Rapeseed to Canola: Rags to Riches

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This story began some 65 years ago, during World War II. It is a story of successful genetic manipulation of an introduced crop by a small, self-motivated team of chemists, plant breeders and animal nutritionists. As a result of their efforts, the crop now rivals wheat as Canada's most valuable agricultural commodity and is the world's third most important source of edible vegetable oil (Table 1).

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Table 1. World edible vegetable oil production by crop (millions of tonnes).

Oil crop	Production year 83–84	93–94	02–03	% growth in 20 years
Soybean	13	18	31	142
Palm	6.3	13	28	343
Canola/Rape	4.9	9.2	12	151
Sunflower	5.4	7.2	8.6	59
Cotton	3.0	3.4	3.9	30
Peanut	2.9	3.6	4.4	52
Other*	4.7	6.4	9.5	103
Total	40	61	98	144

*Olive, coconut, palm kernel, corn, *etc*.

Critical Need for Lubricants

During World War II, all trains and ships were steam-powdered and rapeseed-oil lubrication was essential to keep them running. When metal surfaces are washed with steam or water, rape oil clings better than any other natural or synthetic lubricant. When supplies of the oil from Europe and Asia were cut off, Canada was asked to attempt to grow the crop. Experimental plantings showed that with minor adjustments to seeding and harvesting equipment the crop could be grown in the cooler, moister regions of the Canadian prairies.

Two species of the crop, *Brassica napus* and *B. rapa* were marketed as a single commodity. The black, brown or yellow seed is small and round and when crushed yields 40 to 46% oil and a nutritionally well balanced, high protein (36–37%) meal. The seed looks like those of turnip, mustard or cabbage, to which they are closely related.

Commercial production began in 1943 with a government-guaranteed price of $.06/lb and production expanded from a few acres in 1943 to 79,000 by 1948 when the price support was withdrawn and steam power was displaced by diesel. The crop almost disappeared in 1950 until an edible oil market was established in Japan where rapeseed oil was preferred for deep frying (tempura). After the war, the Japanese no longer had the farm labor to transplant rapeseed into the rice stubble to obtain two crops per year. Thus, the Canadian crop was saved while providing time to develop a domestic market.

Edible Oil from Rapeseed?

From the beginning it was recognized by scientists that rapeseed could be an important domestic source of edible oil. At the time, Canada was importing 90% of its edible oil needs. Indeed some local companies began to market the liquid oil in the early 1950s. However, the fatty acid composition of rapeseed oil differed from those of other edible oils in having a substantial quantity of the long-chain monoenoic fatty acids, eicosenoic and erucic (Table 2). This difference sparked the interest of nutritionists. Initially they reported that rats fed high levels of rapeseed oil performed poorly under stress and had enlarged adrenals. To counter these reports, it was pointed out that Asian peoples had consumed rapeseed oil for centuries with no ill effects. Thus, the domestic market was allowed to grow.

Table 2. Percent fatty acid composition of Canadian vegetable oils.

Fatty Acid	Symbol	Rapeseed			Soybean	Sunflower
		napus	*rapa*	canola		
Palmitic	C16:0	4.0	4.9	4.7	12	7.2
Stearic	C18:0	1.5	1.6	1.8	3.9	4.1
Oleic	C18:1	17	33	63	25	16
Linoleic	C18:2	13	20	20	52	73
Linolenic	C18:3	9.0	7.6	8.6	8.0	0.0
Eicosenoic	C20:1	15	9.9	1.9	0.0	0.0
Erucic	C22:1	41	23	0.0	0.0	0.0

Decreased Erucic Acid

Because of the nutritional concerns, chemists and breeders turned their attention to developing techniques to search for and develop germplasm with little or no-long chain fatty acids. At the time it required 2 lb of seed and a technician 1 week just to determine the fatty acid chain lengths of an oil. Gas chromatography (GC) was being developed, and home-made instruments were built to screen the world's rapeseed germplasm. With no computers or integrators, each GC peak had to be triangulated and measured by hand. We were fortunate to identify a poorly adapted European forage variety with a much-reduced level of erucic acid. Through selection and breeding the first low-erucic *B. napus* variety, 'Oro,' was developed in 1968, producing an entirely new but natural oil (Table 2). The change in fatty acid composition was achieved by genetically blocking the biosynthetic pathway for fatty acid carbon-chain elongation, from oleic to eicosenoic to erucic, as the oil is laid down in the developing seed. Pilot-plant tests indicated that the new oil was ideal as a salad and cooking oil, and steps were taken to contract its production. Unfortunately, that year tanker loads of sunflower oil were dumped by the Soviet Union on the world market and those plans were shelved. Despite this setback, the breeding program to develop a low erucic *B. rapa* variety was continued, producing the first low erucic variety, 'Span,' in 1971.

Nutritional studies on rapeseed oil continued and in the fall of 1970 the Second International Rapeseed Congress was held in Canada. Nutritionists in Europe and Canada reported abnormal numbers of heart lesions in laboratory animals fed high levels of rapeseed oil. The high content of erucic acid was considered the cause. Again we were in danger of losing our markets. Agriculture Canada immediately made the decision to take what little seed we had of the low-erucic varieties of both species for winter increase in California. The returning seed was sown in the spring of 1971 and the total conversion of the 4-million-acre crop was underway. With the cooperation of the entire industry, the conversion was complete by 1973. As indicated by the earlier pilot-plant tests this entirely new, edible oil was found to have superior properties as a salad and cooking oil as well as being suitable for margarine and shortening blends. As a result, domestic use increased from 19% in 1970 to 49% in 1997 (Fig. 1).

Opening of the US Market

Although the switch to the low-erucic oil removed the stigma from Canadian rapeseed oil, the United States market was closed to canola because rapeseed oil had never been in widespread use there and was not included in the US "GRAS" list of foods (generally regarded as safe). Since the US market was potentially very large, the industry requested that research required to obtain GRAS status be undertaken. A large body of nutritional data was assembled and the petition was successful; GRAS status was granted in 1985. The results of these studies were compiled and published in a book, *High and Low Erucic Acid Rapeseed Oils* (Kramer *et al.*, 1983).

The opening of the US market brought a surprise. We breeders had bred better than we knew. Nutritionists decided that oils high in polyunsaturated fatty acids were no longer the "best" for human consumption. Further, for good health, saturated fatty acids were to

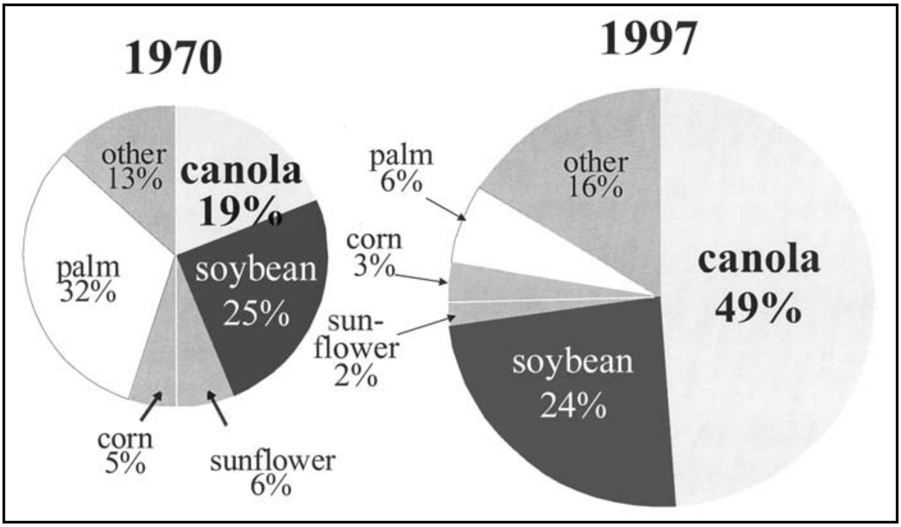

Figure 1. Canadian vegetable-oil usage

be avoided. Since low erucic rapeseed oil had the lowest content of saturated fatty acids of any vegetable oil (Fig. 2) it attracted the interest of large food companies. In addition to the low saturate level, the new oil also had a high concentration of the monounsaturated fatty acid oleic, which lowers the undesirable low density lipoproteins (LDLs) without affecting the desirable high density lipoproteins (HDL's) while retaining suitable levels of the essential, polyunsaturated fatty acids, linoleic and linolenic. Thus the oil was quickly promoted as a highly nutritious specialty oil, receiving the American Heart Foundation's 1989 Food Product of the Year Award and the American College of Nutrition's 1989 Product Acceptance Award.

Decreased Linolenic Acid

As successful as the new oil was, the industry wanted a reduction in the level of linolenic acid from the standard 8 to 10% to less than 3% of the total fatty acids to improve its keeping quality and to reduce the need for hydrogenation. This was accomplished through mutation breeding and the first low-linolenic variety, 'Steller,' was released in 1985. Now company breeders have taken it one step further and produced varieties with an even higher level of oleic acid coupled with low linolenic acid values (Table 3). This oil is gaining rapid acceptance both in North America and Japan and in time will likely make up about half the canola market. A further nutritional improvement will likely soon appear since Dow AgroSciences has patented a canola oil for which they claim zero saturates (Table 3).

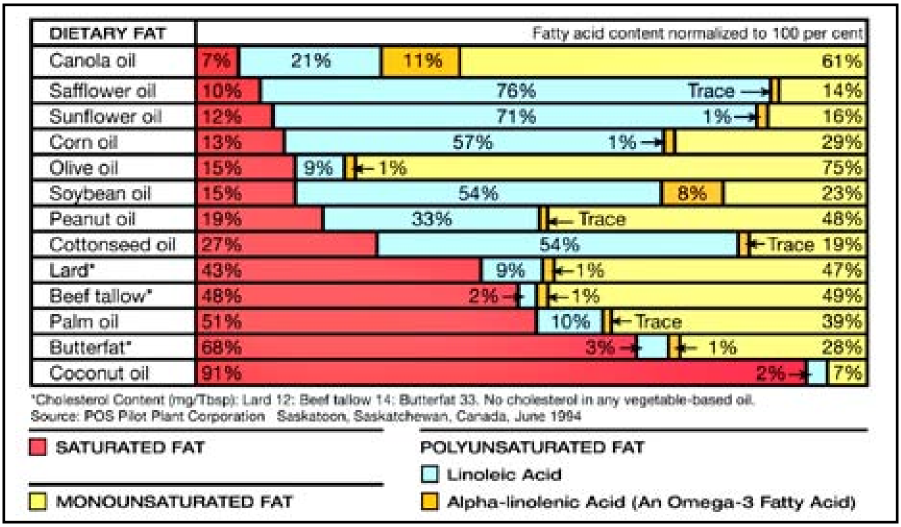

Figure 2. Comparison of dietary fats.

Table 3. Fatty acid composition of normal and modified rapeseed/canola oil in commercial production

Oil type	Fatty acid composition (%)							
	16:0	**16:1**	**18:0**	**18:1**	**18:2**	**18:3**	**20:1**	**22:1**
Canola	4	<1	2	62	20	9	2	<1
Low linolenic	5	<1	2	64	25	<3	1	<1
High oleic/Low linolenic	4	<1	2	78	12	2	<1	<1
Zero saturate	<1	<1	<1	85	12	2	<1	<1
High erucic	2	<1	2	13	12	9	7	54

Meal Utilization

Although the development of a superior edible oil was achieved by 1971, a major market constraint remained, namely the utilization of the high-protein meal remaining after oil extraction. Even though the protein quality of rapeseed meal was equal to that of soy meal, feed efficiency and weight gains with swine and poultry were well below expected levels. This restricted the amount of meal that could be fed and, in turn, limited the amount of seed that could be processed. The problem was associated with the presence in the seed of glucosinolates. These sulphur compounds, of which about ninety are known, give the desired flavor and odor to cabbage, turnips, mustard and other cruciferous crops. However, the plant accumulates and concentrates these compounds in the seed, typically at 100 to 150 *µ*moles/g. As a result, the nutritional value and palatability of the meal is reduced when fed to non-ruminants such as swine and poultry.

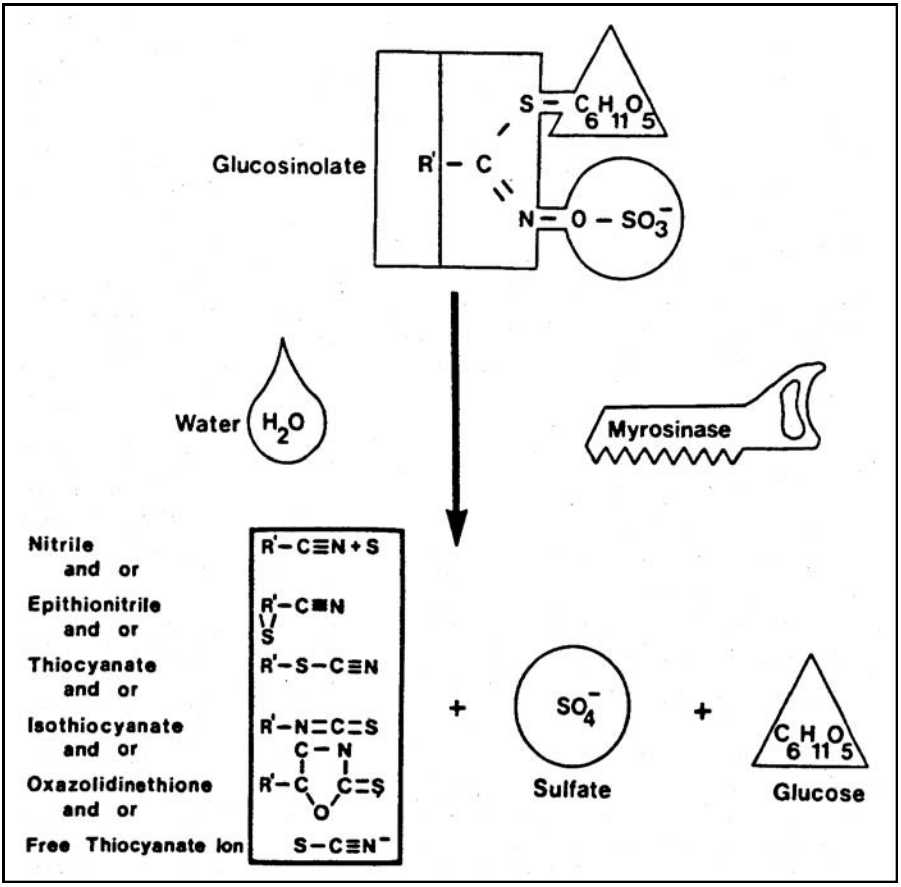

Figure 3. Products of myrosinase hydrolysis of the glucosinolates.

When the cells of rapeseed are broken with moisture present, the glucosinolates are hydrolyzed by myrosinase—an enzyme present in all cruciferous seeds—and sulphur, glucose and isothiocynates are released (Fig. 3). The isothiocyanates are active goitrogens that interfere with iodine uptake by the thyroid gland in swine and poultry, resulting in goiter and poor growth. Early studies showed that the problem could be partly overcome by heat inactivation of the enzyme as the first step in the oil-extraction process. However, some hydrolysis still occurred in the gut. Thus, the ultimate objective was to breed varieties free of glucosinolates. Again, new chemical methodologies had to be developed to rapidly and accurately measure the amounts of the various glucosinolates in small samples of seed. Using these new techniques, breeders were able to genetically block the glucosinolate biosynthetic pathway from the methionine and tryptophane precursor amino acids, resulting in the first low-erucic, low-glucosinolate variety of *B. napus*, 'Tower,' in 1974. However, it took another 3 years to produce the first double-low *B. rapa* variety, 'Candle,' so that the second complete crop changeover could occur.

Global-Market Acceptance

By 1980, the 5-million acre commercial crop was largely converted to the new double-low varieties, thus removing the constraint associated with the feeding of the meal. Animal nutritionists at several universities conducted extensive studies to convince both domestic and foreign feed formulators that the low glucosinolate meal was, indeed, a safe, wholesome and economic high-protein supplement. Eventually Europe, using Canadian germplasm, converted to canola-quality varieties in 1988–1989 and Australia in 1990, while China, India and Pakistan are expected to achieve conversion within the next decade. The market impact of these quality modifications was dramatic, not only domestically (Fig. 1) but also for exports of oil and meal (Fig. 4) as well as seed (Fig. 5). Improvements in seed yield as well as quality resulted in a better return to producers and an expanding production base (Fig. 6). Surprisingly, these significant quality changes were made without adversely affecting the overall agronomic performance of the crop. From the outset in this series of crop changes, Canada consulted closely with its major customer, Japan, meeting with counterparts at least twice a year.

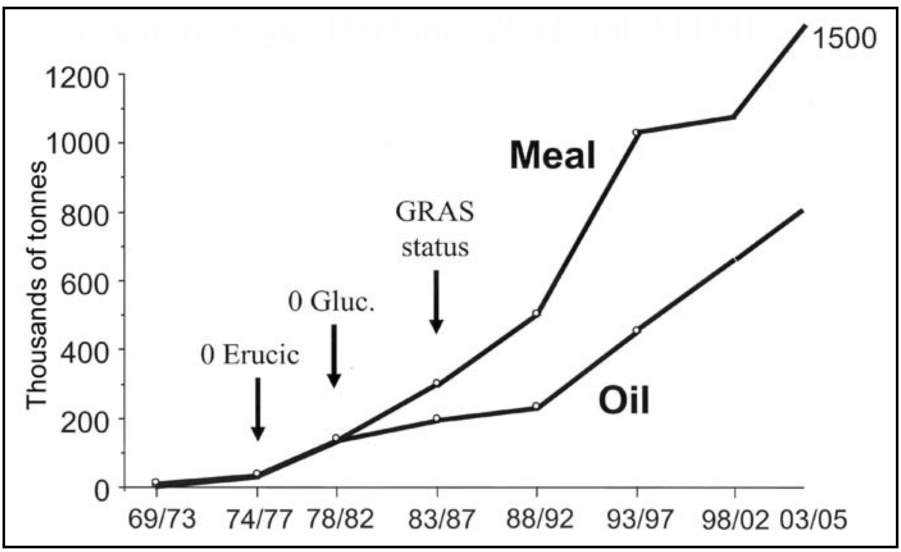

Figure 4. Five-year averages of Canadian rapeseed/canola oil and meal exports.

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"Canola" Coined

As a result of the nutritional upgrading of the oil and meal, a new name was required to distinguish these products from the old-style rapeseed. "Canola" was coined, trademarked and defined as seed, oil or meal having less than 2% erucic acid in the oil and less than 30 μmole/g of aliphatic glucosinolate in the oil-free, moisture-free meal. This definition is due to be further refined to better reflect today's commercial crop. The new definition reduces the erucic acid content to less than 1% and establishes a maximum of 18 μmole/g of all glucosinolates in whole seed. In the oil-free meal, the maximum will be 30 μmole/g, with both seed and meal at 8.5% moisture. As a result of reducing the glucosinolate content from the original 100 to 150 μmole/g, canola meal can now be fed as an economic high-protein supplement.

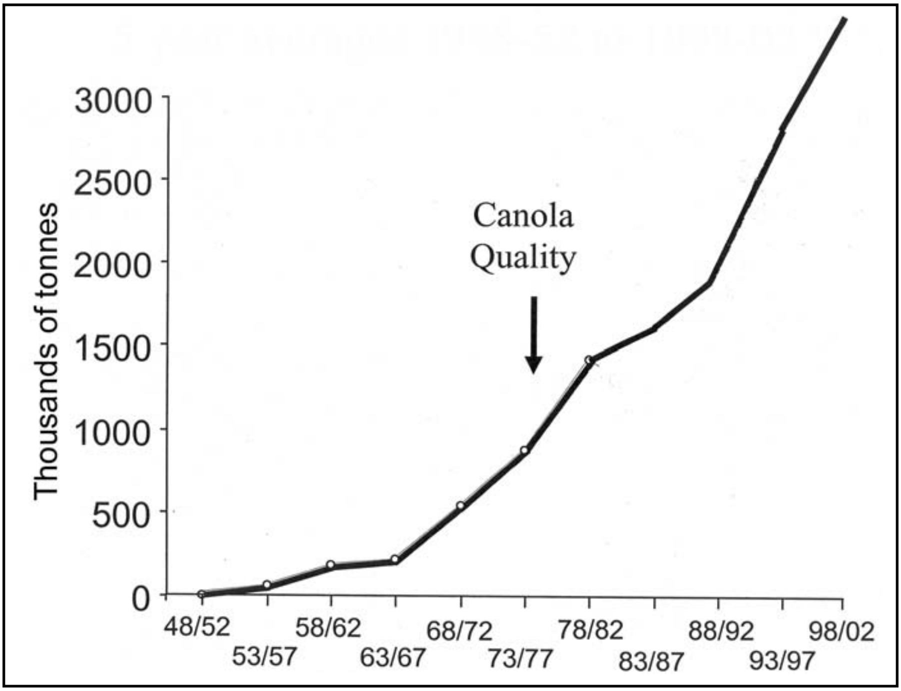

Figure 5. Five-year averages of Canadian rapeseed/canola exports.

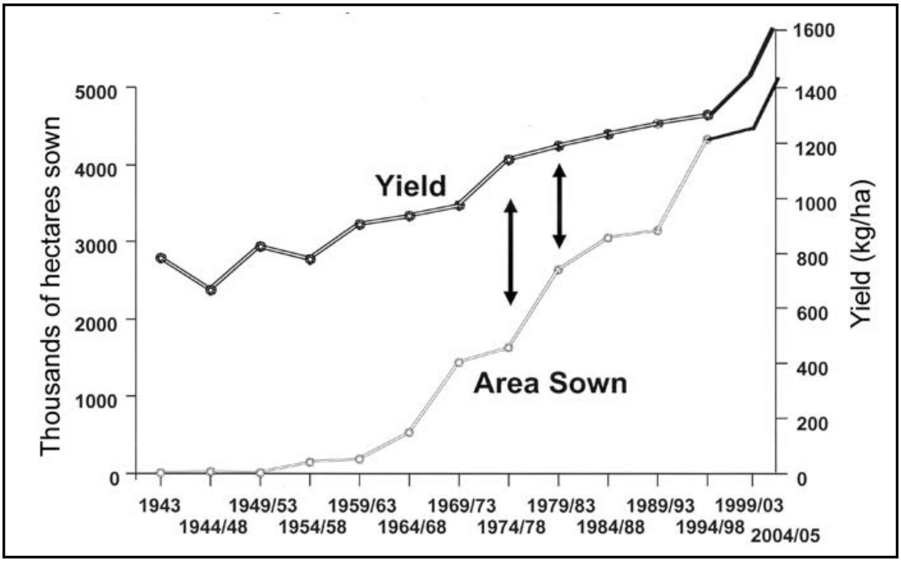

Figure 6. Five-year averages of area sown and yield of rapeseed/canola.

The development of canola is considered a success story because it diversified Canada's agriculture base, eliminating dependence on oil imports and increasing returns to producers while expanding markets at home and abroad. In addition, it resulted in the establishment of a large rural-based, value-added oilseed crushing and refining industry. Eight canola-oil extraction plants are now distributed across the prairie provinces, processing some 3 million tonnes/year of seed, with expansion planned or under way. Canola has also responded to all the biotechnologies with 90% of the crop herbicide-tolerant; hybrid varieties now occupy about 30% of the area planted. The story is not over yet as canola is a preferred biodiesel oil source for northern climates because of its low content of saturated fatty acids.

Reference

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Further Reading

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KEITH DOWNEY was born in Saskatoon, Saskatchewan. He obtained his BSA and MSc from the University of Saskatchewan and PhD from Cornell University. He joined Agriculture and Agri-Food Canada in 1951 where he developed many outstanding rapeseed/canola and condiment mustard varieties. He is widely known as one of the "fathers" of canola and has been instrumental in improving nutritional quality and customer-acceptance of oil and meal from *Brassica* oilseed crops. He has authored over 200 scientific and technical papers, several book chapters and co-edited the book *Oil Crops of the World*.

Dr. Downey has received numerous awards and medals including Officer of the Order of Canada, Fellow of both the Royal Society of Canada and the Agriculture Institute of Canada, the Eminent Scientist Award from the Internation Rapeseed Congress, the James McAnsh Award from the Canola Council of Canada and the Clark-Newman Award from the Canadian Seed Growers Association. Recently, he was inducted to both the Saskatchewan and the Canadian Agriculture Halls of Fame.

In recent years, as senior research scientist emeritus at the Agriculture and Agri-Food Canada Research Centre in Saskatoon, Downey has investigated the impacts on agriculture of biotechnology and gene-flow.