Cultivar Considerations and Pod Sealants for Straight-Combining Canola in Saskatchewan

Chris Holzapfel[1], Cecil Vera[2], Sherrilyn Phelps[3] and Bryan Nybo[4]

[1]Indian Head Agricultural Research Foundation, Box 156, Indian Head, SK, S0G 2K0
[2]Agriculture and Agri-Food Canada (Northeast Agricultural Research Foundation), Box 1240, Melfort, SK, S0E 1AO
[3]Saskatchewan Ministry of Agriculture (Western Applied Research Corporation), Box 10, Highway 374, Scott, SK, S0K 4AO
[4]Wheatland Conservation Area, Box 2015, Swift Current, SK, S9H 4M7

Key Words: *Brassica napus*, harvest management, pod shatter, cultivar

Abstract

While the recommended and preferred harvest practice in western Canada is to swath canola (*Brassica napus* L.), there is appreciable interest in straight-combining this crop. In a recent study, five cultivars were harvested according to one of four harvest treatments and evaluated for seed yield, yield loss due to shattering, percent green seed and seed size. The cultivars included four *B. napus* hybrids and an open-pollinated canola quality *B. juncea* variety. Harvest strategies were swathed, straight-combined without a pod sealant, straight-combined with Pod Ceal DC® and straight-combined with Pod-Stik®. While average yields ranged from 894-3066 kg ha^{-1}, cultivar rankings for yield were generally consistent across sites. Seed yields were equal when averaged across harvest treatments and sites, but swathed yields differed from straight-combined yields 50% of the time for individual sites. At two sites, straight-combining produced 142-370 kg ha^{-1} higher yields than swathing while, when harvest was delayed due to unfavourable weather, swathed yields were 276-413 kg ha^{-1} higher. A 217 kg ha^{-1} yield increase occurred with pod sealants at one site, but there were no differences amongst the two products and pod sealants did not affect yields of straight-combined canola at the remaining seven sites. Pod sealants did not have a measurable effect on shattering losses, even under high shattering conditions. In contrast, cultivar effects on seed loss were generally significant with losses from one of the *napus* cultivars being particular and consistently low, especially when overall shattering losses were high. On average, losses for all cultivars were 4% of the total yield when harvest was completed reasonably close to the optimal stage. Straight-combining resulted in a small but significant increase in percent green seed and seed size but pod sealants did not affect seed quality in any cases. In conclusion, straight-combining can be a viable alternative to swathing, but substantial yield losses may occur if harvest is delayed too long. Important varietal differences in shattering losses were detected and cultivar selection appears to be a factor of greater importance than pod sealants for growers planning to straight-combine canola.

Introduction

The generally recommended and preferred practices when harvesting canola (*Brassica napus*) in Saskatchewan is to swath at 40-60% seed colour change and harvest the crop when the seed has matured and is dry enough to store. Earlier harvest management research with canola focussed primarily on the effects of time of swathing on time to maturity, seed quality and yield (Cenkowski et al. 1989, Thomas et al. 1991, Anonymous 1998a, Anonymous 2000). An important benefit to swathing canola is that doing so hastens moisture loss and chlorophyll degradation in the seed relative to canola left standing (Cenkowski et al. 1989) and swathing helps variable fields mature evenly while, at the same time, desiccating any green weeds. However, timing of this operation is critical as swathing too early can prevent the crop from reaching its full yield potential (Vera et al. 2007) while the risk of pod shattering can be high when canola is swathed too late (Thomas et al. 1991, Anonymous 1999, Anonymous 2000). Swathing canola too early can also result in increased green seed, reduced seed size and lower seed oil concentrations (Hocking and Mason 1993, Anonymous 1998a, Anonymous 2000, Vera et al. 2007). Perhaps most importantly from a producer's perspective, swathing is labour intensive and must be completed at a time when labour is in high demand. For many growers, canola is the only crop routinely swathed. Generally speaking, straight-combining *Brassica napus* canola has not been recommended because the risks of yield losses from shattering have frequently outweighed the potential benefits. Field trials and grower experiences alike have shown that, while it is not uncommon to straight-combine canola successfully, substantial yield losses can occur and have been reported as high as 50% relative to swathing (Thomas et al. 1991; Anonymous 1998b, Anonymous 1998c, Anonymous 1999, Gan et al. 2008). Nonetheless, there is considerable interest in straight-combining canola and technology has been striving to make this practice more feasible and less risky.

One of the first things to consider by canola growers planning on straight-combining is selecting a species and/or cultivar that is relatively resistant to shattering. *B. rapa* and canola quality *B. juncea* canola are often touted as being better candidates for straight-combining than *napus* cultivars because of their shattering resistance; however, these two species do tend to yield less than *napus* canola (Gan et al. 2008, Wang et al. 2007). Recent research has shown large variation amongst *napus* germplasm in resistance to shattering, with certain genotypes exhibiting comparatively low losses which were similar to those of *B. juncea* (Wang et al. 2007). It has been suggested that canola crops with a high yield potential are better suited to straight-combining than lower yielding canola; thus, adequate fertility and seeding rates are important to ensure a strong, even stand (Watson et al. 2008). Strong, uniform plant stands will also contribute to even and early maturity (Angadi et al. 2003), an important consideration for straight-combining. Another attribute which many canola crops that are successfully straight-combined frequently share is a dense canopy where the plants are somewhat lodged and heavily intertwined with one another (Watson et al. 2008). Yield Shield™ is a device used to cause artificial lodging (pushing) on canola crops, with the intent of reducing plant movement and render fields less prone to shattering and thus better suited for straight-combining (Ag Shield Manufacturing 2011). Research at Brandon, Manitoba (Irvine 2003) found that pushed canola typically yielded equal to or higher than swathed canola, provided that the crop was not pushed too early. Irvine (2003) also noted that pushing canola worked better in dense canopies, as the sparser canopies tended to stand back up, especially when pushed too early. In contrast, other trials showed no benefit to pushing relative to straight-combining canola that had not been pushed (Anonymous 2001a, Anonymous 2001b, Anonymous 2002). The greatest drawbacks of pushing are that this practice does not eliminate a field operation relative to swathing, requires special equipment and pushed canola must be cut closer to the ground than canola that has not been pushed, slowing down harvest and leaving less stubble behind to capture snow for subsequent crops.

Pod sealants, such as Pod Ceal DC (Brett Young 2011) and Pod-Stik (United Agri-Products 2011), are another technology available to growers wanting to straight-combine canola. Pod sealants are designed to protect the pods from shattering as the seeds inside mature and are applied when approximately 30-40% of the pods have changed color but are still generally pliable and not brittle. Pod Ceal DC is an organic turpene polymer, or pine resin, that regulates moisture transfer by allowing moisture to move out of the pod but not into it, thus reducing pod contraction and expansion due to wetting and drying cycles. Pod-Stik is a latex polymer that does not affect moisture transfer through the pod but provides physical reinforcement as the pods dry down and the seeds mature inside. If effective, pod sealants could lengthen the time period that canola could safely be left standing, increasing harvest flexibility and allowing producers to fully capture the benefits of straight-harvesting without some of the drawbacks of pushing. The total cost of applying a pod-sealant (product plus application) is similar to that of swathing; however more acres can be covered in a shorter time period with a high-clearance sprayer compared with a swather. Third party data evaluating the effectiveness of pod sealants for straight-combined canola in the Canadian prairies have been limited. In North Dakota, there was no yield benefit or reduction in shattering for straight-combined canola treated with pod sealants relative to straight-combined, untreated canola (Johnson et al. 2009). Similarly, data from east central Saskatchewan have not shown a clear benefit to pod sealants (Kim Stonehouse, personal communication). Despite uncertainty regarding their effectiveness, canola growers are interested in pod sealants and an appreciable number of acres have been treated over the years since these products have become available.

A study was initiated in Saskatchewan with the objectives of evaluating 1) the importance of cultivar selection when straight-combining canola, 2) the ability of commercial pod sealants to reduce shattering losses and increase yields in straight-combined canola and 3) the overall feasibility of straight-combining canola.

Materials and Methods

Site Descriptions

Field trials were completed in 2009 and 2010 at four locations in Saskatchewan; Melfort (52º49' N, 104º36' W), Indian Head (50º33' N, 103º39' W), Scott (52º22' N, 108º50' W) and Swift Current (50°16' N, 107°44' W). Melfort (480 m elevation) is in the moist Black Soil Zone, has an average annual precipitation of 413 mm, a mean annual temperature of 1 ºC and a frost free period of 101 days (Environment Canada 2011). Indian Head (579

m) is in the thin-Black Soil Zone, has an average annual precipitation of 447 mm, a mean annual temperature of 2.6 ºC and a frost free period of 110 days. Scott (660 m) is in the Dark-Brown Soil Zone, has an average annual precipitation of 359 mm, a mean annual temperature of 1.6 ºC and frost-free period of 97 days. Finally, Swift Current (825 m) is in the Brown Soil Zone, has an average annual precipitation of 349 mm, a mean temperature of 3.9 ºC and a frost-free period of 118 days.

Design and Treatments

The treatments were a factorial combination of five cultivars and four harvest treatments, for a total of twenty separate entries. Each entry was replicated three times in a randomized complete block design (RCBD) at all sites. The harvest treatments were 1) swathed, 2) straight-cut with no pod sealant, 3) straight-cut with Pod Ceal DC and 4) straight-cut with Pod-Stik. The cultivars evaluated were 1) InVigor 5440, 2) 4362, 3) 45H26, 4) InVigor 5020 and 5) EXCEED 8571. The cultivars 5440 (Bayer CropScience), 4362 (Brett Young) and 45H26 (Pioneer Hi-Bred) were chosen by the respective seed companies, who were each invited to contribute a variety of their choice for the project. InVigor 5020 was included because, when the study was initiated, this hybrid was one of the standards to which others were compared to in variety performance trials. XCEED 8571 (Viterra) is an Imidazolinone-tolerant canola quality *juncea* variety that was primarily included because *B. juncea* is considered relatively resistant to shattering and well-suited for straight-combining (Gan et al. 2008).

Crop Management

Canola at Indian Head and Melfort was seeded into standing cereal stubble while plots at Scott and Swift Current in 2009 were planted on chem-fallow and tilled in the fall. At Swift Current in 2010, the plots were established on durum stubble. Seeding dates ranged from May 14 to June 23 (Table 1) and seeding rates were adjusted for seed size with a targeted seeding rate of 135 seeds m^{-2}, except at Swift Current where canola was seeded at 6.7 and 7.8 kg ha^{-1} in 2009 and 2010, respectively. Dates of seeding and other pertinent field operations are provided in Table 1. Plot size and the specific seeding equipment used at each location varied. At Indian Head, each plot was established with two passes of a ConservaPak drill equipped with 14 openers on 30 cm row spacing. Fertilizer at Indian Head was applied as side banded urea, monoammonium phosphate, potash and ammonium sulphate to supply 130, 34, 17 and 17 kg ha^{-1} of N, P_2O_5, K_2O and S, respectively, in 2009 and 122, 30, 15 and 15 kg ha^{-1}, respectively, in 2010. At Melfort, plots were seeded with one pass of a ConservaPak drill, with 16 openers spaced 23 cm apart. Fertilizer rates were 61 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} as side-banded urea and monoammonium phosphate in 2009 while 99, 23, 45 and 15 kg ha^{-1} of N, P_2O_5, K_2O and S were applied in 2010. At Scott, plots were seeded using a hoe press drill equipped with Atom Jet openers on 25 cm row spacing. In 2009, only 34 kg P_2O_5 ha^{-1} was applied as seed-placed mono-ammonium phosphate, while in 2010, 29, 13, 2 and 2 kg ha^{-1} of N, P_2O_5, K_2O and S, respectively were side-band applied. At Swift Current, canola was planted with a Flexi-Coil air drill with 20 openers spaced 23 cm apart in 2009 while plots were seeded using two passes of a Fabro no-till drill equipped with Atom-Jet openers on 23 cm spacing in 2010. Fertilizer rates of 40, 20 and 8 kg ha^{-1} of N, P_2O_5 and S, respectively, were applied in a side-band in 2009 and in 2010 the rates were 45, 23 and 9 kg ha^{-1} of N, P_2O_5 and S, respectively, applied in a side-band.

Table 1. Selected agronomic information for canola straight-combining studies at Indian Head, Melfort, Scott and Swift Current in 2010.

	------ Site-Year (Site) ------							
Operation / Data Collection	**Indian Head**		**Melfort**		**Scott**		**Swift Current**	
	2009	2010	2009	2010	2009	2010	2009	2010
Seeding	May-14	May-16	May-27	Jun-3	May-16 (napus) May-25 (juncea)	May-19	May-25	Jun-2
Plant counts	Jun-3	Jun-8	Jun-30	June-30	Oct-23	Jun-2	Jul-23	Jul-20
Pod sealant	Aug-27	Aug-9	Sep-5	Sep-2	Aug-27 (napus) Sep-4 (juncea)	Aug-25	Sep-1	Aug-20
Height / Lodging	Sep-1	Aug-12	Sep-4	Sep-4	Sep-2	Sep-16	n/a	Sep-23
Swathing	Sep-3 (5440/5020) Aug-27 (rest)	Aug-22 (5440/5020) Aug-27 (rest)	Sep-16	Sep-16	Sep-2 (napus) Sep-4 (juncea)	Aug-25	Sep-2 (napus) Sep-7 (juncea)	Sep-2
Harvest	Sep-16/17 (swathed) Sep-24 (straight)	Sep-27	Nov-13	Oct-7	Sep-17 (swathed napus) Sep-23/24 (rest)	Sep-18 (LL) Sep-28 (RR) Sep-30 (juncea)	Sep-15	Sep-24 (rest) Oct-3 (juncea-straight)
Seed Loss[1]	Sep-18 (napus) Sep-24 (juncea)	Sep-21	n/a	Oct-6	Sep-23	Sep-18 (LL) Sep-28 (RR) Sep-30 (juncea)	Sep-15	Sep-25 (rest) Oct-3 (juncea-straight)
Seed Loss[2]	Oct-19/20	Oct-8	Nov-12	n/a	Oct-5	Oct-3	Oct-20	Oct-8 (rest) Oct-16 (juncea-straight)

n/a – data not available (entire plots were harvested so only one seed loss measurement was completed at Melfort; data were grouped into the late measurements in 2009 due to the unusually late harvest

Competition from weeds, insects and disease were controlled using only registered crop protection products selected for the specific pests encountered at each location. For in-crop weed control at Indian Head, Melfort and Swift Current, each cultivar was sprayed with its partner herbicide (ie: glyphosate for Roundup Ready varieties, Liberty for InVigor varieties and Odyssey or Solo for Clearfield varieties) using a field sprayer. No herbicides were applied in-crop at Scott in 2009; however, trifluralin was applied the previous fall followed by incorporation through cultivation. Fall tillage and trifluralin was used again at Scott in 2010 but partner herbicides were also applied in-crop. No insecticides or fungicides were required except for at Indian Head in 2009 where the plots were sprayed with Decis (7.4 g deltamethrin ha^{-1}) on June 24 to control flea beetles. At Scott in both years and Swift Current in 2009, the straight-combined treatments were desiccated prior to harvest using diquat while desiccants were not used at Indian Head or Melfort. Pod sealants were applied with field sprayers at approximately 30-40% pod colour change (when the pods were turning colour but still somewhat pliable) at a solution volume of 113 L ha^{-1}.

The specific equipment used to harvest the plots varied with location but wheel tracks from the pod sealant applications were not permitted in the harvested plot areas. All plots were harvested along the full plot length and outside rows were excluded at all locations except for Melfort where the entire plots were harvested. The targeted harvest dates were as soon as the seed was mature and dry enough to store or slightly earlier, but harvest was delayed due to unfavourable weather in certain cases, notably Melfort in 2009 and Indian Head in 2010. At Melfort in 2009, harvest was not completed until November 13 because cool conditions during the season delayed maturity and wet, snowy weather prevented the plots from being harvested in October. At Indian Head in 2010, recurring rains in September prevented harvest from being completed until approximately seven to ten days past the optimal stage. At Indian Head, canola was swathed using a 3.5 m self propelled swather and combined using a modified Massey Ferguson MF300 equipped with either a pickup header or 3.5 m straight-cut header. At Scott, a 3.6 m swather was used for the swathed treatments and both the straight-combined and swathed plots were harvested using a Wintersteiger plot combine (1.6 m width). At Melfort, canola was swathed using a 5.8 m self propelled swather and harvested using a modified Massey Ferguson MF550 equipped with either a 3.9 m pickup header or 3.6 m straight-cut header. At Swift Current a 4.2 m swather and Wintersteiger plot combine equipped with 1.35 m straight-cut header was used (swaths were undercut using the same combine in swathed treatments). Depending on the location and equipment used, grain was either weighed in the field with a sub-sample used to determine grain moisture, dockage and quality or the entire harvest sample was bagged and processed at a later date.

Data Collection and Analysis

The specific data collected throughout the growing season included plant density, plant height, lodging, days to maturity, grain yield, seed loss, percent green seed and seed size; however, only seed yield, seed losses, green seed and seed size are reported in detail. Grain yields were measured by determining the mass of clean seed harvested from each plot and are corrected to 10% seed moisture content and expressed in kg ha^{-1}. Seed losses were determined by placing either one or two mesh-lined catch trays in each plot at the early pod filling stage and determining the mass of the seed contained in the trays at later dates. Seed losses were only measured once at Melfort, just prior to harvest, but were measured at two distinct time periods for the other three locations; once approximately at the time of harvest and again 2-4 weeks later. The seed collected from each of the trays were separated into two categories, dropped pods or shattered pods, and losses from each category were measured separately and results are expressed in kg ha^{-1} and as a percentage of the total seed yield (harvested yield plus measured losses). Green seed was determined from the harvest sample for each plot by crushing a total of 500 seeds, counting distinctly green seeds and converting to a percentage. Seed size was determined either by manually counting and weighing 200 seeds or using automated seed counters and seed size is expressed as g 1000 seeds^{-1}.

Data were analyzed using the Mixed procedure of SAS 9.1 (Littel et al. 1991) with separate analyses completed for each site in addition to a combined analysis that included all sites. For the individual sites, effects of cultivar and harvest treatment were considered fixed while the effects of replicate were considered random. In the combined analysis, which included data from all eight sites, the effects of site were considered fixed under the justification that observed differences between sites could likely be explained by environment, harvest conditions and observed seed quality parameters. Analyses of individual sites were justified by the fact that significant interactions between site and the main fixed effects occurred frequently for all variables. Treatment means were separated using Tukey's studentized range test which controls the type 1 experimentwise error rate; thus is somewhat more conservative than Fisher's least significant difference (LSD) test. Contrasts were used to compare 1) swathing versus straight-combining, 2) straight-combining with pod sealants versus straight-combining without pod sealants and 3) *B. napus* canola versus canola quality *B. juncea*. All treatment effects and differences between means were considered significant at $P \leq 0.05$.

Results and Discussion

Growing Season Weather

Overall, growing season temperatures were generally lower than the long-term normal (1971-2000) at all four locations over both years of the study; however September was warmer than average in 2009 and October was warmer in 2010 (Table 2). Except for Swift Current, canola was damaged by frost at all locations in early June of 2009, with the greatest stand reductions observed at Scott and Melfort. In terms of precipitation, the 2009 growing season (May-October) was drier than normal at each of the locations except for Melfort. While Melfort in 2009 was wetter than normal on average, a substantial amount of the precipitation was received in October (400% of normal), too late for the crop to utilize, while May and June were drier than normal. Despite the dry spring, soil moisture conditions at all locations tended to improve over late July and August with normal to above normal precipitation received during this period. At Scott in 2009, hail damaged the plots on July 8th and the cultivar 8571 was damaged more severely than the other varieties due to the difference in seeding dates and earlier growth stage. The higher temperatures and reasonably dry weather in September 2009 permitted a timely harvest at all locations except for Melfort where the canola was less advanced and harvest was delayed to mid-November. In 2010, well above normal precipitation was received across all locations. May and June were generally the wettest months while precipitation was closer to normal from July through to early August. Above normal precipitation resumed in September and created challenging harvest conditions for many of the sites; however harvest was, for the most part, completed before the end of the September.

Table 2. Mean monthly temperatures and total precipitation for the 2009-10 growing seasons (May-Oct.) at Indian Head, Melfort, Scott and Swift Current (Environment Canada 2011).

Location/Year	May	Jun	Jul	Aug	Sep	Oct	Mean / Total
	Month						
	------------ Mean Monthly Temperature (ºC) ------------						
Indian Head							
2009	8.6	14.3	14.9	15.7	16.1	1.7	11.9
2010	9.6	15.6	17.4	16.3	11	7	12.8
LT[‡]	11.4	16.1	18.4	17.5	11.4	4.6	13.2
Scott							
2009	8.6	14.0	15.7	15.3	14.8	1.2	11.6
2010	8.8	15.0	16.5	15.3	9.7	5.9	11.9
LT	10.9	15.2	17	16.3	10.4	3.8	12.3
Melfort							
2009	7.4	14.5	14.8	14.9	15.6	0.7	11.3
2010	9.2	15.4	17.6	16.2	9.7	10.0	13.0
LT	10.8	15.7	17.4	16.4	10.5	3.6	12.4
Swift Current							
2009	10.0	14.6	17.0	16.8	17.0	2.1	12.9
2010	8.2	15.5	17.1	16.6	10.9	8.1	12.7
LT	11.1	15.6	18.1	17.9	11.8	5.5	13.3
	------------ Total Monthly Precipitation (mm) ------------						
Indian Head							
2009	14.6	60.6	87.4	85.4	39.4	54.7	342.1
2010	63.2	122.4	27.6	92.8	65.0	102.9	473.9
LT	55.7	78.9	67.1	52.7	39.5	17.6	311.5
Scott							
2009	19	30.4	74.6	57.6	19.4	36.5	237.5
2010	128.1	145.6	122.4	61.8	44.2	17.8	519.9
LT	35.9	62.5	70.9	43.1	29.1	9.9	251.4
Melfort							
2009	22.6	10.2	75.6	81.6	32.8	80.6	303.4
2010	66.6	113	63.6	56.8	92.2	18.4	410.6
LT	45.6	65.8	75.7	56.8	39.9	24.7	308.5
Swift Current							
2009	18.4	9.8	43	56.8	19.2	24.6	171.8
2010	145.7	112.8	68.0	85.2	86.8	48.7	547.2
LT	49.5	66	52	39.9	30.2	16.2	253.8

[‡]LT – Long-term Normal (1971-2000)

Seed Yield and Seed Loss

Overall seed yields ranged from 894 kg ha^{-1} at Swift Current in 2009 to 3066 kg ha^{-1} at Scott in 2010; thus the treatments were evaluated over a wide range of yield potential environments (Table 3). Across sites (locations-years), seed yields were affected by site and cultivar but not by harvest treatment; however, the interactions for site by cultivar and site by harvest treatment in the combined analysis were significant ($P < 0.001$). Seed yields were affected by cultivar at all eight individual sites ($P < 0.001$-0.004) and by harvest treatment 38% of the time ($P < 0.001$-0.006). No interactions between cultivar and harvest treatment were observed for any individual sites (P = 0.095-0.867) and, in the combined analysis, the interactions for cultivar by harvest treatment (P = 0.892) and site by cultivar by harvest treatment (P = 0.900) were not significant.

Table 3. Type 3 tests of fixed effects for canola seed yields for each site (location-year) and across sites and least squares means for site, cultivar and harvest treatment.

Source Treatment Contrast	**Indian Head**		**Scott**		**Melfort**		**Swift Current**		**All Sites‡**
	2009	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	--------
	P values								
Site (S)	–	–	–	–	–	–	–	–	<0.001
Cultivar (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001
Harvest (H)	0.289	<0.001	0.006	0.448	0.072	0.091	<0.001	0.985	0.706
C × H	0.867	0.862	0.534	0.749	0.717	0.445	0.095	0.581	0.892
S × C	–	–	–	–	–	–	–	–	<0.001
S × H	–	–	–	–	–	–	–	–	<0.001
S × C × H	–	–	–	–	–	–	–	–	0.900
	Least Squares Means (kg ha^{-1}) †								
Site	2933^{a}	2212^{b}	3066^{a}	2509^{b}	1301^{c}	1516^{c}	894^{d}	1288^{c}	–
5440	3253^{a}	2676^{a}	3511^{a}	2909^{a}	2220^{a}	1800^{a}	1043^{a}	1382^{a}	2349^{a}
4362	2826^{b}	2032^{b}	2995^{b}	2112^{c}	791b^{c}	1315^{b}	845^{b}	1304^{ab}	1778^{d}
45H26	3155^{a}	2530^{a}	3333^{ab}	2597^{abc}	1865^{a}	1676^{a}	962^{ab}	1426^{a}	2193^{b}
5020	3048^{ab}	2310^{ab}	3275^{ab}	2648^{ab}	1051^{b}	1594^{a}	926^{b}	1233^{ab}	2011^{c}
8571 (*juncea*)	2384^{c}	1502^{c}	2215^{c}	2276^{bc}	580^{c}	1198^{b}	695^{c}	1092^{b}	1493^{e}
SE	78.3	107	122.7	137.3	102.0	120.6	21.0	61.4	40.0
Swathed	3033^{a}	2556^{a}	2788^{b}	2365^{a}	1508^{a}	1492^{a}	788^{b}	1285^{a}	1977^{a}
Untreated	2914^{a}	2078^{b}	3117^{a}	2607^{a}	1181^{a}	1380^{a}	937^{a}	1295^{a}	1939^{a}
Pod Ceal DC	2882^{a}	2175^{b}	3169^{a}	2567^{a}	1225^{a}	1583^{a}	954^{a}	1271^{a}	1979^{a}
Pod Stik	2904^{a}	2030^{b}	3190^{a}	2495^{a}	1291^{a}	1610^{a}	898^{a}	1298^{a}	1965^{a}
SE	72.5	98	114.9	125.3	91.2	115.7	18.9	54.9	36.6
	Contrasts								
Swathed vs Straight-Cut	0.061	<0.001	<0.001	0.146	<0.001	0.688	<0.001	0.964	0.605
Untreated vs Treated	0.772	0.804	0.554	0.583	0.497	0.014	0.630	0.879	0.320
B. napus vs *B. juncea*	<0.001	<0.001	<0.001	0.045	<0.001	<0.001	<0.001	0.001	<0.001

†Values within a column for each group of main effects are not significantly different from each other if followed by the same letter (Tukey's; $P \leq 0.05$)

Despite the site by cultivar interaction in the combined analysis, the relative yield performance of the five cultivars was consistent overall. While the statistical significance of differences between cultivars varied somewhat from site to site, 5440 and 45H26 were always amongst the top yielders followed by 5020, 4362 and 8571. Taking all sites into consideration, all cultivar differences were significant ($P \leq 0.05$) with an overall yield ranking of 5440 > 45H26 > 5020 > 4362 > 8571. Yield values of all harvest treatments were not significantly different when averaged across sites; however, higher yields were observed for swathing at two sites while higher yields were recorded for straight-combining at the other two sites where yields differed between the two harvest methods ($P < 0.001$). At both Swift Current and Scott in 2009, straight-combining yields were 142 and 371 kg ha^{-1}, or 15% and 12% higher than yields with swathing. On the other hand, straight-combining yields were only 82% of those observed for swathing at both Melfort in 2009 (276 kg ha^{-1}) and Indian Head in 2010 (462 kg ha^{-1}). As for the pod sealants, they did not affect seed yields at seven of eight sites, but at Melfort in 2010, their use increased yields by 217 kg ha^{-1} (16%) compared with straight-combined, untreated canola ($P = 0.014$). There was no difference between the effect that each of the two pod sealant products had on seed yield at any of the sites ($P \leq 0.05$).

Total seed losses due to pod shattering and whole pods dropping, just prior to harvest, ranged from less than 1% of the total yield to over 14% for individual sites (Table 4). Averaged across sites, seed losses at harvest were affected by cultivar ($P < 0.001$) with a significant site by cultivar interaction ($P < 0.001$). Harvest treatment did not impact seed losses ($P = 0.852$), nor was there a cultivar by harvest treatment interaction ($P = 0.844$). While cultivar affected seed losses at harvest time for all of the individual sites ($P <$ 0.001-0.042), Tukey's multiple range test did not reveal any specific cultivar differences at Scott in 2010 and at Indian Head in 2010. The higher losses prior to harvest observed for 8571 (*juncea*) at Indian Head in 2009 were due, at least in part, to experimental bias. To account for observed differences in maturity and an anticipated later harvest date, losses for 8571 were measured five days later than for the other cultivars while, in the meantime, 8571 plots were exposed to high temperatures and wind gusts approaching 50 km h^{-1} (data not shown). For the sites where treatment differences were observed at the time of harvest, losses from *B. napus* 5440 were consistently low, while losses from the *B. juncea* 8571 were lower than all *B. napus* cultivars at three sites but higher at Indian Head in 2010 (expressed in kg ha^{-1}). Losses from 8571 were never lower than those observed for 5440 while losses from 4362, 45H26 and 5020 tended to be intermediate and were equal when averaged across sites. This is not in disagreement with Wang et al. (2007) who indicated that, while losses for *B. juncea* were lower than for *B. napus* overall, losses from *B. juncea* were similar to those observed for the better adapted *napus* cultivars. Wang et al. (2007) concluded that pod shatter resistance was significantly higher in *B. napus* lines with a history of interspecific hybridization with *B. rapa*, *B. juncea* and *B. carinata*. Both Wang et al. (2007) and earlier work by Summers et al. (2003) showed that pod shatter resistance in *B. napus* was correlated with certain pod characteristics, reporting increased resistance with shorter pods and heavier valves and septums. Averaged across sites, the percentage of total losses contributed by whole pods dropping ranged from 37-57% for *B. napus* and was 15% for the canola quality *juncea* variety, 8571. In the current study, pod sealants did not impact shattering losses when all sites were combined and, with no significant site by harvest treatment interaction, this was consistent at all individual sites (P = 0.491-0.912). With contributions ranging from 39-43% on average, pod sealants did not impact the proportion of total seed losses contributed from whole pods dropping.

Table 4. Type 3 tests of fixed effects for canola seed losses (kg ha^{-1}) observed for straight-combined canola at harvest time for each site (location-year) and across sites and least squares means for site, cultivar and harvest treatment. Losses expressed as a percentage of total yield are presented in parentheses.

Source Treatment Contrast	**Indian Head** **2009**	 **2010**	**Scott** **2009**	 **2010**	**Melfort** **2009**	 **2010**	**Swift Current** **2009**	 **2010**	**All Sites‡** --------
					P values				
Site (S)	–	–	–	–	–	–	–	–	0.002
Cultivar (C)	<0.001	0.002	0.004	0.042	–	<0.001	<0.001	<0.001	<0.001
Harvest (H)	0.037	0.652	0.976	0.374	–	0.557	0.972	0.676	0.852
C × H	0.386	0.845	0.451	0.963	–	0.018	0.642	0.700	0.844
S × C	–	–	–	–	–	–	–	–	<0.001
S × H	–	–	–	–	–	–	–	–	0.913
S × C × H	–	–	–	–	–	–	–	–	0.899
					Least Squares Means (kg ha^{-1}) †				
Site	20.5^{b} (0.8^{b})	344.1^{a} (14.0^{a})	15.7^{b} (0.5^{b})	24.7^{b} (1.0^{b})	n/a	122.6^{ab} (7.1^{ab})	35.2^{b} (3.5^{b})	225.5^{ab} (14.2^{a})	–
5440	5.9^{b} (0.2^{b})	145.6^{c} (5.3^{b})	4.3^{b} (0.1^{b})	13.5^{a} (0.4^{a})	–	59.5^{bc} (3.2^{b})	12.2^{cd} (1.2^{c})	56.1^{b} (3.7^{b})	42.6^{c} (2.0^{c})
4362	15.9^{b} (0.6^{b})	253.6^{abc} (10.9^{b})	20.8^{a} (0.7^{a})	17.1^{a} (0.8^{a})	–	136.5^{abc} (8.6^{a})	35.6^{bc} (3.8^{b})	255.2^{a} (16.8^{a})	105.0^{b} (6.0^{b})
45H26	11.3^{b} (0.4^{b})	224.9^{bc} (7.8^{b})	21.7^{a} (0.6^{a})	34.1^{a} (1.4^{a})	–	221.0^{a} (11.9^{a})	76.8^{a} (7.3^{a})	403.2^{a} (21.9^{a})	141.9^{ab} (7.3^{ab})
5020	11.3^{b} (0.4^{b})	518.9^{ab} (21.1^{a})	20.5^{a} (0.6^{a})	28.4^{a} (1.2^{a})	–	150.9^{ab} (8.6^{a})	43.2^{b} (4.2^{b})	337.8^{a} (22.0^{a})	158.7^{a} (8.3^{a})
8571 (*juncea*)	58.0^{a} (2.5^{a})	575.5^{a} (27.9^{a})	10.8^{ab} (0.5^{ab})	30.6^{a} (1.3^{a})	–	45.4^{c} (3.2^{b})	8.1^{d} (1.2^{c})	75.2^{b} (6.5^{b})	114.9^{ab} (6.1^{b})
SE	4.0 (0.2)	150.4 (5.7)	4.0 (0.1)	5.3 (0.2)	–	22.7 (1.5)	6.5 (0.7)	38.8 (2.2)	22.2 (0.9)
Untreated	21.4^{ab} (0.8^{ab})	338.4^{a} (13.8^{a})	16.0^{a} (0.5^{a})	24.3^{a} (1.0^{a})	–	112.6^{a} (7.1^{a})	34.7^{a} (3.5^{a})	212.3^{a} (13.4^{a})	108.5^{a} (5.7^{a})
Pod Ceal DC	25.1^{a} (1.0^{a})	306.6^{a} (14.1^{a})	15.8^{a} (0.5^{a})	20.8^{a} (0.9^{a})	–	138.1^{a} (7.3^{a})	36.2^{a} (3.5^{a})	247.2^{a} (15.3^{a})	112.8^{a} (6.0^{a})
Pod Stik	15.0^{b} (0.6^{b})	386.7^{a} (15.9^{a})	15.2^{a} (0.5^{a})	29.1^{a} (1.2^{a})	–	117.2^{a} (6.9^{a})	34.7^{a} (3.6^{a})	217.0^{a} (13.8^{a})	116.5^{a} (5.9^{a})
SE	3.3 (0.2)	142.0 (5.4)	3.3 (0.1)	4.1 (0.2)	–	17.6 (1.2)	5.1 (0.5)	30.0 (1.7)	20.7 (0.8)
					Contrasts				
Untreated vs Treated	0.670	0.912	0.882	0.897	–	0.491	0.910	0.594	0.615
B. napus vs *B. juncea*	<0.001	0.004	0.134	0.229	–	<0.001	<0.001	<0.001	0.843

†Values within a column for each group of main effects are not significantly different from each other if followed by the same letter (Tukey's; $P \leq 0.05$)

As expected, overall seed losses were higher when canola was left standing for two to four weeks past harvest (17.3 versus 5.9% of total yield), but treatment effects were similar to those observed for the earlier measurements (Table 5). Site and cultivar affected seed losses at the later date ($P < 0.001$) and the site by cultivar interaction was highly significant ($P < 0.001$). Seed losses were not affected by harvest treatment ($P =$

0.394) and there was no interaction between cultivar and harvest treatment (P = 0.617), site and harvest treatment (P = 0.628) or site, cultivar and harvest treatment (P = 0.962). Looking at individual sites, cultivar affected shattering losses 86% of the time for the late seed loss measurements.

Table 5. Type 3 tests of fixed effects on canola seed loss (kg ha^{-1}) two to four weeks past harvest time for each site (location-year) and across sites and least squares means for site, cultivar and harvest treatment. Losses expressed as a percentage of total yield are presented in parentheses for main effects.

Source / Treatment / Contrast	**Indian Head 2009**	**Indian Head 2010**	**Scott 2009**	**Scott 2010**	**Melfort 2009**	**Melfort 2010**	**Swift Current 2009**	**Swift Current 2010**	**All Sites‡** --------
					P values				
Site (S)	–	–	–	–	–	–	–	–	<0.001
Cultivar (C)	<0.001	<0.001	<0.001	0.188	<0.001	–	<0.001	<0.001	<0.001
Harvest (H)	0.265	0.477	0.351	0.139	0.650	–	0.119	0.742	0.394
C × H	0.357	0.733	0.864	0.876	0.921	–	0.631	0.970	0.617
S × C	–	–	–	–	–	–	–	–	<0.001
S × H	–	–	–	–	–	–	–	–	0.628
S × C × H	–	–	–	–	–	–	–	–	0.962
					Least Squares Means (kg ha^{-1}) †				
Site	793.0^{a} (27.8^{a})	563.7^{ab} (24.4^{ab})	182.5^{cd} (5.8^{c})	48.7^{d} (2.0^{c})	247.7^{cd} (22.2^{ab})	n/a	160.0^{cd} (16.8^{b})	347.0^{bc} (21.8^{ab})	–
5440	247.1^{c} (7.6^{c})	227.3^{b} (8.4^{c})	77.1^{d} (2.1^{c})	32.0^{a} (1.1^{a})	81.2^{b} (4.0^{b})	–	108.4^{c} (10.3^{c})	119.3^{b} (7.9^{b})	127.5^{c} (5.9^{b})
4362	882.4^{b} (32.2^{b})	435.3^{b} (19.0^{c})	244.4^{ab} (8.0^{a})	40.5^{a} (1.8^{a})	233.6^{b} (25.6^{a})	–	187.6^{ab} (20.2^{ab})	393.3^{a} (26.2^{a})	345.3^{b} (19.0^{a})
45H26	1303.5^{a} (41.4^{a})	380.7^{b} (13.7^{c})	175.9^{bc} (5.1^{b})	60.8^{a} (2.4^{a})	220.7^{b} (10.6^{b})	–	243.5^{a} (23.1^{a})	606. 8^{a} (33.1^{a})	427.4^{a} (18.5^{a})
5020	795.6^{b} (26.8^{b})	854.8^{a} (33.1^{b})	284.4^{a} (8.3^{a})	61.9^{a} (2.5^{a})	456.7^{a} (32.0^{a})	–	134.9^{bc} (13.2^{bc})	525.2^{a} (33.9^{a})	444.8^{a} (21.4^{a})
8571 (*juncea*)	736.2^{b} (30.8^{b})	918.8^{a} (47.9^{a})	130.7^{cd} (5.5^{b})	48.1^{a} (2.0^{a})	246.5^{b} (38.9^{a})	–	125.5^{bc} (17.1^{abc})	90.5^{b} (7.8^{b})	328.3^{b} (21.4^{a})
SE	75.9 (3.1)	174.3 (5.7)	25.2 (0.7)	10.0 (0.4)	46.9 (3.6)	–	19.7 (2.2)	57.8 (3.6)	29.3 (1.2)
Untreated	790.5^{a} (27.7^{a})	558.3^{a} (24.4^{a})	194.6^{a} (6.2^{a})	53.5^{a} (2.1^{a})	225.6^{a} (21.5^{a})	–	181.5^{a} (18.8^{a})	326.1^{a} (20.8^{a})	332.9^{a} (17.4^{a})
Pod Ceal DC	738.5^{a} (25.9^{a})	500.9^{a} (22.8^{a})	188.6^{a} (6.2^{a})	35.7^{a} (1.5^{a})	273.3^{a} (23.4^{a})	–	139.2^{a} (14.2^{a})	371.5^{a} (22.9^{a})	321.1^{a} (16.7^{a})
Pod Stik	849.8^{a} (29.7^{a})	631.0^{a} (26.1^{a})	164.4^{a} (5.0^{a})	56.8^{a} (2.3^{a})	244.3^{a} (21.8^{a})	–	159.6^{a} (17.4^{a})	343.4^{a} (21.6^{a})	350.0^{a} (17.7^{a})
SE	65.4 (2.8)	163.5 (5.3)	21.9 (0.6)	7.8 (0.3)	36.3 (2.8)	–	16.1 (1.9)	46.7 (3.0)	26.6 (1.0)
					Contrasts				
Untreated vs Treated	0.950	0.933	0.343	0.457	0.462	–	0.070	0.544	0.883
B. napus vs *B. juncea*	0.306	<0.001	0.007	0.954	0.976	–	0.041	<0.001	0.715

†Values within a column for each group of main effects are not significantly different from each other if followed by the same letter (Tukey's; $P \leq 0.05$)

Similar to the early measurements, losses for 5440 were amongst the lowest in all cases and, expressed as a percentage of total yields, were significantly lower for each of the other *napus* varieties at 43% of the individual sites and averaged across sites ($P \leq 0.05$). On average, losses were similar for 4362, 45H26, 5020 and 8571 (19-21% of total yield) but this varied somewhat for individual sites. Expressed in kg ha^{-1}, losses observed for straight-combined *juncea* canola were higher than *napus* canola at Indian Head in 2010 ($P < 0.001$) but lower at Scott in 2009 ($P = 0.007$) and Swift Current in both years ($P <$ 0.001-0.041). For the late seed loss measurements, contributions from pod drop ranged from 28-57% of total losses for the *B. napus* varieties and 16% for 8571 (data not shown). As with measurements just prior to harvest, equal seed losses were always observed for each the three straight-combining treatments; thus, pod sealants had no effect on the total seed losses measured in this study. Similarly, pod sealants had no impact on the proportion of total seed losses that was attributable to whole pods dropping (35-38%). Although data is limited, other field trials from the Northern Great Plains have reported no reduction in canola pod shattering or impact on yields with pod sealants relative to straight-combining untreated canola (Johnson et al. 2009).

Seed Quality

The two seed quality parameters considered were percent green seed (Table 6) and seed size (Table 7). Green seed is an important grading factor for canola whereby No. 1 and No. 2 Canada canola grades may contain a maximum of 2.0 and 6.0% distinctly green seed, respectively. Seed size is not a grading factor but, as an important yield component, is important to growers and reduced seed size can be a potential indication of swathing too early (Hocking and Mason 2003, Vera et al. 2007).

Across sites, green seed content was affected by cultivar ($P < 0.001$) but not by harvest treatment ($P = 0.088$). The site by cultivar, site by harvest treatment and site by cultivar by harvest treatment interactions were all significant ($P < 0.001$). Cultivar differences for individual sites were attributed to genetic differences in days to maturity and the specific environmental factors encountered at each site. For example, based on our observations, 8571 was the latest maturing variety included in the study and percent green seed for 8571 was significantly higher than for the averaged *B. napus* varieties in all cases ($P <$ 0.001-0.049). Green seed in swathed canola differed from that of straight-combined canola 25% of the time with swathing resulting in lower green counts at Swift Current in 2010 ($P < 0.001$; 0.5% versus 3.1%) and slightly higher green counts with swathing at Indian Head in 2009 ($P = 0.005$; 0.67% versus 0.37%). Across site years, slightly less green seed was observed for swathing with 1.5% green seed observed for swathed canola and 1.8% with straight-combining. Pod sealants had no effect on percent green seed in any cases ($P =$ 0.16-0.91).

Table 6. Type 3 tests of fixed effects on the percentage of distinctly green canola seed for each site (location-year) and across sites and least squares means for site, cultivar and harvest treatment.

Source Treatment Contrast	**Indian Head**		**Scott**		**Melfort**		**Swift Current**		**All Sites‡**
	2009	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	--------
	P values								
Site (S)	–	–	–	–	–	–	–	–	<0.001
Cultivar (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Harvest (H)	0.008	0.108	0.144	0.693	0.278	0.912	0.796	<0.001	0.088
C × H	0.042	0.133	0.060	<0.001	0.208	0.968	0.062	<0.001	0.406
S × C	–	–	–	–	–	–	–	–	<0.001
S × H	–	–	–	–	–	–	–	–	<0.001
S × C × H	–	–	–	–	–	–	–	–	<0.001
	Least Squares Means (%) †								
Site	0.44^{c}	0.85^{c}	1.43^{bc}	2.38^{b}	0.30^{c}	5.48^{a}	0.36^{c}	2.45^{b}	–
5440	0.08^{b}	0.25^{b}	0.17^{b}	0.33^{c}	0.00^{b}	3.42^{b}	0.10^{b}	1.80^{bc}	0.77^{d}
4362	0.17^{b}	0.87^{b}	2.58^{a}	5.00^{a}	0.08^{b}	9.83^{a}	0.62^{a}	6.07^{a}	3.15^{a}
45H26	0.02^{b}	0.17^{b}	1.42^{ab}	3.17^{b}	0.08^{b}	4.13^{b}	0.38^{ab}	2.47^{b}	1.48^{c}
5020	0.07^{b}	0.17^{b}	0.50^{b}	0.25^{c}	0.17^{b}	2.83^{b}	0.00^{b}	1.43^{cd}	0.68^{d}
8571 (*juncea*)	1.88^{a}	2.81^{a}	2.50^{a}	3.17^{b}	1.17^{a}	7.17^{a}	0.68^{a}	0.47^{d}	2.48^{b}
SE	0.097	0.23	0.35	0.46	0.13	0.89	0.14	0.25	0.14
Swathed	0.67^{a}	0.55^{a}	1.0^{a}	2.67^{a}	0.10^{a}	5.80^{a}	0.43^{a}	0.53^{b}	1.47^{a}
Untreated	0.49^{b}	1.04^{a}	1.5^{a}	2.07^{a}	0.40^{a}	5.13^{a}	0.36^{a}	3.09^{a}	1.77^{a}
Pod Ceal DC	0.36^{ab}	1.12^{a}	1.2^{a}	2.27^{a}	0.37^{a}	5.50^{a}	0.36^{a}	2.99^{a}	1.77^{a}
Pod Stik	0.25^{b}	0.70^{a}	2.0^{a}	2.53^{a}	0.33^{a}	5.47^{a}	0.28^{a}	3.17^{a}	1.84^{a}
SE	0.088	0.21	0.32	0.42	0.11	0.82	0.13	0.23	0.13
	Contrasts								
Swathed vs Straight-Cut	0.004	0.066	0.122	0.400	0.057	0.566	0.437	<0.001	0.013
Untreated vs Treated	0.077	0.565	0.864	0.484	0.731	0.662	0.752	0.962	0.762
B. napus vs *B. juncea*	<0.001	<0.001	0.002	0.049	<0.001	0.013	0.003	<0.001	<0.001

†Values within a column for each group of main effects are not significantly different from each other if followed by the same letter (Tukey's; $P \leq 0.05$)

Across sites, seed size ranged from 3.0-4.2 g 1000 seeds^{-1} and was affected by cultivar ($P < 0.001$), harvest treatment ($P < 0.001$), site by cultivar ($P < 0.001$) and site by harvest treatment ($P < 0.001$). Despite the interaction, seed size differences amongst cultivars were generally consistent; *juncea* canola always had smaller seeds than the *napus* varieties ($P < 0.001$) while the 4362 and 5020 tended to have the largest seed sizes and the remaining varieties were more intermediate. Seed size was larger with straight-combining than swathing at five of eight sites and ($P < 0.001$), tended to be larger at one site ($P = 0.098$) and no difference in seed size between swathing and straight-combining was observed for the remaining two sites ($P = 0.40$-0.74). Averaged across sites and cultivars, seed size increased from 3.22 to 3.41 g 1000 seeds^{-1} with straight-combining relative to swathing ($P < 0.001$). It is well established that swathing too early can result in reduced seed size and that canola seeds are frequently larger with straight-combining as opposed to swathing (Hocking and Mason 1993, Vera et al. 2007).

Table 7. Type 3 tests of fixed effects on canola seed size for each site (location-year) and across sites and least squares means for site, cultivar and harvest treatment.

Source Treatment Contrast	Indian Head 2009	Indian Head 2010	Scott 2009	Scott 2010	Melfort 2009	Melfort 2010	Swift Current 2009	Swift Current 2010	All Sites‡ --------
	P values								
Site (S)	–	–	–	–	–	–	–	–	<0.001
Cultivar (C)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Harvest (H)	0.044	<0.001	0.369	<0.001	<0.001	0.165	0.971	<0.001	<0.001
C × H	0.377	0.740	0.890	0.069	0.628	0.188	0.785	0.070	0.429
S × C	–	–	–	–	–	–	–	–	<0.001
S × H	–	–	–	–	–	–	–	–	<0.001
S × C × H	–	–	–	–	–	–	–	–	0.462
	Least Squares Means (g 1000 seeds^{-1}) †								
Site	3.01^{c}	3.01^{c}	3.85^{b}	4.15^{a}	3.80^{b}	2.97^{c}	3.05^{c}	3.05^{c}	–
5440	3.02^{b}	3.11^{b}	3.95^{b}	4.02^{b}	3.83^{b}	3.12^{ab}	3.22^{a}	3.21^{b}	3.44^{b}
4362	3.25^{a}	3.30^{a}	4.09^{ab}	4.73^{a}	4.11^{a}	3.06^{bc}	3.21^{a}	3.39^{a}	3.64^{a}
45H26	2.95^{b}	3.06^{b}	4.12^{ab}	4.31^{b}	3.87^{b}	2.96^{c}	2.95^{a}	2.90^{c}	3.39^{b}
5020	3.24^{a}	3.27^{a}	4.41^{a}	4.34^{b}	3.92^{b}	3.18^{a}	3.26^{a}	3.19^{b}	3.60^{a}
8571 (*juncea*)	2.57^{c}	2.30^{c}	2.71^{c}	3.33^{c}	3.25^{c}	2.54^{d}	2.60^{b}	2.58^{d}	2.74^{c}
SE	0.027	0.04	0.085	0.08	0.05	0.03	0.09	0.05	0.02
Swathed	2.95^{a}	2.88^{b}	3.74^{a}	3.69^{b}	3.52^{b}	2.95^{a}	3.07^{a}	2.93^{b}	3.22^{b}
Untreated	3.03^{a}	3.04^{a}	3.91^{a}	4.38^{a}	3.89^{a}	2.95^{a}	3.03^{a}	3.07^{a}	3.41^{a}
Pod Ceal DC	3.02^{a}	3.06^{a}	3.85^{a}	4.26^{a}	3.89^{a}	2.95^{a}	3.03^{a}	3.09^{a}	3.40^{a}
Pod Stik	3.03^{a}	3.06^{a}	3.91^{a}	4.25^{a}	3.88^{a}	3.02^{a}	3.07^{a}	3.12^{a}	3.42^{a}
SE	0.024	0.04	0.076	0.07	0.04	0.03	0.08	0.05	0.02
	Contrasts								
Swathed vs Straight-Cut	0.005	<0.001	0.098	<0.001	<0.001	0.400	0.764	<0.001	<0.001
Untreated vs Treated	0.906	0.539	0.718	0.160	0.888	0.288	0.832	0.428	0.701
B. napus vs *B. juncea*	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

†Values within a column for each group of main effects are not significantly different from each other if followed by the same letter (Tukey's; $P \leq 0.05$)

Summary and Conclusions

Overall, this study supports previous findings that straight-combining canola is a viable alternative to swathing in western Canada; however, doing so comes with considerable risk, especially when harvest cannot be completed close the optimal growth stage. In the two cases where harvest was delayed due to unfavourable weather, yields were reduced by 18% relative to swathing. However, this was balanced out overall by two locations where yields were higher with straight-combining, presumably due to larger seed size and allowing the pods to fill for a longer period of time. Pod sealants increased seed yields by 16% over untreated, straight-combined canola at only one site but did not affect seed yields at all the other sites, which is probably not sufficient to justify a generalized recommendation of applying pod sealants when straight-combining canola. Another factor to consider when using a field sprayer to apply pod sealants or desiccants to canola fields destined to be straight-combined is the effect of wheel tracks on seed yield. While wheel tracks were not a factor in the current study, it should be acknowledged that driving over the crop at this late stage causes irreversible damage and could reduce yields by 2-5%, depending on the width of the sprayer. While pod sealants did not affect the observed shattering losses, important cultivar differences in resistance to shattering were observed and variability in shattering resistance amongst *napus* canola varieties should be explored further. Pod sealants did not affect seed quality in any cases; however straight-combining resulted in slightly higher incidence of green seed and consistently larger seeds compared to swathing. Our results suggest that choosing a cultivar that is high yielding and relatively resistant to shattering is likely a factor of greater importance for canola growers considering straight-combining than deciding whether or not to apply a pod sealant.

Acknowledgements

Financial support for this research was provided by the Saskatchewan Canola Development Commission and the Saskatchewan Ministry of Agriculture through the Agricultural Demonstration of Practices and Technologies program. In-kind contributions were provided by Bayer CropScience, Brett Young, Pioneer Hi-Bred, Viterra and United Agri-Products. Special thanks are extended to Agriculture and Agri-Food Canada, the Indian Head Agricultural Research Foundation, the Northern Agricultural Research Foundation, Western Applied Research Corporation and Wheatland Conservation Area along with all of the technical staff and summer students involved in the project at the various locations.

References

Ag Shield Manufacturing. 2011. Yield-Shield Product Information. Online [Available]: http://www.agshield.com/yield.htm (17 March 2011).

Angadi, S. V., Cutforth, H. W., McConkey, B. G. and Gan, Y. 2003. Yield adjustment of canola grown at different plant populations under semiarid conditions. Crop Sci. **43:**1358-1366.

Anonymous. 1998a. XVII Time of swathing trial. Canola Production Centre. Annual Report. Canola Council of Canada. Winnipeg, MB. pp. 181-182.

Anonymous. 1998b. XVI Straight combining vs swath *B. napus* trial. Canola Production Centre. Annual Report. Canola Council of Canada. Winnipeg, MB. pp. 179-180.

Anonymous. 1998c. XIX Straight combining vs swath *B. napus* trial. Canola Production Centre. Annual Report. Canola Council of Canada. Winnipeg, MB. pp. 147-149.

Anonymous. 1999. XVI Straight combining vs swath *B. napus* trial. Canola Production Centre. Annual Report. Canola Council of Canada. Winnipeg, MB. pp. 182-183.

Anonymous. 2000. XVI Time of swathing trial. Canola Production Centre. Annual Report. Canola Council of Canada. Winnipeg, MB. pp. 163-164.

Anonymous. 2001a. XVII Pushing trial. Canola Production Centre. Annual Report. Canola Council of Canada. Winnipeg, MB. pp. 189-190.

Anonymous. 2001b. XXII Harvest management (pushing) trial. Canola Production Centre. Annual Report. Canola Council of Canada. Winnipeg, MB. pp. 150-153.

Anonymous. 2002. XIV Pushing trial. Canola Production Centre. Annual Report. Canola Council of Canada. Winnipeg, MB. pp. 195-196.

Brett Young. 2011. Pod Ceal DC Information Sheets. Online [Available]: http://www.brettyoung.ca/Western_Canada/Products/Pod_Ceal/podceal_products.php (17 March 2011).

Cenkowski, S., Jayas, D. S. and Daun, J. K. 1989. Effect of harvest date and swathing on moisture content and chlorophyll content of canola seed. Can. J. Plant Sci. **69:**925-928.

Environment Canada. 2011. Canadian climate data. Online [Available]: http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html [17 March 2011].

Gan Y., Malhi, S. S., Brandt, S. A. and McDonald, C. L. 2008. Assessment of seed shattering resistance and yield loss in five oilseed crops. Can. J. Plant Sci. **88:**267-270.

Irvine, B. 2003. Comparison of pushing canola at various stages and swathing on canola yield and quality. Manitoba Agriculture, Food and Rural Initiatives ARDI Project #00-429. Online [Available]: http://www.gov.mb.ca/agriculture/research/ardi/projects/00-429.html (17 March 2011).

Johnson, B. L., McKay, K. R., Henson, R. A., Erikmoen, E. D. and Novak, L. 2005. Comparing straight harvest with an anti-shattering agent to swathed harvest of canola and the evaluation of field scale straight combining compared to swathed canola. North Dakota State University. Online [Available]: http://www.ag.ndsu.edu/CarringtonREC/agronomy-1/research-documents/production-management/05%20Harvest%20Management%20of%20Canola.pdf/view (17 March 2011).

Littel, R. C., Milliken, G. A., Stroup, W. W. and Wolfinger, R. D. 1996. SAS System for Mixed Models. SAS Institute, Cary NC. 656 pp.

Summers, J. E., Bruce, D. M., Vancanneyt, G., Redig, P., Werner, C. P., Morgan, C. and Child, R. D. 2003. Pod shatter resistance in the resynthesized *Brassica napus* line DK142. J. Agric. Sci. **140:**43-52.

Thomas, D. L., Breve, M. A. and Raymer, P. L. 1991. Influence of timing and method of harvest on rapeseed yield. J. Prod. Agric. **4:**266-272.

United Agri-Products. 2011. Pod-Stik Product Label. Online [Available]: http://www.uap.ca/products/documents/POD-STIK-LPI_10L_G2808EngFre.pdf (17 March 2011).

Vera, C. L., Downey, R. K., Woods, S. M., Raney, J. P., McGregor D. I., Elliott, R. H. and Johnson, E. N. 2007. Yield and quality of canola seed as affected by stage of maturity at swathing. Can. J. Plant. Sci. **87:**13-26.

Watson, P. R., Brandt, S. A., Clayton, G. W. and Harker, K. N. 2008. Canola Harvest Management Study: Final Report. Alberta Canola Producers Commission.

Wang, R., Ripley, V. L. and Rakow, G. 2007. Pod shatter resistance evaluation in cultivars and breeding lines of *Brassica napus*, *B. juncea* and *Sinapsus alba*. Plant Breeding. **126**:588-595.