Brassica (canola) oilseed breeding in Canada

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Rapeseed (canola) production in Canada occurs in the three western Canadian prairie provinces of Manitoba, Saskatchewan and Alberta where more than 95% of total Canadian rapeseed is grown (Table 1). About 95% of the total canola acreage of approximately 4.6 million ha is sown to short season (~100 days) summer annual forms of *Brassica napus* canola. This is a drastic change to the situation in the early 1990s when only about 50% of the acreage was planted to *B. napus* and 50% to *B. rapa*. *Brassica rapa* was preferred by growers in the short season growing areas of northern Saskatchewan and Alberta, where it matures in 80 to 85 days from planting while *B. napus* cultivars require a minimum of 100 growing days to mature. The change to *B. napus* canola resulted from the introduction of herbicide tolerant cultivars which now occupy about 90% of the total canola acreage in Canada (Table 2). Herbicide tolerant *B. rapa* cultivars are not available which was one of the reasons for the decline in the *B. rapa* acreage.

Table 1: Rapeseed (canola) production in Canada (average for 10-year period 1995-2004)

	Area (1000 ha)		Production (1000 tonnes)	Yield
Province	Seeded	Harvested	Average	kg/ha
Manitoba	943.1	922.5	1,492.3	1,620
Saskatchewan	2,242.0	2,183.7	2,757.4	1,260
Alberta & BC	1,541.7	1,491.7	2,233.6	1,450
W. Canada	4,726.8	4,597.9	6,483.3	1,440
Canada	4,757.6	4,628.2	6,546.0	1,410

1994: 50% *Brassica napus*, 50% *B. rapa*,
2000: 95% *Brassica napus*, 5% *B. rapa*
Source: Canada Grains Council, Statistical Handbook 2004 "Field Crop Reporting Series," Catalogue 22-2002, Statistics Canada

Table 2: Area (%) of herbicide tolerant canola western Canada, 1996-2003

Year	% herbicide-tolerant				Total area
	Roundup[1]	Liberty[2]	Clearfield[3]	Total	1000 ha
1996	<1	3	6	10	3,451
1997	4	8	14	26	4,869
1998	23	12	16	51	5,560
1999	33	20	20	73	5,564
2000	39	14	21	74	4,816
2001	45	16	20	81	3,765
2002	42	23	20	85	2,857
2003[4]	46	21	23	90	4,736

Source: R.K. Downey and JoAnne Buth 2003: Transgenic rapeseed – grower adoption and consumer acceptance. Proc. 11th Int. Rapeseed Congress, Copenhagen, Denmark, Vol. 4: pages 1190-1194.
1 Roundup Ready → glyphosate, 2 Liberty Link → glufosinate ammonium,
3 Clearfield → imidazolinone, 4 R.K. Downey personal communication

In 2003, 46% of the total canola acreage was sown to Round-up Ready (glyphosate) tolerant cultivars, 21% to Liberty Link (glufosinate ammonium) and 23% to Clearfield (Imidazolinone) tolerant cultivars which indicates the agronomic importance of herbicide tolerance for effective weed control in oilseed rape production in Canada.

The average 10-year (1994-2003) canola production in Canada was 6,326,900 tonnes of seed of which about 50% was exported as seed; one half of total seed exports went to Japan, Canada's longest standing and most important customer of canola seed. One half of the canola production was crushed in Canada; 77% of the derived canola oil as well as 80% of canola meal exported to the United States. This highlights the importance of the US market for Canadian canola oil and meal.

Breeding for oil quality

Canola oil is a high quality vegetable oil with a well balanced fatty acid composition of 60-65% oleic acid, 18 to 20% linoleic acid and 6.5 to 8% linolenic acid (Table 3). It also has a low total saturated fat content of less than 7% of total fatty acids. Examples are the official check cultivars 46A65 and Q2, and the new yellow-seeded AAFC Saskatoon Research Centre breeding line YN01-429 in Table 3. There is an increasing demand, in Canada and the USA, for temperature stable vegetable oils which requires the breeding of high oleic-low linolenic (so called HOLL) cultivars. Table 3 shows one example of such a line, developed by AAFC Saskatoon with >75% oleic acid and <3% linolenic acid. These oils are also of great importance for the production of solid fats in that they require little or no hydrogenation, thereby eliminating the formation of trans fatty acids in the production of margarines. About one half of the total Canadian canola acreage could be planted to high oleic – low linolenic acid cultivars to meet future market demand. High

oleic – low linolenic acid cultivars have been developed and are commercially grown in Canada, but patents in this area restrict the free flow of germplasm between plant breeders and hinder breeding progress towards higher yielding cultivars. Currently grown cultivars are lower yielding than standard canola cultivars and contractors have to pay a premium to secure production contracts with producers.

Table 3: Fatty acid composition of *Brassica napus* canola, Saskatoon, SK, 2001-03

	Fatty acid composition (% of total)							
Lines	16:0	18:0	18:1	18:2	18:3	20:1	22:1	T. Sat
B. napus								
YN01-429[1]	3.6	2.0	65.4	19.0	6.6	1.3	0.1	6.7
46A65/Q2[1]	3.6	2.0	64.7	18.2	7.9	1.4	0.1	6.8
HOLL[2]	3.9	2.0	77.8	8.7	2.8	1.4	0.1	7.4
Low Sat A[2]	2.4	1.1	55.0	29.3	8.5	1.8	0.1	4.3
Low Sat B[2]	3.1	1.2	67.7	16.7	7.8	1.5	0.1	5.3

1=4 station mean, Saskatoon + Scott, SK. 2002-03, 2=Saskatoon 2001, T. Sat = Total of C12+C14+C16+C18+C20+C22+C24

For North America (in particular the USA), the breeding of cultivars with low contents of saturated fats is of importance. The total saturated fat content in food products must be <7% to be able to label products as "low in saturated fat." The classification as "zero saturated fat" is possible for products containing <3.5% saturated fatty acids. Table 3 shows two low saturated fat mutant lines with saturated fat contents of 4.3% and 5.3% developed by AAFC Saskatoon through seed mutagenesis which could be used for the breeding of low saturated fat cultivars.

Breeding for meal quality

Canola meal is a high protein supplement in animal feed and is widely used in dairy rations in California. It is also used in pig and poultry feed rations. Despite its favourable amino acid composition, canola meal is sold for only 60-70% of the price of soybean meal. The reason for the price discount is the relatively high fibre content of canola meal which limits inclusion rates in feed formulations, in particular for pigs and poultry.

The Saskatoon Research Centre developed yellow-seeded forms of *B. napus* canola which have much reduced fibre contents (Table 4). The yellow seeded line YN01-429 had seed yields equal to or better than standard check cultivars 46A65/Q2 in 3 years of field testing (2002-04). It had superior oil content, large seed weight and low glucosinolate content. The meal had significantly reduced fibre contents, ADL, ADF and NDF. Feeding studies have shown improved nutritional value of meal from yellow-seeded lines, resulting in greater weight gains, increased metabolizable energy contents as well as improved protein digestibility.

Table 4: Performance of the yellow-seeded *Brassica napus* line YN01-429 in field tests

	yield[1]		Oil[2]	Protein[3]	SW	T-GSL	Fibre (% dry meal)[4]		
Lines	kg/ha	%	(%)	(%)	(g/1000)	(µmol/g)	ADL	ADF	NDF
YN01-429	2030	109	49.1	46.9	3.30	12.9	1.3	8.2	14.9
46A65/Q2	1890	100	45.8	49.0	2.77	17.7	5.4	13.6	19.1
Station yrs	6	6	6	5	4	4	4	4	4

1=AAFC Saskatoon, Scott and Melfort, 2002-2004, 2=Oil by NMR, 3=Protein by Leco combustion, 4=Fibre by Ankom 200 Fibre Analyzer.
ADL=acid detergent lignin, ADF=acid detergent fibre (cellulose + lignin), NDF=neutral detergent fibre (hemicellulose + cellulose + lignin + pectin)

Our goal is to develop true breeding, yellow-seeded *B. napus* cultivars and hybrids with high seed yields, disease resistance, and high oil and protein contents, and to convert the total Canadian canola production to yellow-seeded cultivars. This would create a new high quality meal for use as animal feed and possibly for human consumption. We will attempt the development of yellow-seeded cultivars with "standard" canola fatty acid profiles as well as cultivars with high oleic-low linolenic acid contents. Yellow-seeded cultivars will have an inherently higher seed oil content of 1 to 2% over black-seeded cultivars which will be an additional benefit to oilseed crushers. However, we need more animal feeding studies with meal from yellow-seeded cultivars to fully document the meal quality advantages of yellow-seeded forms. During the initial phase of commercialization, it will be necessary to separate the production of yellow-seeded cultivars from that of standard black-seeded cultivars to guarantee the improved meal quality for end users.

A further aspect of canola meal quality improvement is the reduction or complete elimination of glucosinolates from canola seed. AAFC has developed lines of *B. napus* canola with freedom from alkenyl glucosinolates (less than one µmole per one gram of seed), and lines with reduced indole glucosinolate content of about one µmole per one gram seed. The low alkenyl, low indole characteristics have been combined into one genotype, and this trait is now introgressed into yellow-seeded germplasm. This will further improve the feed value of yellow-seeded canola meal.

Work is also underway to incorporate the high oleic-low linolenic acid and low saturated fat traits into yellow-seeded, zero glucosinolate lines of *Brassica napus* canola.

Canola cultivar breeding and research

The commercial breeding of new canola cultivars and hybrids in Canada is primarily done by private breeding firms. The focus is on the development of adapted, early maturing, blackleg disease resistant, herbicide tolerant and high quality oil and meal cultivars of *B. napus* canola. There is no breeding work, by private companies, to develop new cultivars of *B. rapa* canola. However, the Saskatchewan Wheat Pool and

Pioneer Hi-Bred Ltd. have breeding projects in *B. juncea* canola. The Saskatchewan Wheat Pool is now marketing the first *B. juncea* canola cultivars.

Brassica napus canola breeding is conducted by:

- Bayer CropScience → Liberty Link hybrids
- Pioneer Hi-Bred (Dupont) → Round-up Ready and Clearfield hybrids
- Monsanto (formerly Advanta) → Round-up Ready hybrids
- Svalöf-Weibull/Saskatchewan Wheat Pool→ Round-up Ready and Clearfield open pollinated and hybrid cultivars
- Agriprogress, DSV, Lembke and others

High stability oil (HOLL) canola breeding work is conducted by:

- Cargill Ltd. → Clear Valley hybrid cultivars with Round-up Ready tolerance.
- Dow AgroSciences → Nexera brand HOLL cultivars.

There is also canola breeding research conducted at universities and by Agriculture Canada.

- University of Manitoba → HOLL cultivars, high erucic acid (HEAR) cultivars
- University of Alberta → canola breeding
- University of Guelph, Ontario → canola breeding
- AAFC Saskatoon Research Centre → research focuses on germplasm development with emphasis on oil and meal quality, and diversification of oilseed production into *B. rapa, B. juncea, B. carinata* and *Sinapis alba*.

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