The profitability of seeding the F_2 generation of hybrid canola

Elwin G. Smith[1], M. Lucila Favret[2], George W. Clayton[1], Stewart A. Brandt[3], K. Neil Harker[4], Robert E. Blackshaw[1], and John O'Donovan[4]
[1]Agriculture and Agri-Food Canada, Lethbridge, Alberta; [2]Lethbridge, Alberta; [3]Agriculture and Agri-Food Canada, Scott, Saskatchewan; and [4]Agriculture and Agri-Food Canada, Lacombe, Alberta.

ABSTRACT

The profitability of using farm saved F_2 generation hybrid canola seed was evaluated using eight site-years of field data from western Canada. Net returns were computed for the experimental data taking into account yield, grade, seed costs, and all other production costs. Canola production with hybrid seed was more profitable than using open pollinated seed. Farm saved F_2 hybrid seed was never more profitable than the F_1 hybrid, even when canola prices were low and the best seed treatment was applied to the F_2 seed. Higher seeding rates for the F_2 canola seed and seed sizing to try and obtain more vigorous plants did not increase the net return for the F_2 hybrid seed to that of the F_1 hybrid seed. Canola producers will not increase their net return by using farm saved F_2 seed because the lost value of production exceeds the higher cost of the F_1 hybrid seed.

INTRODUCTION

Variety development of canola in Canada has evolved from open pollinated varieties to hybrids now dominating the seeded area. Open pollinated varieties are based on pure lines that reproduce themselves with high precision and are stable from generation to generation. Most producers using open pollinated varieties purchase certified seed, some use farm saved seed until adopting a newer variety. The total cost of farm saved seed is about one-half of certified seed cost, but cleaning and treating are the only direct costs of farm saved seed. Hybrids (F_1 generation) are the product of a cross of genetically dissimilar parent inbred lines that result in hybrid vigour. The F_1 generation is very uniform, but segregation in the F_2 hybrid generation results in the loss of hybrid vigour. Hybrid canola seed costs vary, but are about 55% higher (weight basis) than open pollinated certified seed, and considerably higher than farm saved seed. Hybrid seed tends to be larger in size, requiring higher seeding rates (25-30% higher) to obtain the desired plant population. The per area cost of hybrid seed is about twice that of certified open pollinated.

Producers have questioned whether the additional costs of certified seed are adequately covered by the higher yield and quality. They also want to know if there are methods to reduce seed costs without losing yield and quality. Producers want to know whether farm saved seed could be used instead of certified seed, especially the F_2 generation seed from hybrids. There is an expectation among producers that most of the yield advantage from the F_1 hybrid will still be present in the F_2 generation of the hybrid. The legality of using farm saved seed is another consideration. There are no legal impediments to using farm saved seed for most open pollinated canola varieties, but this is not the case for most F_2 hybrids.

Producers have also questioned whether the lower seed quality of farm saved seed could be off-set by higher seeding rates, or by screening for larger seeds when cleaning seed. A higher

seed rate would increase seed costs, but farm saved seed costs are relatively low. Cleaning for larger seed size could result in more vigorous plants and higher yield. The seed of F_1 hybrid canola is generally larger in size than open pollinated and F_2 hybrid seed. Some of the improved yield performance of hybrids could be due to this larger seed size and more vigorous seedlings.

Canola seed is treated for insects that attack the emerging plants (flea beetles) and for seedling diseases. The preferred seed treatments though are not available to producers using farm saved seed protected by Plant Breeders Rights or other legal agreements and conditions. Certified seed has higher costs, but there are yield, quality, and seed treatment benefits. The benefits of certified seed, especially hybrid seed, will largely be determined by the yield advantage. Corn production from hybrids is so beneficial that producers do not consider any other seed source. The advantage of corn hybrids over the F_2 hybrid generation was confirmed by Valdivia-Bernal and Vidal-Martinez (1995) and Ochieng and Tanga (1995). Guillen-Portal et al. (2002) reported winter wheat yield in the Nebraska Panhandle from hybrid (F_1) wheat was 10% higher than open pollinated varieties, and the yield of F_2 hybrid wheat was 12% lower than the open pollinated varieties. Kratochvil and Sammons (1990) reported the F_2 hybrid generation of soft red winter wheat yielded 8.3% less than certified F_1 hybrids. Lapinski and Stojalowski (1999) found a similar result for hybrid rye, the yield reduction was 14% for using F_2 hybrid seed. 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). Seed production and storage practices also affect the yield difference (Reddy et al., 2000).

For canola, hybrid production has been determined to have yield superiority over open pollinated varieties (Harker et al., 2003; Clayton/Brandt et al., 2007??). In Northern Idaho, hybrid canola (F_1) and farm saved seed (F_2 hybrid) yielded higher than open pollinated varieties (Starmer, Brown and Davis, 1998). These results were in agreement with those of Grosse, Leon and Diepenbrock (1992) and Lefort-Buson (1987b) (referenced in Starmer, Brown and Davis, 1998).

The majority of field studies examining farm saved seed have focussed on yield comparisons. There has been no consideration of the trade-off between seed cost, yield, and quality on net return. The objective of this study was to evaluate the farm-level economic implications of using farm saved seed from canola hybrids rather than certified seed. The hybrid comparisons were contrasted with using farm saved seed of open pollinated cultivars. The effect of seed treatment and seed size on certified and farm saved seed was evaluated. The analysis accounted for yield and quality affects and seed costs. Sensitivity analysis examined the impact of canola price on the profitability of F_1 hybrid canola versus farm saved F_2 hybrid seed.

MODEL

An evaluation of the economic benefits of adopting different seed technologies can be done using a budgeting framework. Adoption of a seed technology has little impact on most crop production processes (field operations) and resource use (machinery, labour) on a farm. Returns can be budgeted on a per hectare basis, with returns dependent upon crop yield and quality, and seed costs. Costs including fertilizer, herbicides and machine will be specified as being the same across different seed technologies. Net return (NR) is computed as the return to land and labour:

$$NR_{itr} = P_{q(it)} \cdot Y_{itr} - SC_{it} - OC \quad (1)$$

where P is the canola price, Y is the canola yield, SC is seed costs, OC are other costs, and subscript i is the seed technology, t is year, r is the rep, and q(it) is the quality that depends on i and t.

Crop yield data from different seed technologies were obtained from two field experiments, conducted at several sites and for up to two years. Net returns were computed for each field plot, based on price, yield and seed costs. The net returns were analyzed for treatment differences using analysis of variance (MIXED procedure of SAS [SAS 2005]). For the first experiment - variety, seed rate and seed source experiment - the fixed treatments were variety, seed rate, seed source and weed pressure. Location and year were defined as random variables. The second experiment - seed size and seed treatment experiment - was analyzed in three components. The first analyzed the effect of seed size and seed source for seed treated with Helix, year and location were random. The second analyzed the effect of seed treatment and seed size for farm saved seed only, for year 2005. Seed treatments Helix and Gaucho (insect and seedling disease control) were contrasted with seedling disease treatment Foundation Lite (no insect control) and untreated seed. Location was random. The third compared F_1 hybrid seed treated with Helix, and F_2 hybrid farm saved seed treated with either Foundation Lite or untreated. Location and year were random.

Field Data

The crop yield and seed data for this evaluation were from a series of field experiments conducted at two sites in 2004 and six sites in 2005. Two different field experiments included: treatments of variety (hybrid and open pollinated), seed rate, seed source (certified and farm saved), and weed competition; and treatments of seed treatment, seed size, and seed source. The first experiment was to address the question of whether farm saved F_2 hybrid seed is as profitable than the F_1 hybrid. An open pollinated variety was also included to identify whether there is a difference between the two genetic types when using farm saved seed. A high seed rate was used to determine whether farm saved F_2 hybrid seed could be seeded at a higher rate to overcome some of its genetic disadvantages. Weed pressure was included by seeding weed seeds to increase early weed competition prior to weed control. The second experiment was to address seed size and seed treatment. Seeding larger seeds could result in plants being more vigorous and competitive, and seed treatment is important especially if there are high flea beetle numbers. Field experiments were conducted in Lacombe, Alberta and Scott, Saskatchewan for 2004 and 2005. Additional sites for 2005 included Beaverlodge and Lethbridge, Alberta, and Melfort and Canora, Saskatchewan.

In the variety, seed rate and seed source experiment, treatments were arranged in a complete factorial design with four replicates. The treatments included: cultivar 46A76 for the open pollinated, and InVigor 2663 for the hybrid; seed sources were certified and farm saved seed (for the hybrid, the farm saved seed would be F_2); the two seed rates were high (240 seeds/m^2) and standard (120 seeds/m^2); and the weed competition required seeding weeds to insure weed pressure prior to weed control. To ensure the seed was broadly representative of what was available to growers, seed was bulked from three different seed lots to make up each of the certified and farm saved seed treatments. Germination rates for all seed lots exceeded 90%, the standard for certified number 1 canola seed. All seed was treated with Helix. Helix provides flea beetle and seedling disease control. In practice, a producer would not be able to treat F_2 hybrid farm saved seed with Helix because seed treaters have an agreement with the manufacturer to treat only 'legal' seed. 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 standard methods described in more detail by Clayton/Brandt et al. (200?).

The estimated seed costs for the genetics, seed sources and seeding rates are in Table 1. Both years of this study are reported because seed weights differed and therefore seeding rates differed to attain the same seed density. The cost of certified seed was the retail price. Farm saved seed included the value of commercial canola plus cleaning and seed treatment. The cost of farm saved seed was about one-half that of certified for open pollinated and the F_2 hybrid was one-quarter of the F_1 hybrid. The seed costs for the high seed rate were twice that of the standard seed rate.

The seed size and seed treatment experiment was designed as a complete factorial design with four replicates, but the treatments differed each year. Only the F_1 and F_2 hybrid generations were used in this experiment. In 2004, treatments included seed source, seed sizing, and seed treatment. The F_1 and F_2 hybrid seed was either as-is or sized, and then either untreated, treated with Helix, or treated with Foundation Lite. Helix provides insect and seedling disease protection, Foundation Lite provides only seedling disease protection. As previously indicated, it is not feasible to treat farm saved F_2 hybrid seed with Helix. Also, in practice it is unlikely the F_1 hybrid seed would be sized. In 2005, the F_1 hybrid seed was treated only with Helix, and the farm saved seed was either untreated, treated with Gaucho (insect and seedling disease protection), Foundation Lite, or Helix. Gaucho, as with Helix, can only be applied to 'legal' seed. Yields were standardized to 10% moisture, and other crop management practices used standard methods described in more detail by Clayton/Brandt et al. (200?).

Seed costs for the seed size and treatment experiment depended on the seed treatment, seed source, and seed sizing (Table 2). Seed costs for using the farm saved F_2 hybrid seed were about one-quarter of the certified cost with Helix treatment. Untreated farm seed costs were \$45-\$55/ha less than F_1 hybrid seed costs. 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.

Price and Cost Data

Other production costs included insurance, marketing, fertilizer, herbicide, and machinery. The insurance cost at Lacombe and Beaverlodge was \$27/ha; at Scott, Canora and Melfort it was \$18/ha; and in Lethbridge it was \$32/ha, for all experiments (AAFC, 2006). The marketing cost was \$10.52/t. 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 Table 3 for the variety, seed rate and seed source experiment, and in Table 4 for the seed size and seed treatment experiment.

The computed net revenue accounted for the impact of green seed on the canola grade and price. Farm saved seed, especially F_2 seed, might be more conducive to increased plant and maturity variability. This could result in higher green seed counts for farm saved seed. The canola price used in the analysis was a 5 year average (\$325/t), with appropriate discounts applied for green seed (AFSC, 2007). The grades were based on green seed: #1 for green seed $\leq$ 2%; #2 for 2.1% $\leq$ green seed $\leq$ 6%, discounted \$13/t; #3 for 6.1% $\leq$ green seed $\leq$ 20%, discounted \$55/t; and sample for green seed $\geq$ 20.1%, discounted \$100/t. A sensitivity analysis of the impact of the canola price included a lower price (\$240 t^{-1}) that has occurred in the past decade, and a higher price (\$380 t^{-1}) to reflect prices in 2007.

The weather conditions were typical at Lacombe (2004), Beaverlodge (2005) and Canora (2005). At Lacombe in 2005, conditions dictated harvesting earlier than desired, increasing the green seed count. Scott had an early fall frost in 2004, reducing yield and resulting in high green seed, and in 2005 hail damage reduced yield and increased green seed count. Melfort had a mid-May frost in 2005 and the experiment was re-seeded on May 30, impacting yield and green seed count due to delayed maturity. At Lethbridge in 2005, yields were greatly reduced because of flooded plots in June and hail in July.

RESULTS

Variety, Seed Rate and Seed Source Experiment

The analysis of variance of the net returns computed for all plots indicated significant treatment effects for weed pressure, and variety by seed source (Table 5). The significance level of the variety by seed rate and seed source by seed rate indicated a trend of interest. Weed pressure did not have any significant interactions with the other treatments, indicating that impacts of variety, seed source and seeding rate were not influenced by weed competition. Recall, that for this experiment all seed was treated with Helix, so the results are conditional on the ability to use Helix for farm saved seed.

Net return from the experiment with weed pressure was lower than from the experiment without weed pressure ($159 ha^{-1}, $P<0.001$). Net return from the certified F_1 hybrid was higher than the open pollinated ($70 ha^{-1}, $P<0.001$). This result was consistent with other studies comparing net return of hybrid and open pollinated canola (Upadhyay et al., 2006). For the open pollinated variety, net return was higher for farm saved, compared with certified seed (Table 6). The result was expected because costs were higher for the certified seed, and yields were similar because the genetics of different generations are stable. For the hybrid seed, the net return between the F_1 and F_2 generations for each of the two seeding rates were not different. Seeding rate had no impact on net return for the open pollinated variety, but decreased the net return for the F_1 hybrid (Table 6). For farm saved seed, there was no economic benefit from seeding at a higher rate.

The comparison of most interest was the certified seed at the low seed rate versus farm saved seed at both seed rates. For the open pollinated variety, there was no difference in net return between the low seed rate for certified seed and either seed rates for the farm saved seed. The slightly lower average net return of $40 ha^{-1} ($P=0.102$) for certified seed at the low seed rate versus farm saved at the high seed rate was primarily due to higher certified seed costs.

The net return for the F_1 hybrid certified seed at the low seed rate was not significantly higher than the farm saved seed at the low seed rate, $P=0.05$. However, the difference of $41 ha^{-1} was significant at $P=0.095$. Additional site years of data, or a design to reduce the variability associated with these treatments might find the difference to be significant. Net return for the certified F_1 hybrid at the low seed rate was significantly higher than the high seed rate F_2. The yield advantage of the certified F_1 hybrid covered the higher seed cost. Net return from using farm saved F_2 hybrid seed exceeded that of open pollinated farm saved seed at the high seed rate ($P=0.056$). Producers could experience increased net return if switching from open pollinated to F_2 hybrid seed, although they would be foregoing additional net returns by not growing the F_1 hybrid.

Canola Price Sensitivity Analysis

The lower canola price resulted in a significant seed source by seed rate interaction and an insignificant variety by seed source interaction, the significance of the remaining variables were similar to those reported in Table 5. The net return from the hybrid ($197 ha^{-1}) was greater than the open pollinated ($153 ha^{-1}). Highest net returns was from the F_1 hybrid certified seed at the low seed rate, farm saved F_2 seed at both seed rates, and open pollinated farm saved at the high seed rate. The certified hybrid net return ($216 ha^{-1}) was similar to the F_2 hybrid ($192 ha^{-1}), P=0.264. Compared to the net return report in Table 6, the net return advantage of the certified F_1 hybrid canola diminished at low canola prices. However, under conditions of low canola prices the farm saved seed was not more profitable than F_1 certified hybrid seed.

The higher canola price resulted in the significance of the variables being similar to those reported in Table 5. Net return from hybrid production ($551 ha^{-1}) was greater than from open pollinated ($463 ha^{-1}). The net return from F_1 hybrid at the low seed rate ($595 ha^{-1}) would exceed that of farm saved F_2 at the low seed rate ($543 ha^{-1}) at P=0.069. The net return advantage of the F_1 seed increased with the higher canola price.

Seed Size and Seed Treatment Experiment

Certified F_1 hybrid seed had higher net returns than farm saved F_2 hybrid seed when treated with Helix (Table 7, 'Helix' column). When treating with Helix, sizing the seed had no effect on net returns, regardless of the seed source. With farm saved F_2 hybrid seed only, the treatment of seed and the size of seed were significant in determining net returns (Table 7, 'Farm Saved' column). There was a significant difference in net returns among F_1 hybrid seed treated with Helix and the F_2 hybrid seed (farm saved) treated with Foundation Lite or untreated (Table 7, 3rd column).

When considering only the seed treated with Helix, net returns from sizing were similar regardless whether the seed was F_1 or F_2 (Table 8). The mean net return for the F_1 hybrid with Helix ($592 ha^{-1}) was greater than the farm saved seed treated with Helix ($504 ha^{-1}). The net return difference was larger than that observed for the variety, seed rate and seed source experiment reported above. For F_1 hybrid seed, it is unlikely farmers would size the seed. The unsized F_1 hybrid seed also had significantly higher net returns than the farm saved F_2 hybrid seed, regardless of sizing. Sizing farm saved seed did not compensate for the decreased hybrid vigour associated with using F_2 hybrid farm saved seed.

For farm saved F_2 hybrid seed, treating the seed with either Helix or Gaucho, and sizing seed resulted in higher net returns (Table 9). Contrasting F_2 hybrid seed treatments that control flea beetle (Helix and Gaucho) against those that do not (Foundation Lite and Untreated) determined the treatments providing flea beetle control had higher net returns ($76 ha^{-1}). Sizing the seed was more important when treating with Foundation Lite (P=0.109) and for untreated seed (P=0.094). For sized seed, seed treated with Helix had higher net return than Foundation Lite (P=0.054) and untreated (P=0.106). For unsized seed, Helix treated seed had higher net returns than Foundation Lite treated seed and untreated seed, and the returns using Gaucho treated seed were higher than Foundation Lite treated seed (P=0.081) and untreated seed (P=0.126).

The final comparison was that of certified F_1 hybrid seed treated with Helix to farm save F_2 hybrid seed either treated with Foundation Lite or untreated. This reflects the situation that producers would experience if they were using F_2 hybrid seed. Net returns from F_1 hybrid unsized seed treated with Helix was significantly higher than F_2 hybrid seed treated with

Foundation Lite or untreated, and either sized or unsized (Tables 8 and 9). There was an economic cost to using farm saved F_2 hybrid canola seed due to reduced yield and returns.

CONCLUSIONS

The yield benefit of producing F_1 hybrid canola off-sets the higher cost of seed, and returns higher profits to producers. Hybrids were found to be more profitable than open pollinated varieties, as has been reported in other studies. Under the most favourable conditions for using farm saved seed, that of being able to treat with Helix, the farm saved F_2 hybrid seed did not increase net return, and it was more likely to be less profitable than using certified F_1 hybrid seed. The advantage of the F_1 hybrid was more pronounced at higher canola prices, and with low canola prices farm saved seed was never more profitable as the F_1 hybrid. Higher seeding rates did not increase the profitability of using farm saved seed. Sizing farm saved F_2 hybrid seed increased net returns only when the seed was either untreated or treated only for seedling diseases. However, these practices had lower net return than the F_1 hybrid seed. Sizing the farm saved seed did not compensate for loss in hybrid vigour when seeding F_2 hybrid seed.

Canola producers in western Canada would be advised to not use farm saved F_2 hybrid seed in an attempt to reduce seed costs. The savings in seed costs will be less than the lost value of production obtained from using F_1 hybrid seed.

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Table 1. Seed cost ($/ha) by year for all locations; variety, seed rate and seed source experiment

Year	2004				2005			
Genetics	Open Pollinated		Hybrid		Open Pollinated		Hybrid	
Seed Rate	High	Normal	High	Normal	High	Normal	High	Normal
Seed source								
Certified	67.32	33.7	128.20	64.10	81.11	40.56	164.11	82.13
Farm Saved	36.79	18.4	32.46	16.23	39.49	19.72	42.99	21.49
Difference	30.52	15.31	95.74	47.87	41.62	20.83	121.13	60.64

The price of Helix treated certified seed was $14.31/kg and $9.26/kg for the hybrid and inbred, respectively. The cost of farm saved seed was computed to be $4.42/kg and included the seed at a commercial price, seed cleaning and treating, and hauling.
Sources: Bayer Crop Sciences (seed treatment costs), Agricore (certified seed retail price).

Table 2. Seed cost ($/ha) for hybrid seed at all locations; seed size and treatment experiment

	2004				2005			
	Certified (F_1)		Farm Saved (F_2)		Certified (F_1)		Farm Saved (F_2)	
Seed Treatment	Unsized	Sized	Unsized	Sized	Unsized	Sized	Unsized	Sized
Untreated*	46.68	58.77	1.69	2.18	-	-	2.24	2.59
Gaucho	-	-	-	-	-	-	13.90	16.13
Foundation Lite	49.64	62.49	4.15	5.36	-	-	5.49	6.37
Helix	65.00	81.84	15.96	20.62	83.29	91.27	21.14	24.53

*Certified seed price without treatment was computed to be $10.45/kg. Farm saved seed price without treatment was $0.33/kg.
Source: Bayer Crop Sciences (seed treatment costs).

Table 3. Selected production cost ($/ha); genetics, seed rate and seed source experiment

Year Location	Variety	with weed pressure Machinery	with weed pressure Herbicide	without weed pressure Machinery	without weed pressure Herbicide	Both Tests Fertilizer
2004						
Lacombe	OP[z]	135	116	135	116	112
	Hybrid	135	82	135	112	112
Scott	OP	135	0	126	44	71
	Hybrid	135	0	126	83	71
2005						
Beaverlodge	OP	135	76	135	76	114
	Hybrid	135	112	135	112	114
Canora	OP	N/A	N/A	126	34	141
	Hybrid	N/A	N/A	126	62	141
Lacombe	OP	135	107	126	95	96
	Hybrid	135	74	126	76	96
Lethbridge	OP	126	60	162	48	71
	Hybrid	126	76	162	48	71
Melfort	OP	135	73	135	90	19
	Hybrid	135	38	135	56	19
Scott	OP	126	59	126	88	8
	Hybrid	126	83	126	130	8

[z] Open Pollinated

N/A indicates not applicable because there was not a weed pressure treatment at this site.

Table 4. Selected production costs ($/ha); seed size and treatment experiment

Year	Location	Fertilizer	Herbicide	Machinery
2004	Lacombe	69	86	135
	Scott	71	69	126
2005	Beaverlodge	114	112	135
	Canora	71	69	126
	Lacombe	96	88	135
	Lethbridge	71	47	162
	Melfort	19	56	126
	Scott	8	83	126

Table 5. Significance of variables in explaining net returns; variety, seed rate and seed source experiment

Variable	Pr > F
Weeds (W)	<0.0001
Variety (V)	<0.0001
W*V	0.7106
Seed Source (SS)	0.3305
W*SS	0.3427
V*SS	0.0437
W*V*SS	0.8733
Seed Rate (SR)	0.1745
W*SR	0.7871
V*SR	0.1028
W*V*SR	0.6152
SS*SR	0.1460
W*SS*SR	0.3185
V*SS*SR	0.4041
W*V*SS*SR	0.3259

Table 6. Mean net return ($/ha) by variety; variety, seed rate and seed source experiment

	Open Pollinated - 46A76			Hybrid - InVigor 2663		
Seed Rate	Certified	Farm Saved	Average	Certified	Farm Saved	Average
Low	324 d	353 cd	339 c	450 a	409 ab	429 a
High	320 d	363 cd	342 c	385 bc	400 bc	393 b
Average	322 c	359 b		417 a	404 a	

Letters following the net return value indicate significant difference among treatment combinations. Significance levels are computed for the columns (variety by seed rate) and row (variety by seed source) separately.

Table 7. Significance of variables in explaining net returns; seed size and treatment experiment

Variable	Helix	Farm Saved	F_1 and Helix, F_2 and Foundation Lite or Untreated
Treatment/ Source (TS)	<0.0001	0.0034	<0.0001
Seed Size (Z)	0.9566	0.0185	0.3701
TS*Z	0.3658	0.8817	0.4920

Table 8. Mean net return ($/ha) for seed treated with Helix; seed size and treatment experiment

Seed Source	Sized	Unsized	Average
Certified (F_1)	584 a	600 a	592 a
Farm Saved (F_2)	513 b	495 b	504 b

Table 9. Mean net return ($/ha) for F_2 hybrid seed; seed size and treatment experiment

Seed Treatment	Sized	Unsized	Average
Helix	513 a	497 a	505 a
Gaucho	497 a	479 ab	488 ab
Foundation Lite	472 ab	438 b	455 c
Untreated	479 ab	444 b	461 bc
Average	490 a	464 b	