The Profitability of Seeding the F_2 Generation of Hybrid Canola

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ABSTRACT

The high cost of hybrid (HY) canola (*Brassica napus* L.) seed has some producers considering F_2 generation hybrid farm-saved seed (HY-FSS), or open-pollinated (OP) varieties (both certified and farm-saved seed). The net return (NR) of different varieties, genetic backgrounds, seeding rates, seed treatments, and seed sizing was evaluated from three experiments over eight site-years of field data from western Canada. One set of experiments included variety, genetic background and seeding rate, while another included seed treatment, genetic background and seed sizing. The experiments used randomized complete block designs. The NR accounted for yield, green seed price discount, seed costs, and other production costs. Analysis of variance indicated certified F_1 hybrid seed (HYC) was more profitable than HY-FSS (15%, $P = 0.0057$) and OP (22%, $P = 0.0001$). With delayed weed control, NR was lower for HYC and not statistically different than HY-FSS. Higher seeding rates and seed sizing for HY-FSS did not increase NR compared to HYC. The findings of this study support the use of HYC canola seed, especially at high canola prices. Canola producers will not increase their NR by using HY-FSS or OP seed to reduce their seed cost because the lost value of production exceeds the higher cost of HYC seed.

Canola production has evolved from OP varieties to 70% planted to hybrids in 2008 (M. Standford, personal communication, 2009). Open pollinated varieties are pure lines that reproduce themselves with high precision and are stable from generation to generation. Most producers growing OP varieties purchase certified seed, though some use FSS until adopting a newer variety. For OP canola, the total cost of FSS and treatment is about one-half that of open-pollinated certified (OPC) seed, but cleaning and seed treatment costs are the only direct costs. Hybrids are the product of a cross of genetically dissimilar parent inbred lines that result in HY vigor. The F_1 generation is very uniform, but segregation in the F_2 generation results in lost HY vigor. The cost of HYC seed varies, but is about 55% higher (weight basis) than OPC seed. The HYC seed tends to be larger in size, requiring higher seeding rates (weight basis) to obtain the desired plant population. The per area canola cost of seed for HYC is about twice that of OPC.

There have been years when the price of canola was low, and low prices could occur again. Under these economic conditions, producers questioned whether it was a good economic decision to spend money on OPC or HYC seed. The added cost of certified seed might not be covered by the expected higher receipts resulting from higher yield. When returns from canola production were low, producers wanted to explore methods to reduce seed costs without losing yield and quality. One option considered was to use FSS rather than certified seed, including FSS from hybrids (HY-FSS), or the F_2 generation. There was an expectation among some producers that much of the HYC yield advantage would still be present in the HY-FSS. The legality of using FSS was another consideration. There are no legal impediments to using FSS for most OP canola varieties, but this is not the case for most HY seeds as they also offer herbicide tolerance.

To compensate for lower seed quality of FSS, using higher seeding rates and screening for larger seeds have been proposed. When canola prices were low, the added seed cost from using higher seeding rates with FSS was low. The higher seeding rate might maintain the density of the crop stand and crop yield. There were expectations that some of the improved yield performance of HYC canola was due to its larger seed size producing more vigorous seedlings. Cleaning for larger seed size would have little impact on FSS costs, and larger seed size might result in more vigorous plants and higher yield (Elliott and Rakow, 1999). However, sized canola seed has been found to have the same yield as bulked seed (Lamb and Johnson, 2004). Farm-saved seed would still need to be treated for insects (e.g., flea beetles [*Phyllotreta* spp.]) that attack the emerging plants, and for seedling diseases. The preferred seed treatments though are not available to producers using FSS protected by Plant Breeders Rights or other legal agreements and conditions. Users of FSS have access to less effective seed treatments, negating some of the cost savings of using FSS.

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Abbreviations: FSS, farm-saved seed; HY, hybrid; HYC, hybrid certified seed; HY-FSS, farm-saved seed from HY; NR, net return; OP, open-pollinated; OPC, open-pollinated certified seed; OP-FSS, farm-saved seed from OP.

The cost of OPC and HYC seed is higher than FSS, but there are yield, quality, and seed treatment benefits from using certified canola seed (Clayton et al., 2009). The NR benefits of certified seed will be determined by the yield advantage of certified seed, price of the crop, and the cost of seed. The economic benefit of using HYC corn (*Zea mays* L.) seed is high because of the large yield advantage, which was confirmed by Valdivia-Bernal and Vidal-Martinez (1995) and Ochieng and Tanga (1995). Commercial corn producers do not consider any other seed source. The economic benefit of using HYC wheat (*Triticum aestivum* L.) seed is less clear. Using hard red winter wheat HY-FSS would not be profitable, based on yield results in the Nebraska Panhandle that indicated HY-FSS yielded 12% less than OPC, which was 10% less than HYC (Guillen-Portal et al., 2002). A reported yield decline of 8.3% for HY-FSS compared to HYC for soft red winter wheat grown in Maryland (Kratochvil and Sammons 1990) might be small enough for HY-FSS to be as profitable as HYC. Similarly for winter rye (*Secale cereale* L.), a yield reduction of 14% for HY-FSS compared to HYC (Lapinski and Stojalowski, 1999) might result in HY-FSS being as profitable as HYC. Not all studies have shown a yield advantage from certified seed, the benefits largely depended on the purity of the variety and maintaining a weed-free field (Edwards and Krenzer, 2006).

Hybrid canola has been shown to have yield and economic superiority over OP varieties (Harker et al., 2003; Upadhyay et al., 2005; Brandt et al., 2007; Karamanos et al., 2007; Clayton et al., 2009). In 2008, the Prairie canola variety trials indicated the OP check variety yielded 80% of the HY check (Canola Council of Canada, 2008). In Northern Idaho, both HYC and HY-FSS canola had higher yield than OP varieties (Starmer et al., 1998). Trials in Germany reported HYC and HY-FSS canola yielded higher than the parent lines and HY-FSS yielded 8.7% less than HYC (Grosse et al., 1992). Similarly, Clayton et al. (2009) reported a 12% yield advantage of HYC over HY-FSS. The yield advantage of HYC over HY-FSS needs to cover the higher seed cost of HYC seed for HYC to be more profitable.

The majority of field studies examining FSS have focused on yield and other agronomic comparisons. There has been no consideration of the trade-off between seed cost, yield, and the quality of yield on NR. Quality was determined by the percent of green seed–the presence of green seed reduces oil quality. The objective of this study was to evaluate the farm-level NR of using HY-FSS rather than HYC seed to determine whether the seed cost savings from using FSS exceeded the value of additional yield from using certified seed. Hybrid results were also contrasted to OP (OPC and OP-FSS). A second objective was to determine the impact of seed treatment and seed size on NR for HYC and HY-FSS canola. The economic analysis accounted for yield, price discounts due to green seed (quality), seed cost, and other production cost differences. Sensitivity analysis examined the impact of canola price and HYC seed cost on the profitability of (a) HYC vs. HY-FSS, and (b) HYC vs. OP-FSS. Relationships between the seed source combinations were developed to show the canola and HYC seed price combinations, and the 95% confidence intervals, at which HY-FSS and OP-FSS were as profitable as HYC.

Table 1. Machinery, herbicide, and fertilizer production costs by site-year for Experiments 1 (without weed pressure) and 2 (with weed pressure).

		Exp. 1		Exp. 2		Exp. 1, 2
Year/Site	Variety	Mach.†	Herb.‡	Mach.	Herb.	Fertilizer
		$ ha^{-1}				
2004						
Lacombe	OP§	135	116	135	116	112
	HY	135	82	135	82	112
Scott	OP	126	44	–¶	–	71
	HY	126	83	–	–	71
2005						
Beaverlodge	OP	135	76	135	76	114
	HY	135	112	135	112	114
Canora	OP	126	34	–	–	141
	HY	126	62	–	–	141
Lacombe	OP	126	95	135	107	96
	HY	126	76	135	74	96
Lethbridge	OP	162	48	126	60	71
	HY	162	48	126	76	71
Melfort	OP	135	90	135	73	19
	HY	135	56	135	38	19
Scott	OP	126	40	126	59	8
	HY	126	83	126	83	8

† Machinery costs were adapted from Alberta Agriculture and Rural Development (2007). Fertilizer was applied based on soil test recommendations.

‡ Herbicide costs differed by site-year because of different pre-seeding weed control and some sites tank mixed additional herbicides to control a broader spectrum of weeds.

§ Open pollinated 46A76, hybrid InVigor 2663.

¶ The Scott site in 2004 did not control weeds in Exp. 2 so these data were not included in the analysis. The Canora site did not include Exp. 2.

MATERIALS AND METHODS

Economic Analysis

Evaluation of the economic benefits of adopting different seed technologies used a partial budgeting framework. Partial budgeting is appropriate because adoption of a seed technology has minimal impact on inputs, field operations, and use of machinery and labor on a farm. Net return was budgeted per hectare, and equaled crop yield times price (depended on green seed) less seed cost less all other relevant production costs. Net return was computed for each experimental plot. Costs for fertilizer and machinery were specified as being the same for a site-year across different seed technologies. Herbicide costs for a site-year were the same for each seed variety, but costs differed by site-year because of different preseeding weed control and some sites tank mixed additional herbicides to control a broader weed spectrum (Table 1).

The canola price used in the analysis was a 5-yr (2001–2005) average ($325 t^{-1}). To account for highly variable canola prices over time and the potential for changes to seed prices, a sensitivity analysis was used to develop a relationship between canola price and the HYC seed price at which the producer would expect the same NR from: (a) HYC and HY-FSS; and (b) HYC and OP-FSS. The seed cost of HYC was adjusted to equate the NR of HYC with HY-FSS or OP-FSS. The canola prices for the sensitivity analysis ranged from $250 to $650 t^{-1}. Confidence intervals for the relationship were determined where NR from the two sources was statistically different ($\alpha = 0.05$). Canola price was adjusted to account for green seed, which reduces the grade and price. The percent green seed was determined by randomly selecting 100 seeds from each

Table 2. Seed cost by year, variety, seeding rate, and genetic background for Experiments 1 (without weed pressure) and 2 (with weed pressure).

Genetic background and seed cost difference	Seeding rate, m^{-2}†							
	2004				2005			
	46A76		InVigor 2663		46A76		InVigor 2663	
	120	240	120	240	120	240	120	240
	$ ha^{-1}							
Genetic background								
Certified‡	33.70	67.32	64.10	128.20	40.56	81.11	82.13	164.11
Farm saved	18.40	36.79	16.23	32.46	19.72	39.49	21.49	42.99
Difference	15.31	30.52	47.87	95.74	20.83	41.62	60.64	121.13

† Viable seeds.

‡ The price of Helix-treated certified seed was $14.31 and $9.26 kg^{-1}, respectively, for the InVigor 2663 and 46A76 seed. The cost of farm-saved seed was computed to be $4.42 kg^{-1} and included the seed at a commercial price, seed cleaning and treating, and transportation. Seed treatment costs were for Helix at $3.89 kg^{-1} seed (M. Klaas, personal communication, 2007).

Table 3. Seed cost of hybrid InVigor 2663 by year, genetic background, seed treatment, and sizing for Exp. 3.

Seed treatment	2004				2005			
	HYC†		HY-FSS		HYC		HY-FSS	
	Unsized	Sized	Unsized	Sized	Unsized	Sized	Unsized	Sized
	$ ha^{-1}							
Foundation Lite	49.64‡	62.49	4.15	5.36	–§	–	5.49	6.37
Gaucho	–	–	–	–	–	–	13.90	16.13
Helix	65.00	81.84	15.96	20.62	83.29	91.27	21.14	24.53
Untreated	46.68	58.77	1.69	2.18			2.24	2.59

† HYC = hybrid certified seed, HY-FSS = hybrid farm-saved seed.

‡ Certified seed price without seed treating was computed to be $10.45 kg^{-1}. Farm-saved seed price without seed treating was $0.33 kg^{-1}. Seed treatment costs were for Helix at $3.89 kg^{-1} seed (M. Klaas, personal communication, 2007).

§ The cells with missing values were not part of the treatment for that year.

plot, placing them onto a piece of masking tape, crushing with a roller, and counting the number of distinctly green seeds. Farm-saved seed, especially HY-FSS, might be more conducive to increased variability of maturity, resulting in higher green seed counts. Canola grades and price discounts were based on green seed: (i) no. 1 for green seed ≤ 2%; (ii) no. 2 for 2.1% ≤ green seed ≤ 6%, discounted $13 t^{-1}; (iii) no. 3 for 6.1% ≤ green seed ≤ 20%, discounted $55 t^{-1} and; (iv) sample for green seed ≥ 20.1%, discounted $100 t^{-1} (AFSC, 2007).

Other costs included insurance, marketing, fertilizer, herbicide, and machinery. The all peril crop insurance cost at Lacombe and Beaverlodge was $27 ha^{-1}; at the Saskatchewan locations it was $18 ha^{-1} and at Lethbridge it was $32 ha^{-1}, for all experiments (AAFC, 2006). The marketing cost was $10.52 t^{-1}. An opportunity interest cost was calculated for the cost of financing crop input and machinery operating costs until harvest (7% per annum). Details of the production costs included in the analysis are in Tables 1 to 4.

Field Data

The crop yield and seed data for this evaluation were from three field experiments conducted at six sites for eight site-years (Table 5). Atypical growing conditions at some of the sites are an indication of the weather-related variability that can exist. Experiments 1 and 2 included treatments of: (i) variety (HY and OP); (ii) genetic background (certified and FSS); and (iii) seeding rate (120 and 240 viable seeds m^{-2}). The two experiments were duplicates, except Exp. 1 controlled in-crop weeds at the recommended two-leaf stage (GS12, Canola Council of Canada, 2003) while Exp. 2 included weed pressure in the form of seeded tame oats (*Avena sativa* L.) and in-crop weed control was left until the six-leaf stage (GS16). There were six site-years for Exp. 2 (Table 5). Experiments 1 and 2 were to address the question of whether HY-FSS and OP-FSS were as profitable as HYC in the absence and presence of weeds. Including the OP variety allowed determining whether there was a difference between the two genetic types when using FSS.

The third experiment (experiment three) was to address seed size and seed treatment. The experiment included treatments of: (i) seed treatment; (ii) seed size; and (iii) genetic background. Seeding larger seeds could result in more vigorous and competitive plants, and seed treatment is important especially if there is the potential for flea beetle insect damage to seedlings.

Experiments 1 and 2

Experiments 1 and 2 (variety by genetic background by seeding rate) were 2 × 2 × 2 factorial arrangements of the three treatments randomized in complete blocks with four replications. The treatments for each experiment included: (i) variety 46A76 for the OP, and InVigor 2663 for the HY; (ii)

Table 4. Fertilizer, herbicide, and machinery production costs for Exp. 3.

Year/Site	Fertilizer†	Herbicide	Machinery
	$ ha^{-1}		
2004 Lacombe	69	86	135
Scott	71	69	126
2005 Beaverlodge	114	112	135
Canora	141	62	126
Lacombe	96	88	135
Lethbridge	71	47	162
Melfort	19	56	126
Scott	8	83	126

† Fertilizer was applied based on soil test recommendations. Herbicide costs differ by site and year because the weed spectrum was different. Machinery costs were adapted from Alberta Agriculture and Rural Development (2007).

Table 5. Sites, years, experiments, and atypical growing conditions for this study.

Site	Latitude, Longitude	Year	Experiments†	Atypical growing conditions
Beaverlodge, Alberta	55°13′ N, 119°24′ W	2005	1, 2, 3	none
Canora, Saskatchewan	51°38′ N, 102°26′ W	2005	1, 3	none
Lacombe, Alberta	52°27′ N, 113°45′ W	2004	1, 2, 3	none
		2005	1, 2, 3	early harvest & higher green seed
Lethbridge, Alberta	49°38′ N, 112°47′ W	2005	1, 2, 3	plot flooding (June); hail (July)
Melfort, Saskatchewan	52°79′ N, 104°30′ W	2005	1, 2, 3	late spring frost (reseeded 30 May)
Scott, Saskatchewan	52°21′ N, 108°50′ W	2004	1, 3	early fall frost (August)
		2005	1, 2, 3	hail (July)

† The experiments are explained in the Materials and Methods section.

genetic background included certified and FSS; and (iii) seeding rates were normal (120 viable seeds m^{-2}) (Canola Council of Canada, 2005) and high (240 viable seeds m^{-2}). The variety 46A76 is a Pioneer Hi-Bred Production Ltd. Clearfield (imidazolonone resistance) canola and received grant of rights on 21 Feb. 2000. InVigor 2663 is a Bayer CropScience Co. Liberty (glufosinate ammonium) canola and registered on 5 May 2000. Days to flowering and maturity are 1 d longer for 46A76, and InVigor 2663 is taller (10%) and has higher yield potential (17%). Germination rates for all seed lots exceeded 90%, the standard for certified no. 1 canola seed, and were used to adjust the seeding rate. To have broadly representative seed, reflective of that available to growers, seed was bulked from three different seed lots to make up each of the certified and FSS treatments.

Canola was seeded during May using hoe-type openers with row spacing of 30, 30, 25.5, and 24 cm at Lacombe, Beaverlodge, Scott, and Canora, respectively. A double-disc press seeder with 23 and 18 cm row spacing was used at Lethbridge and Melfort, respectively. Plot size was 3.6 by 15 m at Lacombe, Beaverlodge, Melfort, and Canora, 1.5 by 5m at Scott, and 2.5 by 6 m at Lethbridge. Data collected included plant density, emergence, days to maturity, seed yield, seed weight, percent green seed, and oil content. These data have been reported elsewhere (Clayton et al., 2009). At maturity, plants were windrowed with a swather (width of plot) and when dry the swath was harvested with a plot combine. In 2005, the Scott site was direct combined.

All seed was treated commercially with Helix (Syngenta Crop Protection Canada Inc., Guelph, ON, Canada) (thiamethoxam [3-[(2-chloro-5-thiazolyl)methyl]tetrahydro-5-methyl-N-nitro-4H-1,3,5-oxadiazin-4-imine], difenoconazole [1-[2-[2-chloro-4-(4-chlorophenoxy)phenyl]-4-methyl-1,3-dioxolan-2-ylmethyl]-1H-1,2,4-triazole], metalaxyl-M [methyl N-(2,6-dimethylphenyl)-N-(methoxyacetyl)-D-alaninate] plus fludioxonil [4-(2,2-difluoro-1,3-benzodioxol-4-yl)-1H-pyrrole-3-carbonitrile]) at the labeled rate of 15 mL kg^{-1} seed. Helix provides flea beetle and seedling disease control. In practice, a producer would not be able to treat HY-FSS with Helix, or most other effective seed treatments, because the agreement between treatment manufacturers and those treating seed requires that only 'legal' seed be treated. However, for experimental purposes the treatment was included to balance the experimental design. Yields were standardized to 10% moisture. Seeding, weed control, and other crop management practices were described in more detail by Clayton et al. (2009).

The estimated seed costs for the variety by genetic background by seeding rate experiment are in Table 2. Costs were reported for both years because seed weights differed and therefore seeding rates differed to attain the same seeding density of viable seeds. The cost of certified seed was the retail price. The FSS included the value of commercial canola plus cleaning plus seed treatment. The FSS cost was about one-half that of OPC and about one-quarter of HYC canola. Seed costs for the high seeding rate were twice that of the normal seeding rate.

Experiment 3

Experiment 3 (seed size by seed treatment) included only HYC and HY-FSS, using the same seed sources as Exp. 1 and 2. Seeding, plot size, and harvesting were the same as reported for Exp. 1 and 2, except at Lacombe seeding was with a double-disc press drill with 23 cm row spacing. The treatments changed from 2004 to 2005, so are analyzed as two distinct experiments. In 2004 (Exp. 3a), treatments included genetic background, seed sizing, and seed treatment as a 2 × 2 × 3 factorial in a randomized complete block design with four replications. The genetic background included HYC and HY-FSS, seeds were either as-is or sized over a 2.0 mm round hole screen, and seed treatments were treated with Foundation Lite (Bayer CropScience Inc., Calgary, AB, Canada) (iprodione [3-(3,5-dichlorophenyl)-*N*-(1-methylethyl)-2,4-dioxo-1-imidazolidinecarboxamide] plus thiram [tetramethylthioperoxydicarbonic diamide ($[[(CH_3)_2N]C(S)]_2S_2$)]) at a label rate of 22.5 mL kg^{-1} seed, treated with Helix, or untreated. Helix provides insect and seedling disease protection, Foundation Lite provides only seedling disease protection. As previously indicated, Helix is not commercially available to treat HY-FSS. Also, in practice it is unlikely the HYC seed would be sized. All treatment combinations were included to balance the experimental design.

In 2005 (Exp. 3b), there were five treatments of seed treatment combined with genetic background, each with unsized and sized seed, in a randomized complete block design with four replications. The treatments were: (i) Foundation Lite applied to HY-FSS, (ii) Gaucho (Bayer CropScience Inc., Calgary, AB, Canada) (imidacloprid [(2*E*)-1-[(6-chloro-3-pyridinyl)methyl]-*N*-nitro-2-imidazolidinimine] plus carbathion [methylcarbamodithioic acid] plus thiram [tetramethylthioperoxydicarbonic diamide ($[[(CH_3)_2N]C(S)]_2S_2$)]) at a label rate of 14 mL kg^{-1} seed for insect and seedling disease protection applied to HY-FSS; (iii) Helix applied to HYC; (iv) Helix applied to HY-FSS; and (v) untreated HY-FSS. Gaucho can only be applied to "legal" seed. Yields were standardized to 10% moisture, and other crop management practices were described in more detail by Clayton et al. (2009).

Seed costs for the seed size by seed treatment experiment depended on the seed treatment, genetic background, and

Table 6. Mean yield and price discount by variety, genetic background and seeding rate for Exp. 1 (without weed pressure), and Exp. 2 (with weed pressure).

	46A76		InVigor 2663	
Seeding rate, seeds m^{-2}	Certified	Farm saved	Certified	Farm saved
Yield	kg ha^{-1}			
	Experiment 1			
120	2532c†	2523c	3138a	2749b
240	2649bc	2631bc	3101a	2800b
	Experiment 2			
120	1991d	2068d	2577ab	2381bc
240	2112d	2136cd	2669a	2367bc
Price discount	$ t^{-1}			
	Experiment 1			
120	23.41a	17.19ab	14.06b	22.75a
240	20.97ab	18.48ab	18.53ab	16.50ab
	Experiment 2			
120	29.46a	29.46a	34.63a	35.44a
240	27.50a	26.70a	30.96a	36.31a

† Letters following yield or price discount within each experiment indicate significant difference (P = 0.05) among the treatment combinations.

seed sizing (Table 3). Seed costs for HY-FSS were about one-quarter the cost of HYC with Helix treatment. Untreated farm seed costs were $45 to $55 ha^{-1} less than HYC. The cost of sized seed was higher because sizing selected larger seeds and, therefore, the seeding rate was higher to attain the desired seed density of viable seeds.

Statistical Analysis

Yield and the price discount resulting from green seed were analyzed using analysis of variance (MIXED procedure of SAS [SAS Institute, 2005]) to provide a summary background for the economic results. Detailed analyses of yield and green seed have been reported (Clayton et al., 2009). The summary was for Exp. 1 and 2, and for the three-way interaction of variety × genetic background × seeding rate. Replicate and site-year were random. Analysis of variance was also used to produce a summary of yield and price discount values for Exp. 3.

Net return for Exp. 1 and 2 were analyzed separately using analysis of variance. Significant differences were at the 5% level, and trends of interest at the 10% level were indicated. The analysis included variety, genetic background, and seeding rate as fixed effects, and replicate and site-year as random effects. Site-year × variety × genetic background × seeding rate was used for the error structure. Experiment 1 (eight site-years, Table 5) and Exp. 2 (six site years, Table 5) were not combined in a single analysis because a comparison would be invalid due to the experiments themselves not being replicated. The analysis of variance of NR for Exp. 3 was by year because the experiment was altered from 2004 to 2005. For 2004 (Exp. 3a), the analysis included seed treatment, genetic background, and seed size as fixed effects and replicate and site as random effects (two sites, Table 5). Site × seed treatment × genetic background × seed size was used for the error structure. For 2005 (Exp. 3b), the seed treatment combined with genetic background and seed size were fixed effects, replicate and site were random effects, and site × seed treatment-genetic background × seed size was used for the error structure.

Table 7. Probabilities for sources of variation explaining net return for Exp. 1 (no weed pressure) and 2 (with weed pressure).

Source of variation	Experiment 1	Experiment 2
Variety (V)	<0.0001	<0.0001
Genetic background (GB)	0.5976	0.0739
V × GB	0.0710	0.2592
Seeding rate (SR)	0.2088	0.1957
V × SR	0.1205	0.2244
GB × SR	0.0660	0.6059
V × GB × SR	0.1381	0.9753
Number of site-years	8	6
Degrees of freedom†	49	35

† For the error term and pooled across sources of variation.

RESULTS

Experiments 1 and 2 (Variety by Genetic Background by Seeding Rate)

The three-way interaction of variety × genetic background × seeding rate for price discount due to green seed was a trend of interest (P = 0.0885), so the yield and price discount summary was reported for the three-way interaction (Table 6). For yield, the variety × genetic background was significant (P = 0.0017 Exp. 1, P = 0.0202 for Exp. 2). Yield for Exp. 1 was highest for HYC and lowest for the OP variety, and HYC yield was greater than HY-FSS. For Exp. 2, the yield benefit of HYC over HY-FSS was negated, and OP had lower yield than the HY. For Exp. 1 and the low seeding rate, the price discount was higher for HY-FSS and OPC, and lower for HYC. For Exp. 2, there was a trend that the price discount for the OP canola ($28.29 t^{-1}) was less than for the HY ($34.23 t^{-1}), ($P$ = 0.08012). Both yield and the price discount affected the NR.

In Exp. 2 where there was weed pressure, the analysis of variance indicated variety significantly affected NR (Table 7). The NR from using HY seed was greater than from OP seed ($320 ha^{-1} vs. $244 ha^{-1}, data not shown, LSD = 32) when averaged across genetic background, seeding rate and site years, which was consistent with the findings of Upadhyay et al. (2006). The genetic background was a trend of interest (NR was $268 ha^{-1} for certified and $297 ha^{-1} for FSS, data not shown, LSD = 32). The price of canola, after discounting for green seed, was equal across genetic background, so canola price had limited impact on the relative NR of the genetic background treatments. The higher yield of HYC (Table 6) was not adequate, compared with HY-FSS, to cover the higher seed cost. Edwards and Krenzer (2006) also found that certified seed benefits can be negated by weed competition. In this study, weed pressure suppressed crop yield and revenue which resulted in FSS being as profitable as certified seed.

Experiment 1 (without weed pressure) is of most relevance to canola producers because weeds were controlled at the recommended two-leaf stage (GS12). The analysis of variance indicated the NR for HY ($477 ha^{-1}) was greater than for OP ($406 ha^{-1}) (data not shown, LSD = 35), which is consistent with Exp. 2 and Upadhyay et al. (2006). There was a trend of interest for variety × genetic background (HYC ≥ HY-FSS ≥ OP-FSS ≥ OPC, P = 0.071, Table 8) when averaged across seeding rate and site years, and genetic background × seeding rate (certified,120 ≥ FSS,240 = FSS,120 ≥ certified,240, P = 0.066, Table 8) when average across variety and site years. Recall, for this experiment all seed was treated with Helix,

Table 8. Mean net return for interactions variety × genetic background and seeding rate × genetic background for Exp. 1 (without weed pressure).

Genetic background	Variety		Seeding rate, seeds m^{-2}	
	46A76	InVigor 2663	120	240
	$ ha^{-1}			
Certified	385c†	488a	464a	410b
Farm-saved seed	426bc	465ab	441ab	451ab

† Letters following the net return within each interaction indicate significant difference (P = 0.05) among the treatments within the interaction. The LSD for variety × genetic background and genetic background × seeding rate is 49.0.

so the results are conditional on the ability to use this seed treatment.

It was more profitable to grow HYC than OPC canola, because of higher yield and in this study the discount for green seed was lower for the HYC canola (Table 6). If growing OP canola, there was a trend that FSS was more profitable than certified ($41 ha^{-1}, Table 8), primarily due to lower seed cost. There was no significant difference in NR for HYC and HY-FSS, when averaged across seeding rate. The NR from using certified seed was $54 ha^{-1} higher at the 120 seeds m^{-2} seeding rate compared to the 240 seeds m^{-2} seeding rate, when averaged across varieties (Table 8). A high seeding rate with certified seed did not increase yield or lower the price discount enough to cover the additional seed cost. At the high seeding rate, there was a trend that the NR from certified seed was $41 ha^{-1} lower than FSS (P = 0.0947). The yield of HYC was greater than HY-FSS and there was some price benefit at the low seeding rate for HYC, but the additional cost of HYC seed at the high seeding rate ($82 ha^{-1}) negated the yield and price benefits of HYC over HY-FSS. It was not profitable to use certified seed at the high seeding rate. For FSS, seeding rate had no impact on NR, a slightly higher yield and lower price discount covered the higher seed cost. At the 120 seeds m^{-2} seeding rate, the NR for HYC was $81 ha^{-1} higher than HY-FSS (P = 0.0227).

The growing conditions across the site-years varied (Table 5) and could impact the results reported for Exp. 1 and 2. The analyses for these two experiments were run by site-year to determine if the site-year results were consistent with those reported in Tables 7 and 8. Both experiments had some site-years with significant variety × genetic background interactions. The NR values by site-year varied because of yield and price discount differences, but the pattern of NR and significance was consistent with Tables 7 and 8. For Exp. 1, NR for HYC was at least as high as other treatments, the high seeding rate was less profitable for certified seed, and the HY had higher NR than OP. For Exp. 2, the NR for the HY treatments was similar, and the NR for OP was never higher than for the HY.

Canola Price Sensitivity Analysis, Experiment 1

The above results are conditional on the canola and seed prices specified for the analysis. Because there was a yield advantage from growing HYC, it would be expected that higher canola prices would show higher NR for HYC, compared to either OP-FSS or HY-FSS canola. Conversely, low canola prices or high HYC seed costs would reduce the NR of HYC canola, resulting in the NR of HY-FSS canola being more competitive with HYC.

At a canola price of $250 t^{-1} and current seed costs, NR was $74.6 ha^{-1} (P = 0.001) greater for HYC compared to OP-FSS. For HYC compared to HY-FSS, there was a trend that NR was $51.3 ha^{-1} (P = 0.069) higher for HYC. At a low price for canola, HYC was more profitable than OP-FSS, but was not statistically greater than HY-FSS. At a canola price of $650 t^{-1}, the NR of HYC seed was $322 ha^{-1} (P < 0.0001) higher than OP-FSS, and $209 ha^{-1} (P = 0.0025) higher than HY-FSS. The NR advantage of the HYC seed increased with increased canola price.

Canola prices of $250, $350, $450, $550, and $650 t^{-1} were used in the sensitivity analysis. Price discounts for green seed were as previously reported. For each of these canola prices, the price that could be paid for HYC was determined such that the NR from HYC equaled the NR from HY-FSS (Fig. 1a) and from OP-FSS (Fig. 1b). The seeding rate of 120 seeds m^{-2} was used in the analysis. The relationship illustrates the price that could be paid for HYC seed for different canola prices. Prices for HYC seed below the mean line indicate HYC canola

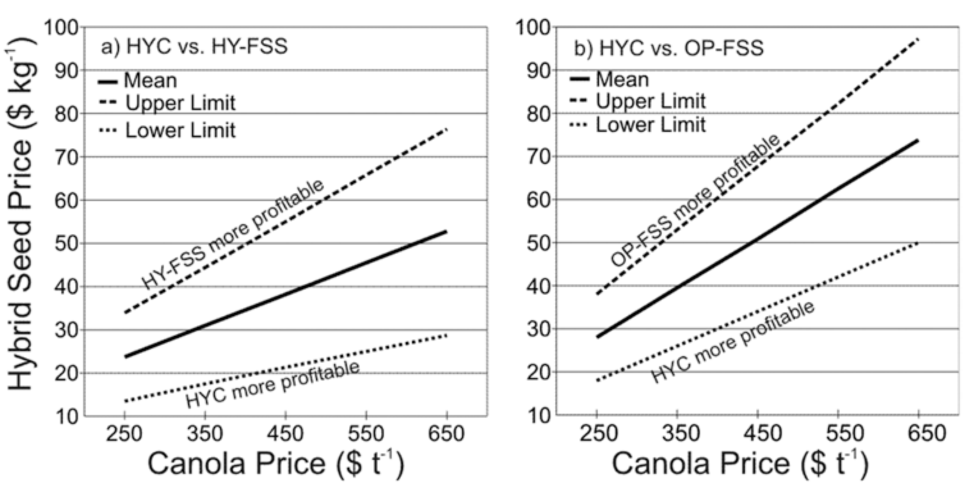

Fig. 1. The combination of hybrid certified seed (HYC) seed price and canola price, and 95% upper and lower confidence intervals, at which net return would be equal for (a) HYC (hybrid certified seed) and HY-FSS (hybrid farm-saved seed), and (b) HYC (hybrid certified seed) and OP-FSS (open-pollinated farm-saved seed).

Table 9. Summary of yield and price discount data for Exp. 3.

Seed treatment	Yield	Price discount	
		Unsized	Sized
	kg ha^{-1}	$ t^{-1}	
2004 (Exp. 3a)			
Foundation Lite	3256b†	53ab	48ab
Helix	3592a	41b	49ab
Untreated	3254b	58a	43b
2005 (Exp. 3b)			
Foundation Lite (FSS)§	2689c	20ab	
Gaucho (FSS)	2786bc	18b	
Helix (certified)	3190a	12c	
Helix (FSS)	2833b	20ab	
Untreated (FSS)	2704c	24a	

† Letters following yield and price discount within each group indicate significant difference (P = 0.05) among the treatments within the group.

‡ Genetic background.

§ Farm-saved seed.

Table 10. Probabilities and degrees of freedom for sources of variation explaining net return for Exp. 3.

Source of variation	df	Probability
2004 (Exp. 3a)		
Treatment of seed (TS)	2	0.0486
Genetic Background (GB)	1	<0.0001
TS × GB	2	0.9436
Seed size (Z)	1	0.4857
TS × Z	2	0.1912
GB × Z	1	0.5008
TS × GB × Z	2	0.4743
Sites	2	
df†	11	
2005 (Exp. 3b)		
Seed treatment and genetic background (SG)	4	<0.0001
Seed size (Z)	1	0.0618
SG × Z	4	0.9693
Sites	6	
df†	204	

† For the error term and pooled across sources of variation.

was more profitable than FSS. The confidence intervals were determined based on the HYC seed cost at which the NR distributions were statistically different. The lower confidence level would reflect the HYC break-even seed price when growing conditions were such that the genetic potential of the HYC canola was not fully expressed. The upper confidence level would reflect the HYC break-even seed price when growing conditions for HY canola were ideal.

The mean price of HYC seed at which it was as profitable to use HY-FSS, ranged from \$23.7 kg^{-1} with canola priced at \$250 t^{-1} to \$52.8 kg^{-1} when canola was priced at \$650 t^{-1} (Fig. 1a). When canola price was less the \$357 t^{-1}, the NR of HYC and HY-FSS were not statistically different. When compared to OP-FSS, the seed cost of HYC could range from \$28 to \$73.8 kg^{-1} for the two to have equal NR (Fig. 1b). The estimated 95% confidence intervals around these estimates were large, reflecting the variability of yield over space and time. The lower confidence level shows that with a combination of low canola price, high HYC seed cost, and poor growing conditions then HY-FSS or OP-FSS could be as profitable as HYC seed. For this to occur, the cost of HYC seed would need to be greater than \$13.5 kg^{-1} when the alternative was HY-FSS, and \$18 kg^{-1} when the alternative was OP-FSS.

Experiment 3 (Seed Size and Seed Treatment Experiment)

A summary of yield and the canola price discount due to green seed indicated that in 2004 yield was highest for Helix treated seed (P = 0.0197). The price discount was greater for untreated and unsized seed compared to Helix treated unsized, and untreated sized seed (Table 9, P = 0.0395). The yield for certified seed (3060 kg ha^{-1}) was greater than FSS (3670 kg ha^{-1}, P < 0.0001, data not shown). For 2005, the Helix seed treatment with certified seed had the highest yield (P < 0.0001) and the lowest price discount (P < 0.0001) (Table 9). For FSS, the seed that was untreated or treated with Foundation Lite yielded 113 kg ha^{-1} lower (P = 0.0029) than seed treatments Gaucho and Helix. There was a trend for the price discount to be higher (\$3.33 t^{-1}, P = 0.0550) for FSS that was untreated or treated with Foundation Lite.

For 2004 (Exp. 3a), seed treatment and genetic background were significant at explaining NR (Table 10). Seed size had no significant impact on NR. NR for HYC (\$620 ha^{-1}) was greater than for HY-FSS (\$443 ha^{-1}) when averaged across seed treatment, seed size, and site years (data not shown). The difference was due to the higher yield for certified seed. When averaged across genetic background, seed size and site years, the NR for seed treated with Helix (\$592 ha^{-1}) was greater than untreated (\$506 ha^{-1}), which equaled Foundation Lite (\$498 ha^{-1}) (data not shown). The higher NR for Helix treated seed was due to both higher yield and lower canola price discount from green seed (Table 9). The NR advantage for HYC was larger than reported for Exp. 1 and 2 because the site years differed. For HYC seed, it is unlikely farmers would size the seed. Sizing HY-FSS did not financially compensate for the decreased HY vigor and yield from using HY-FSS.

For 2005 (Exp. 3b), the comparison of seed treatment combined with genetic background by seed size found that only seed treatment-genetic background had an impact on NR (Table 10). The NR for Helix-treated HYC (\$563 ha^{-1}) was greater than for all four seed treatments with HY-FSS (\$487 ha^{-1}) (data not shown). The higher NR for Helix-treated HYC was due to higher yield and lower price discount for green seed (Table 9). The best possible seed treatment option for FSS, that of controlling flea beetles with Gaucho or Helix, resulted in the NR (\$501 ha^{-1}) being less than Helix-treated HYC (\$563 ha^{-1}). For FSS, treatment with either Gaucho or Helix had higher NR (\$27 ha^{-1}, P = 0.0191) than Foundation Lite or untreated. Flea beetle pressure was low at these sites so the seed treatment results could be expected to be greater with high flea beetle pressure. Sizing seed was a variable of interest (P = 0.0618) as there was a trend for higher NR from sizing, primarily for FSS (\$22 ha^{-1}). The most important factor determining NR in this experiment was the genetic background of the seed, HYC seed was more profitable than FSS. There was an economic cost to using HY-FSS due to the reduced value of yield being greater than seed cost savings.

CONCLUSIONS

This study determined the benefits of using HYC, compared to HY-FSS canola seed, off-sets higher seed costs, resulting in higher NR from using HYC seed. The main benefit of HYC canola was higher yield, but the price discount from green seed tended to be lower as well. Hybrid canola was more profitable than OP canola, confirming the findings of other studies. Under the most favorable conditions for using HY-FSS, that of being able to treat seed with Helix, the NR from HY-FSS was about 13% less than for HYC seed. The advantage of the HYC seed was more pronounced at higher canola prices. However, if weeds are not adequately controlled, canola prices are low, or HY seed costs are high, HY-FSS could be a profitable option for canola producers. The study also determined that a higher seeding rate did not increase the profitability of using FSS, nor did sizing HY-FSS seed. Sizing HY-FSS did not compensate for the loss in HY vigor reported from using HY-FSS. Canola producers in the Northern Great Plains would be advised to not use HY-FSS in an attempt to reduce seed costs. The savings in seed costs will be less than the lost value of production.

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