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for the

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Seeding Rate and Seeding Date Effects on Flax Establishment and Yield

(Adopt #20140388)

Principal Applicant: Wayne Thompson, Executive Director
Saskatchewan Flax Development Commission (SaskFlax)
A5A – 116 – 103rd Street East
Saskatoon, SK, S7N 1Y7
Report prepared by:
Chris Holzapfel, Stewart Brandt and Mike Hall

Project Identification

1. **Project Title:** Seeding Date and Seeding Rate Effects on Flax Establishment and Yield
2. **Project Number:** 20140388
3. **Producer Group Sponsoring the Project:** Saskatchewan Flax Development Commission (SaskFlax)
4. **Project Location(s):** Indian Head, Saskatchewan, R.M. #156
5. **Project start and end dates (month & year):** April 2015 to February 2016
6. **Project contact person & contact details:**

Administrator
Wayne Thompson, Executive Director
Saskatchewan Flax Development Commission
A5A-116-103rd Street East
Saskatoon, SK, S0G S7N 1Y7
Phone: 306-664-1901
Email: wayne@saskflax.com
Web: www.saskflax.com

Project Manager(s)
Chris Holzapfel, Research Manager
Indian Head Agricultural Research Foundation
P.O. Box 156, Indian Head, SK, S0G 2K0
Phone: 306-695-4200
Email: cholzapfel@iharf.ca
Web: www.iharf.ca

Stewart Brandt, Field Research Manager
Northeast Agriculture Research Foundation
P.O. Box 1240, Melfort, SK, S0E 1A0
Phone: 306-843-7811
Email: sbrandt@neag.ca
Website: www.neag.ca

Mike Hall, Research Manager
East Central Research Foundation
75 Haultain Avenue
Yorkton, SK, S3N 1X6
Phone: 306-621-6032
Email: m.hall@parklandcollege.sk.ca

Objectives and Rationale

7. **Project objectives:**

The objective of this project was to demonstrate the effects of low, medium and high seeding rates at early and late seeding dates on establishment and seed yield of two flax varieties.

8. **Project Rationale:**

For optimal flax yields, minimum plant populations of 300 plants m^{-2} are typically recommended in Saskatchewan. Past research has shown that this minimum threshold was only achieved 60% and 73% of the time with early and late plantings, respectively. This suggests that producers must pay close attention to emergence with their seeding practices, adjusting rates if necessary, and that future flax agronomic research needs to focus on management effects on flax establishment. Flax is a poor competitor with weeds early in the season and experience has shown that this crop has difficulty recovering from a poor start; therefore, problems with plant establishment often result in sub-optimal yields. Postponing seeding until soils have warmed up can result in more rapid and complete emergence; however, flax requires a relatively long growing season and yields can be compromised if seeding is delayed too long. It is typically recommended that flax be seeded by mid-May. The proposed project will help producers see the potential benefits of using higher seeding rates, particularly when seeding early into cool soils.

Methodology and Results

9. Methodology:

Field trials were completed in 2013, 2014 and 2015 by the Indian Head Agricultural Research Foundation (IHARF) and by the Northeast Agriculture Research Foundation (NARF) in 2014 and 2015 as well as the East Central Research Foundation (ECRF) at Yorkton in 2015, on behalf of the Saskatchewan Flax Development Commission. The trials were located on no-till fields (spring wheat stubble) near Indian Head, (R.M. #156), and on conventionally tilled fields near Melfort, SK (R.M. 428). The treatments were a factorial combination of two seeding dates (early May and late May), three seeding rates (low, normal and high) and, beginning in 2014, two varieties for a total of 12 treatments. The treatments were arranged in split-plot design with seeding dates as the main plots and seeding rates and varieties as the sub-plots. The targeted seeding dates (SD) were early (as early as possible) and late (late-May). The actual seeding rates (SR) for three SR treatments were 35-39 kg ha^{-1} (low), 50-55 kg ha^{-1} (normal) and 69-75 kg ha^{-1} (high). The two variety (VAR) treatments were CDC Bethune (traditional) and FP2454 (northern adapted). In 2015, the normal seeding rate had to be excluded from the analyses at IHARF due to the factorial design and a seeding error which resulted in an incorrect rate for the late-seeded FP2454 at the 55 kg ha^{-1} target seeding rate. Actual dates of seeding are provided in Table 1. Seeding progressed earlier at Indian Head than at Melfort in both 2014 and 2015. This likely reflected that the snow cover leaves and soil warm up earlier at the more southerly located Indian Head site.

Table 1. Early and late seeding dates at Indian Head, Melfort and Yorkton SK during 2013 to 2015.

Seeding Date	Indian Head			Melfort		Yorkton
	2013	2014	2015	2014	2015	2015
Early	May11	May 11	May 2	May 16	May 19	May 2
Late	May 29	May 27	May 28	June 2	June 2	May 22

At Indian Head in all three years, flax was direct-seeded using a SeedMaster plot drill equipped with 8 openers spaced 30 cm apart and a trimmed plot length of 10.5 m. Urea, monoammonium phosphate, potassium chloride and ammonium sulphate were side-banded at rates considered sufficient to ensure that nutrient availability was not limiting. Weeds were controlled using registered pre-emergent and in-crop herbicide applications with products and application times tailored to control the specific species encountered each year and for each seeding date. To help ensure that pasmo infection was not a limiting factor, foliar fungicide was applied in both years, again, with separate applications for each seeding date. Plant densities were estimated by counting the number plants in 4 x 1 m sections of crop row. No lodging was observed in any of three growing seasons, therefore detailed notes were not taken and lodging data are not presented. Days from planting to maturity were recorded for all plots and the plots were considered mature when approximately 75% of the bolls had turned colour. Pre-harvest glyphosate was applied in 2014 and 2015 to terminate weeds and assist with crop dry down with separate applications for each seeding date. The centre five rows of each plot was straight-combined using a Wintersteiger plot when it was fit to so with separate harvest dates for each seeding date whenever feasible. The harvest samples were cleaned and weighed with yields expressed in kg ha^{-1} and corrected to 10% seed moisture content.

In preparation for seeding at Melfort, in both years, 100 kg N/ha as 34-0-0 was broadcast over the entire plot area. For each seeding date, the soil was tilled and packed 1 to 3 days before seeding. Flax was seeded using a Fabro seeder (7 in row spacing) and 15 kg of P_2O_5/ha of 11-52-0 was added to the seed row. CDC Bethune and FP2454 were used for both dates. For post-emergent weed control, registered in-crop herbicide applications which were selected to control the specific species encountered on the site. Plant densities were estimated by counting the number plants in 2 x 1 m sections of crop row in each plot. Lodging at Melfort was estimated using the Belgian lodging scale but treatment related differences were very small and not significant and lodging data are not presented. Days from planting to maturity were recorded for all plots in both years and were defined as the date when approximately 75% of the bolls had turned colour. Pre-harvest glyphosate was applied in to terminate weeds and assist with crop dry down with a separate application for each date. Each plot was straight-combined using a Wintersteiger plot when it was fit to so. The harvest samples were cleaned and weighed with yields expressed in kg ha^{-1} and corrected to 10% seed moisture content.

All data was subjected to statistical analysis, but actual statistical procedures differed between sites depending on capabilities at each. No attempt was made to perform a combined statistical analysis across sites. All treatment effects and differences between means were considered significant at $P \leq 0.05$. Growing season weather data were monitored and recorded using online data from the nearest Environment Canada weather station which was always located within approximately 5 km of the trial sites.

10. Results:

Weather:

Mean monthly temperatures and precipitation amounts for the 2013-15 growing seasons at Indian Head are presented relative to the long-term averages in Table 2. In general, 2013 was an excellent growing season for flax with adequate but not excessive moisture and slightly below normal temperatures. The 2014 growing season was more challenging with wet conditions in May and especially June which delayed herbicide applications and resulted in significant crop stress. In 2015, there was adequate moisture at seeding for both dates but no significant precipitation until late June, at which point moisture conditions improved and stayed adequate for the remainder of the season. Overall, the weather conditions were conducive to flax yields which were considered above-average in 2013, below-average in 2014 and approximately average in 2015.

At Melfort, temperatures were near normal during both 2014 and 2015 except that June of 2014 was quite cool. Precipitation during 2014 was above normal from June through August with very wet conditions delaying weed control in June and likely causing damage from saturated soil conditions. The 2015 growing season was very dry in May and dry conditions prevailed until late June. Dry conditions at seeding coupled with drying due to intensive pre-seeding tillage reduced emergence and resulted in somewhat variable crop stands that filled in later. On July 27, more than 100 mm of rain fell in 6 hours, causing flooding which persisted briefly at this trial site and likely caused some variable damage.

At Yorkton in 2015, temperatures were more than 1 degree above normal during June and July and near normal for May and August. Precipitation was much below normal during May and June at Yorkton, and these dry conditions likely adversely impacted crop emergence. Above normal precipitation during July followed by somewhat below normal for August improved the moisture situation for this site, but did not restore precipitation for the growing season to normal levels. Frost in late May at this site appeared to cause more damage to early seeded flax than late seeded which was just at the cotyledon stage when this occurred.

There were several statistically significant interaction between the three factors being evaluated. While some of these interactions were of scientific value, none appeared to have much practical significance, and are therefore not presented in this report.

Seeding date affected plant density at 5 of 6 location years (Table 3). Densities increased as seeding was delayed at 3 location years and increased with delayed seeding at 2 location years. Plant density was not affected by seeding date at Indian Head in 2014.

At Indian Head in 2013, plant populations were 148 plants m^{-2} lower with early seeding (342 vs 490 plants m^{-2}) while in 2015 plant populations were much higher overall but emergence was better with early seeding (574 vs 505 plants m-2). The response in 2013 was typical for a late, cool spring whereby, with early seeding, soils can be cold resulting in reduced or delayed emergence relative to later seeding under such conditions. In contrast, the weather was dry after seeding in 2015 and the slight reduction in emergence detected with late planting may have been due to drier soils at this time. While there was a seeding date effect, flax was seeded into adequate moisture at both dates in 2015 and precipitation later in June ensured excellent emergence for the later seeded plots as well. At Melfort, higher plant densities with early seeding likely reflected better seedbed moisture conditions compared with later seeding; a situation that may have also been related to the impacts of pre-seeding tillage. This same explanation would not account for the differences in emergence associated with seeding date in 2015. Conditions were quite dry at both seeding dates, however seed was likely placed somewhat deeper at the later date, ensuring that a greater proportion of seeds were placed into moist soil. Very dry conditions at Yorkton in 2015 played a role in the overall low emergence noted at this site. Increased plant density with late vs early seeding may have reflected differences in soil temperatures or seed placement between seeding dates. When averaged across all location years, differences in plant densities between seeding dates were relatively small. The observation that overall differences due to seeding date were small while individual site year differences were large and variable reflects the conflicting effects of differences in soil temperature, seedbed moisture and depth of seed placement. All of these factors are known to affect plant densities. Successful crop establishment is often determined by the ability of growers to understand how these factors can be managed by selecting appropriate seeding dates or depths that reflect conditions in the field in any given year.

Table 1. Mean monthly temperatures and precipitation amounts along with long-term (1981-2010) normals for the 2013, 2014 and 2015 growing seasons at Indian Head, Saskatchewan and for 2014 and 2015 at Melfort, Saskatchewan.

Location	Year	May	June	July	August	Avg. / Total
		Mean Temperature (°C)				
Indian Head	2013	11.9	15.3	16.3	17.1	15.2
	2014	10.2	14.4	17.3	17.4	14.8
	2015	10.3	16.2	18.1	17.0	15.4
	Long-term	***10.8***	***15.8***	***18.2***	***17.4***	***15.6***
Melfort	2014	10.0	14.0	17.5	17.6	14.8
	2015	9.9	16.4	17.9	17.0	15.3
	Long-term	***10.7***	***15.9***	***17.5***	***16.8***	***15.2***
Yorkton	2015	10.5	16.7	19.3	17.5	16.0
	Long-term	***10.4***	***15.5***	***17.9***	***17.1***	***15.2***
		Precipitation (mm)				
Indian Head	2013	17	104	50	6	177
	2014	36	199	7.8	142	385
	2015	16	38	95	59	207
	Long-term	***52***	***77***	***64***	***51***	***244***
Melfort	2014	24	170	95	60	349
	2015	7	55	150	57	269
	Long -term	***43***	***52***	***77***	***52***	***226***
Yorkton	2013	8	28	123	46	205
	Long-term	***51***	***80***	***78***	***62***	***272***

Variety affected plant density at 4 of 5 location years (Table 3). The traditional variety resulted in significantly higher plant densities than the northern adapted variety in 2014, but in 2015 the reverse occurred at 2 locations and tended to occur at the third location. This suggests that differences associated with variety were most probably due to seed quality differences in the seed lots used each year. Seed size may have also contributed to the observed differences as the rates were based on mass per unit area as opposed to viable seeds per unit area. Thus seed of the traditional variety had better quality than the northern adapted variety in 2014, and the reverse occurred in 2015. When averaged across all location years, differences in plant density between varieties were relatively small and likely not significant.

As expected, the effect of SR on plant densities was significant at all location years with incremental increases in actual plant populations at each seeding date. Averaged across seeding dates (and varieties in 2014-15), plant populations at the LOW seeding rate were above the recommended minimum in all but 1 location year (Yorkton 2015). However for individual variety by date by location year combination densities did fall below this threshold in several more cases (data not shown). This suggested that yield might be affected adversely in these cases due to inadequate plant density.

Table 3. Main effect means for flax plant density (plants/m^2) at Indian Head, Melfort And Yorkton SK during 2013-2015.

	Indian Head			Melfort		Yorkton	ALL
Main effect	**2013**	**2014**	**2015**	**2014**	**2015**	**2015**	
Seeding date							
Early	342b*	484a	574a	627a	313b	284b	437
Late	490a	458a	505b	325b	416a	345a	423
Variety							
Traditional	na	497a	496b	513a	345a	301b	430
Northern adapted	na	446b	583a	440b	384a	325a	436
Seed Rate							
Low	336c	364c	393b	348c	331c	221c	320
Medium	411b	482b	na	466b	353b	318b	406
High	501a	567a	686a	614a	408a	445a	507

* means followed by the same letter do not differ significantly at P=0.05

**averages are for 6 location years for seed date, and 5 location years for variety and seed rate.

Treatment means for days to maturity are presented in Table 4. While maturity was affected by all factors (seeding date, seeding rate and variety), only the seeding date effects were large enough to be of agronomic importance. In all cases, delayed seeding greatly reduced the length of time required for flax to reach maturity; however, it must be noted that the early seeded flax was still always mature and ready to harvest ahead of the late seeded treatments. This effect is common for all crops and is a result of warmer soil and air temperatures later in the spring and early summer. Crops seeded later typically emerge more quickly and progress through the early growth stages much more quickly than crops seeded early into cool soils; however, this does not necessarily translate into higher yields.

At Yorkton, maturity was recorded as the percentage of bolls that had turned brown on 4 occasions as the crop neared maturity. While this data is very accurately measured progression of maturity it was difficult to convert to days to mature. It did indicate very clearly that the early seeded treatments matured earlier than the late seeded ones but did require more days from seeding to maturity. As well the northern adapted variety was later maturing when seeded early but not when seeded late. There was a very clear trend for maturity to be hastened as seeding rate increased (data not shown).

Table 4. Main effect means for flax plant maturity (days from seeding to maturity) at Indian Head, Melfort and Yorkton SK during 2013-2015.

	Indian Head			Melfort		Yorkton	ALL
Main effect	**2013**	**2014**	**2015**	**2014**	**2015**	**2015**	
Seeding date							
Early	107.9a	109.4a	104.0a	98a	102a	114a	106.4
Late	100.4b	104.7b	97.2b	95b	101b	99b	100.1
Variety							
Traditional	na	107.2a	100.5b	97a	102a	107a	102.7
Northern adapted	na	106.9b	100.7a	97a	101a	107a	102.5
Seed Rate	na						
Low	104.7a	107.7a	101.5a	97a	103a	109a	104.3
Medium	104.1b	107.1a	na	97a	102b	107b	103.4
High	103.8b	106.4b	99.7b	97a	101c	105c	102.6

* means followed by the same letter do not differ significantly at P=0.05
**averages are for 6 location years for seed date, and 5 location years for variety and seed rate.

One important interaction was that between seed date and cultivar (Table 5). This interaction was statistically significant at Indian head in both 2014 and 2015, as well as at Yorkton in 2015. However the trend was not consistent at all location years. At Indian Head in 2014 and at Yorkton in 2015, the northern adapted variety was later maturing than the traditional variety. When they were late seeded the northern adapted variety was earlier maturing than the traditional variety at the same location years. However this trend was not consistent since at Indian Head in 2015, both varieties matured at the same time when seeded early, but the norther adapted variety was slightly later maturing when seeded late. At Melfort there was no indication that this interaction was significant. This would suggest that under at least some conditions the northern adapted variety was able to compensate for late seeding by maturing somewhat earlier than a variety that was not selected for adaptation to northerly conditions.

Table 5. Interaction effect of seed date and variety in maturity (days from seeding) of flax at Indian Head (2014 1nd 2015), and Yorkton (2015).

	IH 2014	IH 2015	Yorkton 2015
Early seeded traditional variety	109.2b	104.1a	113.0b
Early seeded Northern adapted variety	109.6a	104.0a	115.6a
Late seeded traditional variety	105.3c	96.9c	100.5c
Late seeded northern adapted variety	104.2d	97.4b	98.1d

* means followed by the same letter do not differ significantly at P=0.05

Overall, flax yields were very high at Indian Head in 2013, high at Melfort in 2014 and Indian Head in 2015, moderate at both Melfort and Yorkton in 2015 and lowest at Indian Head in 2014 (Table 6). This provided a clear indication that climate has a greater influence on flax yield than geographic location. Early seeding significantly increased yield at 1 location year, and decreased it significantly at 2 other location years, while having minimal impact in 2 at 2 other location years. Overall, late seeding tended to provide higher yield than early seeding when averaged across all location years (although we did not test this statistically). Dry conditions early in 2015 at all locations followed by ample rain in July likely contributed to enhanced yield with late seeding. Later seeded crop would be less likely to be affected by early drought stress, and better able to more fully utilize moisture later in the growing season. By contrast, moisture conditions were quite favorable throughout the 2013 growing season at Indian Head, allowing the crop to develop very high yield potential. Under these conditions earlier seeding may have allowed the crop to accumulate more assimilates needed to set additional seed compared with later seeding. The major yield limiting factors at Indian Head in 2014 were flooding in June and heavy weed pressure due to Group 1 resistant wild oats which could not be controlled with in-crop herbicide applications. Seeding date did not significantly affect flax yields in any of the three years; however, based on the overall averages, early seeding tended to produce higher yields in 2013 ($P = 0.150$) while later seeding had a slight advantage in 2015 ($P = 0.075$). In 2014, mean yields were virtually identical for the two dates.

Variety significantly affected yield at three of six location years, with the northern adapted variety being higher yielding in all three cases. When averaged over all location years, the northern adapted variety was almost 5% higher yielding. Because this variety was selected for being well adapted to northern climatic conditions, it would be expected to fare well at the most northerly location, Melfort. In these trials the northern adapted variety was significantly higher yielding in one year at each location, suggesting that it may be inherently higher yielding across a broader range of climatic conditions.

Seeding rate had a highly variable impact on yield, increasing with seeding rate increases in one case, peaking at the lowest rate in another case, or being largely unaffected in several cases. When averaged across all location years, differences in yield between seeding rates were surprisingly small. Most surprising was that at Yorkton in 2015, yield was highest at the low seeding rate where plant population was below 300 plants per square meter.

Table 6. Main effect means for flax grain yield (kg/ha) at Indian Head, Melfort and Yorkton SK during 2013-2015.

	Indian Head			Melfort		Yorkton	
Main effect	**2013**	**2014**	**2015**	**2014**	**2015**	**2015**	**ALL**
Seeding date							
Early	3012a	1262a	2121a	2310a	1671b	1509b	1980
Late	2846b	1309a	2457a	2282a	1836a	1935a	2111
Variety							
Traditional	na	1287a	2286b	2230b	1699a	1658b	1832
Northern adapted	na	1284a	2341a	2362a	1805a	1790a	1916
Seed Rate							
Low	2874b	1226b	2294a	2333a	1732a	1823a	1998
Medium	2923b	1325a	na	2296a	1750a	1640b	1987
High	2998a	1305ab	2284a	2258a	1779a	1704ab	2009

* means followed by the same letter do not differ significantly at P=0.05

**averages are for 6 location years for seed date, and 5 location years for variety and seed rate.

Project Extension Activities

This demonstration was shown at the Indian Head Crop Management Field Days in 2013 (July 23), 2014 (July 22) and 2015 (July 21). These field days were sold out events which were attended by approximately 200 producers and industry representatives per annum. A dedicated Flax tour was co-hosted by IHARF and SaskFlax in 2013 (July 25) which was attended by 68 participants and featured speakers from the Saskatchewan Ministry of Agriculture, University of Saskatchewan, FMC Corporation and IHARF. At the 2014 IHARF field day, the discussion at the site was led by Zafer Bashi (Saskatchewan Ministry of Agriculture) and revolved around some the current opportunities and challenges of flax production in Saskatchewan. In 2015, this section of the Field Day was led by Chris Holzapfel (IHARF) and Barbara Ziesman (Saskatchean Ministry of Agriculture). At Melfort, logistics did not allow us to show the demonstration in either year. Signs were in place to identify treatments and acknowledge the support of the Agricultural Demonstrations of Technologies and Practices (ADOPT) program for all tours. The results from this demonstration were also presented by Chris Holzapfel (IHARF) at the Agronomy Research Update (December 2013), Agri-ARM Research Update (January 2015), at 5 Saskatchewan Oilseed Producer Meetings (November 2015 by Holzapfel or Brandt) and CropSphere (January 2016). Results from this project have also been made available in IHARF Annual Reports (www.iharf.ca) and several articles in popular agricultural press, as well as on the NARF website (www.neag.ca).

11. Conclusions and Recommendations

This project has demonstrated the response of two flax varieties to varying seeding dates and seeding rates at 3 locations in the Black soil zone of Saskatchewan over a total of 6 location years. The overall performance of this crop was relatively insensitive to the specific seeding dates and rates that were evaluated. Seeding date affected plant density at 5 of 6 location years. Densities increased as seeding was delayed at 3 location years and increased with delayed seeding at 2 location years. In all cases, delayed seeding greatly reduced the length of time required for flax to reach maturity; however, it must be noted that the early seeded flax was still always mature and ready to harvest ahead of the late seeded treatments. Overall, late seeding tended to provide somewhat higher yield than early seeding when averaged across all location years. While seeding early is usually recommended, preferably not later than the 15th of May, this demonstration showed that postponing seeding to the end of May will not typically result in lower yields or maturity issues. The variety grown had a variable effect on plant density that more likely reflected seed quality differences between seed lots than genetic potential. Maturity differences between varieties tended to be small and somewhat inconsistent. The northern adapted variety did tend to show a small yield advantage over the traditional variety, but this was not always consistent, and did not occur only at the most northerly location. Increasing seeding rate consistently increased plant density and decreased days to maturity. However seeding rate had only a small and inconsistent effect on yield. This suggested that across the range of seeding rates used in the trial, plant populations were sufficient so as not to greatly limit yield potential. If plant population and it's interaction with other factors like seed dates or varieties is a concern, future studies need to use a broader range of seeding rates to ensure that such relationships can be investigated.

Supporting Information

12. Acknowledgements:

The project was initiated by SaskFlax and financially supported by the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canada-Saskatchewan Growing Forward 2 bi-lateral agreement. Acknowledgement of the Saskatchewan Ministry of Agriculture's support for this demonstration and that of SaskFlax will be included as part of all written reports and oral presentations that arise from this work. Seed for northern adapted flax variety used in the project was provided in-kind by Crop Production Services and crop protection products used over the years were provided in-kind by BASF, Bayer Cropscience, FMC and Syngenta.

13. Abstract/Summary:

Field trials were conducted at Indian Head, Melfort and Yorkton in 2013-15 to demonstrate flax response to seeding rates with early and late planting dates. Early seeding sometimes reduced plant density and in other cases increased it. The overall effect of seeding date on plant density was relatively small. Late seeding did consistently reduce days from seeding to maturity, but the early seeded treatments still matured before the late seeded ones. Seeding date had a variable effect on yield, but on average, late seeding was slightly higher yielding. Variety had small and variable effects on plant density, days to maturity and yield. Effects on plant density and maturity likely were of minimal practical significance, but the small yield advantage of the northern adapted variety when averaged across trials is worth noting even though we did not test the statistical significance of this difference. As expected higher seeding rates resulted in increased plant density and slightly earlier maturity but had only a small effect on yield. Any observed benefits to rates beyond the typical 45-55 kg ha^{-1} were unlikely to justify the added seed cost.