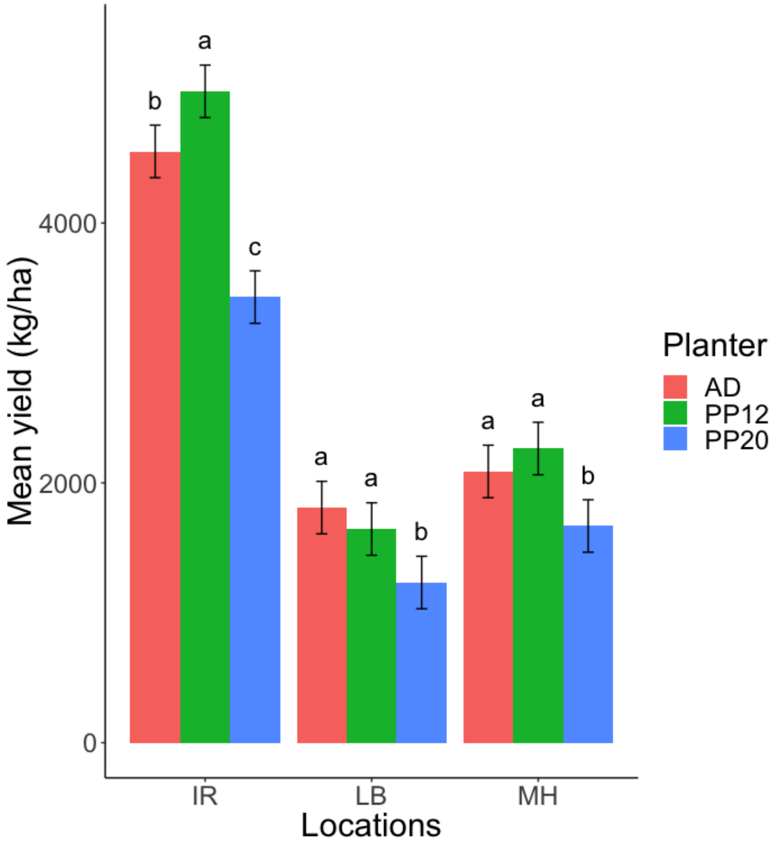

Figure 8: Average canola yield (kg/ha) for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) at three locations (IR - Lethbridge irrigated, LB - Lethbridge dryland, MH - Medicine Hat) averaged across different seeding rates and study years (2016-2019)

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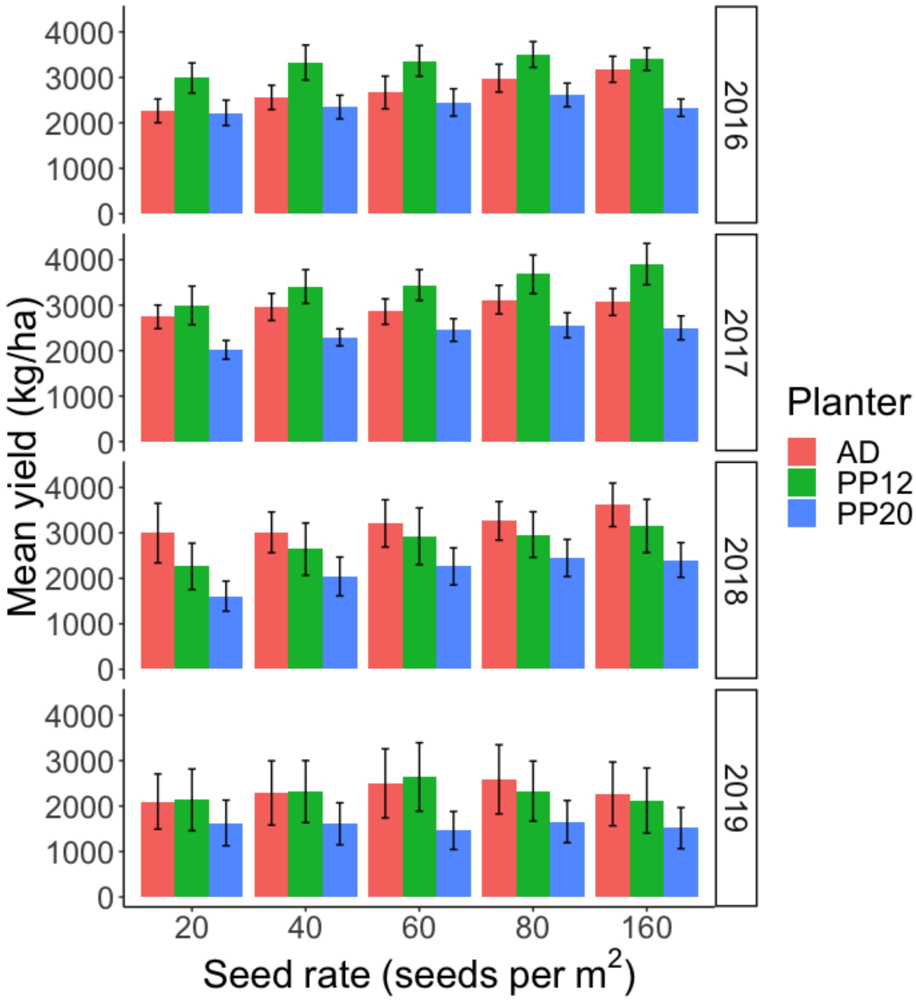

Figure 9: Average canola yield (kg/ha) for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) for years 2016-2019 at five different seeding rates averaged across three locations (LB irrigated, LB dryland, MH)

The research team collected data on seed quality parameters including green seed (%), dockage and oil content. Both green seed percentage and dockage did not show any statistically significant differences for planters or seed rates. While the oil content showed statistically significant differences for both factors, the magnitude of these differences was very small (< 1%), and hence not further discussed in this report. The data associated with seed quality parameters is included in Appendix I.

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Liquid Phosphorous Study

The major purpose of this trial was to estimate the seed-safe rates of in-row liquid P fertilizer when using precision planters. The data were obtained on plant establishment, growth and yield parameters similar to the previous trial.

Addition of liquid P at any rate did not affect the plant stand density for the air drill. However, with the precision planters (12" and 20"), plant density at fertilizer rate of 60 kg/ha was lower (Figure 10), thus indicating that high P fertilization rate at 60kg/ha may have led to some degree of seedling mortality in case of precision planters.

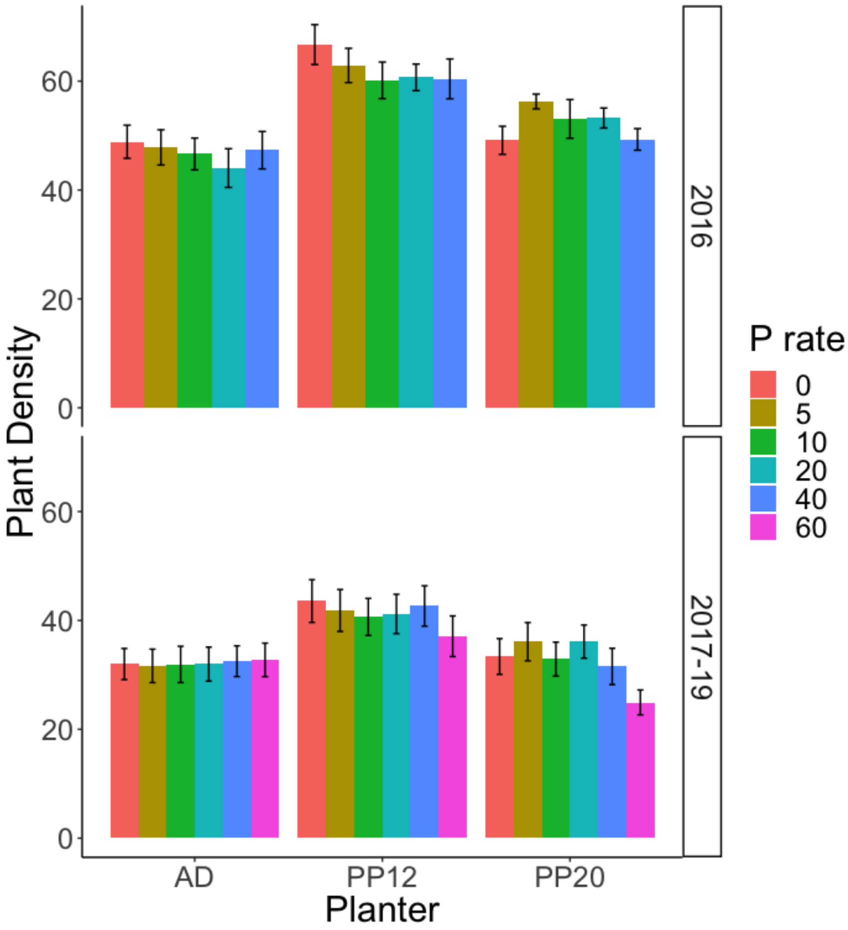

Figure 10: Plant density (plants/m2) at for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) at different application rates of liquid P for years 2016 & 2017-2019.

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FGCC measurements also indicated that the canopy closure for the precision planters (12" and 20") at 60 kg P/ha was less compared to other fertilizer rates, while no such trend was observed for the air drill (Figure 11). However, these differences were not statistically significant. NDVI measurements, which were obtained only in the years 2016 and 2018, on the other hand did not indicate any difference in photosynthetic activity between different P rates for precision planters and the air drill (Figure 11). Other parameters related to plant growth such as ratings for plant vigor also did not show substantial differences between different P rate applications. Average plant vigor rating for different P application rate varied from 4.5 - 4.7 for year 2016, and 3.6 - 3.8 for years 2017-2019 (Figure 12). While the difference in plant vigor for these time periods can be attributed to variations in amount of precipitation (2016 had higher annual precipitation; Appendix 1), the difference in plant vigor for different P application rates is minimal, thus indicating very similar estimates of plant vigor.

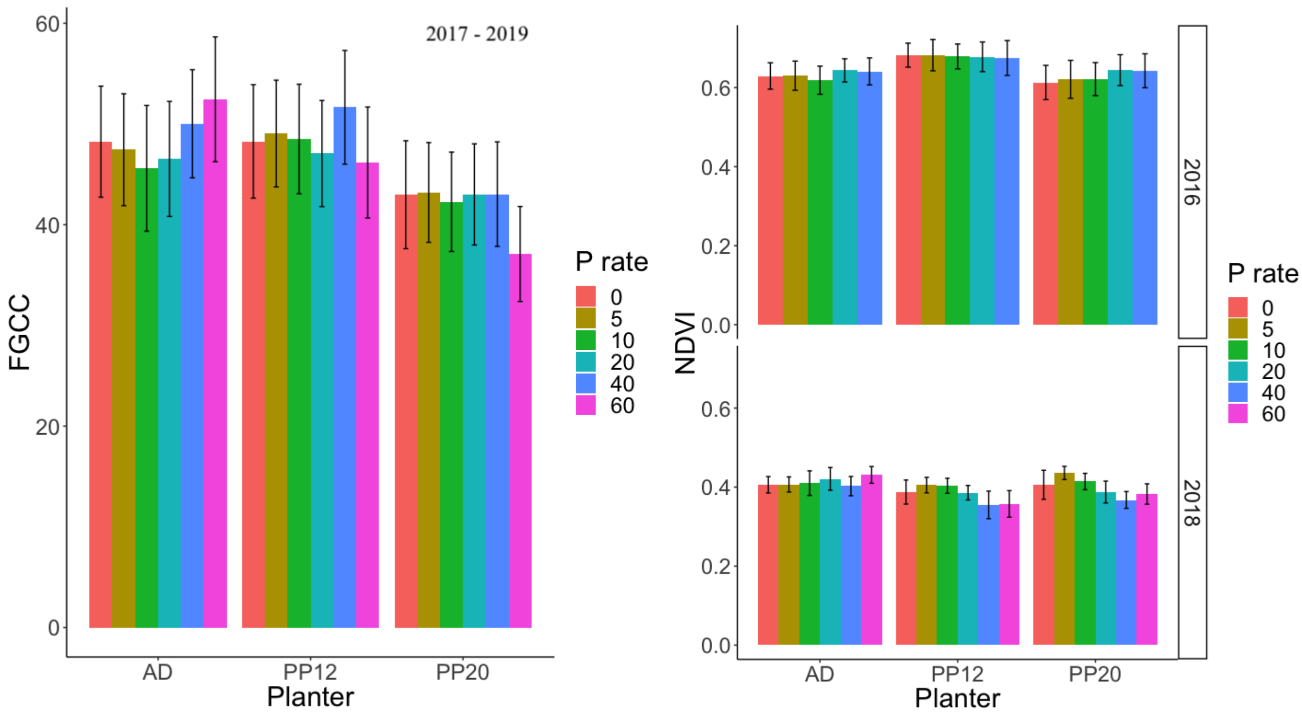

Figure 11: a) FGCC and b) NDVI measurements for measuring canopy closure for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) at different application rates of liquid phosphorus

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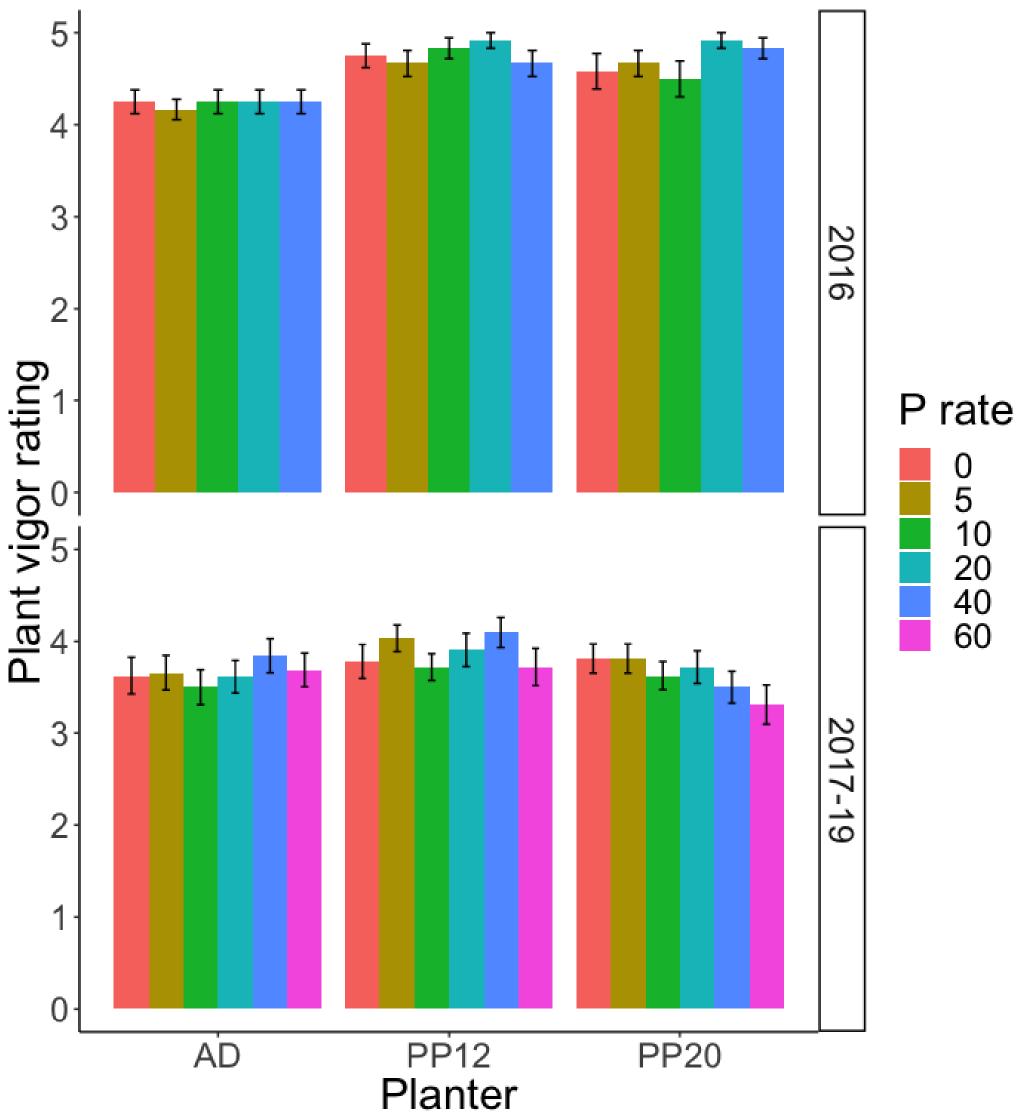

Figure 12: Average plant vigor ratings for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) at different rates of application of liquid P averaged across different locations for different study years (2016, and 2017-2019)

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Similar to plant growth parameters, the crop yield did not show any differences amongst the P application rates. When observed across the planters, the air drill and precision planter with 12" spacing showed similar trends with no differences in yield across different liquid P application rates. However, the precision planter with 20" spacing showed lower yield with liquid P application rate of 60 kg/ha, although the differences are not statistically significant (Figure 13). Crop yields at different irrigated and dryland locations were also similar for all fertilizer application rates (Figure 14). When comparing the relative performance of planters at irrigated and rainfed plots, precision planter with 12" spacing led to higher yield compared to the air drill, while the precision planter with 20" spacing led to significantly lower yields compared to both seeders (Figure 15). These trends in comparative performance of different seeders did not change substantially at different P rates (Figure 15), and they were similar to the observations in the seeding rate trial comparing planters yields at different seeding rates (Figure 7), and thus, supporting the conclusions of the seeding rate trial.

These results in aggregate indicate that higher liquid P application rates (60 kg/ha) may have led to increased seedling mortality in case of precision planters (12" and 20") thus reducing plant stand density at the initial crop establishment phase. However, crops were able to recover from the initial losses thus leading to no substantial differences between different P rates for crop yield. The recovery may, however, be less effective for the precision planter with 20" spacing compared to the 12" planter, since the 20" planter had lesser crop yield for liquid P application rate of 60 kg/ha compared to other fertilizer rates. The application of liquid P to canola crop at any rate did not improve plant emergence, growth or yield significantly compared to no application of liquid P. Thus, the use of liquid P for canola crop production may be re-evaluated under these conditions.

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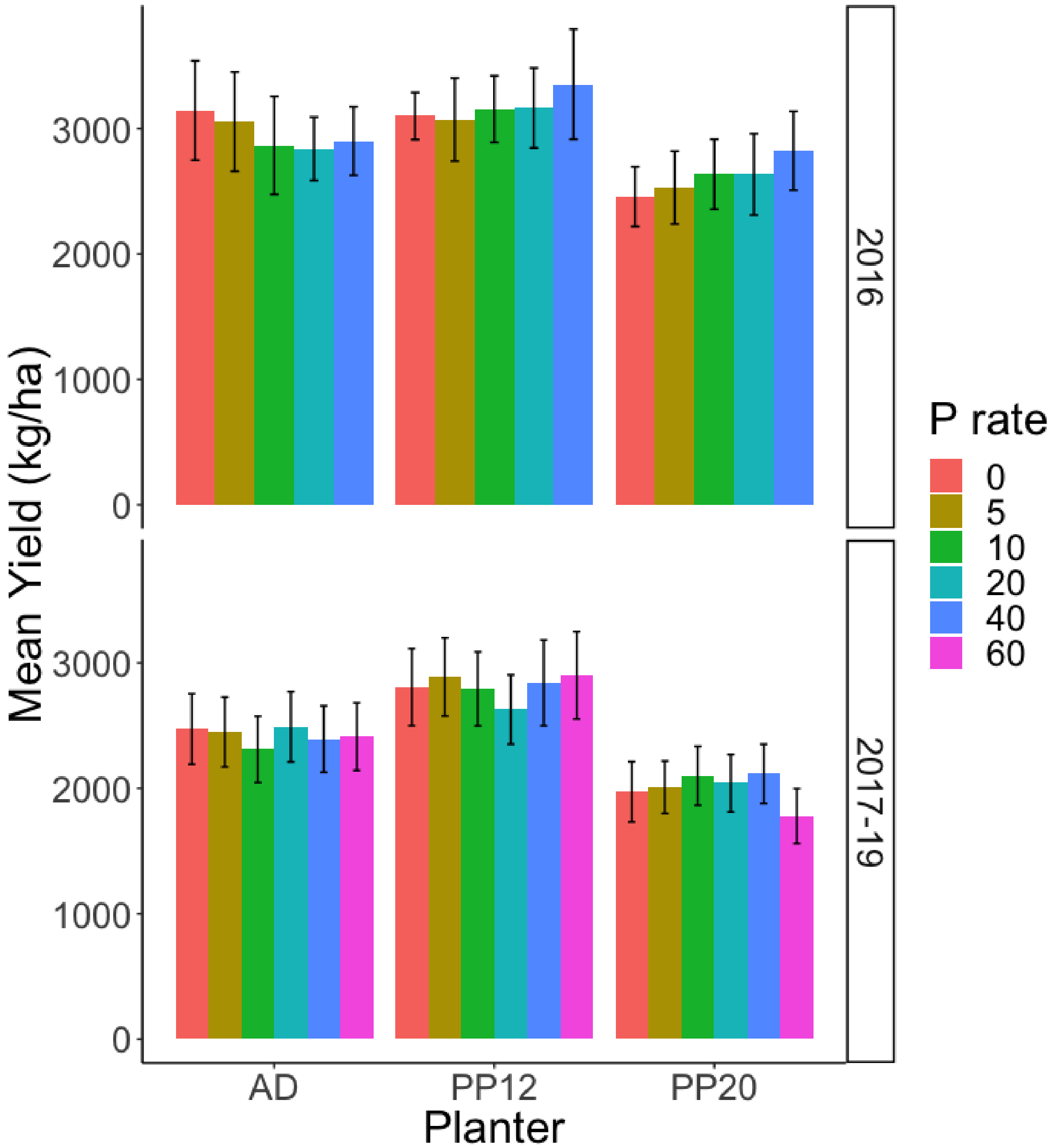

Figure 13: Average canola yield (kg/ha) for the planters (AD - Air Drill, PP12 - Precision planter 12' spacing, PP20 - Precision planter 20' spacing) at different application rates of liquid phosphorus for years 2016 & 2017-2019.

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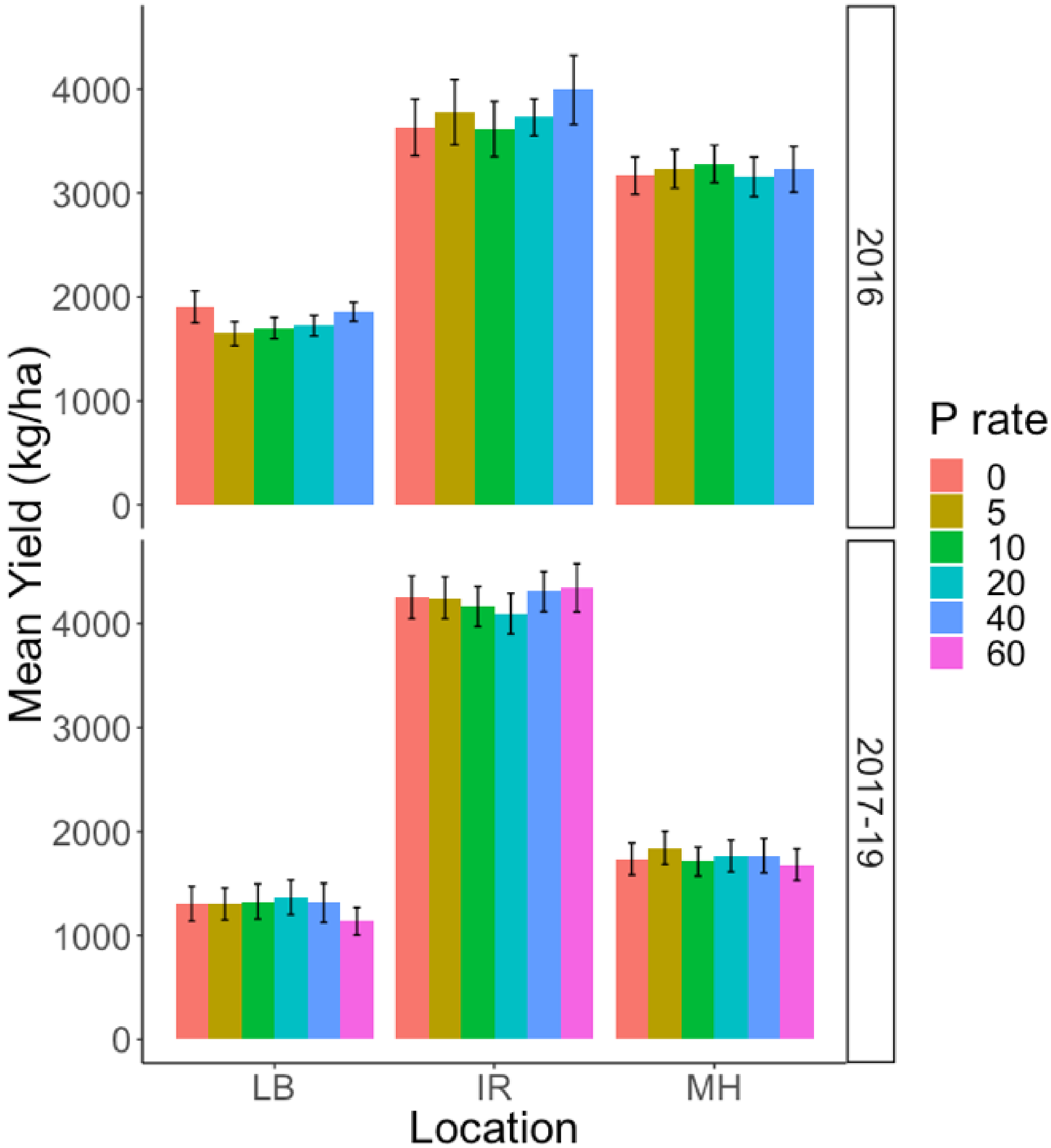

Figure 14: Average canola yield (kg/ha) at the study locations (IR - Lethbridge irrigated, LB - Lethbridge dryland, MH - Medicine Hat) at different application rates of liquid phosphorus for years 2016 & 2017-2019.

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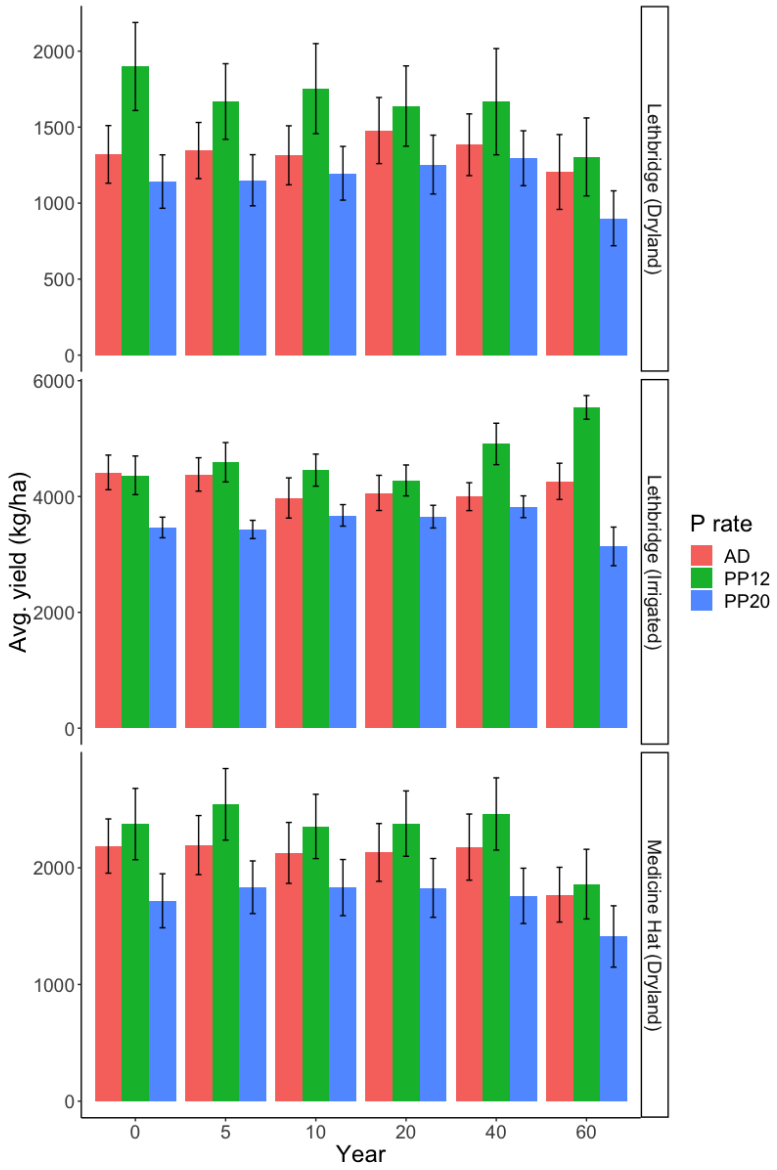

Figure 15: Average canola yield (kg/ha) at the irrigated and rainfed locations for different application rates of liquid P averaged across years 2016-2019.

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Appendix I

Table 1. Average values of plant growth matrices (including canopy closure rating, days to start and end of flowering and days to maturity), and seed quality parameters (including green seed percentage, dockage, oil concentration and 1000 kernel weight) across three locations from 2016 - 2019 for different seed rates and planters.

Planter	Seeding rate (seeds/m^2)	Visual canopy closure	Days to flowering	Days to end of flowering	Days to maturity	Green seed (%)	Dockage	Oil concentration	1000 kernel weight (g)
Air drill	20	49.75	36.42	70.88	93.40	0.43	2.98	45.98	3.09
	40	49.00	36.29	70.50	93.13	0.60	3.22	46.54	3.19
	60	59.25	36.17	70.46	93.33	0.60	3.23	46.94	3.15
	80	64.50	36.13	68.92	93.05	0.56	3.65	46.77	3.08
	160	65.25	36.04	68.63	92.50	0.46	3.86	47.32	3.12
Precision planter (12" spacing)	20	40.75	36.50	70.00	94.43	0.53	3.21	46.21	3.05
	40	50.75	35.71	69.38	93.48	0.35	3.29	46.76	3.07
	60	59.50	36.50	69.46	93.18	0.50	3.65	46.97	3.10
	80	67.00	36.17	69.25	93.00	0.43	3.08	47.20	3.15
	160	71.50	36.54	68.33	92.30	0.38	3.25	47.08	3.12
Precision planter (20" spacing)	20	30.50	36.79	69.96	93.55	0.47	3.16	45.76	3.01
	40	37.00	36.29	69.63	93.18	0.52	3.28	46.38	3.09
	60	37.75	36.08	69.38	93.40	0.46	3.04	46.99	3.05
	80	40.75	36.21	69.13	92.53	0.39	3.66	46.75	3.14
	160	48.50	35.92	68.54	92.43	0.46	3.21	46.73	3.15

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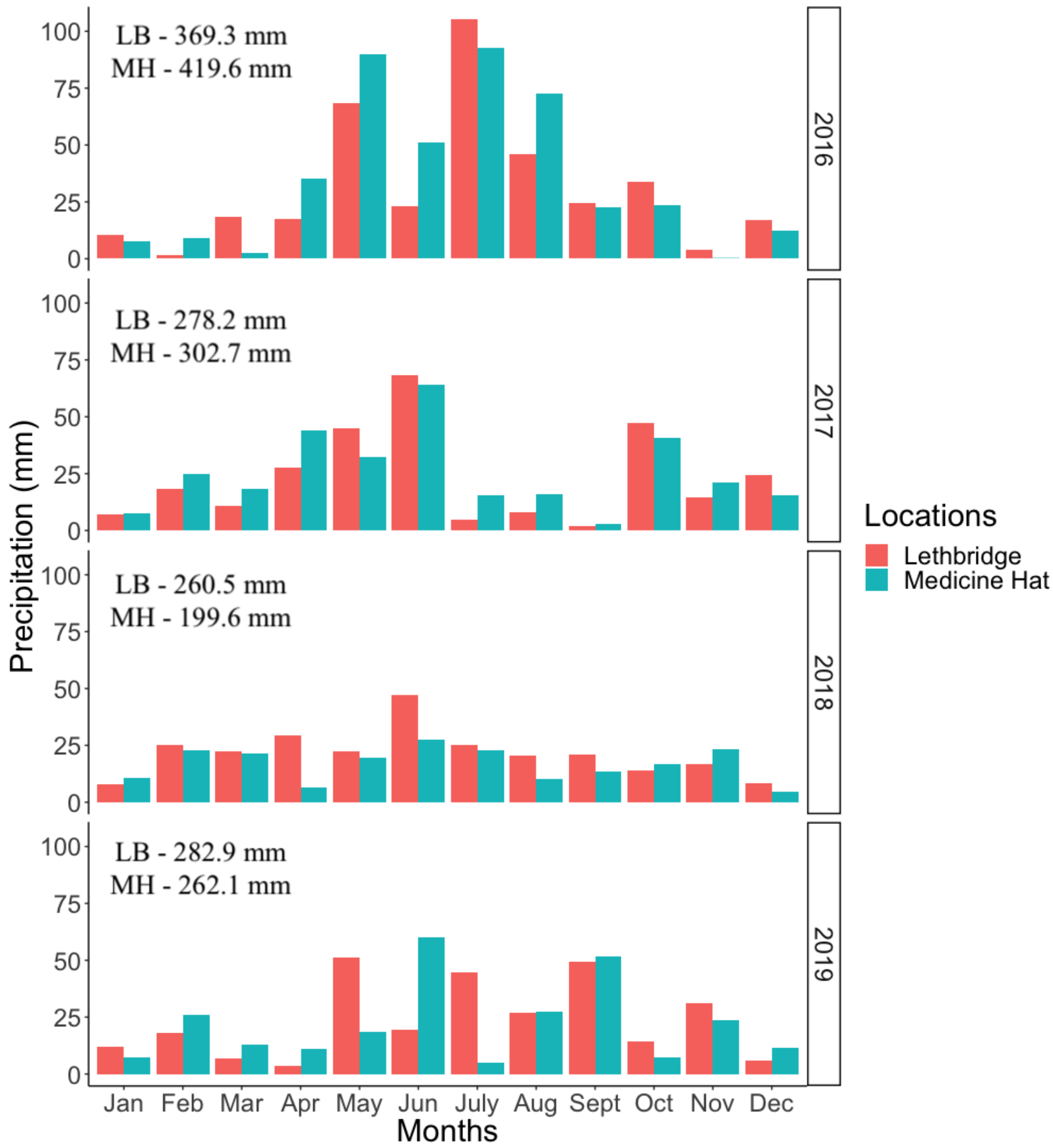

Figure 1. Cumulative monthly (bars) and annual (inset) precipitation (mm) for Lethbridge and Medicine Hat location for years 2016-2019.

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