

## **YUKON AGRICULTURE BRANCH**



## **OILSEEDS PRODUCTION FOR BIODIESEL POTENTIAL IN THE YUKON**

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Funding: Advancing Canadian Agriculture and Agri-Food ACAAFF

Objective: To evaluate oilseed production in Yukon

### **Introduction**

The evaluation of oilseed production in Yukon has been conducted over the last four years to determine:

- if oilseeds production is viable for producing biodiesel in the Yukon;
- which oilseeds produce the best yields and total oil content; and,
- which agricultural areas are more productive for oilseed production.

The first two years of the trial demonstrated some potential for growing oilseeds in Yukon; 2008 was a cold growing season that limited oilseed production and 2009 proved to be a success with the highest oil content of the four year trial. The results of the study demonstrated the year-to-year variability of agricultural production in the Yukon.

The four oilseed varieties that were used for the study were false flax (*Camelina sativa*), Polish canola (*Brassica rapa*), Argentine canola (*Brassica napus*) and Flanders flax (*Linum usitatissimum*). Seed selection was made with consultation from Kevin Falk, Ph.D., and Richard Gugel, M.Sc., from Agriculture and Agri-Food Canada, Saskatoon Research Centre, and Scott Horner, HyTech Production Ltd. Genetically modified varieties were not used for the study.

### **Site Descriptions**

The oilseeds were planted within six site locations during the four year trial. All, with the exception of the Agriculture Branch research farm, were established within private farmland with cooperation from Yukon farmers.

Site HN (Heiko Nyland) is located in the central Yukon, west of Pelly Crossing near Crosby Creek. The soil texture is sand loam to loamy sand over gravel sand.

Site DH (Dan Halen) is located on the north side of the Takhini valley. The soil texture is silty loam to fine loamy sand.

Site DG (Dorine Girouard) is also located on the north side of the Takhini valley, near the DH site. The soil texture is silty loam to fine loamy sand.

Sites DG, DH and HN were not considered to be successful due to issues either with severe frost or crop loss to pests.

The three sites that showed the most success were Site RF, SM and MC.

The Agriculture Branch research farm (site RF) is located in the Whitehorse area. This site is located in the Gunnar Nilsson and Mickey Lammers Research Forest located at the junction of the Yukon and Takhini River valleys. The research site is two hectares surrounded by lodgepole pine forest. The forest provides shelter from winds, but consequently creates a frost pocket. The soil, landscape and climatic properties of the site are typical of the farms in this region of Yukon. The area was cleared of willow, aspen, spruce, lodgepole pine, and underbrush in 1987 and has been worked intensively for a variety of research projects since. The soil texture is silty loam to fine loamy sand and moderately well to well drained; pH is 7.0 with organic matter levels around 2%.

Yukon Grain Farm (site SM) is located in the Yukon River valley, near the southern tip of Lake Laberge. This site is located within the warmest summer microclimate in the Whitehorse area. The field experiments were located on the northwest corner of a large 50 hectare field. The soils in the area are a range of medium to coarse loamy sand to sand which is moderately well to rapidly drained; pH is around 7.2 and organic matter is between 2% to 3%.

In 2009, a new site was selected in central Yukon located at McCabe Creek (site MC). This site is within the central Yukon climatic region and provides research results that are applicable for farms between Carmacks, Dawson and Mayo. The site is located on the east side of the Yukon River, on the north side of a large hay field providing excellent solar radiation and frost drainage. The soils in the area are fine sandy loam to silt loam which are moderately well drained; pH is around 7.5 and organic matter levels are around 2%. Table 1 shows the different sites used at each year.

Table 1: Sites used from 2006 to 2009.

<b>Year</b>	<b>Sites</b>
<b>2006</b>	SM, HN, RF, DG, DH,
<b>2007</b>	SM, HN, RF
<b>2008</b>	SM, HN, RF
<b>2009</b>	SM, RF, MC

## Climate

Climate data is collected from Environment Canada, the Yukon government and portable weather stations to better understand the season-to-season variability in growing conditions.

The climate data is used to calculate agroclimatic capability which is based on Growing Degree Days (GDD). GDDs are calculated using the average daily temperature minus a basic mean temperature of 5°C required for cool season crop growth.

To account for the boost plants receive from the long hours of daylight north of 60° latitude, the GDD is adjusted upward and reported as Effective Growing Degree Days (EGDD). For example, the 926 GDD recorded at Site RF, is multiplied by a factor of 1.16 and becomes 1074 EGDD. The daylight factor changes with latitude, for example in Dawson a factor of 1.18 is used and for Watson Lake a factor of 1.14 is used<sup>1</sup>. Agroclimatic capability class information is included in Appendix A.

Table 2 shows a summary of the agroclimatic data for 2006 to 2009 and a ten year average.

Table 2: Agroclimatic data summary for 2006 to 2009 and the 10 year average.

	RF				
	2006	2007	2008	2009	10 Year Average
EGDD	912	964	681	1074	886
Start of growing season	May 19	May 18	Apr 29	May 1	May 10
End of growing season	Sep 2	Aug 27	Aug 10	Sep 2	Aug 19
Agroclimatic capability class	Class 4	Class 4	Class 6	Class 3	Class 5
Number of frosts during growing season	24	20	32	42	22
	SM				
	2006	2007	2008	2009	Whitehorse Airport 10 Year Average
EGDD	1003	1043	720	1236	1072
Start of growing season	May 18	May 16	May 11	May 1	May 7
End of growing season	Sep 5	Aug 27	Aug 10	Sep 27	Sep 15
Agroclimatic capability class	Class 4	Class 4	Class 5	Class 2	Class 3
Number of frosts during growing season	12	9	9	17	11
	Pelly Farm (used to represent HN and MC)				
	2006	2007	2008	2009	10 Year Average
EGDD	1208	1529	1130	1462	1224
Start of growing season	May 6	Apr 26	Apr 29	Apr 30	May 5
End of growing season	Aug 22	Sep 22	Aug 31	Sep 18	Sep 6
Agroclimatic capability class	Class 2	Class 1	Class 3	Class 1	Class 2
Number of frosts during growing season	14	23	13	17	14

Table 3 shows the precipitation totals for each month from May to September for the four year trial and a ten year average.

Table 3: Precipitation totals in millimetres for May to September, 2006 to 2009 and the 10 year average.

Location	2006	2007	2008	2009	10 Year Average
Whitehorse Airport	120.1	184.8	172.0	135.2	163.1
Research Farm	116.9	180.3	201.1	125.6	147.2
Pelly Farm	144.3	149.3	216.5	139.0	183.7

### Materials and Methods

The trial utilized the same oilseed crops over the four years. See Appendix B for the more information on the oilseed varieties and seeding rates used in the trial.

Sixteen 2m x 2m were used at each location for the oilseeds trial. Each variety was planted into four plots in a completely randomized design, with four varieties per location. Each site was raked to remove sticks and debris and was laid out with measuring tape and survey markers. Seed lines were drawn in the soil with a modified rake that spaced the seed rows 20 cm apart with 11 rows per plot. The seeds were seeded with a single row seeder or by hand. Following seeding, each plot was raked and rolled with a weighted roller. A 0.5 m buffer was left between the plots.

The plots were seeded at end of May. At the time of seeding composite soil samples were sent to Exova Laboratories (previously Bodycote Labs) and analyzed to assess optimum fertilizer rates. Fertilizer was added according to these results in early June.

The oilseed plots were irrigated as required, ranging from approximately 100 mm to 180 mm of irrigation between May and early August. These numbers are approximations as it was difficult to measure the exact volume of water the plots received.

At minimum, monthly visits were made to each site to record presence of species, stage of growth, plant height, and pod stage. A standard area of 1 m<sup>2</sup> was harvested from each plot using hand trimmers and a 1 m<sup>2</sup> frame. Harvest was conducted from August to October based on crop maturity.

The harvested plants were put through a small seed thresher. The threshing separated the seeds from the plant stock and straw material. Further cleaning was done by a Clipper Seed Separator which separated the seed from the left over scrap material from the thresher. The samples were weighed to determine yields and sent to Agriculture and Agri-Food Canada in Saskatoon for oil and protein content analysis. Near infra-red (NIR) technology was used to determine the percent oil and protein in the seeds.

## **Results and discussion**

### **2006**

The first year of the trial showed varied success with the oilseed growth. The HN site was seeded in late May and there was some growth noted in June and July, however by September, there was no evidence of plants at the site. The main reason for the lack of crop is believed to be because of ground squirrels and other pests.

Good maturity or growth was noted for the *B. rapa* at sites RF and SM, however it was found that the plants were not establishing well. A germination test was conducted on the *B.rapa* to determine if this was a result of the growing conditions at the test plots or the seed itself not germinating. Two separate germination tests were conducted and the results were 38 of 100 seeds and 42 of 100 seeds germinated. The test indicated that the seed did not germinate well and this resulted in poor establishment contributing to lower yields.

Yields and quality varied with each site and crop. The quality, although not graded, can be generalized with noticeable more mature seeds for the irrigated sites. The *C.sativa* from site to site was most consistent in seed size and uniformity. The quality of the *B.napus* was observed to be poorer compared to the *B.rapa*, having more damage and immature seeds in the samples. The yield was highest for the *C. sativa* at site RF with 1.9 T/ha. The *B. napus* and *B. rapa* also did well, yielding, on average, 1.2 T/ha. The DH and DG sites did not produce well, as expected, yielding 0.2 and 0.4 T/ha of the *C. sativa*. These sites did not produce enough seed to harvest the *B. napus* and *B. rapa* was harvested only at site DH, yielding 0.2 T/ha.

The results of the seed analysis can be found in Appendix C. The oil content ranged from 38.9 percent for the *C.sativa* to as high as 52.4 percent for the *B.rapa*. These results were higher than expected, as the Canadian 10 year average for canola is 43 percent<sup>2</sup> and documentation for *C.sativa* reports oil content at approximately 35 to 40

percent<sup>3</sup>. The protein results ranged from 14.9 for the *B.napus* to 24.6 for the *C.sativa*. This indicates that the meal component (mash) after oil separation would have good nutritional value as animal feed.

## **2007**

The 2007 growing season was an exceptional year in the central Yukon with high temperatures observed at the HN site. The Whitehorse area had a normal climatic year with average temperatures and frosts. Most of the plots showed good emergence and growth through the season.

Various observations were noted during the growing season. There was excessive weed growth throughout the HN plots, competing with the oilseed crops. Extensive hand weeding in July showed immediate impact and improved growth and maturity. At Site SM, volunteer oats were observed throughout the plots, extensive weeding was conducted to reduce the competition. The crops were sprayed in July which reduced growth of the *L. usitatissimum* and one plot of the *B. rapa* (Spirit River).

The plots were harvested in late September and early October ensuring maturity which may have been too late in the season as the seed showed high incidence of lodging and shattering (photos shown in Appendix D). Site RF and SM had heavy snow cover at harvest and Site HN had light snow and ice cover which was melting during the day. At site SM, only one flax plot was harvested due to poor maturity.

The seed was sent to the lab in Saskatoon and further cleaned to remove shattered and immature seed. Observations during seed cleaning found the *C. sativa* was most consistent in seed size and uniformity. The *Brassica* seeds were found to have less uniformity and more damaged or immature seeds.

The oil content of each of the species and varieties averaged between 41.8 and 46.7 percent, with the *B.rapa* having the highest oil content followed by the *C. sativa* (refer to Appendix C for oil and protein analysis). The *C. sativa* was found to have the highest average percentage of protein, although the range for the entire test was relatively narrow, ranging between 23.3 to 25.7 percent protein. The yield for the *C. sativa* ranged from 1.7 to 2.2 T/ha.

## 2008

The 2008 growing season was cool noted by below average accumulation of growing degree days (GDD) and the high incidence of frost experienced during the growing season.

Most plots showed good emergence with the exception of *B. rapa*. The plots at Site HN were lost to wildlife and weeds resulting in the trial being aborted. The other two sites were harvested in late September. During harvest there was noticeable lodging in most plots and some shattering. The *L. usitatissimum* was still in the soft dough stage at both sites and therefore not harvested. At Site RF only two plots of the *B. napus* were harvested due to the lack of maturity and severe frost damage of the seeds. All the *C. sativa* and *B. rapa* was harvested at the Site RF. A decision was made to only harvest two plots of the *B. rapa*, *B. napus* and *C. sativa* from the SM site because of the poor seed development observed before harvest. Yield was low at both sites (RF and SM) with an average from all plots of 0.4 T/ha for the *B. napus*, 0.7 T/ha for the *B. rapa* and 0.7 T/ha for the *C. sativa*. Oil and protein analysis was not conducted in 2008 due to the lack of harvested seed.

## 2009

The 2009 growing season was the warmest since 2004. Fewer frosts and a longer season provided optimal conditions for the oilseed trial.

Table 4 shows the oil and protein percentage of the four varieties at the different locations and the yield per hectare. The yield values were extrapolated from 1m<sup>2</sup>. The four plots with each variety were averaged.

Table 4: 2009 Oilseed Results

	RF			SM			MC		
	Yield (T/ha) <sup>1</sup>	Protein (%)	Oil (%)	Yield (T/ha)	Protein (%)	Oil (%)	Yield (T/ha)	Protein (%)	Oil (%)
Camelina	2.66	21.61	47.69	0.92	27.03	40.96	1.94	22.6	45.93
Napus	2.06	21	49.04	0.25	23.58	47.03	0.76	18.61	52.27
Rapa	1.87	20.36	49.6	0.42	24.95	43.54	0.90*	21.03	49.47
Flax	1.44	19.63	49.59	0.64	22.81	48.15	1.65**	18.7	51.2

<sup>1</sup>Harvested seed weight in tonnes/hectare

\*Average of three samples

\*\* Average of two samples

The oil content averaged between 40.9 to 52.2 percent, with the *B. napus* at McCabe Creek having the highest oil content. The range for protein was 18.7 to 27 percent.

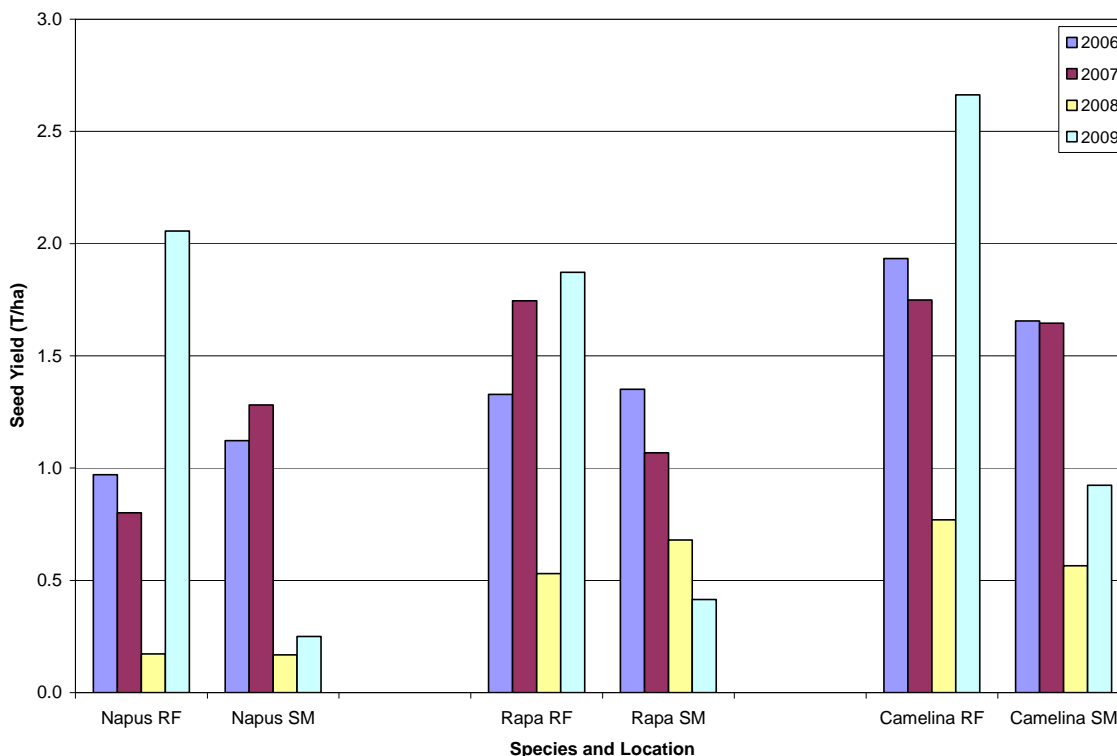
The *B. napus* performed well at all sites, producing between 0.13 to 3.66 T/ha of seed. Most of the numbers were well above the Canadian averages for canola yield as shown in table 5, with eleven samples above 2 T/ha. The *C. sativa* and *L. usitatissimum* varieties did favorably at the McCabe Creek site. Graph 1 shows the yield comparison for the four years from sites RF and SM.

Table 5: Canadian Canola Yield 22-Year Average (yield converted into tonnes/hectare)

Year	Ontario	Manitoba	Sask.	Alberta	British Columbia	Total Canada
1986 - 2009 Average	0.32	0.25	0.22	0.25	0.22	0.23

Source: <http://www.canola-council.org>

Graph 1: Oilseed Trial Yield Comparison for 2006 to 2009



### Economic Assessment

The purpose of this trial was to grow oilseeds for fuel, generating biodiesel as the final product.

After the oilseeds are harvested there are two options for getting the oil out of the seed, a chemical extraction process which is able to remove 96% of the oil or a mechanical process which is able to extract up to 85% of the oil<sup>4</sup>. The chemical extraction process is more appropriate for large scale, so the data assumes an efficient mechanical extraction. The biodiesel potential in litres for the Yukon oilseed was therefore calculated at an 85% oil recovery using the percent oil content analyzed by NIR combined with the total yield per hectare. The biodiesel potential varied greatly due to the variation in yields in the different varieties and at the different sites. In other studies, a general average for canola ranges from approximately 1000 L/ha to 1350 L/ha.

Once the oil is extracted it is considered a straight vegetable oil and is suitable for burning in some converted diesel engines such as those in late-model Mercedes. The by-product of the mechanical extraction is a mash that is suitable for animal feeds. The value of the oil at this stage is approx \$1.00/L and the value of the mash varies but is considered a suitable animal feed and could fetch a price of approximately \$0.20/kg.

In order to convert the straight vegetable oil into biodiesel another set of steps is required. Lye and methane must be mixed with the vegetable oil. This additional process requires specific equipment, the appropriate chemicals, and time. At the end of the process one litre of straight vegetable oil equals approximately one litre of biodiesel. There are also additional by-products such as glycerine produced during the process. Once biodiesel is produced, called B100, it can be used in some engines, but more often is cut with diesel to produce lower percentage biodiesel (B20 is 20% biodiesel)<sup>5</sup>.

The following economics of production assessment was carried out on the *C. sativa* grown in the Whitehorse area.

Table 6: Yields of *C. sativa* Mash and Biodiesel 2006-2009

<b>Camelina</b>	<b>Mash (T/ha)</b>	<b>Biodiesel (L/ha)</b>
2006	1.3	726.1
2007	1.1	643.1
2008	~ 0.8	n/a
2009	1.6	1,193.0
<b>Average</b>	<b>1.3</b>	<b>854.1</b>

The average mash yield over three of the four years of assessment was 1.31 T/ha with the potential price for the mash estimated at \$200.00/T. This mash is suitable for hog or cattle rations, but the market must be developed for these sales to occur.

The average diesel yield over the four years of assessment was 854 L/ha. The price per litre at the pumps is currently \$1.10/L. The total value of the diesel per hectare would be \$939.40.

There are a number of expenses that must be factored into this calculation.

Table 7: Estimated expenses of growing *C. sativa* per hectare

Ground Preparation*		\$50/ha
Seed	5 kg/ha @ \$8/kg	\$40/ha
Seeding*		\$35/ha
Fertilizer	400 kg/ha @ \$600/T	\$240/ha
Fertilizing*		\$15/ha
Weeding/Spraying*		\$50/ha
Irrigation*		\$250/ha
Harvesting*		\$50/ha
<b>Total**</b>		<b>\$730/ha</b>

\* Custom rates estimated from the Yukon cost of development guidelines and the 2008 Alberta Custom rates survey summary

\*\* Does not include the cost of processing, handling, depreciation of equipment or storage.

Table 8: The estimated earnings per hectare for growing *C. sativa*

<b>Earnings per hectare (average of 3 years)</b>	
Income	\$1,139.40
Expenses	\$730.00
<b>Earnings</b>	<b>\$409.40</b>
<b>Earnings for 2009 per hectare</b>	
Income	\$1,512.30
Expenses	\$730.00
<b>Earnings</b>	<b>\$782.30</b>

## Conclusion

The average earnings from oilseed production per hectare are low. Excluding the poor growing season of 2008, the income generated over the other 3 years would average \$1,139.40. Expenses on each farm will vary, as a general rule when growing oilseeds you might expect a net income of around \$400.00 per ha. In 2009, the production was much higher than the other years and the value per hectare and net income would be greater (Table 8). If we are to experience warmer, more productive growing seasons in future, or, if the lands used to grow these crops are located in the central Yukon these results show agronomic and economic viability. It is important to note that in 2008, which was a very cold year, most of the crops were lost. Around the Whitehorse area, with the short growing seasons and low average summer temperatures, it will prove difficult to maintain a substantial income year after year from these crops.

## References

1. Agriculture and Agri-Food Canada (2010). A National Ecological Framework for Canada <http://sis.agr.gc.ca/cansis/nsdb/ecostrat/index.html>
2. Canadian Canola Yields (2010). <http://www.canola-council.org/>
3. Akk, E., Ilumäe, E. 2005. Possibilities of growing *Camelina sativa* in ecological cultivation
4. Canola info.org. (2010) <http://www.canolainfo.org/canola/index.php?page=6>
5. Biodiesel Production (2010) [journeytoforever.org](http://journeytoforever.org)
6. Government of British Columbia, Agriculture Land Reserve (2010). Agriculture Capability [http://www.alc.gov.bc.ca/alr/Ag\\_Capability.htm](http://www.alc.gov.bc.ca/alr/Ag_Capability.htm)

## Appendix A – Agroclimatic Capability Classes<sup>6</sup>

Definitions and operational constraints of agroclimatic capability classes for cultivated agriculture in Yukon

Class 1	1,400-1,600 GDD	These lands have no significant limitations that restrict the production of the full range of common Canadian agricultural crops.
Class 2	1,200-1,400 GDD	These lands have slight limitations that restrict the range of some crops but still allow the production of grain and warm season vegetables.
Class 3	1,050-1,200 GDD	These lands have moderate limitations that restrict the range of crops to small grain cereals and vegetables.
Class 4	900-1,050 GDD	These lands have severe limitations that restrict the range of crops to forage production, marginal grain production and cold-hardy vegetables.
Class 5	700-900 GDD	These lands have very severe limitations that restrict the range of crops to forages, improved pastures and cold-hardy vegetables.
Class 6	<700 GDD	These lands have such severe limitations for cultivated agriculture that cropping is not feasible.

## Appendix B – Oilseed Varieties and Seeding Rates

<b>Species</b>	<b>False Flax</b>	<b>Polish Canola</b>	<b>Argentine Canola</b>	<b>Flanders Flax</b>
	<i>Camelina sativa</i>	<i>Brassica rapa</i>	<i>Brassica napus</i>	<i>Linum usitatissimum</i>
<b>Seed name/ variety</b>	CN30476	SW Spirit River (Reward used in some plots in 2007)	6803-01	Flanders
<b>Supplier</b>	Crop Development Centre	Bonis & Co. Ltd.	HyTech Productions Ltd.	Se-Can Association
<b>Breeder</b>	Crop Development Centre, Saskatoon	Svalof Weibull Ltd.	DSV Canada	Crop Development Centre, Saskatoon
<b>Seeding rate</b>	5 kg/ha	8 kg/ha	8 kg/ha	30 kg/ha

## Appendix C – Oilseed Yield, Oil and Protein Analysis 2006-2009

2006

Year	Location	Species	Oil %	Protein %	Yield g/m <sup>2</sup>	Yield kg/ha	Calculated Oil kg/ha	Calculated Protein kg/ha
2006	RF	Napus	39.3	19.7	115.1	1151	452.8	227.1
2006	RF	Napus	43.9	15.3	127.4	1274	559.3	195.3
2006	RF	Napus	39.2	18.5	82.6	826	324	152.9
2006	RF	Napus	33.4	20.6	63	630	210.4	129.5
2006	SM	Napus	50.2	14.9	115.1	1151	577.5	172
2006	SM	Napus	49.8	15	95.4	954	475	142.9
2006	SM	Napus	53.8	13.9	141.9	1419	762.8	197.7
2006	SM	Napus	51.9	15.8	96.5	965	500.4	152.5
2006	RF	Rapa	45.3	20.8	143.3	1433	649.4	298.7
2006	RF	Rapa	45.5	21.6	111.9	1119	508.7	241.3
2006	RF	Rapa	45.4	23.1	126.2	1262	572.4	291.1
2006	RF	Rapa	47.4	21.3	150	1500	710.9	320
2006	SM	Rapa	55.8	14.8	149.3	1493	833.8	220.8
2006	SM	Rapa	49.6	17.8	85.6	856	424.9	152.6
2006	SM	Rapa	51.1	16.6	172.2	1722	880	285.8
2006	SM	Rapa	52.9	17.5	133.5	1335	706.9	233.8
2006	DH	Rapa	N	N	31.5	315	N	N
2006	DH	Rapa	N	N	7.5	75	N	N
2006	DH	Rapa	N	N	16.4	164	N	N
2006	DH	Rapa	N	N	6.1	61	N	N
2006	RF	C. Sativa	38.9	25	212.7	2127	828.1	531.3
2006	RF	C. Sativa	39.0	22.8	185.1	1851	721.5	422.7
2006	RF	C. Sativa	37.5	24.1	184.6	1846	692.1	445.7
2006	RF	C. Sativa	43.6	20.6	191.1	1911	833.5	393.3
2006	DG	C. Sativa	39.8	24.6	21.1	211	84.1	52
2006	DG	C. Sativa	39.8	24.6	43.1	431	171.7	106.2
2006	DG	C. Sativa	39.8	24.6	45.8	458	182.5	112.8
2006	DG	C. Sativa	39.8	24.6	49.1	491	195.6	121
2006	DH	C. Sativa	38.9	24.3	24.5	245	95.3	59.5
2006	DH	C. Sativa	38.9	24.3	25.7	257	100	62.4
2006	DH	C. Sativa	38.9	24.3	22.6	226	87.9	54.9
2006	SM	C. Sativa	49.7	18.9	147.4	1474	732.7	279.1
2006	SM	C. Sativa	49.0	19.7	169.8	1698	831.7	333.7
2006	SM	C. Sativa	45.4	23.4	219.4	2194	995.4	513.6
2006	SM	C. Sativa	49.2	19.9	125.8	1258	619.1	250
2006	DH	N	N	N	N	N	N	N

2007

Year	Location	Species	Oil %	Protein %	Yield g/m2	Yield kg/ha	Calculated Oil kg/ha	Calculated Protein kg/ha
2007	HN	C. Sativa	43.78	26.67	265.14	2651.4	1160.7	707.2
2007	HN	C. Sativa	45.25	24.04	198.74	1987.4	899.3	477.8
2007	HN	C. Sativa	44.39	25.08	226.14	2261.4	1003.9	567.1
2007	HN	C. Sativa	44.60	24.97	181.24	1812.4	808.3	452.6
2007	SM	C. Sativa	40.82	26.98	129.44	1294.4	528.3	349.2
2007	SM	C. Sativa	40.78	26.84	76.04	760.4	310.1	204.1
2007	SM	C. Sativa	41.32	26.79	162.74	1627.4	672.5	436.0
2007	SM	C. Sativa	41.83	26.84	289.94	2899.4	1212.8	778.3
2007	HN	Flax	43.69	22.90	365.74	3657.4	1597.9	837.6
2007	SM	Flax	39.82	26.30	82.84	828.4	329.9	217.8
2007	HN	Napus	47.75	22.32	155.24	1552.4	741.2	346.4
2007	HN	Napus	44.26	24.96	85.22	852.2	377.2	212.7
2007	HN	Napus	46.20	21.97	107.14	1071.4	495.0	235.4
2007	HN	Napus	N	N	40.64	406.4	N	N
2007	RF	Napus	37.13	24.29	59.12	591.2	219.5	143.6
2007	RF	Napus	39.37	22.86	58.22	582.2	229.2	133.1
2007	RF	Napus	35.88	23.71	82.72	827.2	296.8	196.1
2007	RF	Napus	32.24	23.45	120.42	1204.2	388.2	282.4
2007	SM	Napus	42.49	26.20	127.92	1279.2	543.6	335.2
2007	SM	Napus	44.28	25.66	204.12	2041.2	903.9	523.8
2007	SM	Napus	44.29	23.33	82.82	828.2	366.8	193.2
2007	SM	Napus	46.27	22.31	97.92	979.2	453.1	218.5
2007	HN	Rapa	43.63	25.07	124.24	1242.4	542.0	311.4
2007	HN	Rapa	45.31	24.17	128.74	1287.4	583.3	311.1
2007	HN	Rapa	46.63	22.99	132.14	1321.4	616.1	303.7
2007	HN	Rapa	43.93	24.03	114.44	1144.4	502.7	275.0
2007	RF	Rapa	44.44	23.87	98.34	983.4	437.0	234.7
2007	RF	Rapa	41.97	26.47	205.84	2058.4	863.8	544.8
2007	RF	Rapa	44.05	23.89	148.64	1486.4	654.7	355.1
2007	RF	Rapa	40.68	27.64	172.04	1720.4	699.9	475.4
2007	RF	Rapa	44.83	23.94	173.34	1733.4	777.1	415.0
2007	RF	Rapa	52.19	17.16	161.12	1611.2	840.9	276.4
2007	RF	Rapa	47.53	21.84	214.92	2149.2	1021.5	469.3
2007	RF	Rapa	48.49	20.92	224.02	2240.2	1086.4	468.6
2007	SM	Rapa	45.38	23.68	108.72	1087.2	493.4	257.5
2007	SM	Rapa	47.83	22.52	109.52	1095.2	523.8	246.7
2007	SM	Rapa	47.50	23.77	132.22	1322.2	628.1	314.4
2007	SM	Rapa	44.81	23.55	76.82	768.2	344.2	180.9
2007	RF	RapaR*	43.70	23.14	138.14	1381.4	603.7	319.6
2007	RF	RapaR	44.25	23.20	112.22	1122.2	496.5	260.3
2007	RF	RapaR	N	N	N	N	N	N
2007	RF	RapaR	44.74	22.82	191.42	1914.2	856.5	436.7
2007	RF	Rapa	46.81	20.85	98.22	982.2	459.7	204.7
2007	SM	RapaR	43.23	23.97	150.54	1505.4	650.7	360.9
2007	SM	RapaR	44.52	24.12	52.12	521.2	232.0	125.7
2007	SM	RapaR	46.25	21.94	68.24	682.4	315.6	149.7
2007	SM	RapaR	44.34	23.57	89.72	897.2	397.8	211.5

**2008**

<b>Year</b>	<b>Location</b>	<b>Species</b>	<b>Oil %</b>	<b>Protein %</b>	<b>Yield g/m2</b>	<b>Yield kg/ha</b>	<b>Calculated Oil kg/ha</b>	<b>Calculated Protein kg/ha</b>
2008	RF	Napus	N	N	17.25	172.50	N	N
2008	SM	Napus	N	N	16.85	168.50	N	N
2008	Average	Napus	N	N	17.05	170.50	N	N
2008	RF	Rapa	N	N	53.05	530.50	N	N
2008	SM	Rapa	N	N	68.80	688.00	N	N
2008	SM	Rapa	N	N	131.70	1317.00	N	N
2008	Average	Rapa	N	N	68.78	687.83	N	N
2008	RF	C. Sativa	N	N	76.98	769.75	N	N
2008	SM	C. Sativa	N	N	56.55	565.50	N	N
2008	Average	C. Sativa	N	N	70.17	701.67	N	N

2009

Year	Location	Species	Oil %	Protein %	Yield kg/ha	Calculated Oil kg/ha	Calculated Protein kg/ha
2009	SM	C. Sativa	42.05	25.38	233	98.03	59.17
2009	SM	C. Sativa	36.66	30.72	686	251.49	210.77
2009	SM	C. Sativa	41.83	25.40	904	378.20	229.66
2009	SM	C. Sativa	43.30	26.60	1871	810.21	497.74
2009	RF	C. Sativa	46.47	23.64	3337	1550.92	789.05
2009	RF	C. Sativa	48.86	19.02	1022	499.38	194.35
2009	RF	C. Sativa	46.88	22.78	3074	1441.00	700.34
2009	RF	C. Sativa	48.57	20.99	3215	1561.43	674.85
2009	MC	C. Sativa	47.14	21.48	1949	918.85	418.64
2009	MC	C. Sativa	46.54	21.67	1659	772.13	359.60
2009	MC	C. Sativa	45.82	22.45	2076	951.32	466.12
2009	MC	C. Sativa	44.20	24.79	2092	924.77	518.63
2009	SM	Napus	50.10	20.39	335	167.87	68.31
2009	SM	Napus	45.41	25.74	379	172.14	97.58
2009	SM	Napus	46.22	24.87	156	72.15	38.82
2009	SM	Napus	46.40	23.33	131	60.83	30.59
2009	RF	Napus	50.86	19.64	2325	1182.60	456.57
2009	RF	Napus	47.66	22.65	3666	1747.26	830.19
2009	RF	Napus	46.66	22.60	176	82.18	39.80
2009	RF	Napus	50.97	19.12	2055	1047.48	392.94
2009	MC	Napus	53.48	17.58	1289	689.41	226.61
2009	MC	Napus	49.04	20.30	627	307.54	127.30
2009	MC	Napus	52.09	19.10	86	44.85	16.45
2009	MC	Napus	54.48	17.47	1037	565.03	181.18
2009	SM	Flax	50.14	19.95	734	368.06	146.47
2009	SM	Flax	47.79	23.90	656	313.54	156.82
2009	SM	Flax	49.42	21.36	658	325.21	140.56
2009	SM	Flax	45.26	26.02	496	224.54	129.08
2009	RF	Flax	50.16	18.89	1017	510.13	192.15
2009	RF	Flax	48.73	21.09	1785	869.87	376.45
2009	RF	Flax	48.62	20.61	1764	857.70	363.50
2009	RF	Flax	50.84	17.95	1209	614.69	217.03
2009	MC	Flax	N	N	13	N	N
2009	MC	Flax	51.20	18.18	2510	1285.13	456.31
2009	MC	Flax	50.32	20.69	1874	943.08	387.72
2009	MC	Flax	52.02	17.24	2183	1135.71	376.45
2009	SM	Rapa	46.36	21.39	576	267.06	123.20
2009	SM	Rapa	41.18	25.70	154	63.45	39.60
2009	SM	Rapa	43.51	25.76	528	229.77	136.06
2009	SM	Rapa	43.13	26.95	401	173.00	108.09
2009	RF	Rapa	49.14	19.64	1401	688.55	275.19
2009	RF	Rapa	48.93	21.15	1730	846.56	365.88
2009	RF	Rapa	50.33	20.24	2076	1044.92	420.25
2009	RF	Rapa	50.00	20.41	2283	1141.58	466.06
2009	MC	Rapa	N	N	13	N	N
2009	MC	Rapa	47.62	22.36	1809	861.40	404.60
2009	MC	Rapa	N	N	10	N	N
2009	MC	Rapa	51.32	19.69	1767	906.88	347.95

## Appendix D – Photos



Photo 1: Example of a 4m x 4m plot layout staked out and rolled (2006)



Photo 2: Seeding individual plot was done by hand in 2006



Photo 3: Pod shattering of *B. rapa* at HN (2007)



Photo 4: Lodging and snow cover at RF during harvest (2007)



Photo 5: 1m<sup>2</sup> frame used to define the area to harvest



Photo 6: Plant growth at HN (July 5, 2007)



Photo 7: Plant growth at RF (July 17, 2007)



Photo 8: Plots showing limited growth at HN (July 13, 2008)



Photo 9: Canola and flax at Site RF (August 8, 2008)



Photo 10: Emerging growth at McCabe Creek (June 2009)

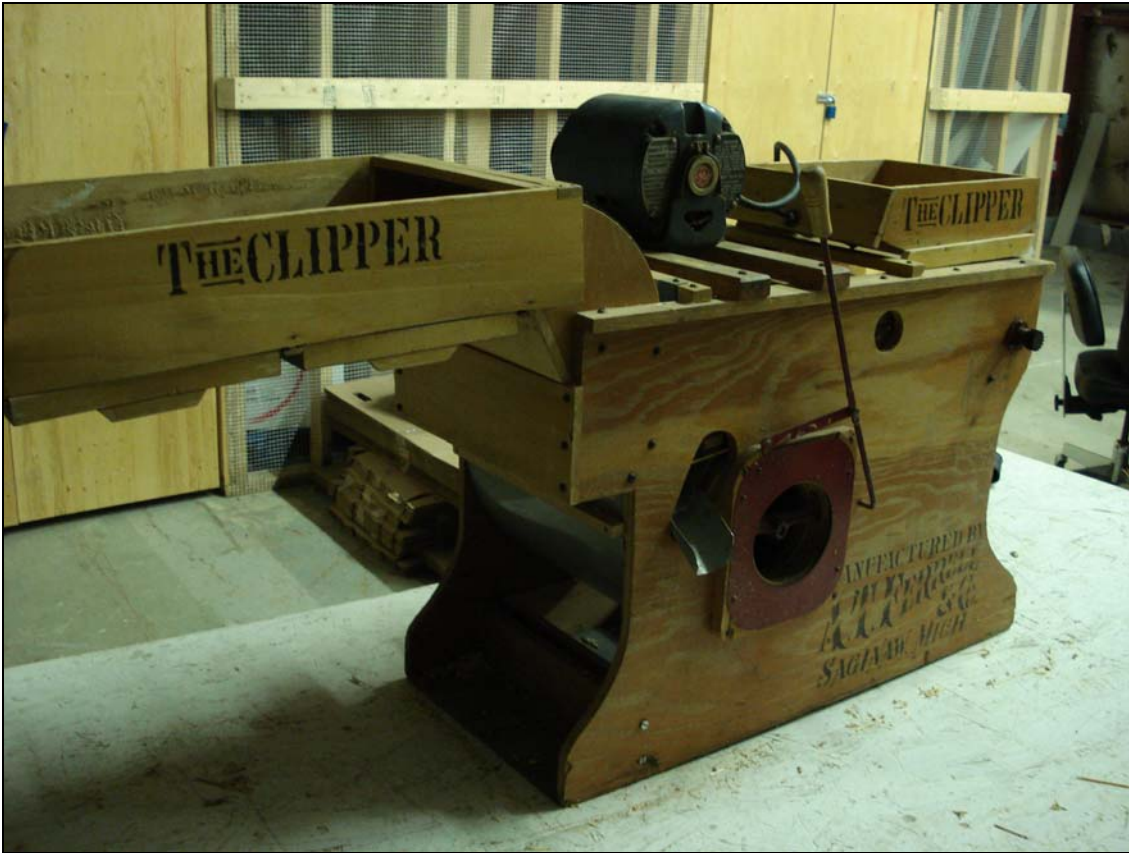


Photo 11: The Clipper seed separator used to clean seed after threshing