Optimizing Seeding Rates and Plant densities for *Camelina sativa*

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Abstract

Camelina is a relatively new oilseed crop to western Canada. Currently there is little research available for camelina seeding rates in western Canada. A field study was conducted in 2007 and 2008 for 9 site years at locations in western Canada to determine the effect of seeding rate on various agronomic aspects of camelina like yield, days to maturity, lodging, and plant height. The seeding rates used were 12, 25, 50, 100, 200, 400, 800, and 1600 seeds m^{-2}. Camelina exhibited a plastic yield response to seeding rate. Maximum yield was reached at 450-500 seeds m^{-2}. Small yield increases were seen with seeding rates greater than 100 seeds m^{-2}. Days to maturity decreased by up to seven days as seeding rate increased. The optimum seeding rate was approximately 500 seeds m-2 because of the positive effect on maturity, plant height, and yield. 500 seeds m^{-2} would supply enough seeds to produce an acceptable plant density under poor seeding conditions to help prevent crop failure due to poor emergence or seedling mortality.

Introduction

Camelina (*Camelina sativa* (L.) Crantz) is a Brassicaceae oilseed also known as flax, linseed dodder or gold-of-pleasure (Putnam et al. 1993; Zubr 1997). It is a minor crop in western Canada but was grown in European countries and Russia up to the 1950s (Zubr 1997). Abramovič and Abram (2005) report that some camelina production still exists in the Koroska region of Slovenia. Interest in the crop is increasing since it possesses a number of desirable agronomic traits, including some drought tolerance, and a unique fatty acid profile (Putnam et al. 1993; Gugel and Falk 2006).

Camelina has a small seed size compared to other currently grown crops in western Canada. The average thousand seed weight is 1.0 gram with variations of 0.3 to 2.0 grams (Plessers et al. 1962; Schuster and Friedt 1998; Gugel and Falk 2006; Vollmann et al. 2007). The tiny seed size makes seeding and establishing the crop difficult because of the need to seed at a very shallow depth. Urbaniuk et al. (2008) reported better stand establishment broadcasting the seed followed by light packing compared to a double disk press drill in the Canadian Maritimes. Field emergence of camelina ranged from 28% to 72% in the Maritime study and a seeding rate of 400 to 600 seeds m^{-2} was recommended. There is no data on optimum seeding rate for camelina on the Canadian Prairies; therefore, studies were initiated in 2007 to address this issue.

Materials and Methods

Sites. The experiment was conducted in 2007 and 2008. In 2007 it was grown at Beaverlodge AB, Melfort SK, Scott SK, Redvers SK, and Swift Current SK. In 2008 it was grown at Beaverlodge AB, Melfot SK, Scott SK, and Lethbridge AB.

Experimental Design and Treatments. The experiment was grown as a factorial randomized complete block design with four replicates. All of the sites were under dryland production and planted on summerfallow due to the lack of broadleaf weed control options. When needed, a preseed burnoff with glyphosate was applied. If weed pressure was expected to be high trifluralin or ethalfluralin were applied. In season hand weeding was done to keep the study weed free. Fertilizer was applied but rates were based on soil tests from each site year. Total soil available N targeted at Melfort was 120 kg N ha^{-1}, Scott was 100 kg N ha^{-1}, Swift Current was 80 kg N ha^{-1}. The main factors were cultivar (CS0005 and CS0006) and planting density (12, 25, 50, 100, 200, 400, 800, and 1600 seeds m^{-2}). Actual seeding rates were based on viable seeds and thousand seed weights. Germination for both cultivars was greater than 95 and 99 percent in 2007 and 2008, respectively.

Data Collection. The data collection that occurred was plant emergence (plants m^{-2}), lodging, days to flowering (days), days to maturity (days), plant moisture content (%), seeds per pod, seed yield (kg ha^{-1}), thousand kernel weight (g), and post harvest plant density (plants m^{-2}). Plant emergence counts were done at approximately three weeks after seed rows became visible. Lodging and plant height were measured immediately prior to harvest. Lodging was estimated and a scale of 1 to 4 applied with 1 being no lodging and 4 being completely flat on the ground. Days to flower were calculated as days from seeding date to 10 percent flower. Similarly days to maturity was the number of days from seeding to harvest maturity. Plant moisture content was measured at harvest maturity where plants from two 0.25 m^{-2} quadrats in each plot were clipped, weighed and then oven-dried. The plants were re-weighed after drying and moisture content was calculated. Seeds per pod was measured at harvest maturity by harvesting 50 randomly selected pods per plot and counting the seed in each pod. Seed yield was weighed after combine harvest and calculated to kg ha^{-1}. Post harvest plant counts were taken after harvest where the stubble was counted to determine plants m^{-2} at harvest.

Statistical Analyses. Statistical analysis was done using PROC Mixed in SAS. Most of the data was combined. Site-year and site-year by treatment interactions were considered a random

effect. Years and sites were not combined in this analysis but rather analyzed by site year because the experiment did not occur at the same sites in 2007 and 2008.

Results and Discussion

Results from the analysis of variance (Table 1) indicate that cultivar had a marginal effect on plant emergence, lodging, and thousand kernel weight (significant at $p < 0.10$). Cultivar had a significant effect on days to flowering and seeds/pod. Planting density had a significant effect on all variables measured with the exceptions of seeds/pod and thousand kernel weights. The only cultivar by rate interaction occurred with moisture content which was significant at $p < 0.10$.

Table 1: Analysis of variance results for camelina planting density study across 9 sites in Alberta and Saskatchewan. 2007-08.

Source	Plant emergence	Lodging	Days to Flowering	Days to Maturity	Moisture Content (%)	Seeds per pod	Plant Height	Seed Yield	1000-kw
Cultivar	0.09	0.08	0.04	0.35	0.98	<0.0001	0.89	0.32	0.09
Rate	<0.001	<0.0001	0.01	<0.0001	0.03	0.22	0.01	<0.001	0.2
Cultivar X rate	0.54	0.39	0.87	0.84	0.09	0.61	0.76	0.41	0.85

Plant Emergence

When averaged over locations and densities, 42% of the planted seeds emerged (Table 2). This varied from a low of 12% at Melfort in 2008 to a high of 67% at Swift Current in 2007. The percent emergence was higher at lower planting densities and declined as planting density increased (Table 3).

Table 2: Overall percent emergence of camelina seed at sites in Alberta and Saskatchewan. 2007-08.

Site	Year	Percent Emergence
Beaverlodge	2008	51%
	2007	58%
Melfort	2008	12%
	2007	29%
Scott	2008	44%
	2007	27%
Lethbridge	2008	47%
Redvers	2007	41%
Swift Current	2007	67%
MEAN		**42%**

Table 3: Percent emergence of camelina seed at different planting densities. Mean of nine site-years. 2007-08.

Seeds m^{-2}	Emerged Plants m^{-2}	Percent Emergence
12	7	59%
25	12	50%
50	22	43%
100	43	43%
200	79	39%
400	147	37%
800	277	35%
1600	444	28%

Lodging

Lodging was evaluated visually using a scale of 1-4 with 1 being erect and 4 being flat on the ground. The cultivar CS0006 had a slightly higher lodging rating of 1.6 compared to 1.4 for CS0005. Lodging ratings declined as planting density increased; however, there was a slight increase at the highest density (Fig. 1)

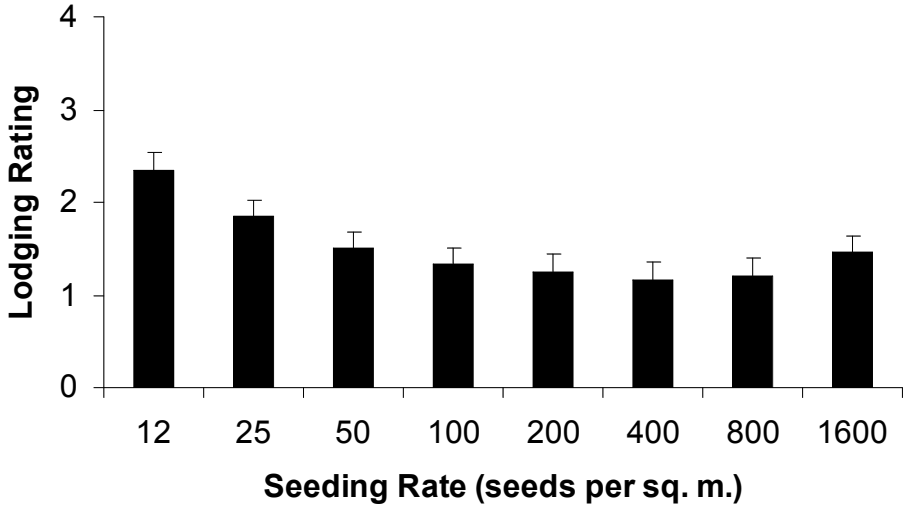

Fig. 1: Lodging ratings for camelina plants at a range of seeding rates. Lodging rating evaluated visually using a scale of 1-4: 1 = erect; 4 = flat on the ground. Error bars are the standard error of the mean.

Days to Flowering

Mean days to flowering for CS0006 was 46 days, 1 day earlier than CS0005. Seeding rates of > 200 seeds m^{-2} generally reduced days to flowering by 1 day, compared to seeding rates of 12 to 100 seeds m^{-2} (data not shown),

Days to Maturity

Both cultivars matured in 92 days when averaged across all planting densities; however, higher seeding densities reduced the days to maturity by as much as 7 days (Figure 2).

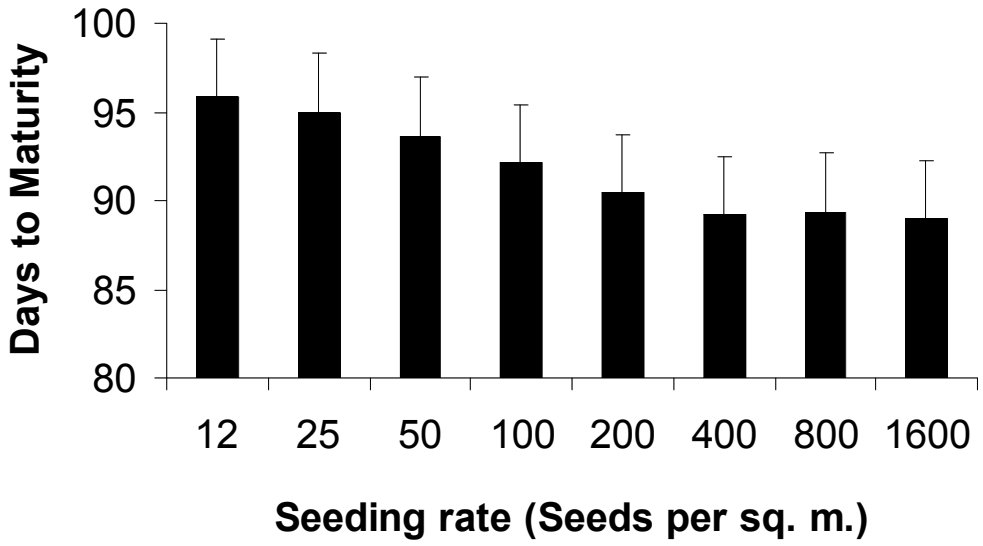

Fig. 2: Effect of camelina seeding rates on days to maturity. Error bars are the standard error of the mean.

Plant Moisture

Plant moisture content provided a subjective evaluation of plant maturity. Trends were similar to days to maturity (Fig. 3) validating that higher seeding rates hastened plant maturity.

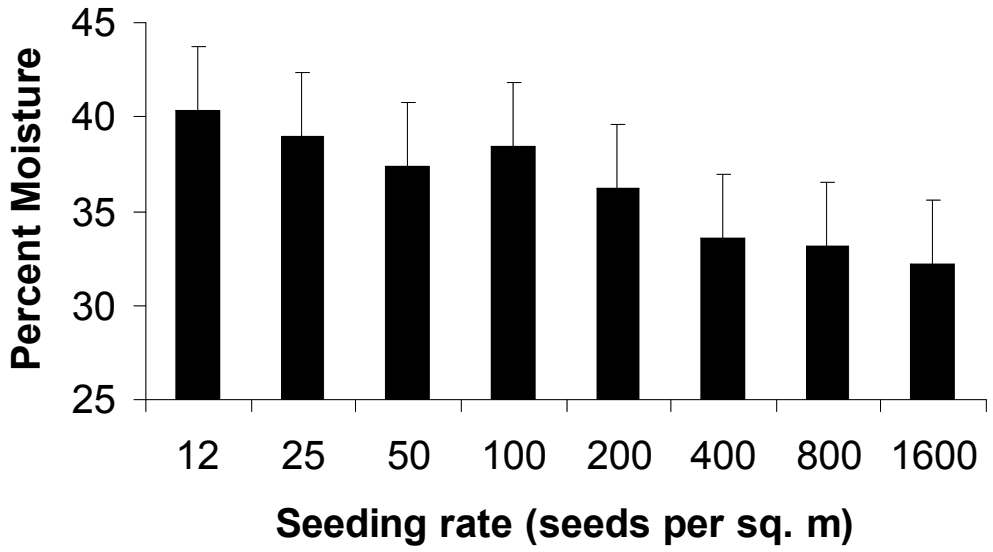

Fig. 3: Effect of camelina seeding rates on plant moisture content. Error bars are the standard error of the mean.

Seeds per pod

Although statistically significant, the cultivar CS0006 had 1 seed per pod more than CS0005; therefore, it is of limited biological significance. The mean number of seeds per pod for CS0006 was 9 (data not shown).

Post-harvest plant density

Plant counts were taken following harvest to provide an indication of plant mortality during the growing season. Statistical analysis was not performed on plant mortality for this report but it appears that seeding rate had little effect (Figure 4).

Plant Height

Plant height increased as seeding rate increased from 12 to 400 seeds m^{-2} then declined at rates higher than 400 seeds m^{-2} (Figure 5).

Seed Yield

Seed yield was regressed against seeding rate and plant emergence using non-linear regression. An asymptotic Michaelis-Menten model was used to fit the data. Seed yield increased dramatically as seed rate density increased and levelled off at about 450 to 500 seeds m^{-2} (Figure 6). Correspondingly, yields increased until plant emergence numbers reached about 125 to 200 plants m^{-2} (Figure 7); therefore, low densities could not fully compensate by producing more pods. Yields declined by greater than 10% when plant densities dropped below 70 plants m^{-2}.

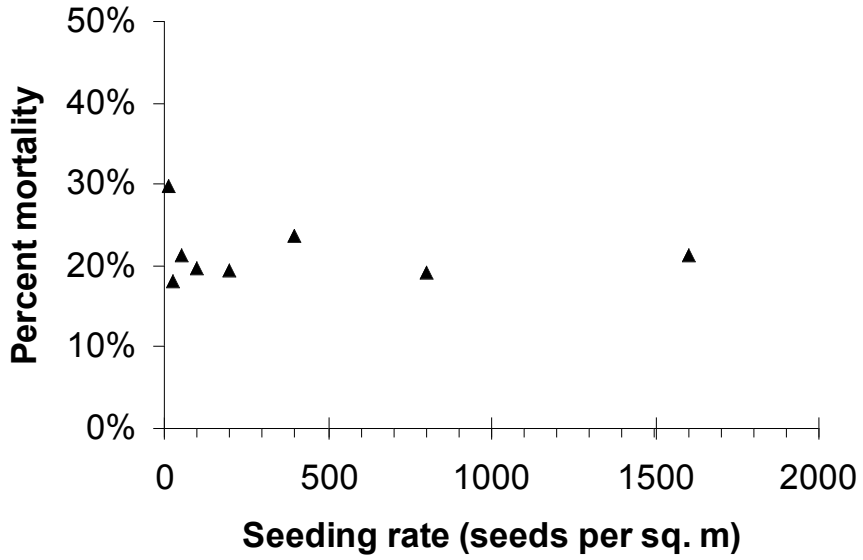

Fig. 4: Effect of camelina seeding rates on percent plant mortality during the growing season. Plant mortality was based on plant counts taken post-harvest compared to plant counts taken 3 weeks after emergence.

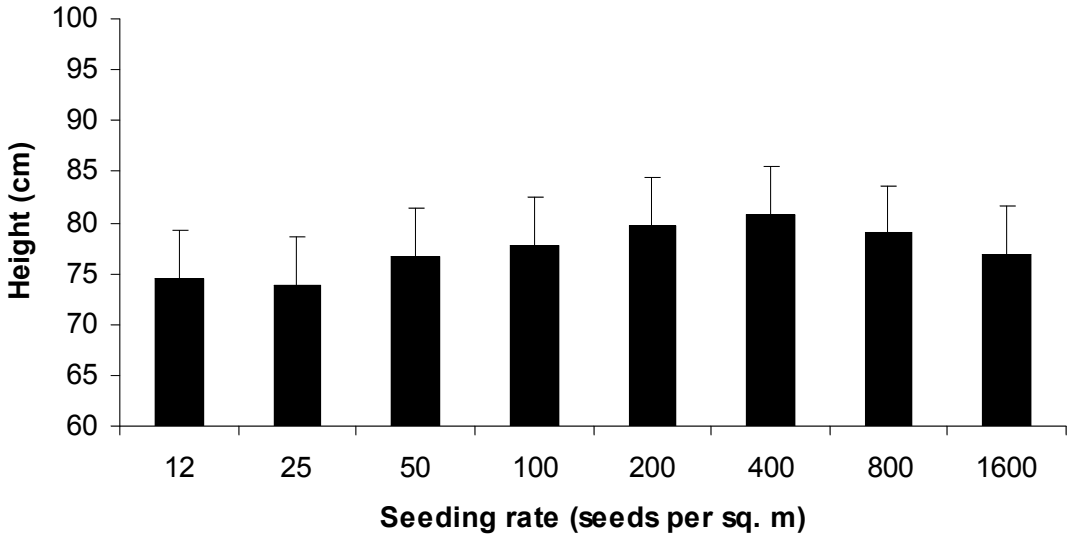

Fig. 5: Effect of camelina seeding rates on plant height (cm). Error bars are the standard error of the mean.

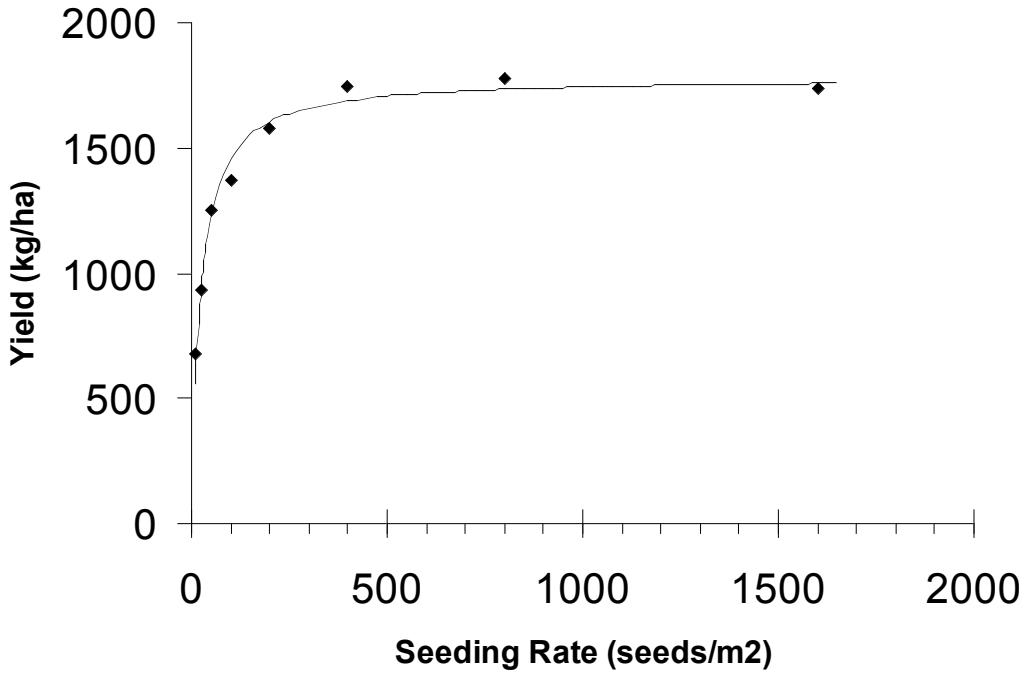

Figure 6: Relationship between planting density (viable seeds m^{-2}) and camelina seed yield. Mean of nine sites in Alberta and Saskatchewan. 2007-08.

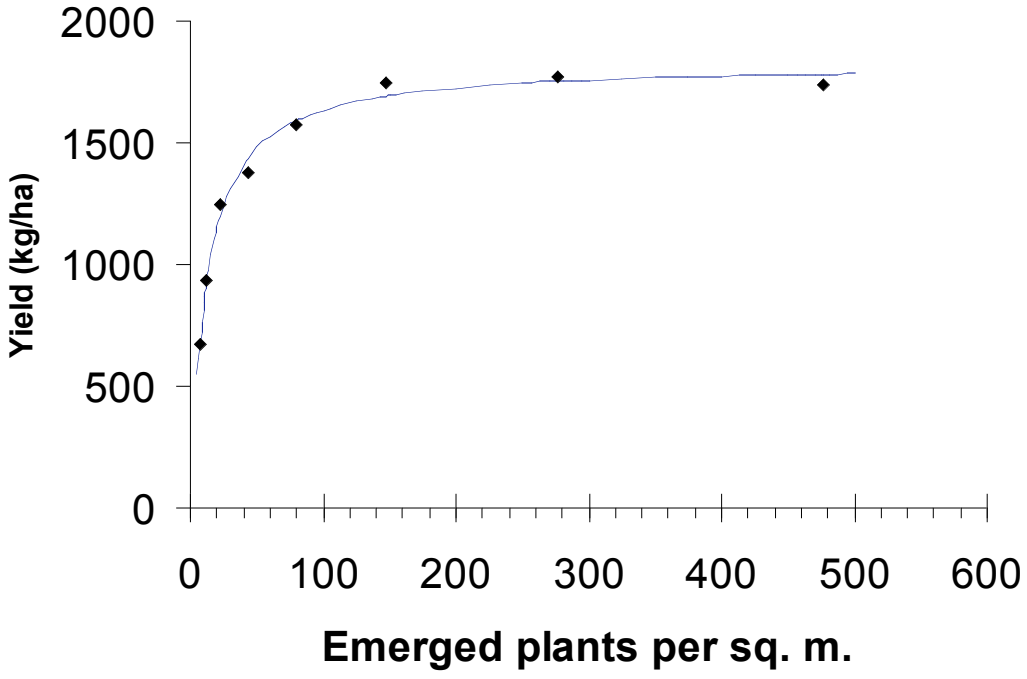

Figure 7: Relationship between camelina plant emergence (seeds m^{-2}) and seed yield. Mean of nine sites in Alberta and Saskatchewan. 2007-08.

Thousand kernel weight

The mean thousand kernel weights for CS0005 and CS0006 were 1.20 and 1.18 grams, respectively. Seeding rate had no effect on thousand kernel weight (Table 1).

Conclusions

Seeding at a rate of 500 seeds m^{-2} (about 6.0 kg ha^{-1} or 5.3 lb $acre^{-1}$) would result in 210 plants per m^{-2} if emergence is 42% (average emergence in this study) but only 60 plants per m^{-2} if emergence is 12% (lowest emergence in this study). This seeding rate is satisfactory if emergence is greater than 25% (to achieve minimum of 125 plants m^{-2}). Growers should be aware that these plant population studies were conducted under weed-free conditions. Camelina has limited broadleaf weed control options; therefore, a higher plant density may be warranted under weedy conditions. Based on the results from this study, a minimum seeding rate of 500 seeds m^{-2} (6.0 kg ha^{-1} using a thousand kernel weight of 1.2 grams) is recommended.

Acknowledgements

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