Response of canola to low plant populations and evaluation of reseeding options

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Abstract

There is limited information available on the response of hybrid canola to low plant populations, and information is required to assist producers with their decision to reseed when faced with low plant densities. While hybrid canola has a high degree of phenotypic plasticity that allows it to compensate for low plant populations, producers need to know when the plant population is likely too low to compensate for the reduced plant stand. The objectives of this project are to determine the plant populations at which canola hybrids yield 90% of maximum, the effect of plant population on maturity, seed size and green seed, the minimum plant density at which reseeding would be recommended for hybrid canola, and the risks with each reseeding option in terms of maturity, yield and quality. Experiments were conducted at five locations in Saskatchewan in 2010, 2011 and 2012. To evaluate the response of hybrid canola to low plant densities canola was seeded at rates of 5, 10, 20, 40, 80, 150 and 300 seeds m^{-2}. Canola was found to achieve 90% of maximum yield at 18 plants m^{-2}. In general, days to maturity and percent green seed increased as plant density decreased; however, the plant densities at which maturity and quality were affected were lower than the plant density required to produce maximum yield. At lower plant densities the canola was able to compensate for the reduced plant stand by increasing branching and podding. To evaluate reseeding options, two varieties of *Brassica napus* and one variety of *Brassica rapa* were reseeded into existing stands of low density canola in early and mid-June. When faced with a low density of canola there was a yield benefit to reseeding with *B. napus* in early June but no yield benefit to reseeding in mid-June. There was no advantage to reseeding with *B. rapa*, even when reseeding was postponed to mid-June. When reseeding is required, it is recommended that producers reseed as early as possible to reduce the risk of poor stand establishment and yield and quality reductions due to fall frost.

Introduction

Current canola seeding rate recommendations are for seeding rates to be adequate to achieve a target plant population of 70-140 plants m^{-2}, which, based on a typical 50% seed survival rate translates to a seeding rate of 140-280 plants m^{-2} (Canola Council of Canada 2013). There have been numerous studies looking at canola seeding rates; however, there is limited data on the response of canola, particularly hybrids, to extremely low plant populations. When producers are faced with low plant populations, knowledge of the response of yield to low plant populations would assist with the decision to reseed. The response of canola to low plant populations and the ability of a hybrid canola plant to compensate for low plant populations is also important information for crop insurance adjustors when attempting to settle an insurance claim.

In a study using open pollinated canola cultivars, Angadi et al. (2003) found that when plant populations are uniformly distributed, reducing the plant population by half from 80 to 40 plants m^{-2} did not reduce seed yield. McGregor (1987) concluded that plant density could be reduced from 100-200 plants m^{-2} to 40 plants m^{-2} with less than 20% yield loss. Seed yield is a function of the number of plants per unit area, pods per plant, seeds per pod, and seed weight (McGregor 1987). It is thought that the newer hybrid canola cultivars have a higher degree of phenotypic plasticity than open pollinated cultivars, and are able to compensate for reduced densities with increased plant size.

In a meta-analysis of canola seeding rate and plant population trials, Shirtliffe (2009) found hybrid and open pollinated canola cultivars to respond differently to low plant populations. Hybrid canola achieved 90 percent of its yield potential at 45 plants m^{-2} compared to 90 plants m^{-2} for open pollinated canola (Shirtliffe 2009). In studies comparing open pollinated and hybrid cultivars, Van Deynze et al. (1992) and Hanson et al. (2008) did not find a significant cultivar x seeding rate interaction, indicating that hybrid and open pollinated cultivars respond similarly to varying seeding rates.

The potential drawbacks to low plant populations include reduced weed competition (Harker et al., 2003), extended maturity (Degenhardt and Kondra 1981; Angadi et al. 2003), difficult swathing, and increased infestations of root maggot (Dosdall et al., 1996). These potential drawbacks need to be compared to the risks and benefits of reseeding a canola stand. There is a need to understand the response of canola to low plant populations in comparison to reseeding in terms of the effect on maturity and yield.

Updating the research on low plant populations in hybrid canola will allow producers to be better informed when it comes to reseeding decisions. The objectives are this project are to determine: 1) the plant population at which canola hybrids yield 90% of maximum; 2) the effect of plant population on maturity, seed size and green seed; 3) the minimum plant density at which reseeding would be recommended for hybrid canola; 4) the risks with each reseeding option in terms of maturity, yield and quality.

Materials and Methods

Field experiments were conducted at Indian Head, Melfort, Saskatoon, Scott and Swift Current, Saskatchewan in 2010, 2011 and 2012. Research sites were chosen to provide a range of growing conditions within the province of Saskatchewan.

Table 1. Total monthly precipitation and long-term climate normals (1971-2000) during the 2010, 2011 and 2012 growing seasons at Indian Head, Melfort, Scott, Swift Current and Saskatoon, Saskatchewan.

Site	Year	May	June	July	Aug	Sep	Growing season (May-Sep)
		---------------------- Precipitation (mm) ----------------------					
Indian Head	2012	79	51	125	30	0	285
	2011	71	133	42	44	16	307
	2010	51	119	20	69	34	293
	Normal	56	79	67	53	41	296
Melfort	2012	55	112	98	68	13	346
	2011	11	104	73	11	1	199
	2010	67	113	64	57	92	392
	Normal	46	66	76	57	40	284
Scott	2012	51	165	56	51	24	347
	2011	31	190	76	52	4	353
	2010	121	147	122	62	44	497
	Normal	36	63	71	43	31	244
Swift Current	2012	98	107	17	8	5	236
	2011	57	117	68	30	11	283
	2010	94	122	72	85	100	471
	Normal	50	66	52	40	30	238
Saskatoon	2012	108	121	81	49	1	359
	2011	17.5	94	69	17	6	203
	2010	128.5	169	46	44	88	475
	Normal	43.6	61	57	35	31	227

Table 2. Mean temperature and long-term climate normals (1971-2000) during the 2010, 2011 and 2012 growing seasons at Indian Head, Melfort, Scott, Swift Current and Saskatoon, Saskatchewan.

Site	Year	May	June	July	Aug	Sep	Growing season (May-Sep)
		---------------------- Temperature (°C) ----------------------					
Indian Head	2012	9.9	16.5	19.2	17.1	12.6	15.1
	2011	9.5	15.1	18.8	17.8	13.9	15.0
	2010	9.2	15.8	17.3	15.5	10.8	13.7
	Normal	11.4	16.1	18.4	17.5	11.4	15.0
Melfort	2012	9.6	15.2	18.9	17.1	12.4	14.6
	2011	10.1	15.4	17.5	17.1	13.7	14.8
	2010	9.2	15.4	17.5	16	9.5	13.5
	Normal	10.8	15.7	17.4	16.4	10.5	14.2
Scott	2012	9.7	15.1	18.6	17	12.2	14.5
	2011	10.1	14.4	17	16.3	13.7	14.3
	2010	8.8	14.9	16.5	15.2	9.5	13.0
	Normal	10.9	15.2	17	16.3	10.4	14.0
Swift Current	2012	9.4	15.5	20	19	13.8	15.5
	2011	9.5	14.3	18.2	18.2	15.1	11.8
	2010	7.7	15.4	17	16.5	10.7	13.5
	Normal	11.1	15.6	18.1	17.9	11.8	14.9
Saskatoon	2012	10.1	15.8	19.7	17.3	13	15.2
	2011	10.9	15.5	18.4	17.2	14.7	15.3
	2010	9.7	15.3	17.6	16.1	10.5	13.8
	Normal	11.8	16	18.3	17.6	11.5	15.0

Experiment 1: Plant density response

The experimental design was a randomized complete block design with four replicate blocks. The glufosinate tolerant canola (*Brassica napus*) cultivar 5440LL was seeded at rates of 5, 10, 20, 40, 80, 150 and 300 seeds m^{-2}. At Scott and Melfort two canola cultivars, 5440LL and 5770LL, were planted at the seven seeding rates for a total of 14 treatments. The 150 seeds m^{-2} rate is considered to be a standard seeding rate and is referred to as the check for comparison purposes. An elemental sulfur bulking agent was mixed with the seed to ensure even seed distribution. Plot size and row spacing varied between locations depending on seeder type. Plot size ranged from 12 to 40 m^{-2} and row spacing ranged from 0.2 to 0.3 m. Plots were fertilized to soil test recommendations and registered herbicides, insecticides and fungicides were applied as required by each site. Plots were straight combined at maturity using a Wintersteiger plot combine.

Data collection included spring plant density, days to start and end of flowering, days to maturity, lodging index, grain yield, thousand kernel weight, percent distinctly green seed and fall plant density. At the Scott and Saskatoon locations data was also collected on branching, pods per plant and seeds per pod. Spring plant density was measured at the two leaf stage by counting plants in two random 1 m paired rows within each plot. Days to start of flowering was recorded when 10% of the plants in a plot had at least one flower. Days to end of flowering was recorded when 90% of the plants in a plot had finished flowering. Lodging measurements were completed between the stage where the crop is considered ready to swath and the first harvest date. Lodging index was calculated as the ratio of canopy height divided by actual plant height. Canopy height was measured at the front and back of each plot. Plant height was measured on 10 plants per plot and was measured at the top portion of the main stem where pods are developed. Days to maturity was recorded when 60% of the seeds in pods on the main stem have changed colour. Grain yield was measured as clean seed weight per plot dried to an even moisture level. Percent green seed was calculated from one 500 seed crush per plot. Fall plant density was measured after harvest by counting plants in two random 1 m paired rows within each plot. Plant survival was calculated from the spring and fall plant densities.

All variables were analyzed separately using analysis of variance (ANOVA) in the Proc Mixed procedure (SAS Institute, Inc. 2001). Site years were analyzed separately and combined. In the combined analysis treatment was considered a fixed effect and block and site year were considered random effects. Homogeneity of variance was assessed with Levene's test and normality was assessed using Shapiro-Wilks (SAS Institute, Inc. 2001). Data transformations were performed when necessary to normalize the data so that all data conformed to the assumptions of the ANOVA. All data is presented as untransformed data. Separation of means was performed by Fisher's protected Least Significant Difference (LSD) test to determine significant differences ($P \leq 0.05$) among treatments. The plant density above which there is no significant change in yield, referred to as the breakpoint, and the plant density required to achieve 80 and 90% of maximum yield was determined using quadratic broken-line regression analysis according to procedures outlined by Robbins et al. (2006). The plant density above which there is no significant change in days to maturity, referred to as the breakpoint, was determined using straight broken-line regression analysis according to procedures outlined by Robbins et al. (2006).

Experiment 2: Reseeding options

The experimental design was a randomized complete block design with four replicate blocks. Canola was seeded at three dates. The first seeding date was early May where the glufosinate tolerant canola cultivar 5440 LL was seeded at a rate of 150 seeds m^{-2} in one treatment, and at a rate of 20 seeds m^{-2} to the remaining seven treatments. The 20 seed m^{-2} treatments were used to simulate poor stand establishment. All but one of the treatments planted at 20 seeds m^{-2} was later killed with glyphosate prior to reseeding. After glyphosate application, canola was planted in treatments 3-8 to mimic a reseeding situation in which a poor plant stand is terminated and canola is reseeded. Two hybrid canola cultivars, 5440LL and 9350RR, and a synthetic Polish canola variety were planted at two reseeding dates. The reseeding dates were early and mid-June. For a complete treatment list see Table 3.

Table 3. Seeding date, cultivar and seeding rate for each of the 8 treatments in the canola reseeding study.

Treatment	Seeding date	Cultivar	Seeding rate (seeds m^{-2})
1	Early May	5440LL	150
2	Early May	5440LL	20
3	Early June	5440LL	150
4	Early June	9350RR	150
5	Early June	Polish	150
6	Mid June	5440LL	150
7	Mid June	9350RR	150
8	Mid June	Polish	150

Plot size and row spacing varied between locations depending on seeder type. Plots were fertilized to soil test recommendations and registered herbicides, insecticides and fungicides were applied as required by each site. Plots were straight combined at maturity using a Wintersteiger plot combine.

Data collection included spring plant density, days to start and end of flowering, days to maturity, lodging index, grain yield, thousand kernel weight, percent distinctly green seed and fall plant density. Spring plant density was measured at the two leaf stage by counting plants in two random 1 m paired rows within each plot. Days to start of flowering was recorded when 10% of the plants in a plot had at least one flower. Days to end of flowering was recorded when 90% of the plants in a plot had finished flowering. Lodging measurements were completed between the stage where the crop is considered ready to swath and the first harvest date. Lodging index was calculated as the ratio of canopy height divided by actual plant height. Canopy height was measured at the front and back of each plot. Plant height was measured on 10 plants per plot and was measured at the top portion of the main stem where pods are developed. Days to maturity was recorded when 60% of the seeds in pods on the main stem have changed colour. Grain yield was measured as clean seed weight per plot dried to an even moisture level. Percent green seed was calculated from one 500 seed crush per plot.

All variables were analyzed separately using analysis of variance (ANOVA) in the Proc Mixed procedure (SAS Institute, Inc. 2001). Initially all site years were combined and analyzed with treatment considered a fixed effect and block and site year considered random effects. Because the treatment by site year interaction was significant for each variable, site years were also analyzed separately. Assumptions regarding the conformity of the data were tested using Proc Univariate. Data was tested for normality using the Shapiro-Wilk Statistic; all datasets followed a normal distribution; therefore, transformations were not required. Site years with unequal variance among treatments were corrected using the repeated statement. Separation of means was performed by Fisher's protected Least Significant Difference (LSD) test to determine significant differences ($P \leq 0.05$) among treatments.

Results and Discussion

Weather Conditions

Total growing season precipitation was above average at Scott in all years, at Melfort and Saskatoon in 2010 and 2012 and at Swift Current in 2010 (Table 1). Above average June rainfall at Scott and Melfort in 2010 resulted in very high levels of volunteer canola which artificially increased canola plant populations. As a result, low plant populations were not established and data from Scott and Melfort in 2010 was not analyzed. Soil moisture conditions in the spring of 2012 resulted in the Melfort site not being seeded. Yield and seed quality data was not collected at Scott in 2012 due to a late season hailstorm.

Mean monthly temperatures during emergence in May were lower than average at Indian Head and Swift Current in all years as well as at Melfort and Scott in 2010 and Saskatoon in 2010 and 2012 (Table 2). Temperatures were within 1°C of normal during establishment in June. During the flowering and pod development (July and August) temperatures were near normal with the exception of Indian Head in 2010 which was lower than normal and Scott, Swift Current and Saskatoon in 2012 where temperatures were higher than normal (Table 2).

Plant Density Experiment

Stand Establishment

Plant density increased with increasing seeding rates at all locations (Table 4). Seeding rates of 5 to 300 seeds m^{-2} resulted in plant densities ranging from 5 to 125 plants m^{-2}, when averaged across all site years (Table 4). For the remainder of the paper, the majority of the results will be related to actual plant density and not seeding rate. Percent emergence ranged from 152 to 54 at seeding rates of 5 and 300 plants m^{-2}, respectively (Table 4). Reduced emergence at the highest seeding rates is likely the result of increased plant competition and self-thinning (Linde 2001). At most site years, percent emergence was near or above 100% at the lowest seeding rates, due to the presence of volunteer canola. Wet conditions in the spring of 2010 resulted in greater canola emergence at most sites (Table 4). Data from Melfort and Scott 2010 was not included in the analysis due to the influence of volunteer canola. The high emergence levels were attributed to large numbers of volunteer canola emerging from the seed bank. In subsequent years there were less problems with volunteer canola due to better management practices. At the higher seeding rates emergence was closer to 50%, which is suggested as being representative of average canola emergence under field conditions (Harker et al., 2003).

Seed Yield

Yield increased with increasing plant density at ten of the eleven environments where yield was measured (Table 5). At nine of the site years where plant density had a significant effect on yield, plant densities of 70 and 125 plants m^{-2} yielded significantly greater than densities of 5 and 7 plants m^{-2} (Table 5). There was no significant yield difference between seeding rates of 20, 40 and 80 seeds m^{-2} (corresponding to plant densities of 12-39 plants m^{-2}, on average) at six of eleven site years, and no significant yield difference between seeding rates ranging from 20 to 300 seeds m^{-2} at four site years (Table 5). As plant density increased yield reached a plateau. Plant density was not high enough to result in a yield decrease. Density studies by Angadi et al. (2003) and McGregor (1987) also showed a yield plateau as plant density increased, while Morrison et al. (1990) reported that as plant density increased competition within the row increased, and yield decreased.

Regression of seed yield with plant density showed a strong quadratic relationship in six of the ten site years where regression analysis was able to be preformed (Figures 1 to 6) and in the combined analysis of all site years (Figure 7). Quadratic broken-line regression analysis was used to determine the plant density at which yield plateaus and when 80 and 90% of maximum yield is achieved. At the sites where there was a strong relationship between yield and plant density seed yield plateaued at plant densities ranging from 11 to 30 plants m^{-2} (Figures 1 to 6). Evaluating yield further determined that 90 and 80% of maximum yield was achieved at plant densities ranging from 8 to 20 and 6 to 12 plants m^{-2}, respectively at the individual sites (Figures 1 to 6). When site years were combined yield plateaued at 28 plants m^{-2} and 90 and 80% of maximum yield was achieved at plant densities of 18 and 12 plants m^{-2}, respectively.

The results of this study found that plant density can be reduced to values lower than those previously reported by Angadi et al. (2003) and McGregor (1987), in which reducing plant population to 40 plants m^{-2} had little effect on yield. These studies were performed on open pollinated canola, and it is suspected that hybrid canola has a greater level of plasticity than open pollinated canola.

In a meta analysis of results from canola seeding rate and plant density studies, Shirtliffe (2009) reported that hybrid canola was able to achieve 90% of its yield at 45 plants m^{-2}. The present study reports that 90% of maximum yield was achieved at densities of 8 to 20 plants m^{-2} in the individual sites with an overall average of 18 plants m^{-2}. This suggests that hybrid canola can compensate for lower plant populations than initially thought. However, these numbers are to be used as guidelines for the effect of reduced plant stands on the potential yield impact and should not be used as target seeding rates. The plant densities and associated yields reported in the present study can be used as a guideline for when reseeding is being considered.

It is also important to consider environmental conditions when interpreting these results. With the exception of Melfort 2011, which experienced less than normal precipitation, precipitation was not limiting in any site year (Table 1). Morrison et al. (1990b) suggests that in order for yield compensation at low plant densities to occur, plants must have adequate soil moisture. Compared to years of normal precipitation, Angadi et al. (2003) found that there are greater reductions in seed yield at low plant populations in stressful environments.

Duration of Flowering and Days to Maturity

The length of flowering period generally increased with decreasing plant density (Table 6). Compared to duration of flowering at a plant density of 70 plants m^{-2}, length of flower at 5 plants m^{-2} ranged from 9 to 24 days longer at Indian Head and Scott in all years. Plant density had less of an impact on duration of flowering at Melfort 2011 and Swift Current 2012, although differences were still significant (Table 6). When site years were combined a reduction in plant density from 70 to 21 plants m^{-2} resulted in a 6 day increase in the flowering period (Table 6).

Increasing plant density significantly reduced days to maturity (Table 7). Increasing plant density from 5 to 70 plants m^{-2} resulted in a 3-6 day to maturity reduction at Scott and Swift Current and a 5-19 day to maturity reduction at Indian Head and Melfort (Table 7). Our results at Scott and Swift Current mirror those of Angadi et al. (2003) who observed 3-4 day earlier maturity at 80 compared to 5 plants m^{-2}, while the results at Indian Head and Melfort are more similar to McGregor (1987), who found maturity of low populations to be delayed by as much as 16 days. The combined analysis found that when the plant population was reduced from 70 to 5 plants m^{-2} there was a 9 day increase in days to maturity (Table 7). A reduction in plant density from a traditional density of 70 plants m^{-2} to the density at which 90% of maximum yield is achieved (approximately 21 plants m^{-2}) results in a 3 day increase in days to maturity. The increase in flowering time and days to maturity at lower plant densities was likely a result of increased branching.

Regression of days to maturity and plant density was measured at the nine site years where both plant density and maturity data were collected and in the combined analysis of all site years. At six site years and in the combined analysis there was a strong linear relationship between the two variables ($R^2 > 0.88$) (Figures 8-11 and 15-17). Melfort 2011, Indian Head 2012 and Scott 2012 had R^2 values of 0.64, 0.75 and 0.75, respectively, indicating that there was not as strong of a relationship between plant density and days to maturity (Figures 12-14). Linear broken-line regression analysis was used to determine the breakpoint, the plant density above which there is no significant change in days to maturity. When plant density falls below the breakpoint days to maturity increases. Across the nine site years the breakpoint ranged from plant densities of 8 to 67 plants m^{-2} (Figures 8 to 16). Averaged across all site years, the plant density at which days to maturity plateau's is 19 plants m^{-2} (Figure 17).

Lodging

Plant density had a significant effect on lodging at four of seven sites where lodging was measured (Table 8). At Indian Head in 2011 and 2012 lodging was observed at the higher plant densities, while at Scott in 2011 and 2012 there was more lodging at the lower plant densities (Table 8). Increased lodging at lower plant densities occurred due to the canola plants becoming so large that the stem was unable to support the pant at maturity. In some cases the stems were susceptible to breaking.

Previous research has found lodging increases at greater seeding rates, due to the thinner stems produced at high plant densities (Dosdall et al., 1996; Van Denyze et al., 1992). Morrison et al. (1990b), found that plants with thinner stems were more susceptible to Sclerotinia, which would also lead to increases in lodging; however, this was not observed in the current study.

Survival

There were significant differences in rate of canola survival at only three of eight sites where spring and fall plant density were measured (Table 9). Although not always significant, survival decreased with increasing plant density at five of the sites and increased with increasing plant density at one site. These results are similar to those of Van Denyze et al. (1992) where plant survival decreased with increasing seeding rate. A decrease in survival at the highest seeding rates would be expected due to self-thinning.

Thousand seed weight

Seed weight decreased with increasing plant density at two sites and increased with increasing plant density at two sites, but in general seed weight was not strongly influenced by plant density (Table 10). In previous studies McGregor (1987) did not find a strong relationship between seed weight and density, while Hanson et al. (2008) found very similar results to the present study, where the results were inconsistent across locations.

Green Seed

Percent distinctly green seed decreased with increasing plant density, with significant differences between plant densities at seven of ten sites where green seed was measured. Averaged across site years there were significant differences in percent green seed with a plant density of 5 plants m^{-2} resulted in 0.76% greater green seed than a density of 70 plants m^{-2} (Table 11). A greater percentage of green seed at lower seeding rates reflects the increase in days to maturity when plant density decreases.

Yield Components

The number of pods per plant, branches per plant and seeds per pod were measured at the Saskatoon and Scott locations. Yield component data was only collected on two replicates at each site year, therefore there was not enough data to statistically analyze and results are presented as averages. As plant density decreased the number of branches per plant increased (data not shown) and pods per plant increased (Table 12). Averaged across years and locations, the number of pods per plant increased from 150 at seeding rates of 150 and 300 seeds m^{-2} to 851 at a seeding rate of 5 seeds m^{-2}. In general, the increase in pods per plant was due to increased podding on primary and secondary branches, while the number of pods on the main stem stayed about the same (data not shown).

This and other studies looking at open pollinated canola have found that when canola plant density is reduced, the plant is able to compensate by producing more branches and pods (Morrison et al., 1990b; Angadi et al., 2003). Angadi et al. (2003) found that the most important factor responsible for yield compensation is the number of pods per plant and that a greater expression of plasticity occurs when there is a greater availability of resources. When populations of open pollinated canola are reduced from 86 to 3 plants m^{-2}, McGregor (1987) observed the number of pods per plant increasing from 20 to as many as 600, and branches per plant increasing from a few as 3 to closer to 40.

The number of seeds per pod was fairly stable across the range of plant populations and ranged from 25 to 27 seeds per pod (Table 12). McGregor (1987) also found that the number of seeds per pod was not strongly influenced by plant density.

Effect of Cultivar

Two glufosinate tolerant canola cultivars, 5440LL and 5770LL, were planted at the Scott and Melfort locations to determine how different cultivars respond to changes in plant density. Although six site years of both cultivars were planted, due to environmental conditions there are only three site years available to compare the two canola cultivars.

Compared to 5770LL, 5440LL had a greater spring plant density at the highest seeding rates and matured earlier across all seeding rates (Table 13). There was no significant yield difference between the two cultivars at any seeding rate (Table 13). On average, 5770LL reached maturity three days later than 5440LL, which resulted in 5770LL having a greater percentage of distinctly green seed (data not shown).

Regression analysis was performed on the plant density and yield data from the Scott 2011 location, and both cultivars responded similarly to changes in plant density (Figure 18). Yield data was not available for the Scott 2012 site and the Melfort 2011 data did not fit the model.

Regression of days to maturity and plant density was performed at the three sites. At the Scott 2011 site the plant density at which days to maturity plateau's was greater for 5440LL than 5770LL, while the opposite was true at Scott 2012 (Figures 19 and 21). At the Melfort 2011 site both cultivars responsed similarly to changes in plant density (Figure 20).

Table 4. Influence of seeding rate on plant density and emergence at thirteen site years in Saskatchewan.

Seed Rate	Indian Head 2010	Indian Head 2011	Indian Head 2012	Melfort 2010	Melfort 2011	Saskatoon 2010	Saskatoon 2011	Saskatoon 2012	Scott 2010	Scott 2011	Scott 2012	Swift Current 2010	Swift Current 2011	Swift Current 2012	Mean
							Plant density (plants m^{-2})								
5	9f	5g	4f	22c	8c	10d	10e	8f	7e	2f	6e	-	3f	7f	5g
10	17ef	10f	10e	29c	11c	7d	11de	11f	14de	3f	9e	-	4ef	9ef	7f
20	21e	17e	15e	33c	8c	15d	16de	16e	21de	5e	22d	-	6e	10de	12e
40	35d	39d	35d	37c	10c	47c	22cd	25d	43d	9d	35cd	-	12d	13d	21d
80	64c	85c	55c	48c	17b	65c	40c	49c	97c	19c	51c	-	22c	24c	39c
150	107b	136b	116b	94b	22b	107b	77b	97b	212b	34b	107b	-	41b	51b	70b
300	169a	298a	252a	157a	31a	179a	164a	141a	305a	65a	183a	-	71a	92a	125a
							Emergence (%)								
5	174	106	78	438	158	200	192	150	138	34	128	-	54	132	152
10	174	96	95	288	105	70	113	106	140	25	86	-	41	86	110
20	106	86	73	165	39	75	79	80	104	25	109	-	31	51	78
40	88	97	88	93	25	118	55	62	107	22	87	-	29	34	69
80	80	106	69	60	21	81	51	61	121	23	64	-	28	29	61
150	72	91	77	63	14	71	51	65	141	23	71	-	27	34	62
300	56	99	84	52	10	60	55	47	102	22	61	-	24	31	54

Table 5. Influence of seeding rate on seed yield.

Seed Rate	Plant Density[1]	Indian Head 2010	Indian Head 2011	Indian Head 2012	Melfort 2011	Saskatoon 2010	Saskatoon 2011	Saskatoon 2012	Scott 2011	Swift Current 2010	Swift Current 2011	Swift Current 2012	Mea
						Yield (kg ha^{-1})							
5	5	2122c	2245d	1370	1702de	1404b	1305c	1337c	1075d	1327c	574d	818e	1328
10	7	2010bc	2934c	1853	1627e	1490b	1657b	1594c	1637c	1381bc	1043c	1063d	1660
20	12	2254abc	3080bc	2056	1757cde	1813ab	1919ab	1641c	1778bc	1619abc	1279c	1209cd	1882
40	21	2631ab	3437ab	2075	2070bc	1922a	2337a	2039b	2359a	1852ab	1903b	1314c	2142
80	39	2512ab	3509a	1865	2010bcd	2011a	2326a	2394ab	2422a	1844ab	2140ab	1483b	2214
150	70	2825a	3511a	2018	2403a	2091a	2389a	2491a	2282ab	1930a	2333a	1590b	2347
300	125	2710a	3658a	1873	2280ab	1976a	2429a	2353ab	2512a	1842ab	2344a	1678a	2304

[1]Mean plant density (plants m^{-2})

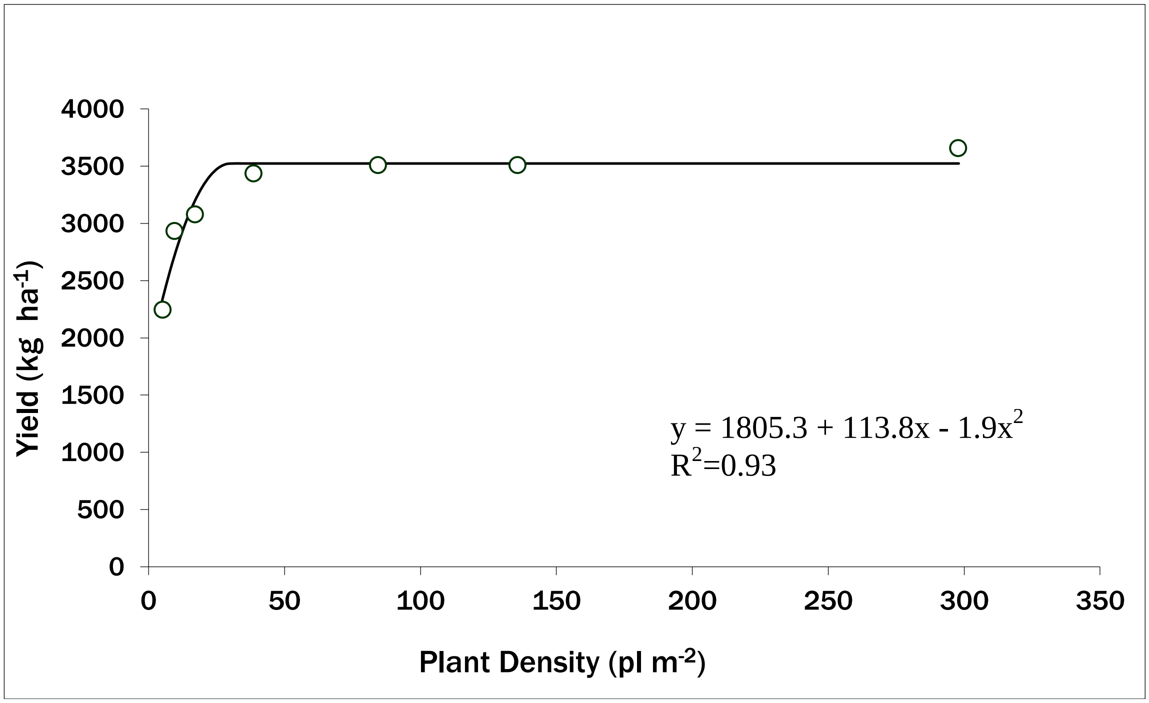

Figure 1. Indian Head 2011. Quadratic regression of yield and plant density. The breakpoint, plant density above which there is no significant change in yield, is 30 plants m^{-2}. 90 and 80% of maximum yield is achieved at plant populations of 20 and 12 plants m^{-2}, respectively.

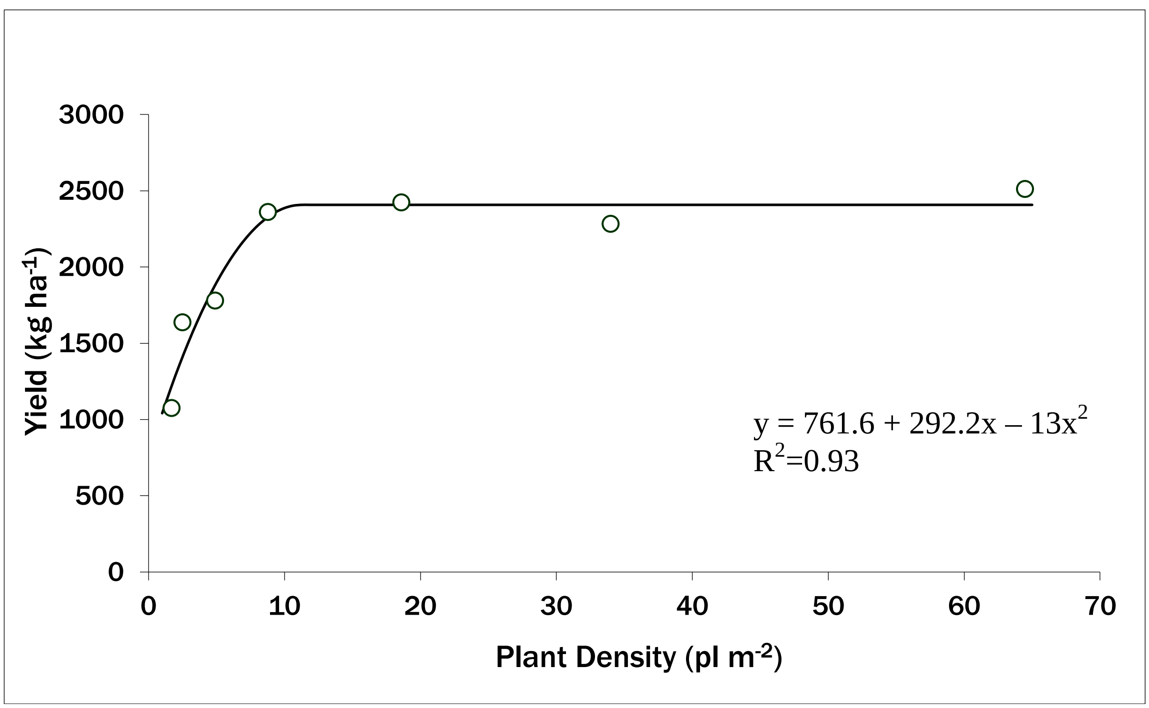

Figure 2. Scott 2011. Quadratic regression of yield and plant density. The breakpoint, plant density above which there is no significant change in yield, is 11 plants m^{-2}. 90 and 80% of maximum yield is achieved at plant populations of 8 and 6 plants m^{-2}, respectively.

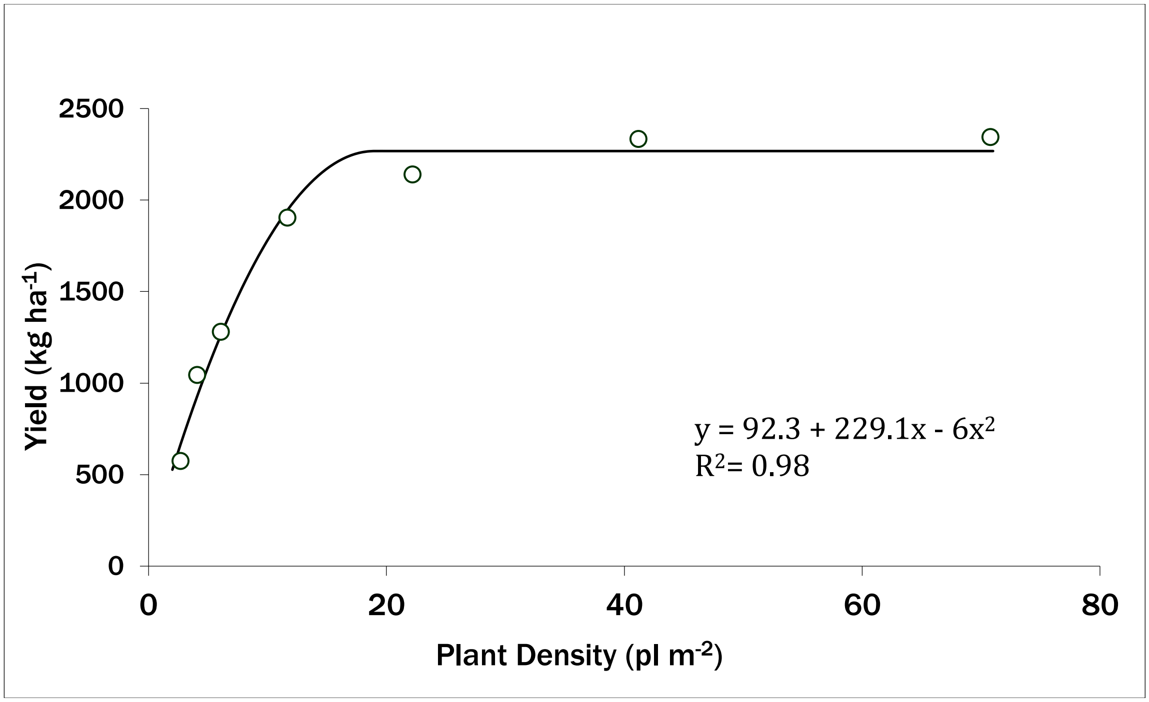

Figure 3. Swift Current 2011. Quadratic regression of yield and plant density. The breakpoint, plant density above which there is no significant change in yield, is 19 plants m^{-2}. 90 and 80% of maximum yield is achieved at plant populations of 14 and 11 plants m^{-2}, respectively.

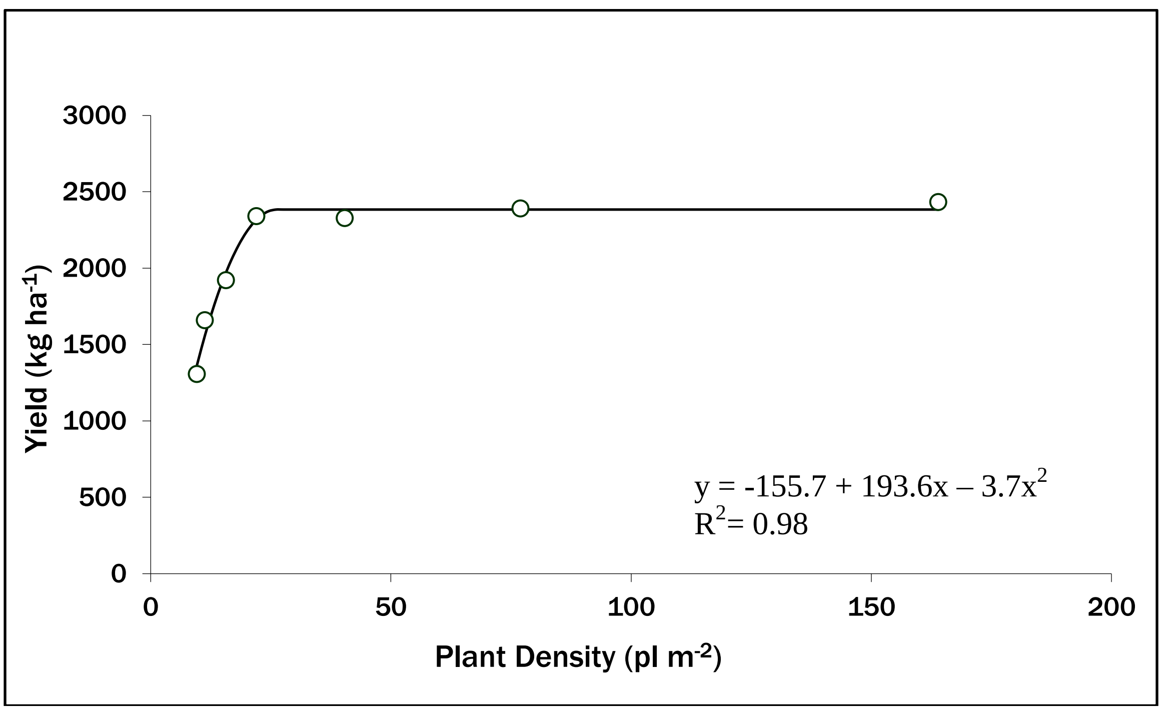

Figure 4. Saskatoon 2011. Quadratic regression of yield and plant density. The breakpoint, plant density above which there is no significant change in yield, is 26 plants m^{-2}. 90 and 80% of maximum yield is achieved at plant populations of 19 and 15 plants m^{-2}, respectively.

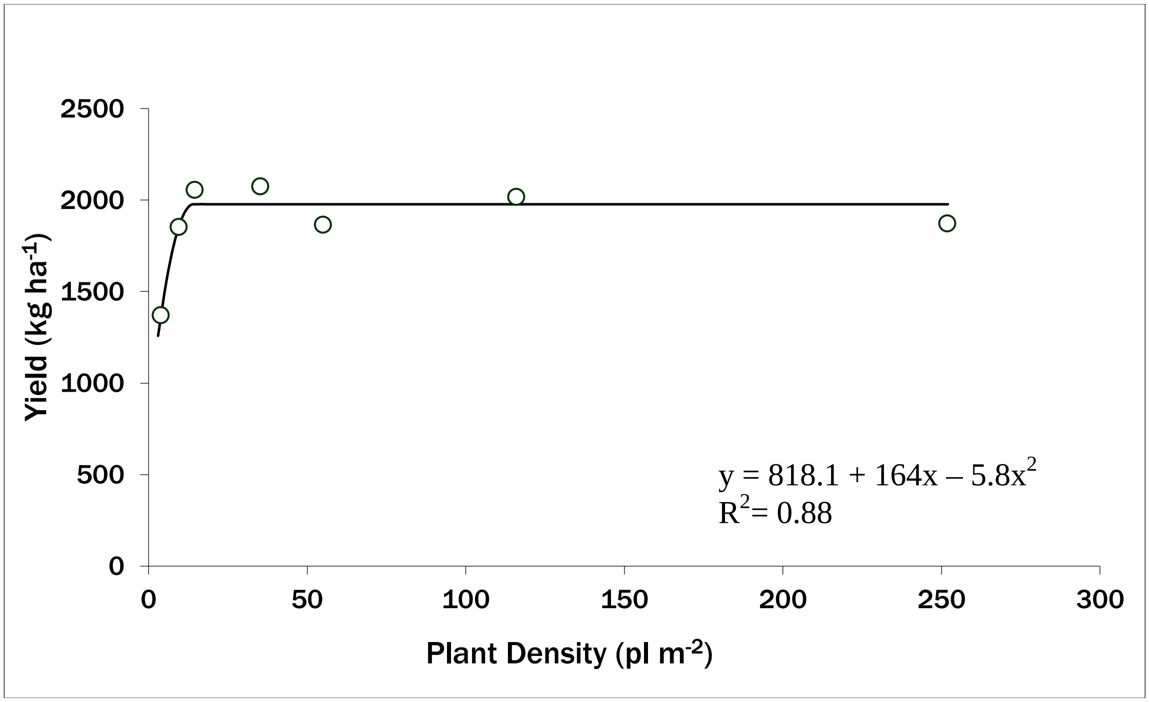

Figure 5. Indian Head 2012. Quadratic regression of yield and plant density. The breakpoint, plant density above which there is no significant change in yield, is 14 plants m^{-2}. 90 and 80% of maximum yield is achieved at plant populations of 9 and 6 plants m^{-2}, respectively.

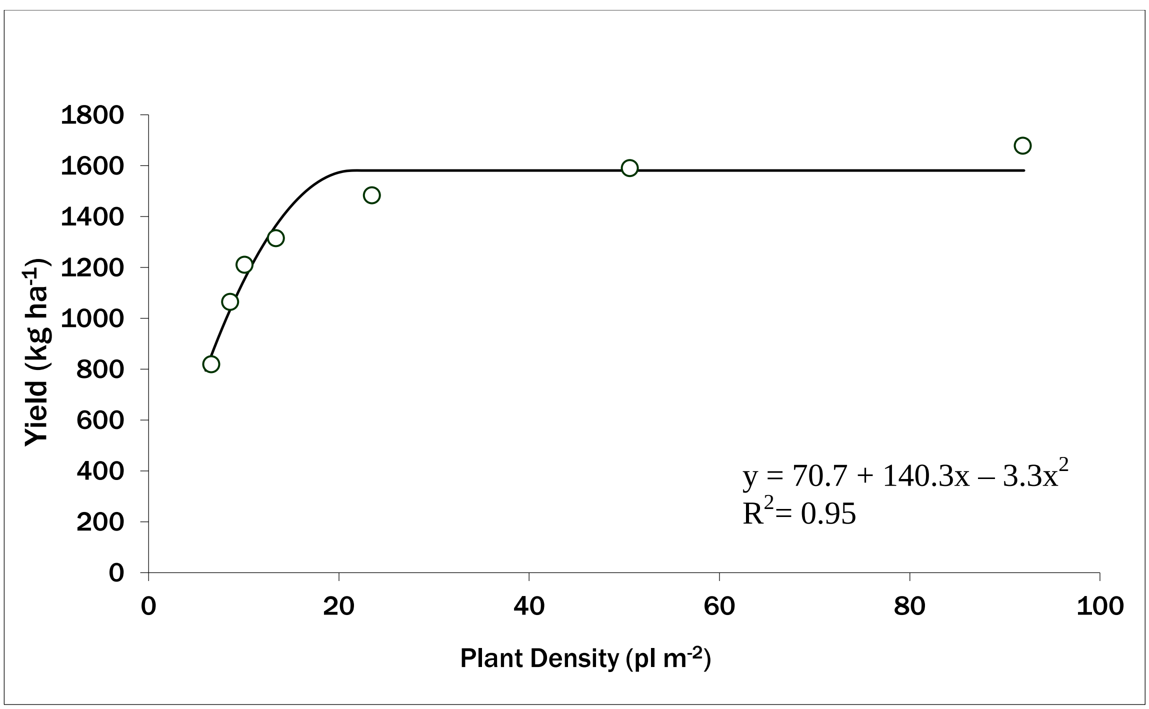

Figure 6. Swift Current 2012. Quadratic regression of yield and plant density. The breakpoint, plant density above which there is no significant change in yield, is 22 plants m^{-2}. 90 and 80% of maximum yield is achieved at plant populations of 15 and 12 plants m^{-2}, respectively.

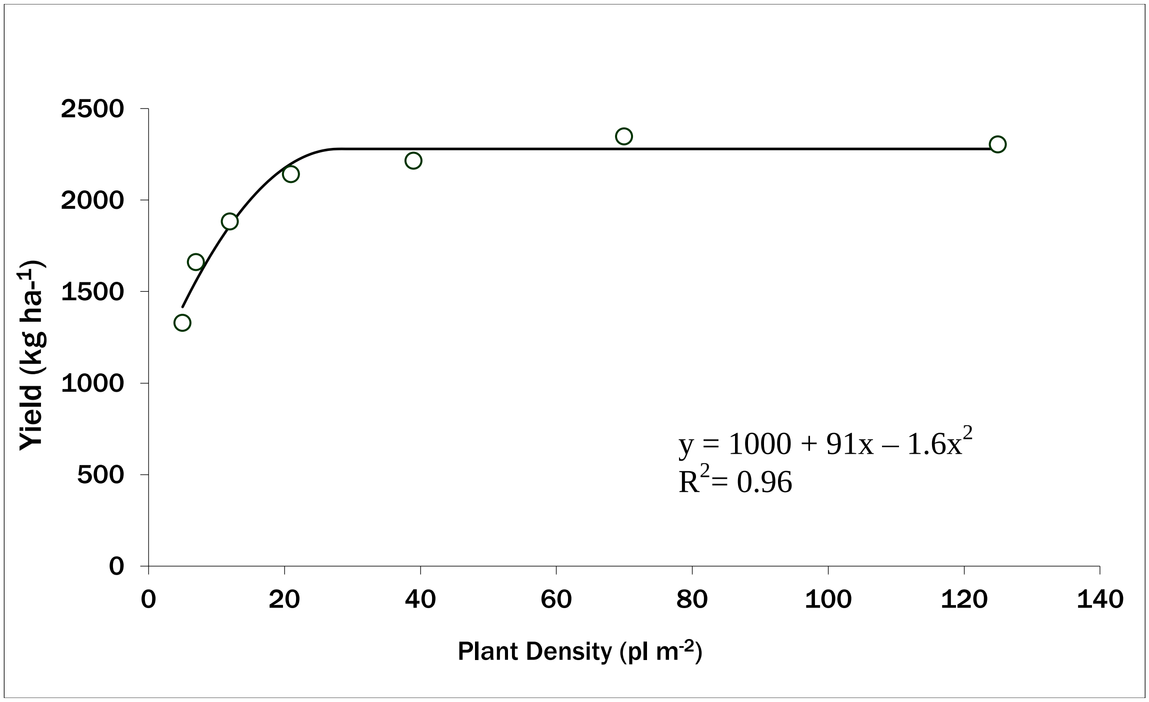

Figure 7. All site years. Quadratic regression of yield and plant density. The breakpoint, plant density above which there is no significant change in yield, is 28 plants m^{-2}. 90 and 80% of maximum yield is achieved at plant populations of 18 and 12 plants m^{-2}, respectively.

Table 6. Influence of seeding rate on length of flowering period.

Seed Rate	Plant Density[1]	Indian Head 2010	Indian Head 2011	Indian Head 2012	Melfort 2011	Scott 2011	Scott 2012	Swift Current 2012	Mean
		Length of Flowering (days)							
5	5	41a	43a	35a	24b	39a	37ab	23a	34a
10	7	39ab	42a	35a	25b	37a	38a	23a	34a
20	12	37ab	37b	27b	25ab	34b	35bc	23a	31b
40	21	33bc	31c	25bc	26a	33b	32c	21b	29b
80	39	27cd	22d	23cd	21d	29c	28d	21bc	24c
150	70	25d	19e	21d	23c	24d	28d	21bc	23cd
300	125	24d	17e	18e	23c	22d	26d	20c	21d

[1]Mean plant density (plants m^{-2})

Table 7. Influence of seeding rate on days to maturity.

Seed Rate	Plant Density[1]	Indian Head 2010	Indian Head 2011	Indian Head 2012	Melfort 2011	Saskatoon 2012	Scott 2011	Scott 2012	Swift Current 2011	Swift Current 2012	Mean
		Maturity (days)									
5	5	112e	104f	97e	116d	97b	107e	100.5c	93c	93d	102e
10	7	109d	103e	97e	116d	97b	106de	99.6bc	92c	91c	101e
20	12	107cd	101d	94d	108c	96b	106cde	98.0abc	90b	86a	98d
40	21	105c	97c	93c	101.5b	93a	105cd	98.7abc	88a	86a	96c
80	39	103b	93b	91b	101ab	92a	105bc	97ab	88a	86a	95b
150	70	99a	91ab	88a	97a	92a	102a	98ab	88a	86a	93a
300	125	98a	89a	87a	97a	90a	103ab	97a	88a	87b	93a

[1]Mean plant density (plants m^{-2})

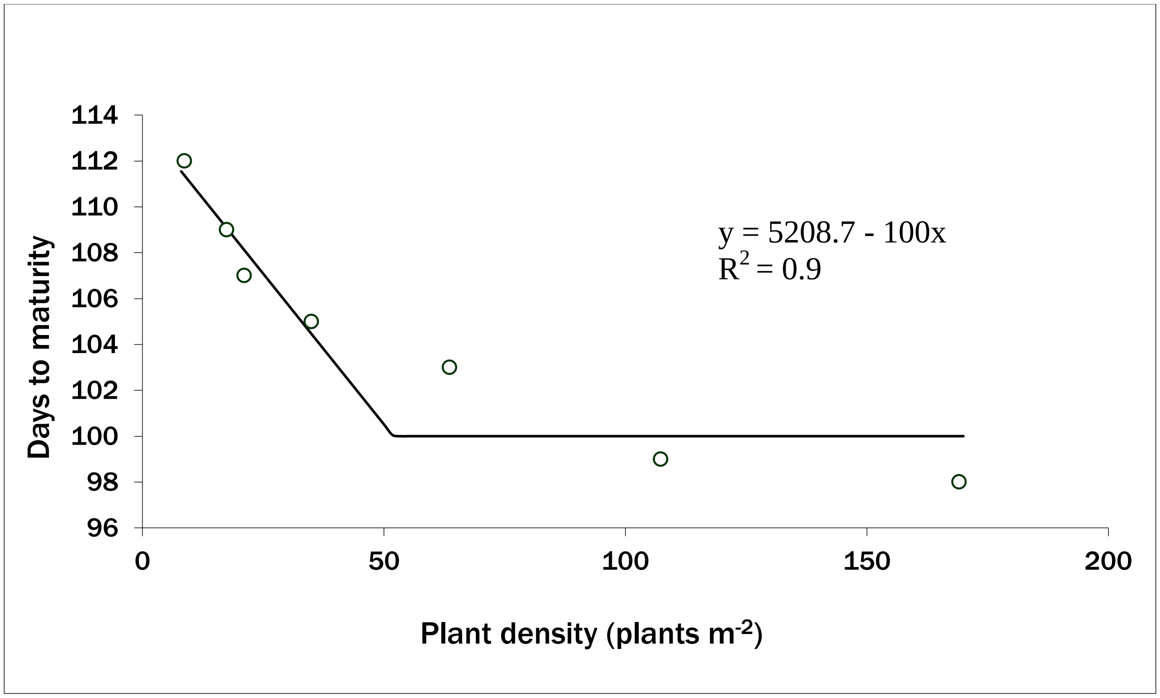

Figure 8. Indian Head 2010. Regression of plant density and days to maturity. The breakpoint, plant density above which there is no significant change in days to maturity, is 52 plants m^{-2}.

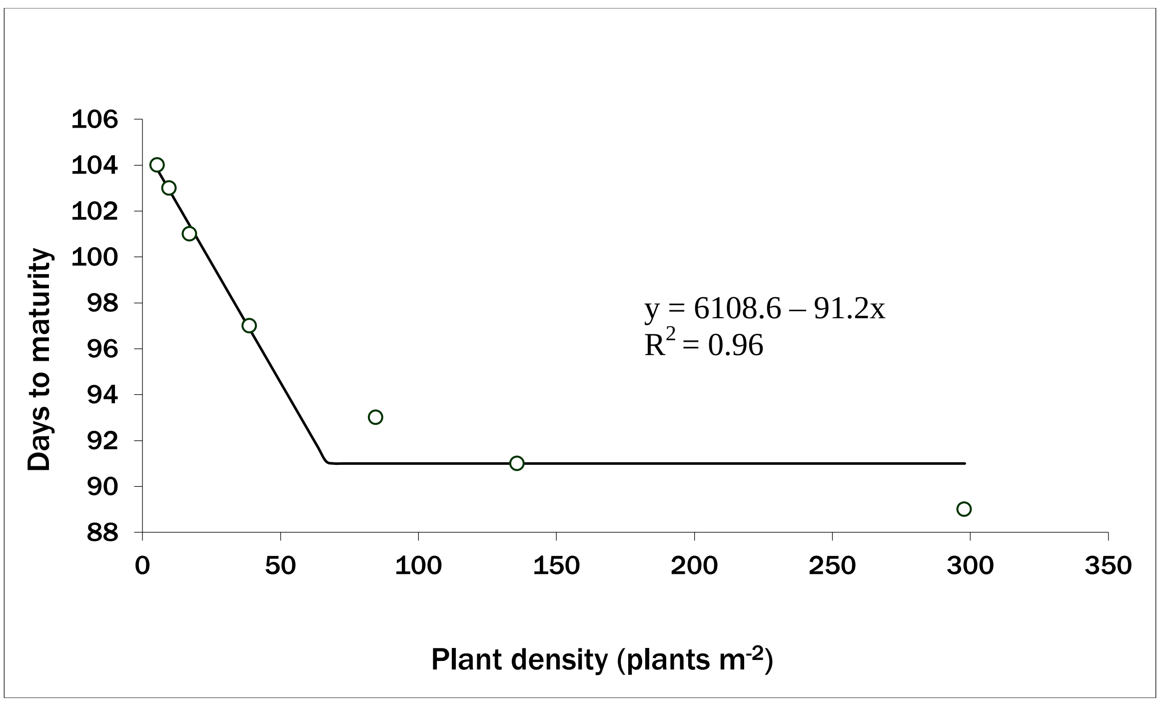

Figure 9. Indian Head 2011. Regression of plant density and days to maturity. The breakpoint, plant density above which there is no significant change in days to maturity, is 67 plants m^{-2}.

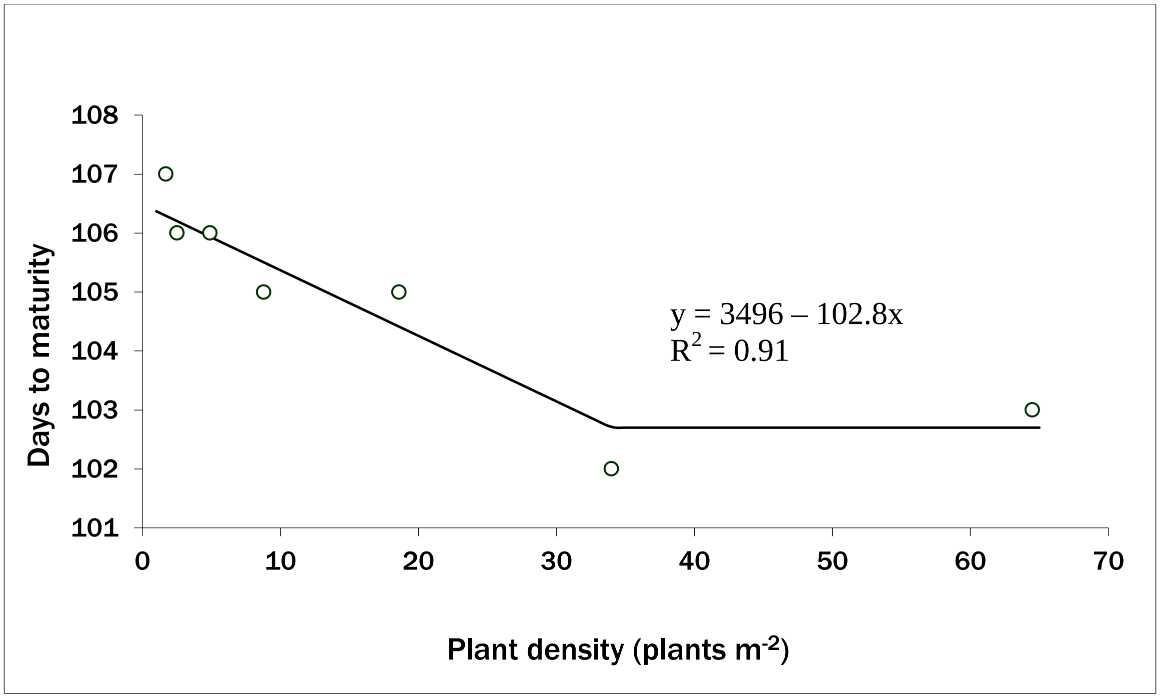

Figure 10. Scott 2011. Regression of plant density and days to maturity. The breakpoint, plant density above which there is no significant change in days to maturity, is 34 plants m^{-2}.

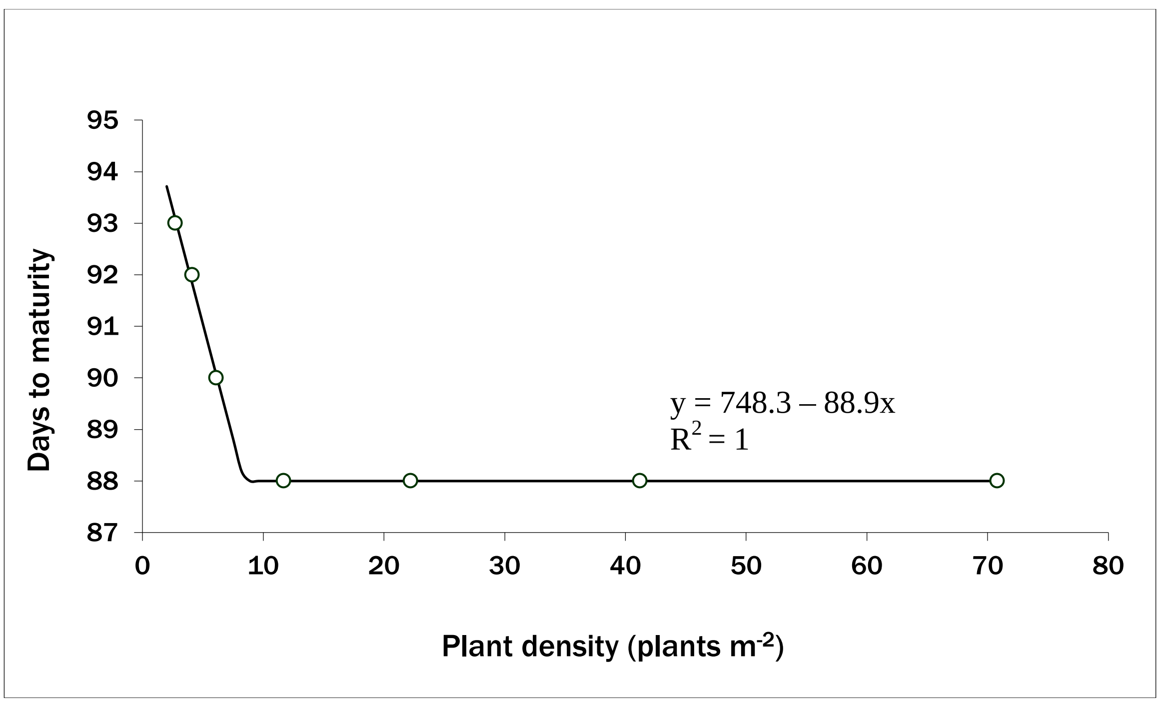

Figure 11. Swift Current 2011. Regression of plant density and days to maturity. The breakpoint, plant density above which there is no significant change in days to maturity, is 8 plants m^{-2}.

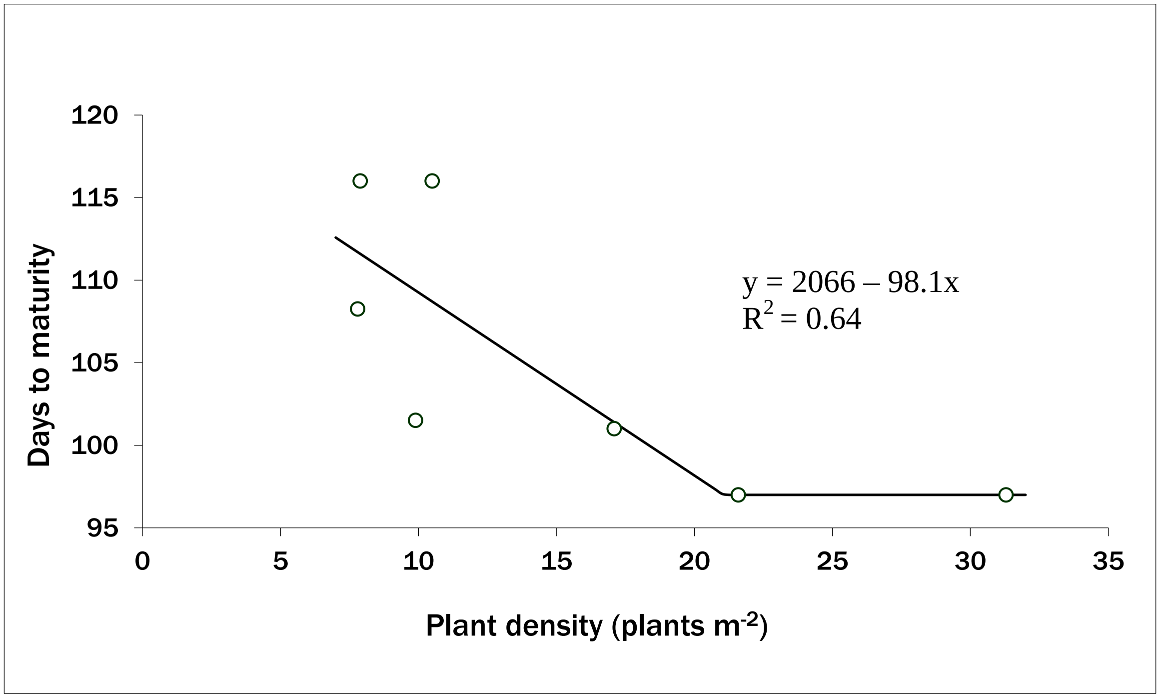

Figure 12. Melfort 2011. Regression of plant density and days to maturity. The breakpoint, plant density above which there is no significant change in days to maturity, is 21 plants m^{-2}.

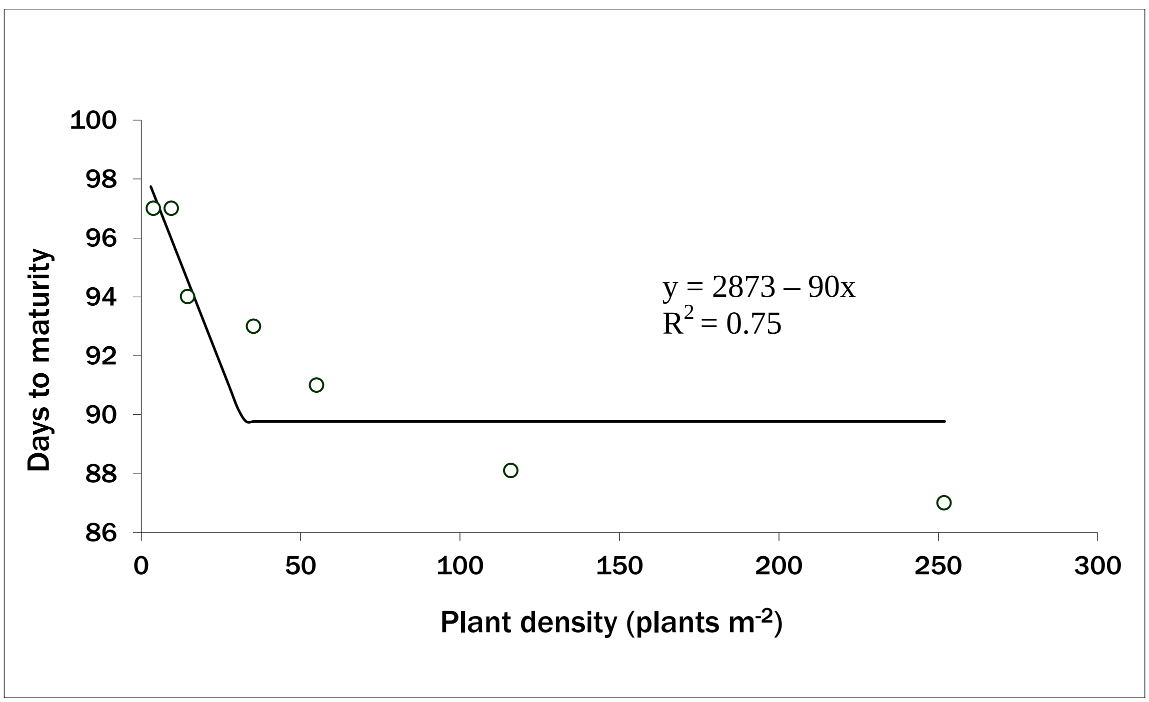

Figure 13. Indian Head 2012. Regression of plant density and days to maturity. The breakpoint, plant density above which there is no significant change in days to maturity, is 32 plants m^{-2}.

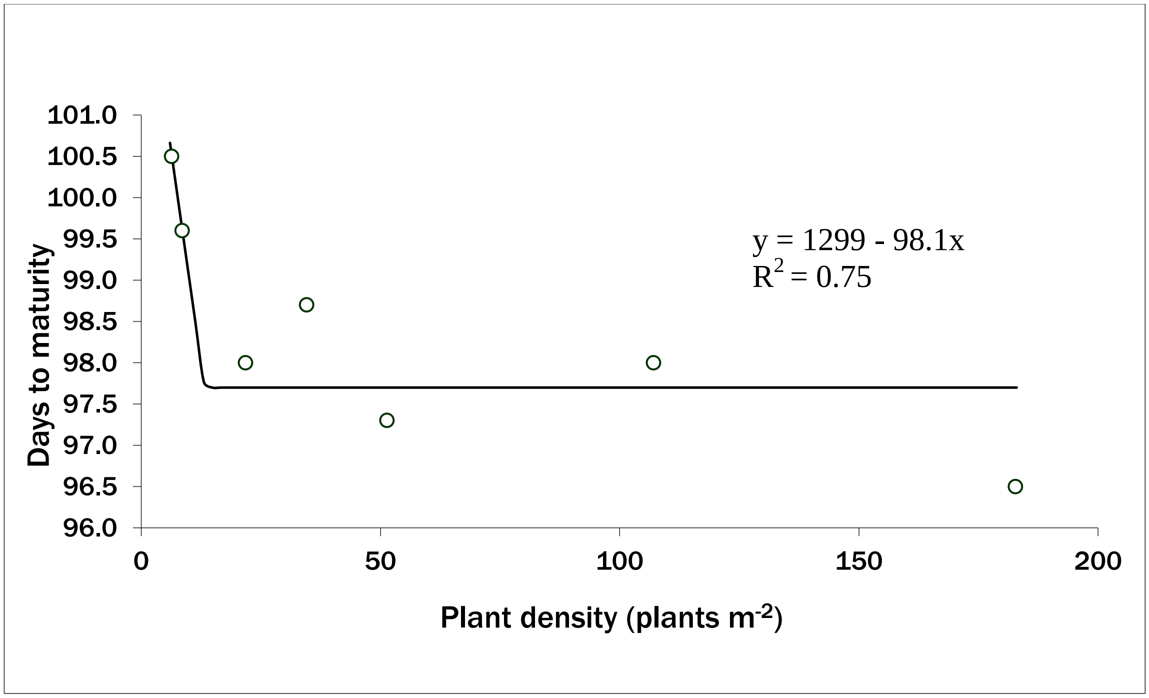

Figure 14. Scott 2012. Regression of plant density and days to maturity. The breakpoint, plant density above which there is no significant change in days to maturity, 13 plants m^{-2}.

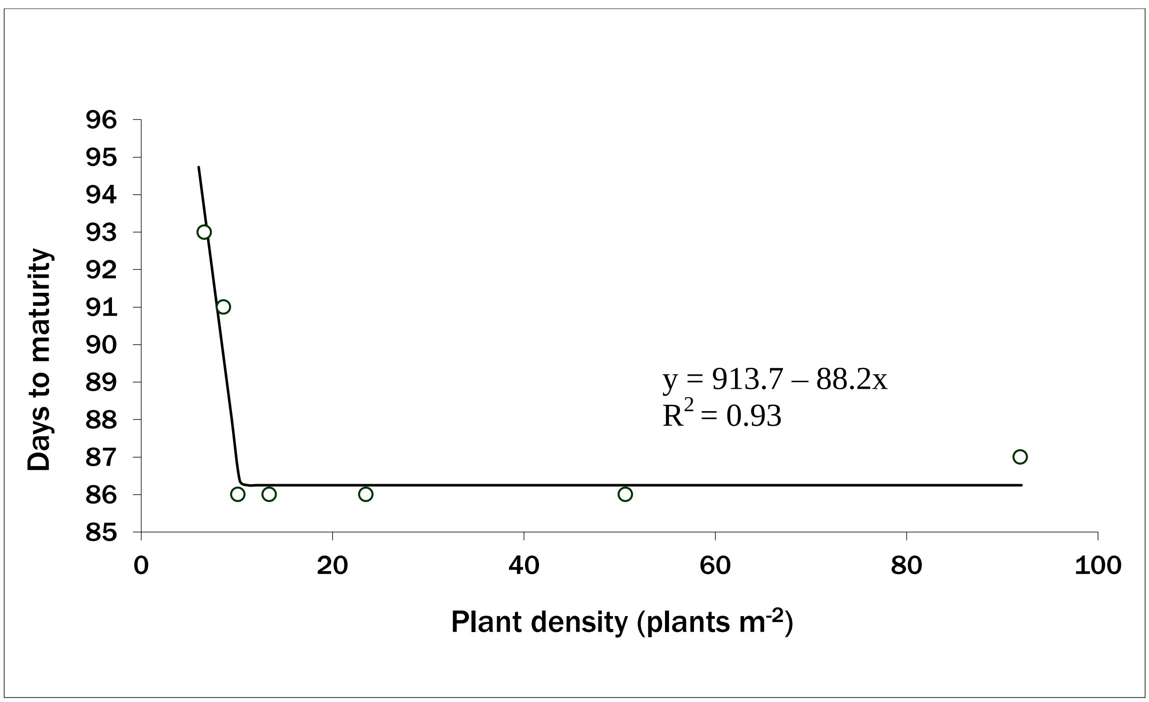

Figure 15. Swift Current 2012. Regression of plant density and days to maturity. The breakpoint, plant density above which there is no significant change in days to maturity, is 10 plants m^{-2}.

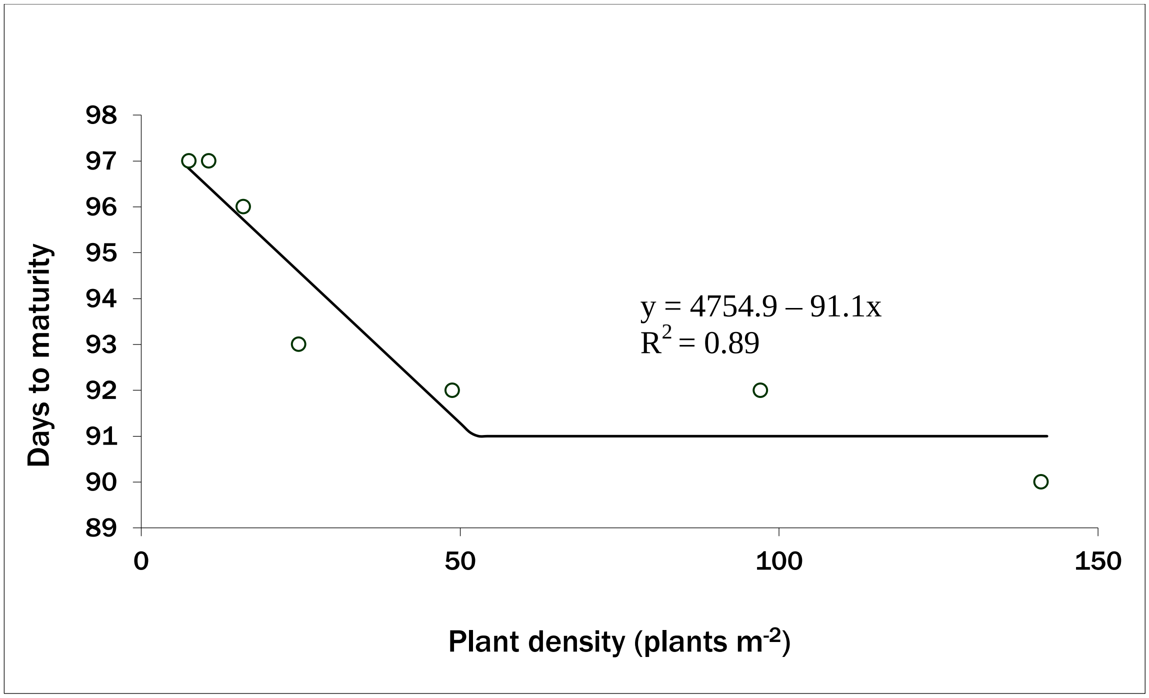

Figure 16. Saskatoon 2012. Regression of plant density and days to maturity. The breakpoint, plant density above which there is no significant change in days to maturity, is 52 plants m^{-2}.

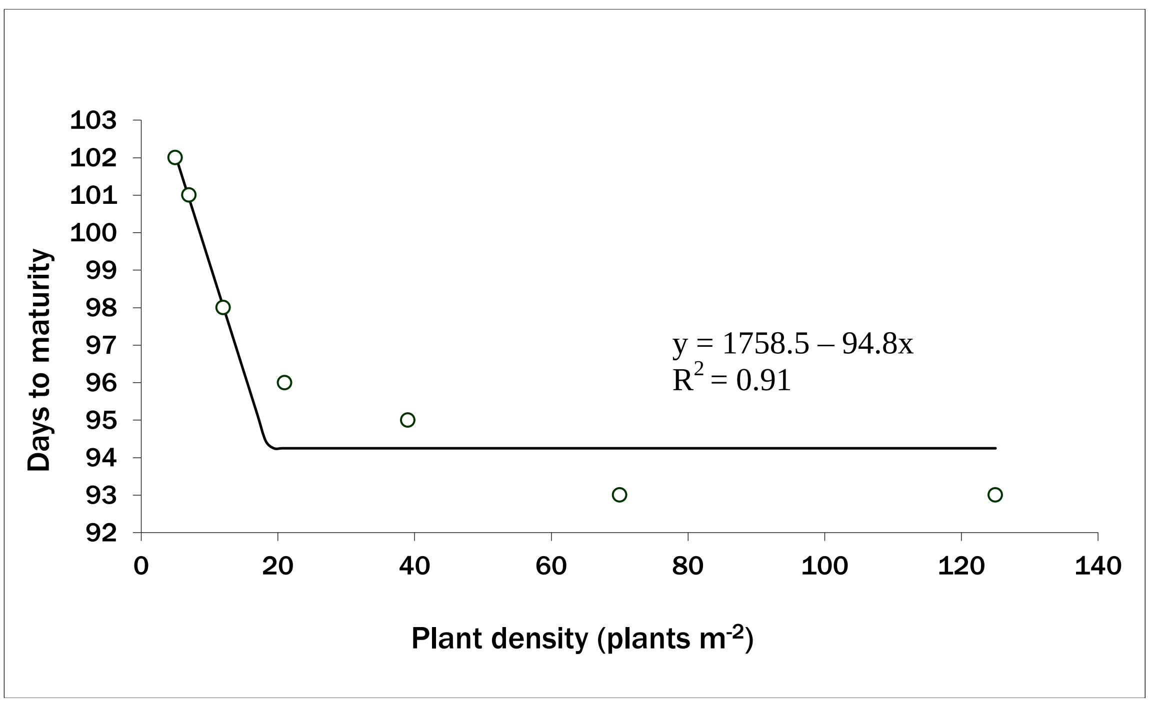

Figure 17. All site years. Regression of plant density and days to maturity. The breakpoint, plant density above which there is no significant change in days to maturity, is 19 plants m^{-2}.

Table 8. Influence of seeding rate on lodging.

Seed Rate	Plant Density[1]	Indian Head 2010	Indian Head 2011	Indian Head 2012	Scott 2011	Scott 2012	Swift Current 2011	Swift Current 2012	Mean
		Lodging Index[2]							
5	5	0.84	0.71b	0.70b	0.76c	0.76b	0.79	0.93	0.79c
10	7	0.87	0.71ab	0.74b	0.82bc	0.77b	0.75	0.93	0.79c
20	12	0.87	0.74ab	0.78a	0.89ab	0.85a	0.79	0.92	0.83ab
40	21	0.85	0.78a	0.75ab	0.96a	0.90a	0.85	0.95	0.86a
80	39	0.84	0.70bc	0.70b	0.96a	0.88a	0.86	0.95	0.84a
150	70	0.85	0.64cd	0.60c	0.94a	0.87a	0.86	0.90	0.81bc
300	125	0.81	0.59d	0.56c	0.95a	0.91a	0.84	0.92	0.80c

[1]Mean plant density (plants m^{-2})
[2]Lodging index is the ratio of canopy height to actual plant height

Table 9. Influence of seeding rate on plant survival

Seed Rate	Plant Density[1]	Indian Head 2010	Indian Head 2011	Indian Head 2012	Saskatoon 2011	Scott 2011	Scott 2012	Swift Current 2011	Swift Current 2012	Mean
		Survival (%)								
5	5	136	102ab	138a	111	103	77	91	50c	100ab
10	7	92	107ab	102ab	115	107	112	90	76b	103ab
20	12	128	112a	111ab	127	114	174	91	89ab	111a
40	21	107	92ab	104ab	86	92	106	116	104a	98ab
80	39	107	90bc	90b	99	84	195	111	111a	104ab
150	70	79	92ab	79b	96	67	107	95	104a	87bc
300	125	82	69c	67b	75	72	71	96	110a	79c

[1]Mean plant density (plants m^{-2})

Table 10. Influence of seeding rate on thousand seed weight.

Seed Rate	Plant density[1]	Indian Head 2010	Indian Head 2011	Indian Head 2012	Melfort 2011	Saskatoon 2010	Saskatoon 2011	Saskatoon 2012	Scott 2011	Swift Current 2011	Swift Current 2012	Mean
		Thousand seed weight (g)										
5	5	2.9d	3.74a	3.34	3.4c	2.95ab	3.3	3.2	3.92a	3.2a	2.86b	3.09
10	7	3.0cd	3.66ab	3.51	3.4c	2.99a	3.3	3.3	3.89ab	3.1ab	2.82b	3.1
20	12	3.1cd	3.72ab	3.60	3.5bc	3.03a	3.3	3.3	3.70ab	3.0abc	2.80bc	3.12
40	21	3.2bc	3.53bc	3.67	3.8ab	3.01a	3.3	2.9	3.18c	2.9c	2.69cd	3.05
80	39	3.4ab	3.44c	3.61	3.5bc	2.81c	3.3	3.1	3.65ab	2.9c	2.64d	3.05
150	70	3.5a	3.38cd	3.46	4.2a	2.83bc	3.2	2.7	3.53bc	2.9bc	2.89b	3.09
300	125	3.5a	3.25d	3.54	3.9ab	2.81c	3.3	3	3.53bc	3.1abc	3.04a	3.13

[1]Mean plant density (plants m^{-2})

Table 11. Influence of seeding rate on green seed.

Seed Rate	Plant Density[1]	Indian Head 2010	Indian Head 2011	Indian Head 2012	Melfort 2011	Saskatoon 2010	Saskatoon 2011	Saskatoon 2012	Scott 2011	Swift Current 2011	Swift Current 2012	Mean
		Distinctly green seed (%)										
5	5	3.2c	0.8c	5.6c	3.9c	0.090c	0.6b	0.98c	1.4	0	0	0.95e
10	7	2.2bc	0.5bc	5.4c	3.8c	0.085c	0.3b	0.46bc	1.3	0	0	0.69e
20	12	0.4a	0.4ab	2.2b	2.8bc	0.043b	0.4ab	0.22abc	0.4	0	0	0.35d
40	21	0.4ab	0.2ab	1.0ab	1.5ab	0.035b	0.4a	0.01ab	0.4	0	0	0.30cd
80	39	0.2a	0.2a	0.9ab	1.5ab	0.007a	0.2a	0a	2.5	0	0	0.21bc
150	70	0.0a	0.2a	0.7ab	1.0a	0.005a	0.1a	0ab	0.9	0	0	0.19ab
300	125	0.1a	0.1a	0.4a	0.9a	0.006a	0.1a	0a	0.3	0	0	0.13a

[1]Mean plant density (plants m^{-2})

Table 12. Influence of seeding rate on pods per plant and seeds per pod at Saskatoon and Scott 2010 to 2012.

Seeding Rate	Pods/Plant	Seeds/Pod
5	851	25
10	637	26
20	426	27
40	291	27
80	178	27
150	147	26
300	148	25

Table 13. Influence of cultivar on spring density, maturity and yield at seeding rates ranging from 5 to 300 plants m^{-2}.

Seed Rate	Spring Density		Maturity		Yield	
	5440 LL	5770 LL	5440 LL	5770 LL	5440 LL	5770 LL
	------ plants m^{-2} -----		------- days -------		------- kg ha^{-1} -------	
5	5.4g	9.6fg	108fg	110h	1388de	1200e
10	7.3g	5.2g	107f	110h	1632bc	1447cd
20	10.8efg	8.7fg	104de	110gh	1767b	1686bc
40	17.9ef	12.5efg	102bc	107f	2215a	2145a
80	30.2cd	21.8de	102bc	105e	2216a	2231a
150	55.4b	34.2c	99a	102cd	2342a	2403a
300	93.9a	64.8b	99a	100ab	2394a	2359a

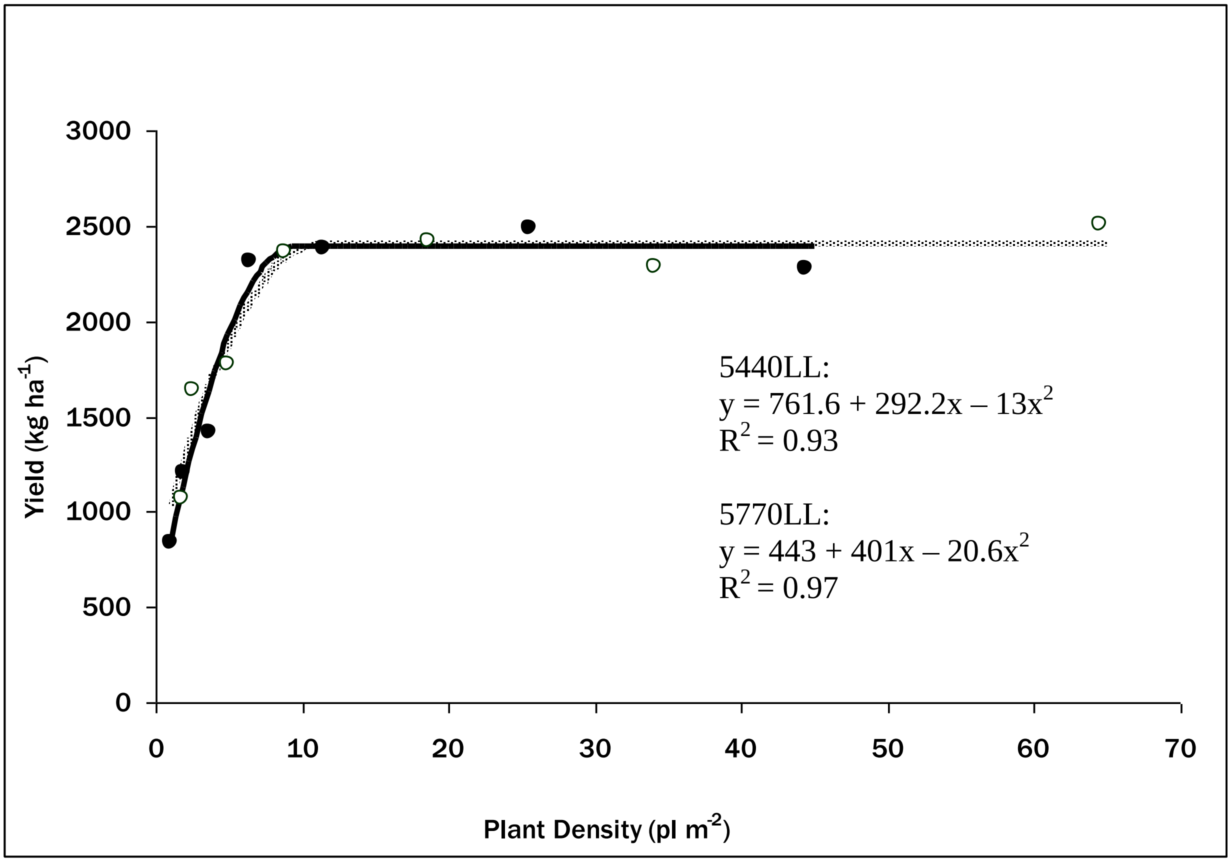

Figure 18. Scott 2011. Quadratic regression of yield and plant density. The cultivar 5440LL is represented by the light line and data points and the cultivar 5770LL is represented by the dark line and data points. The breakpoints, plant density above which there is no significant change in yield, are 11 and 10 plants m^{-2} for 5440LL and 5770LL, respectively. For the cultivar 5440LL 90 and 80% of maximum yield is achieved at plant populations of 8 and 6 plants m^{-2}, respectively. For the cultivar 5770LL 90 and 80% of maximum yield is achieved at plant populations of 7 and 5 plants m^{-2}, respectively.

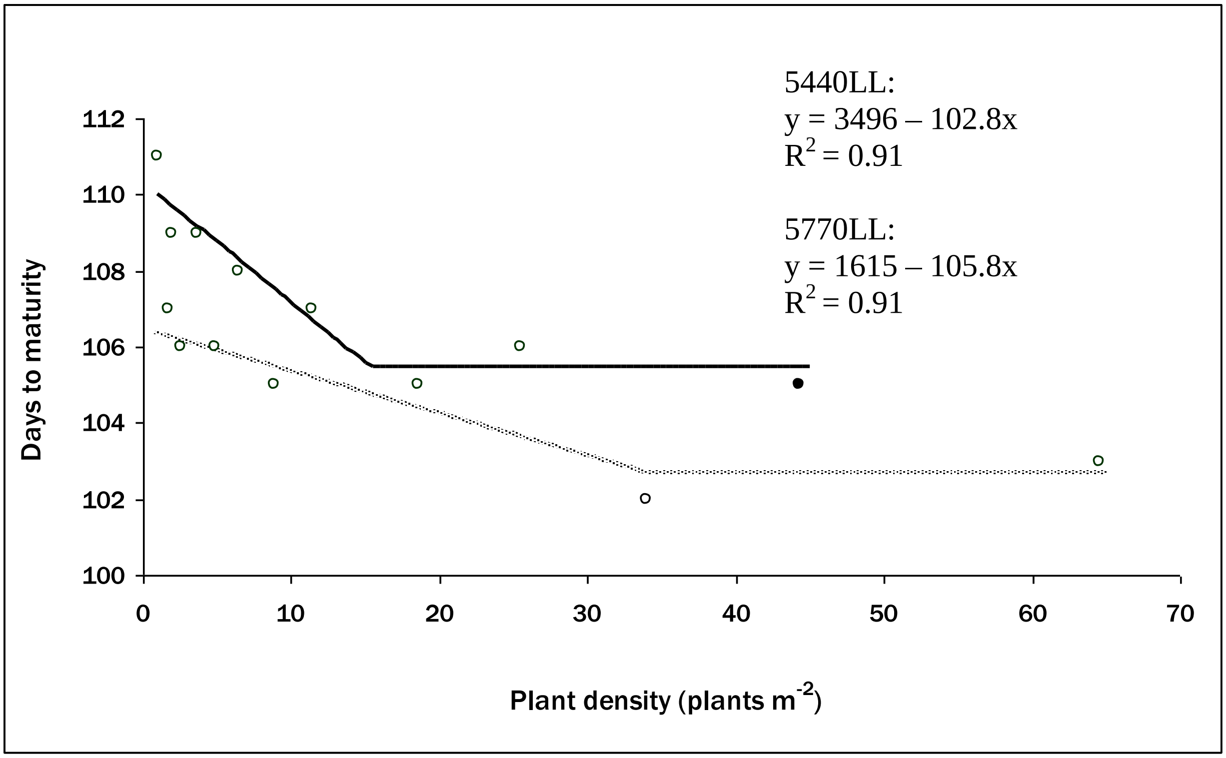

Figure 19. Scott 2011. Regression of plant density and days to maturity. The cultivar 5440LL is represented by the light line and data points and the cultivar 5770LL is represented by the dark line and data points. The breakpoints, plant density above which there is no significant change in days to maturity, are 34 and 15 plants m^{-2} for 5440LL and 5770LL, respectively.

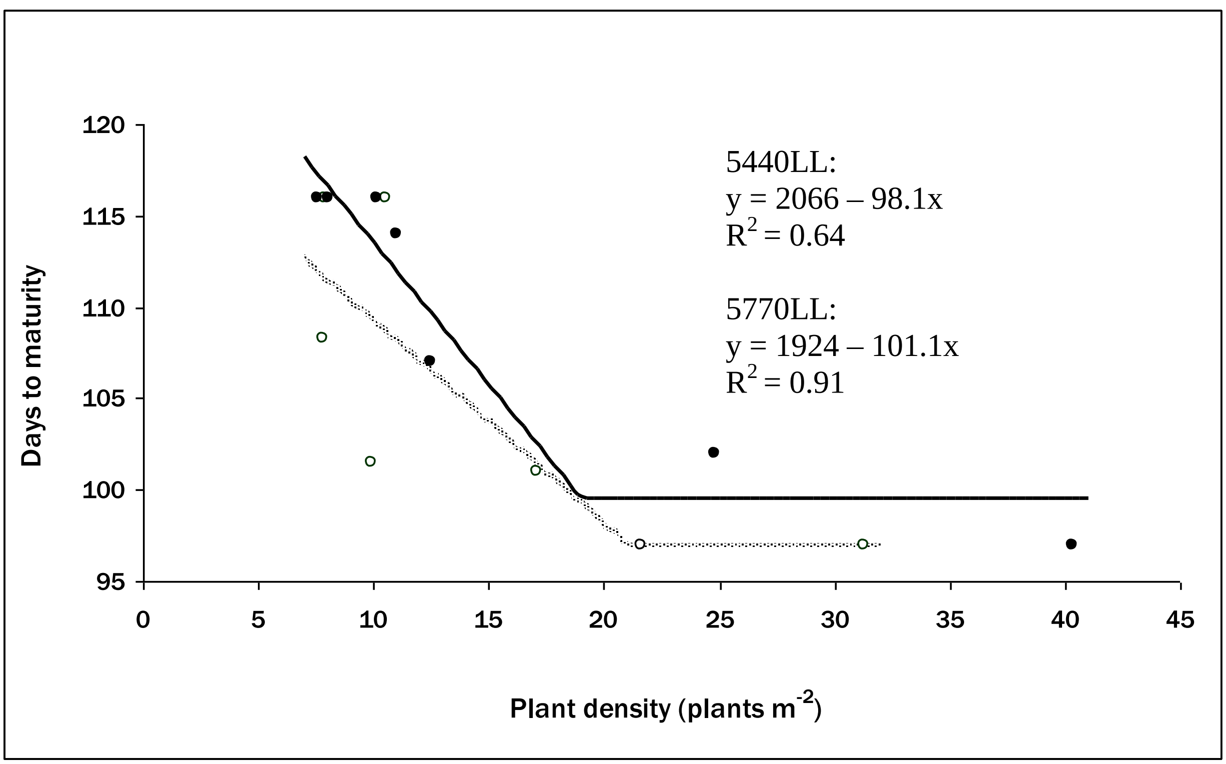

Figure 20. Melfort 2011. Regression of plant density and days to maturity. The cultivar 5440LL is represented by the light line and data points and the cultivar 5770LL is represented by the dark line and data points. The breakpoints, plant density above which there is no significant change in days to maturity, are 21 and 19 plants m^{-2} for 5440LL and 5770LL, respectively.

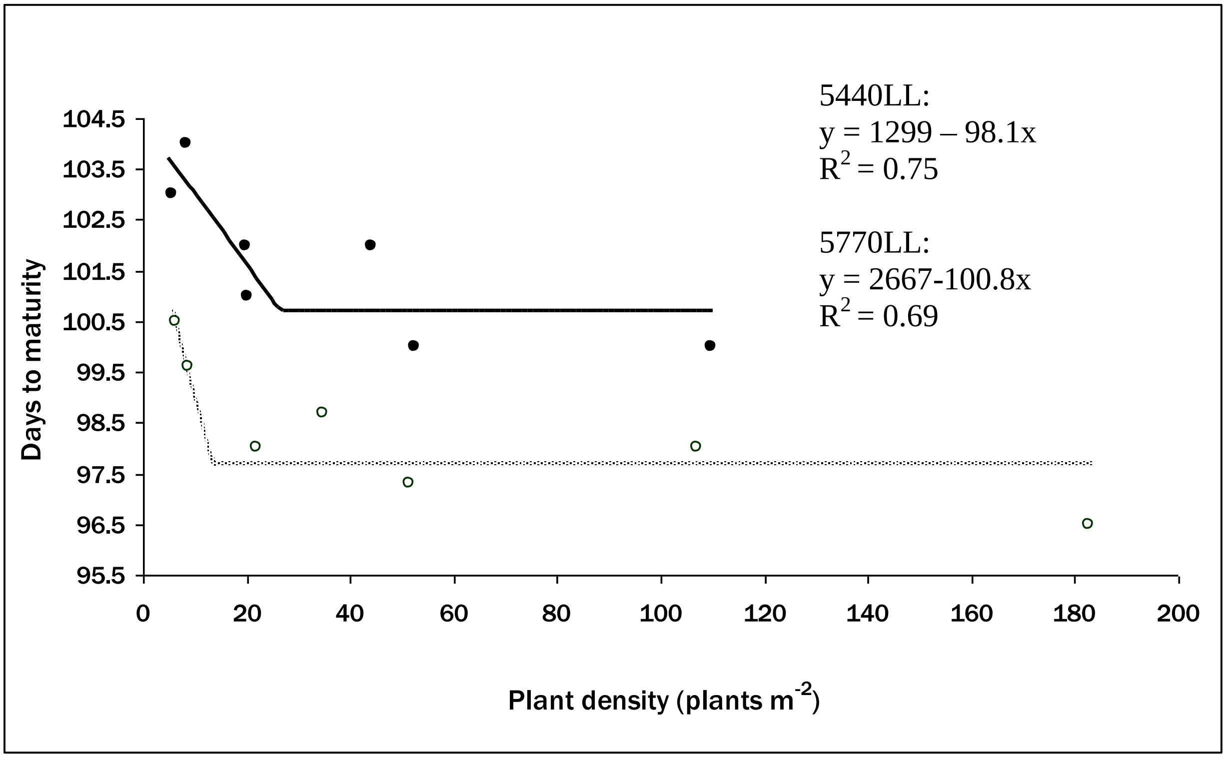

Figure 21. Scott 2012. Regression of plant density and days to maturity. The cultivar 5440LL is represented by the light line and data points and the cultivar 5770LL is represented by the dark line and data points. The breakpoints, plant density above which there is no significant change in days to maturity, are 13 and 26 plants m^{-2} for 5440LL and 5770LL, respectively.

Reseeding Experiment

Stand Establishment

Reseeding in mid June resulted in a reduced plant stand compared to early June seeding (Table 14). There is an increased risk of damaging spring frosts with earlier seeding dates (Canola Council of Canada 2013), which may account for the lower plant densities at the early May seeding date. Stand establishment of a canola crop is depend upon factors such as soil moisture, soil temperature, disease, insects and other climatic factors (Hanson et al. 2008); therefore, it is expected that varying conditions in the spring will lead to differences in plant density when canola is seeded on different dates.

Seed Yield

When faced with a low plant stand, there was a yield benefit to reseeding to 5440 LL in early June approximately half of the time (Table 15). Reseeding a low plant stand of canola to 5440 LL in early June resulted in a significant yield increase in 6 of 12 site years and in the combined analysis (Table 15).

Reseeding to 9350RR resulted in a significant yield increase in only three site years (Table 15). At both Swift Current site years reseeding resulted in a significant yield decrease (Table 15), likely to hot and dry conditions in August (Table 1 and 2).

Generally, reseeding in mid June resulted in a lower yield. Although *B. rapa* (polish canola) requires a shorter growing season, reseeding to *B. rapa* at either reseeding date did not provide a yield benefit over the early May treatment with low plant density (Table 14). The *B. napus* varieties yielded significantly higher than the *B. rapa* when seeded in early June; however, there was no significant yield difference between *B. napus* and *B. rapa* at the mid June seeding date (Table 14).

The Canola Council of Canada (2013) recommends early seeding (late April to mid May) as a way to increase crop yield. Early seeding tends to be beneficial as it allows the crop to utilize water more effectively and may help the crop to avoid flowering during the highest summer temperatures (Canola Council of Canada 2013). This was especially evident at the 2012 Swift Current site where a drought resulted in the mid June seeded canola to senesce prior to seed set (Table 15). In studies comparing April and mid-May seeding dates the earlier seeded treatments were found to yield significantly higher than the mid-May seeded treatments (Kirkland and Johnson 2000; Clayton et al. 2004). Degenhardt and Kondra (1981b) also reported significantly lower seed yields when canola was seeded at the end of May compared to early May. In the present study, when canola was seeded at a normal seeding rate (150 seeds m^{-2}) there was no significant yield difference between 5440 LL seeded in mid May and early June at 7 of 12 site years and in the combined analysis of all site years. Canola seeded in mid May yielded higher at three site years, while canola seeded in early June yielded higher than mid May seeded canola at two site years (Table 15).

Duration of Flowering and Days to Maturity

The length of the flowering period was measured at four site years. Treatment had a significant effect on duration of flowering at three of the site years, with low density canola having a longer flowering period than canola seeded at a typical seeding rate (Table 16). At Melfort 2012 mid June seeded canola had a longer flowering period than canola seeded at other dates; however, there were no strong trends at the other site years. When site years were combined seeding date and cultivar did not have a significant effect on the length of the flowering period (Table 16).

Early May planting dates had extended days to maturity compared to the June reseeding dates (Table 17). The low plant population treatment matured five days later than the 150 seeds m^{-2} seeding rate treatment seeded in early May (Table 17). Longer days to maturity are expected in low plant populations due to increased branching. At both reseeding dates *B. rapa* matured 7-8 days earlier than the *B. napus* varieties (Table 17), a benefit in locations where fall frosts are of great concern. At Swift Current 2012 and Scott 2011 the mid June planted canola did not reach maturity before senescence (Table 17).

Quality

Percent green seed increased as seeding dates were delayed. Averaged across site years, green seed increased from approximately 1% with early May seeded canola to over 5% with mid June seeded canola (Table 18). There was generally no significant difference in percent green seed between cultivars at either reseeding date or between the low and normal seeding rate treatments planted in early May (Table 18).

Thousand seed weight can be variety specific so only differences within varieties across seeding dates were considered. 5440 LL planted in early June had a significantly lower thousand seed weight than 5440 LL planted in early May at six of eleven site years; however, there was no significant difference between early May and early June when site years were combined (Table 19). 5440 LL planted in mid June had a significantly lower thousand seed weight than 5440 LL planted in early May at eight of eleven site years and when all site years were combined (Table 19). Averaged across site years there were no significant differences in seed weight between early and mid June seeding dates for any variety; however at less than half of the site years early June seeded canola had higher thousand kernel weights than mid June seeded canola (Table 19). Kirkland and Johnson (2000) also reported larger seed size with earlier seeding dates. Seed size may have decreased with the later seeding dates because the plants were unable to finish their life cycle under ideal circumstances.

Economic Return

Economic return was calculated for the early May seeding date and June reseeding dates (Table 20). The economic analysis only includes costs that are expected to differ between treatments, seed and herbicide costs. Canola seeded in early May at a rate of 150 seeds m^{-2} provided the greatest economic return (Table 20). In the case of a low plant stand of canola, it made economic sense to reseed to a high yielding variety of hybrid canola in early June. The SCIC establishment benefit of \$148 ha^{-1} is provided to cover some of the costs of reseeding and including this benefit resulted in a positive net return for 9350RR seeded in early June (Table 20). Although the seed costs for the polish variety are lower than that of a hybrid, it did not make economic sense to reseed to polish canola at either reseeding date.

The economic analysis highlights the benefit of targeting good plant populations in early May. Even when the SCIC establishment benefit is included in the calculations the early May treatment seeded at a traditional rate of 150 seeds m^{-2}, results in a net return \$219 and \$276 ha^{-1} greater than 5440LL and 9350RR seeded in early June, respectively (Table 20).

Table 14. Influence of seeding date, variety and seeding rate on spring plant density.

Treatment[1]	Indian Head		Melfort		Swift Current		Scott	Saskatoon		Mean
	2010	2011	2010	2012	2011	2012	2011	2010	2012	
	(plants m^{-2})									
EM - 5440 LL - 20	19d	12b	45cd	28e	18c	16c	4b	29d	17d	21e
EM - 5440 LL -150	90ab	85a	84a	88c	79a	84a	27b	78c	94ab	79abc
EJ - Polish - 150	79bc	87a	46	87c	44b	58b	59a	92bc	79bc	70bc
EJ - 5440 LL - 150	96ab	97a	81ab	114a	83a	80a	69a	128a	111ab	95a
EJ - 9350 RR - 150	103a	95a	58abc	60d	74a	78a	74a	109ab	120a	86ab
MJ - Polish - 150	63c	8b	15d	88c	52b	11c	65a	-	52cd	45d
MJ - 5440 LL - 150	98ab	6b	24cd	108ab	80a	20c	59a	-	85abc	61cd
MJ - 9350 RR - 150	93ab	5b	26cd	93bc	81a	16c	72a	-	90ab	61cd
LSD	21.46	13.40	35.07	19.56	12.87	10.62	23.01	28.38	38.35	21.98
CV	37.31	88.01	71.37	35.03	37.00	69.89	51.56	46.47	47.30	56.47

[1]Seeding date – variety – seeding rate (seeds m^{-2})

Table 15. Influence of seeding date, variety and seeding rate on yield.

Treatment[1]	Indian Head		Melfort			Swift Current		Scott		Saskatoon			Mean
	2010	2011	2010	2011	2012	2011	2012	2010	2011	2010	2011	2012	
	yield (kg ha^{-1})												
EM - 5440 LL - 20	1737c	1841c	1116	2502	2623cd	714b	1023b	1010b	1752d	1051b	1607b	1606	1549bc
EM - 5440 LL -150	2403a	2951a	1310	2239	3001ab	1050a	1634a	2724a	2385bc	1530b	2277a	1916	2121a
EJ - Polish - 150	993e	810d	1147	2559	1594f	266e	380d	635b	1548de	1039b	1162b	1521	1139d
EJ - 5440 LL - 150	2194ab	2374b	1746	3007	3216a	456d	648c	2492a	2664a	2631a	1782ab	1878	2092a
EJ - 9350 RR - 150	2002bc	2109bc	1496	1579	2794bc	590c	700c	2181a	2186c	2259a	1765ab	1985	1808ab
MJ - Polish - 150	1036e	250e	1264	1986	1362f	110f	-	220b	1329e	-	1290b	1103	935d
MJ - 5440 LL - 150	1313d	86e	1379	2790	2475d	173f	-	-	866f	-	1538b	1714	1270cd
MJ - 9350 RR - 150	1342d	198e	1536	2222	1998e	269e	-	571b	1389e	-	1702ab	1859	1246cd
LSD	287.73	396.39	ns	ns	266.78	69.36	256.60	886.03	212.34	516.30	604.65	ns	392.68
CV	35.67	84.12	30.41	29.17	27.82	67.29	53.37	55.26	33.34	42.73	29.84	27.14	52.30

[1]Seeding date – variety – seeding rate (seeds m^{-2})

Table 16. Influence of seeding date, variety and seeding rate on length of flowering period.

Treatment[1]	Melfort 2012	Swift Current 2012	Scott 2011	Saskatoon 2012	Mean
	----------------------- length of flowering (day) ------------------------				
EM - 5440 LL - 20	26e	24a	32a	22	26
EM - 5440 LL -150	22g	21b	28abc	21	23
EJ - Polish - 150	29d	20c	29ab	20	25
EJ - 5440 LL - 150	24f	18d	26bc	21	22
EJ - 9350 RR - 150	29d	19d	28abc	21	24
MJ - Polish - 150	35a	-	28abc	25	28
MJ - 5440 LL - 150	30c	-	26bc	25	26
MJ - 9350 RR - 150	32b	-	24c	18	23
LSD	0.30	0.91	4.72	ns	ns
CV	14.05	10.97	13.56	21.09	20.55

[1]Seeding date – variety – seeding rate (seeds m^{-2})

Table 17. Influence of seeding date, variety and seeding rate on days to maturity.

Treatment[1]	Indian Head 2011	Melfort 2011	Melfort 2012	Swift Current 2011	Swift Current 2012	Scott 2011	Saskatoon 2012	Mean
	-- Maturity (days) --							
EM - 5440 LL - 20	114f	117e	105g	89g	91e	108d	92e	103a
EM - 5440 LL -150	100e	119e	98f	88f	88d	103c	89d	98b
EJ - Polish - 150	78a	89cd	74b	69b	67a	84a	71a	77d
EJ - 5440 LL - 150	88d	88bcd	89c	74d	72c	97b	82c	86c
EJ - 9350 RR - 150	85c	97d	89c	71c	70b	97b	77b	85c
MJ - Polish - 150	81b	79ab	73a	66a	.	.	72a	77d
MJ - 5440 LL - 150	81b	79abc	95e	76e	.	.	.	85c
MJ - 9350 RR - 150	82b	78a	93d	76e	.	.	75b	83c
CV	0.9	7.0	0.0	0.6	1.3	1.4	2.9	10.8

[1]Seeding date – variety – seeding rate (seeds m^{-2})

Table 18. Influence of seeding date, variet and seeding rate on green seed.

Treatment[1]	Indian Head 2010	Indian Head 2011	Melfort 2011	Melfort 2012	Swift Current 2011	Swift Current 2012	Scott 2010	Scott 2011	Saskatoon 2010	Saskatoon 2011	Saskatoon 2012	Mean
	distinctly green seed (%)											
EM - 5440 LL - 20	0.3bc	0.5c	5abc	0.5a	0.3ab	0	1.3a	4a	0a	0a	0a	1.1a
EM - 5440 LL -150	0a	0.3a	5.8bcd	1.5ab	0.3ab	0	0a	0.8a	0a	0a	0a	0.8a
EJ - Polish - 150	2.3bc	5c	3a	1.3ab	0a	0	2a	1.5a	2.3b	0.5a	0a	1.6a
EJ - 5440 LL - 150	2.8c	2ab	3.5ab	2.8bc	1.5abc	0	8.8b	2.5a	6c	4.8b	2b	3.3ab
EJ - 9350 RR - 150	2.3bc	0.3a	9.3d	6.5e	0.5abc	0.3	12c	1.8a	2.8b	0.3a	0.5a	3.3ab
MJ - Polish - 150	5d	5c	8.3cd	5de	0a	-	15c	12b	-	0.7a	0.8a	5.3b
MJ - 5440 LL - 150	5.8d	4bc	6bcd	4.8cd	2.8d	-	-	15bc	-	1a	3b	5.4b
MJ - 9350 RR - 150	6.5d	5.3c	5.3abc	4cd	1.3bc	-	1a	18.3c	-	0.6a	0.5a	4.7b
LSD	2.03	2.40	3.70	2.14	1.23	ns	3.08	3.27	1.79	1.23	1.73	2.85
CV	89.70	94.79	50.74	72.71	144.74	447.21	102.97	98.61	106.80	144.38	169.63	129.16

[1]Seeding date – variety – seeding rate (seeds m^{-2})

Table 19. Influence of seeding date, variety and seeding rate on thousand seed weight.

Treatment[1]	Indian Head 2010	Indian Head 2011	Melfort 2011	Melfort 2012	Swift Current 2011	Swift Current 2012	Scott 2010	Scott 2011	Saskatoon 2010	Saskatoon 2011	Saskatoon 2012	Mean
	thousand seed weight (g)											
EM - 5440 LL - 20	3.33b	3.60a	2.81	4.35a	3.04a	2.64a	3.09ab	3.67a	2.54b	3.59a	2.80a	3.22a
EM - 5440 LL -150	3.69a	3.62a	2.59	3.82b	3a	2.8a	3.4a	3.67a	2.63b	3.26b	2.79a	3.21a
EJ - Polish - 150	2.46e	2.60c	2.62	2.81d	2.13d	1.85b	2.4c	2.65d	2.34c	2.77d	2.36bc	2.45cd
EJ - 5440 LL - 150	3.00c	2.99b	2.65	3.83b	2.73b	2.63a	2.99b	3.26b	2.85a	3.40a	2.76ab	3.01ab
EJ - 9350 RR - 150	2.92c	2.62c	1.97	3.55c	2.32c	2.12b	2.83b	2.79c	2.57b	3.03c	2.46ab	2.65c
MJ - Polish - 150	2.63de	2.75c	2.29	2.17f	1.86e	-	1.84d	2.36e	-	2.74d	2.03c	2.23d
MJ - 5440 LL - 150	2.83cd	2.75c	2.60	2.67d	2.43c	-	-	2.39e	-	3.5a	2.85a	2.66bc
MJ - 9350 RR - 150	2.54e	2.68c	2.50	2.44e	2d	-	2.46c	2.24f	-	2.97c	2.62ab	2.41cd
LSD	0.26	0.23	ns	0.22	0.13	0.39	0.31	0.11	0.16	0.19	0.41	0.27
CV	14.68	14.54	20.64	23.62	17.72	18.05	14.25	19.13	7.42	10.48	13.75	19.17

[1]Seeding date – variety – seeding rate (seeds m^{-2})

Table 20. Influence of reseeding canola on economic return at Indian Head, Melfort, Saskatoon, Scott and Swift Current in 2010, 2011 and 2012.

	Early May		Early June			Mid June		
	5440LL	5440LL (Low)	5440LL	9350RR	Polish	5440LL	9350RR	Polish
Expenses								
Seed cost ($ kg^{-1})[1]	27.56	27.56	27.56	27.56	10.56	27.56	27.56	10.56
Seeding rate (kg ha^{-1})[2]	8.88	8.88	8.88	5.97	3.83	8.88	5.97	3.83
Initial seed cost ($ ha^{-1})	244.73	244.73	244.73	244.73	244.73	244.73	244.73	244.73
Reseeding seed cost ($ ha^{-1})	0	0	244.73	164.53	40.44	244.73	164.53	40.44
Cost of seeding ($ ha^{-1})[3]	38.14	38.14	76.27	76.27	76.27	76.27	76.27	76.27
In crop herbicide[1]	59.28	59.28	33.35	5.56	64.22	33.35	5.56	64.22
Burn off[1]	0	0	5.56	5.56	5.56	5.56	5.56	5.56
Cost of spraying ($ ha^{-1})[3]	24.70	24.70	24.70	24.70	24.70	24.70	24.70	24.70
Total ($ ha^{-1})	366.85	366.85	629.35	521.36	455.93	629.35	521.36	455.93
Income								
Yield (kg ha^{-1})	2121.00	1549.00	2092.00	1808.00	1139.00	1270.00	1246.00	935.00
Crop Value ($ ha^{-1})[4]	1230.18	898.42	1213.36	1048.64	660.62	736.60	722.68	542.30
Income - Expenses ($ ha^{-1})	863.33	531.57	584.01	527.28	204.69	107.25	201.32	86.37
Gain or loss from low ($ ha^{-1})	331.76		52.45	-4.28	-326.87	-424.31	-330.24	-445.19
Gain or loss including reseeding benefit[5]	331.76		200.65	143.92	-178.67	-276.11	-182.04	-296.99

[1]Costs obtained in spring 2013 from industry.
[2]Based on a seeding rate of 150 live seeds m^{-2} for all treatments. Treatment 2 was seeded at 20 seeds m^{-2}; however, this was to mimic a situation where canola was seeded at a typical seeding rate and environmental conditions resulted in a low plant stand.
[3]Based on costs from custom rate guide (Saskatchewan Ministry of Agriculture 2012).
[4]Based on a price of $0.58 kg^{-1}
[5]Includes Saskatchewan Crop Insurance Corporation (SCIC) establishment benefit of $148.20 ha^{-1} to help cover reseeding costs.

Conclusions

Canola plants exhibited a high level of plasticity and were able to maintain seed yield across a range of plant populations. When results from all site years were combined a plant population of 18 plants m^{-2} was required to achieve 90% of maximum yield. When plant density was reduced the canola plant was able to compensate by increasing the number of branches and pods per plant.

A potential drawback of reduced plant populations is increased days to maturity and green seed. Averaged across locations, the highest plant populations matured nine days earlier than canola at the lowest plant populations. The reseeding project also showed a delay in maturity of five days with the low plant population compared to the high plant population seeded on the same date in early May. Higher green seed counts were found at lower compared to higher plant densities; however, in the reseeding project seeding date had more of an impact on green seed than plant populations. There was no significant difference between the low and high plant populations seeded in early May but as seeding date was delayed to Mid June there was a significant increase in green seed content.

Distribution of the canola plants in the field is another consideration. Uniform distribution of plants is a prerequisite for yield stability (Diepenbrock 2000), and non uniform distribution may become especially evident when plant populations are low. Angadi et al. (2003) found that yield was maintained at lower plant populations when plants were uniformly distributed.

If faced with a canola stand with lower than the optimum plant density the decision to reseed will be based on plant density, date and uniformity of the plant stand. The results of the reseeding study show that when faced with a plant stand of 20 plants m^{-2} or less, reseeding in early June to hybrid canola provides a yield and economic benefit compared to leaving the stand of low density canola. Although *B. rapa* will mature earlier than *B. napus* it is lower yielding. This study found no advantage to reseeding with *B. rapa*, even when reseeding was postponed to mid-June. When reseeding is required, it is recommended that producers reseed as early as possible to reduce the risk of yield and quality reductions due to fall frost. If conditions do not allow for reseeding to occur in late May or early June it is not recommended that producers reseed to canola.

Acknowledgements

Funding and support for this project was provided by the Saskatchewan Canola Development Commission and the Saskatchewan Crop Insurance Corporation.

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