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From R&D to Export

Canola Development as a 'Resilient Success'

Matt Wilder

Introduction

Canola was not always the successful crop it is today. Rather, its development and commercialization are relatively recent. The 'canola' moniker was coined in 1978 as a means of differentiating plants that produce oilseeds with desirable attributes from traditional rapeseed. Since then, canola has evolved from a limited-use crop, the oil and meal of which was objectionable to the senses and possibly hazardous to human health, to one of the most popular, versatile, and healthy oilseeds. Canola is also one of a handful of crops that has been subject to genetic engineering.

This chapter proceeds in two steps. The first step traces the evolution of canola from its war-time use as a marine engine lubricant to a popular edible oil with novel industrial applications. The second step evaluates the success of Canadian policy towards canola in light of the programmatic, political, process, and endurance (PPPE) criteria laid out in the introduction to this volume. The thesis is that Canadian policy towards canola constitutes a 'resilient success'. This evaluation stems from the fact that, although policy towards canola encountered some modest opposition and some incidence of programmatic failure, neither has been sufficient to seriously undermine the overall track record of the policy or its continuation. Accordingly, Canadian canola development serves as an example of successful and resilient innovation and industrial policy in a liberal setting.

What accounts for the resilient success of Canadian canola policy? On one hand, canola development has been successful because policy in support of the crop has been consistent with Canada's institutional comparative advantage (cf. Hall and Soskice, 2001). Specifically, Canadian institutions permit governments and firms to pursue risky policies and radically-innovative technologies relatively unencumbered by opposing forces in society. The same cannot be said for many countries in Europe and East Asia, where opposition to transgenic crops has been both more pronounced and more effective than in North America. Moreover, to the extent that liberal institutions create potential pitfalls—namely opportunities

Matt Wilder, *From R&D to Export.* In: *Policy Success in Canada.*
Edited by Evert A. Lindquist et al., Oxford University Press. © Matt Wilder (2022).
DOI: 10.1093/oso/9780192897046.003.0015

for policy-makers to impose unreasonable costs on society—Canadian policy towards canola also benefited from co-production and private regulation, which has internalized considerable cost and risk within the beneficiary group. Government involvement has been largely limited to a supportive role, which has encouraged industry actors to take the initiative in steering the development of the technology.

On the other hand, lack of effective political representation on the part of environmentalists and organic producers created policy losers of these groups. In response, opposition groups have engaged in venue shifting tactics intended to bring potential drawbacks of canola policy to the attention of the media and the courts. While opposition groups have been unsuccessful in achieving policy change, their tactics have entailed costs for commercial interests invested in transgenic crops.

From R&D to Export

Following Phillips (2018), I document four stages of the Canadian canola industry from genesis to maturation (see also Gray et al., 2001). The first stage spanned the 1943–1967 period and was dedicated to basic research conducted predominantly in government and university labs. The second stage, from 1967 to 1973, witnessed the organization of industry associations dedicated to branding, market research, outreach, and extension. In the third stage, between 1974–1990, the initial product was perfected, transgenic processes were introduced, and private actors became noticeably active in the industry. The fourth and final stage, from 1990 to the present time, saw the clearing of regulatory hurdles and concomitant exploitation of canola's potential with respect to herbicide-tolerance, yield improvement, hardiness, genomics, gene editing, and novel applications. The fourth stage also culminated in the vertical integration of the industry in private multinational corporations.

Basic Research in the Public Sector, 1943–1967

The first phase of canola development was characterized by basic research in public laboratories. Basic research takes the form of a public good whenever circumstances prevent private firms from capturing adequate returns on investment (Arrow, 1962; Nelson, 1959). Early canola varieties were not conducive to private investment due to small acreage and because returns were not sufficiently appropriable. The seeds from newly discovered plants with novel traits could be harvested and sown free of charge. It was only with the advent of hybrid canola and technology stewardship agreements in the 1980s and 1990s that private research and development became profitable (Gray et al., 2006).

Canadian production of rapeseed began with a garden crop planted in Shellbrook, Saskatchewan in 1936. In the early years, given its unpalatable flavour, colour, and odour, rapeseed oil was used primarily as a marine engine lubricant, while its meal was used as animal feed and fertilizer. Allied naval demand for Canadian rapeseed oil spiked during World War II when European and Asian supplies were cut off. To supply the war effort, the first commercial scale rapeseed crops were planted in 1942 in Saskatchewan and Manitoba. The effort was overseen by the Forage Crop Division of the Federal Department of Agriculture.

Scientific research on rapeseed began shortly after the wartime scale-up at federal government laboratories in Saskatoon and the University of Manitoba in Winnipeg. The development of a new method of analysing rapeseed oil by B.M. Craig at the National Research Council lab in Saskatoon led to the discovery by Keith Downey and B. Stefansson of plants that exhibited low erucic acid (McLeod, 1974). This was a major breakthrough, as erucic acid is one of two characteristics that make conventional rapeseed nutritionally undesirable, the other being high levels of sulphur compounds called glucosinolates (Boulter, 1983).

Quality improvements regarding erucic acid content created the necessary conditions for largescale commercialization. Although early entrants in the rapeseed business did not have much commercial success, those that remained enjoyed first mover advantages. This group included the Prairie Pool cooperatives, United Grain Growers, Western Canadian Seed Processors, and Canada Packers (now Maple Leaf Foods). The Prairie Pools had a marketing arrangement with Sweden's Svalöf (later acquired by BASF) dating back to the 1950s, which facilitated seed marketing on the part of the Pools. To increase oil production and assist officials in the war effort, crushing operations were established in the late 1940s. Through a joint commercial venture, the Saskatchewan, Manitoba, and Alberta Pools entered the commercial crushing business in 1956 with the establishment of Agra Vegetable Oil (later CSP and Canamera). The same year, rapeseed production spread to Alberta and, in 1960, Western Canadian Seed Processors opened a crushing plant in Lethbridge.

During this period, federal and provincial governments also started offering extension services related to rapeseed, which entailed relaying information to farmers based on results obtained on demonstration farms set up to field test new varieties. In time, universities and agriculture colleges in Alberta, Saskatchewan, and Manitoba joined federal and provincial governments in their research and extension efforts. Extension work was necessary for the success of the crop, as the farm acreage devoted to rapeseed was meagre, amounting to less than 1 per cent market share in the years following World War II (Phillips, 2018, 102).

In the late 1950s, Canada Packers' Toronto and Montréal facilities began producing bleached and deodorized shortening and salad oils from rapeseed supplied by the Prairie Pools. Obtaining regulatory approval for human consumption of

rapeseed oil proved challenging, however. To that end, Canada Packers developed a relationship with the Edible Oils Institute, a Washington-based trade association, to lobby the Canadian government for product approval of margarine and shortening made from rapeseed oil against countervailing pressure from the dairy industry.

In 1965, examination of oil samples from four Western Canadian crushers led to the establishment of initial quality standards by the Edible Oils Institute, which were adopted by the Canadian Government Specification Board (McLeod, 1974). The establishment of quality standards for rapeseed coincided with the formation of the Rapeseed Association of Canada. The emergence of an official organization focused solely on the development of the rapeseed industry marked a new chapter in the story of canola development. Up to that point, industry actors were primarily interested in other agricultural products, having entered the rapeseed business as a means of diversifying their product lines. By 1965, conditions were right for the establishment of a dedicated industry.

Collaboration in Research and Development, 1967–1973

Two objectives defined the second stage of canola development. One objective involved the continuation of basic research in pursuit of plants with novel traits, including improved yield. The other objective entailed an acceleration of applied research on the amenability of novel rapeseed varieties to field conditions. Both basic and applied research involved collaboration between government, the newly formed Rapeseed Association of Canada, and universities. The major policy objective during this period was to convert rapeseed production to low erucic acid varieties, while the major research objective was to develop 'double-low' varieties that exhibited both low erucic acid content and low levels of glucosinolates. Urgency surrounding conversion to low erucic acid varieties followed from an alarming 1970 study that found conventional rapeseed oil caused heart and kidney damage in young animals. Although the findings were rebuffed by subsequent studies, the alarm created sufficient doubt in overseas markets about conventional varieties to accelerate action by government and industry towards low erucic acid varieties.

Following its establishment in 1965, the Rapeseed Association of Canada collected levies from producers on a voluntary basis and directed them towards product and market development, research, and extension. Saskatchewan and Manitoba established provincial associations shortly after the formation of the national association, followed by Alberta in the 1970s and Ontario in the late 1980s. The provincial associations were focused on extension, agronomy, and policy development, leaving the bulk of market development and pre-commercial research to the national association (Gray et al., 2001).

From 1971 to 1991, the Rapeseed Association of Canada's budget was also supplemented by a $12.5 million Rapeseed Utilization Assistance Program dedicated to pre-market research. The program was financed through the Federal Department of Industry on a matching basis with the Rapeseed Association of Canada. The federal government contributed between $200,000 and $350,000 per year, matched on a per dollar basis by the Rapeseed Association of Canada, the latter of which administered the research program in partnership with universities (Darcovich, 1973).

Two programs followed the discovery of low erucic acid producing plants in 1960. One program, undertaken between 1971 and 1974 by the Federal Department of Agriculture and the Federal Department of Health and Welfare, involved a concerted effort to convert rapeseed production to low erucic acid varieties. The other program was dedicated to the discovery and development of double-low varieties containing both low levels of erucic acid and low levels of glucosinolates, which was accomplished in 1974 when University of Manitoba scientists, B.R. Stefansson and Z.P. Kondra, developed the variety *Tower* using low glucosinolate material developed by researchers in Saskatoon. The development of *Tower* prompted the Rapeseed Association of Canada to register the canola trademark in 1978 as a designate for rapeseed containing less than 5 per cent erucic acid and less than 3mg per gram of glucosinolate. With the registration of the canola trademark, the association changed its name to the Canola Council of Canada and began researching and promoting the health benefits of canola.

There remained work to be done, however. Although initial canola varieties exhibited desirable double-low characteristics, there was a price to pay in terms of diminished yield. This 'yield drag' was not in any way related to the plant's double-low characteristics but was rather a consequence of other genetic baggage inherited from varieties in the plant's genetic lineage. It was often the case that improvements on one dimension, such as oil quality, involved trade-offs on other dimensions, such as yield and disease resistance. For instance, the high-yield variety *Westar,* developed by Agriculture Canada, dominated canola acreage for a period in the 1980s but was susceptible to blackleg fungus, which later migrated from Australia.

After the introduction of double-low rapeseed in the mid-1970s, overcoming the next obstacle required finding ways to select and exploit desirable traits without the accompanying genetic frailties. Hybrid plant breeding and transgenics were two means of achieving this objective. Although public sector research continued play a role in hybrid development and genomics, the economics surrounding these varieties were conducive to private sector research and development as well. Whereas conventional canola plants produce seeds that can be harvested and planted year after year, hybrid seed must be purchased by producers every season. For non-hybrids, the advent of licensing agreements also enabled commercial entities to capture returns on investment. Transgenic varieties were especially

well-suited to licensing agreements, as seed could be sold to producers as part of a package containing broad-spectrum herbicide and seed specifically engineered to tolerate it.

Public–Private R&D Partnerships, 1974–1990

Public-private research and development partnerships characterized the third stage of the canola saga. As a consequence of decades of public sector canola research at Agriculture Canada and the National Research Council laboratories, the federal government owned substantial stocks of canola germplasm. This publicly-owned genetic material came to be valued by private sector actors looking to invest in canola. Private research on hybridization and transgenic techniques made strides in the 1980s, but required canola germplasm held by the government to become commercially viable. Public-private partnerships were thus forged with the purpose of bringing together the fruits of basic research conducted by the public sector with new discoveries made in private labs. During this period, government's role shifted from in-house plant breeding and commercialization to industry support and partnerships.

As Canadian researchers were busy developing the first double-low canola varieties, a world-changing event took place in 1973 when American scientists, Stanley Cohen and Herbert Boyer, successfully transplanted recombinant DNA between bacteria *in vitro*. Following the Cohen-Boyer discovery, initial success in transgenic agricultural biotechnology revolved around four plants: carnations, petunias, tobacco, and canola. As one confidential interviewee put it, 'canola was the only food crop, so it got a lot of people's attention.'[1]

In response to the emergence of transgenics, the Government of Canada convened a private sector taskforce in 1980 to assess the industry's potential to exploit new avenues in biotechnology. The taskforce reported favourably in 1981 and a national biotechnology strategy focused on food, forestry, and energy was implemented in 1983. The National Research Council was the lead entity for the national biotechnology strategy. The Government of Saskatchewan assembled its own council on biotechnology in 1981, and a provincial biotechnology policy was announced in 1985. Alberta, Manitoba, and Ontario announced their own provincial biotechnology policies shortly thereafter.

At the federal level, Agriculture Canada put in place complementary programs at its Ottawa and Saskatoon labs, whereby the Ottawa group focused on inserting genes and recovering transgenic plants while the Saskatoon group concentrated on the acceptance of new varieties to field conditions. Researchers from the Saskatoon and Ottawa groups met once a year to compare notes and communicate priorities.

[1] Confidential telephone interview conducted by the author, 2 January 2017.

Agriculture Canada's Ottawa labs also hosted several industrial scientists from multinational corporations as part of the Foreign Investment Review Agency (FIRA) mandate put in place by the government of Pierre Elliot Trudeau in 1973.

At the Ottawa lab, Agriculture Canada researchers worked with a visiting industrial scientist from the German agrochemical firm, Hoechst, on inserting a herbicide-resistant gene owned by Hoechst into canola germplasm. The effort was a success, resulting in the first transgenic herbicide-tolerant variety, *Innovator*. This discovery set the stage for Agriculture Canada plant breeders in Saskatoon to transfer herbicide-tolerance to superior germplasm. The partnerships between Hoechst and Agriculture Canada's Ottawa and Saskatoon labs ultimately led to the commercialization of the herbicide-tolerant *Liberty Link* system in 1995, which was produced by Hoechst's successor company, AgrEvo, and marketed through the Prairie Pools as a package consisting of glufosinate herbicide and seed engineered to withstand it. Meanwhile, two other herbicide-tolerant systems were developed by American seed and chemical companies. One was Monsanto's *Roundup Ready* system, which employed transgenics and the herbicide glyphosate. The other was Pioneer Hi-Bred's *Pursuit* system, which was based on a non-transgenic process called mutagenesis, and compatible with both imidazolinone and sulfonylurea herbicides.

The transgenic technology required to develop Monsanto's *Roundup Ready* canola originated at Calgene, a southern California start-up that had patented agrobacterium transgenic processes in the early 1980s. From the beginning, researchers at Calgene were interested in developing transgenic plants resistant to glyphosate, the active ingredient in Monsanto's *Roundup* herbicide, which had been used as a general purpose weed-killer and for chemical fallowing since 1976. Yet, according to interview respondents, Calgene began working on canola after discussions with investigators affiliated with Agriculture Canada's Ottawa lab.[2] In 1989, Calgene researchers filed a patent for the 'transformation and foreign gene expression in brassica species'. This, and a similar patent filed in 1992, led to the commercialization of *Roundup Ready* canola in 1996, which was marketed by Monsanto as it completed its acquisition of Calgene.

Regarding Pioneer Hi-Bred's *Pursuit* system, the story began in Ontario with the establishment of a provincial biotechnology strategy and a company called Allelix in 1983. Allelix started out as a joint venture between Labatt Ltd., the Canadian Development Corporation, and the Government of Ontario. Although the company's initial strategy was consistent with government objectives to pursue biotechnology in agriculture, forestry, and energy, Allelix dropped energy and forestry from its portfolio in 1984 and focused its attention on specialty chemicals, fermentation, and plant breeding involving corn and potatoes. After consulting

[2] Confidential telephone interview conducted by the author, 22 February 2021.

with Wallace Beversdorf, a plant scientist at the University of Guelph, Allelix adjusted its plant breeding program towards canola. Shortly thereafter, Allelix hired Larry Sernyk from B.R. Stefansson's lab at the University of Manitoba, which had acquired cytoplasmic male sterility technology, useful for cultivating hybrids, from China.

Although more costly to grow, hybrid canola is superior to open-pollinating varieties in terms of yield and potential for specialty oil development. According to one interviewee, even if one could get open pollinated seed for free, it would still be more economical to purchase hybrid seed every season.[3] In 1985, Allelix entered a joint venture with the United Grain Growers marketing cooperative to develop canola hybrids. The following year, Allelix entered into an agreement with Weibull AB of Sweden to diversify its stock of canola germplasm, exchanging germplasm held by Weibull for a hybridization system owned by Allelix. Although production of specialty oil was not perfected until later, Allelix was an early mover in specialty oil and had entered negotiations in 1987 to supply Frito Lay with high stability oil engineered to extend the shelf-life of packaged fried foods.

Production of specialty oil depended on a process called mutagenesis, which involves chemically treating plants for the purpose of altering genetic composition. Mutagenesis technology gave Allelix an early edge over competitors working with transgenes, as transgenic canola did not obtain regulatory approval until the mid-1990s. By contrast, mutagenesis was a well-established and accepted process in both North American and overseas markets. In 1987, Allelix entered into an agreement with the multinational chemical company Cyanamid to develop, through mutagenesis, canola resistant to its imidazolinone herbicide compound.

Allelix staff had some prior experience in non-transgenic herbicide-tolerance. Although discovered as a natural mutation—not via mutagenesis—the first herbicide-tolerant canola was developed in the late 1970s by the same University of Guelph researchers who ended up consulting with, or working for, Allelix. However, this 'triazine-tolerant' canola, which was commercialized by the University of Guelph in 1984, had unavoidable trade-offs regarding photosynthetic efficiency that diminished yield to such an extent that triazine-tolerant varieties were of little value.

Labatt and the Canada Development Corporation divested their shares in Allelix in 1990, and the company was sold to Pioneer Hi-Bred as part of the latter's effort to diversify its investment portfolio. Up to that point, Pioneer Hi-Bred had specialized in hybrid corn. The purpose of acquiring Allelix was to tap into hybrid canola and the specialty oils that could be produced from its seeds. The imidazolinone-tolerant system that materialized from the Allelix-Cyanamid venture was trademarked *Pursuit* by Pioneer in 1990. The complementary seed

[3] Confidential telephone interview conducted by the author, 6 September 2020.

was marketed as *Delta* by United Grain Growers, which maintained its former marketing relationship with Allelix after its acquisition by Pioneer.

Besides providing canola germplasm as a public good, the government also provided infrastructure and absorbed costs associated with coordinating the industry. In 1983, as part of the national biotechnology strategy, the federal government expanded the National Research Council Prairie Regional Lab to establish the National Research Council Plant Biotechnology Institute at the University of Saskatchewan, which incubated several commercial start-ups. In 1987, the Saskatchewan Research Council opened Genserv, a public genetics lab oriented towards commercialization. In 1989, the Saskatchewan government established Ag-West Biotech Inc, a government-subsidized, independent, not-for-profit company with a mandate to coordinate the sector. The Saskatchewan Economic Development Corporation (SEDCO) also invested several hundred million dollars in Innovation Place. Originally built in the late 1970s to attract and incubate an information technology industry in Saskatchewan, Innovation Place was reoriented towards agricultural biotechnology in the early 1980s. Innovation Place continues to house the core of the Saskatchewan agricultural biotechnology cluster.

While government provision of public goods was a major factor in canola development, the importance of a favourable regulatory environment should not be discounted. Phillips (2001) attributes the emergence of the Canadian agricultural biotechnology industry to the amenability of Canadian law to the new technology, namely intellectual property rights, and Canada's regulatory approval of transgenic crops. Although intellectual property rights for whole plants were not established in Canada until 1990, and although regulatory clearance for transgenic crops was not granted until 1995, Phillips argues that expressed intentions from the late 1970s onward were sufficient to both stimulate private activity in agricultural biotechnology and attract private firms to Canada. While a favourable regulatory environment may have been necessary to prompt investment, regulation alone was insufficient to mobilize the industry. Whereas the third stage was predominantly characterized by voluntary partnerships, the fourth phase of canola development was marked by active policy measures to attract firms with competence in hybridization, transgenic processes, and agrochemicals to Canada.

Regulation and Consolidation, 1990–Present

Buoyed by early success with herbicide-tolerant and hybrid canola, the Saskatchewan government arranged for several foreign firms to establish operations in Saskatoon by offering grants, loans, and equity financing as part of its Partnership for Renewal (Saskatchewan, 1992). According to interviewees, this

policy of enticing firms with technical know-how to locate in Canada was encouraged by the scientific community, which believed that geographic dispersion of technical expertise hindered the uptake of innovation in the canola sector.[4] This foreign investment strategy coincided with the push among industry actors to obtain regulatory approval for new plants and agrochemicals. Consistent with the argument from Phillips (2001) summarized above, federal amenability to transgenic crops was signalled, first, by the 1983 National Biotechnology Strategy and, subsequently, by the government's Agricultural Policy Framework and Growing Forward strategies (Canada, 2008). These policies also permitted the consolidation of the industry in a limited number of multinational corporations.

Financing came from a variety of sources. The Royal Bank of Canada (RBC) and the Canadian Imperial Bank of Commerce (CIBC) partnered with the federal Department of Western Economic Diversification in the early 1990s to supply seed money to knowledge-based industries. Provincial funding was also funnelled through government investment entities, like the Saskatchewan Economic Development Corporation (SEDCO), and Crown Investment Corporation (CIC), as well as the government-subsidized but private not-for-profit organization, Ag-West Biotech Inc. Ag-West has operated as a coordinating, networking, and investment entity since 1989, and absorbed the International Centre for Agricultural Science and Technology (ICAST) investment portfolio in 1997. There were also direct government subsidies from various funds administered by government ministries. Although investments made through government investment bodies and Ag-West were not expected to be lucrative, the fact that investments were extended as loans (as opposed to subsidies) allowed some expenses to be recouped. Of the $11.97 million invested by Ag-West from 1989 to 2012, Smyth et al. (2013) found $4.75 million had been repaid. With ICAST write-offs omitted from the calculations, Ag-West's investment recovery rate was 50 per cent.

The Pool cooperatives and growers' associations also devoted significant portions of their budgets to research and development partnerships. Producer associations ramped up their involvement in research and development just as large agrochemical businesses turned their attention to canola in the late 1980s. To finance their research and development efforts, producer associations in Alberta, Saskatchewan, and Manitoba implemented mandatory levies of $0.50 per tonne of canola seed for growers, crushers, and exporters in 1989, 1991, and 1996, respectively (Gray et al., 2001, 100–101).

Whereas investments by producer associations were primarily oriented towards pre-commercial research and development, investments undertaken by government, Ag-West, banks, and the Prairie Pools were directed mainly towards commercial production. Four investments in particular attracted firms with competence useful to the industry to locate their operations to Saskatchewan. The first

[4] Confidential telephone interview conducted by the author, 22 November 2018.

was an investment in Plant Genetic Systems of Belgium organized by the government through the Royal Bank in 1993. The purpose of this investment was to access proprietary genetic markers owned by Plant Genetic Systems. The second investment, the following year, transferred $6 million from SEDCO to French seed giant, Groupe Limagrain, which located its $13 million global canola research centre in Innovation Place as a result. The third major investment was a $500,000 ICAST and Ag-West enticement to US-based Mycogen, owner of several *Bt* genes, in 1997. The fourth investment, executed in 1999, transferred $7.6 million from SEDCO and CIC to the Canadian plant acclimation firm, Performance Plants.

Other notable investments included a ten year strategic alliance between Dow Agrosciences and the National Research Council's Plant Biotechnology Institute to enhance canola seed quality; a 1996 Saskatchewan Wheat Pool partnership with Calgene to exploit complementarities between the former's proprietary germplasm and the latter's transgenic patents; a follow up 1997 investment in Plant Genetic Systems worth $600,000 undertaken by Ag-West for hybrid development; and a 1992–1996 partnership between Ag-West, Western Economic Diversification, Saskatchewan Wheat Pool, and Canamera to develop *Brassica juncea*—a tame mustard species closely related to canola. Hoechst and its successor, AgrEvo, also channelled funding through Western Economic Diversification and the North American Biotechnology Initiative (NABI) to its Saskatoon operations, which is reported by an anonymous interviewee to have 'propelled [Hoechst-AgrEvo] into becoming a significant player in canola development'.[5] Other companies, such as Allelix, DuPont, Ciba-Geigy, Procter and Gamble, and Zeneca have also received assistance through government ministries. Meanwhile, efforts to entice Pioneer and Cargill to set up operations in Innovation Place were unsuccessful, although both established operations in Saskatoon.

This is not to say that all investment in the fourth phase of the industry's development ended up in Saskatchewan. As already discussed, Pioneer Hi-Bred's operations were concentrated in Southern Ontario following its acquisition of Allelix in 1990. Moreover, as Monsanto began its acquisition of Calgene in the early 1990s, Calgene's top canola scientist, Maurice Moloney, was attracted to the University of Calgary in Alberta. Moloney went on to establish a company called SemBioSys Genetics at the University of Calgary, which focused on medical applications using canola and safflower. Limagrain and Performance Plants have also since relocated to Ontario.

Not all of the investments undertaken by government and industry paid dividends, either. For instance, a partnership between Rhone Poulenc, Svalof, and the University of Manitoba to develop varieties resistant to bromoxynil herbicides fell short of commercial success. For its part, *Brassica juncea* never gained much of a foothold in terms of acreage, despite a concerted effort to develop varieties.

[5] Confidential telephone interview conducted by the author, 28 May 2021.

Likewise, *Brassica rapa* continued to command significant research attention even though it was crowded out by *Brassica napus* varieties in the 1990s owing to the latter's favourable characteristics regarding amenability to Canada's production intensive regions, input cost, yield, and disease resistance.

Regarding novel applications, Corteva, which was born from a merger of Dow and Dupont, has commercialized oil for use a wide range of food, industrial, and consumer products. Prior to the merger, Dow developed *Nexera* high stability fry oil for Frito Lay, after acquiring, through a series of mergers and acquisitions, mutagenesis technology originally developed by Allelix. Cargill has also emerged as a major player in specialized oil profiles derived through mutagenesis. University Technologies and Biomira, both associated with the University of Calgary, along with Mycogen, began exploring the use of canola in industrial oil and plastics in the early 1990s. Biomira was also involved in plant protein research for medical applications. Procter and Gamble, in partnership with Canamera and Calgene, began production of high-laurate canola under the trademark *Laurical* in 1997, which was used to make plant-based detergents. While high-laurate canola was abandoned on the basis that it could not compete with detergent made from palm oil, both industrial grade canola oil made from high erucic acid rapeseed (HEAR) and high-oleic fry oil have emerged as non-transgenic niche products.

Whereas commercial seed was traditionally handled as a bulk commodity, the development of 'boutique varieties' with novel traits meant that systems had to be created to segregate seeds destined for different markets. A major impetus for identity preserved production and marketing (IPPM) stemmed from the fact that European and Japanese markets had not registered transgenic canola varieties by the time these varieties became commercially available in North America (Smyth and Phillips, 2002). Consequently, continued access to overseas markets required systems for differentiating transgenic canola from conventional and non-transgenic boutique varieties, like HEAR and high-oleic fry oil. To that end, AgrEvo and Monsanto coordinated with the Canola Council of Canada to devise an IPPM system to prevent contamination of non-transgenic seed during shipping and handling (Smyth and Phillips, 2001).

While the IPPM system entailed significant costs for commercial actors, it proved insufficient due to severely restrictive tolerances being put in place by foreign regulators regarding trace amounts of transgenic material in imports of non-transgenic canola. As with any pollen-producing plant, pollen from transgenic canola can contaminate conventional canola crops, even when distances between transgenic and non-transgenic fields are great (Belcher et al., 2005). The general sentiment among industry representatives is that zero tolerance regulations exist primarily for protectionist purposes. This issue has not posed much of a problem for HEAR or high-oleic boutique varieties because the seed is crushed in North America before it is exported as oil or processed food products. Organic

producers, by contrast, have suffered as a consequence of externalities associated with transgenic canola. Yet, in 2003, when the Saskatchewan Organic Directorate launched a class action lawsuit against Monsanto and Aventis (later Bayer) for damages from crop contamination, the Saskatchewan Court of Appeal dismissed the application to certify the class and the Supreme Court of Canada declined to hear the case.

Although mergers and acquisitions have characterized agribusiness since its beginnings, the advent of biotechnology introduced a dose of competition to agricultural industries, as start-ups began to appear and as multinationals restructured their operations towards the emerging industry. Development of the know-how to exploit the potential of hybrid and transgenic canola led to the acquisition of start-ups by large multinationals and, subsequently, mergers and acquisitions among the large firms that remained. The Pool cooperatives also witnessed consolidation and privatization in the late 1990s. The Saskatchewan Wheat Pool severed its cooperative roots to become a publicly traded company in 1996. The Alberta and Manitoba pools merged in 1998 to form Agricore Cooperative Ltd. In 2001, United Grain Growers joined Agricore under the banner of Agricore United, at which point the venture ceased to be a farmer-owned cooperative. The Saskatchewan Wheat Pool then took over Agricore United, forming Viterra.

Consolidation of the industry was not entirely without critics. Some small farmer associations have lobbied against the federal government's Growing Forward policy for permitting the seed industry to become dominated by a few multinational corporations (National Farmers Union, 2013). Indeed, as of 2010, following the acquisition of Limagrain by Monsanto and the obsolescence of *Pursuit* (Pioneer has since licensed Monsanto's *Roundup Ready* gene), 47 per cent of the Canadian canola crop was seeded with *Roundup Ready* canola, while 46 per cent was seeded for use with the *Liberty Link* system, leaving only 7 per cent of the market to other varieties (Canola Council of Canada, 2010). Moreover, after acquiring controlling interest in Plant Genetic Systems in the late 1990s, AgrEvo was itself acquired by Aventis CropScience, which was then acquired by Bayer in 2002. Bayer's acquisition of Monsanto in 2018 would have given Bayer a virtual monopoly in the Canadian seed and chemical business were it not for a remedy ordered by the Canadian Competition Bureau that Bayer divest a portion of its assets related to research and seed production, which were acquired by BASF (Canada, 2018).

Some environmental critics have also been vocal opponents of Canadian policy towards canola. While unsuccessful in effecting major policy change, these critics have proven apt at drawing negative attention to the industry by appealing to the media and the courts. In 1998, upon being sued by Monsanto for violating its *Roundup Ready* licensing agreement, Saskatchewan canola farmer, Percy Schmeiser, launched a vigorous defence and $10 million countersuit with the support of Greenpeace. The case drew considerable media attention and public

debate about the perceived dangers of biotechnology, but ultimately ended with the Supreme Court of Canada ruling in Monsanto's favour.

More recently, emboldened by jury verdicts in the United States, several class action lawsuits have been launched against Monsanto and Bayer under the auspices that the *Roundup* glyphosate compound causes non-Hodgkin's lymphoma—a claim bolstered by the World Health Organization's controversial classification of glyphosate as 'probably carcinogenic to humans' (World Health Organization, 2015). As food companies and political jurisdictions consider restrictions or outright bans on glyphosate, it remains to be seen what damage may befall the many seed and chemical companies that license *Roundup Ready* canola.

A 'Resilient Success'

Canadian policy towards canola constitutes a 'resilient success' according to the programmatic, political, process, and endurance (PPPE) framework set out in the introduction to this volume. As per the following subsections, dimensions for evaluation include process success, program success, and political success. McConnell (2010) suggests ascertaining process success against four criteria: the extent to which government's policy goals and favoured instruments are preserved throughout the policy process; the extent to which the policy process is legitimate according to accepted norms of legitimacy; the extent to which policy is sustained by a durable coalition of supporting actors; and the extent to which the policy process encourages innovation. Program success reflects the extent to which outcomes are consistent with the objectives of government and stakeholders. Political success represents the extent to which political benefits of policy outweigh political costs, which entails 'marginalizing critics' and maintaining the 'broad values of government' (McConnell, 2010, 353).

Process Success

On the process dimension, although there have been refinements to the policy instruments surrounding canola development, changes have not seriously undermined policy objectives. For instance, certification of canola varieties was initially handled by a division within Agriculture Canada but was transferred to the newly created Canadian Food Inspection Agency in the early 1990s. This change arguably slowed, but did not stop, the approval process for new varieties. Previously, the agriculture policy community monopolized the agenda with a strong focus on the science of quality improvement. Relinquishment of this policy monopoly ushered in a more cautious approach, which coincided with the loss of autonomy for scientists and a concomitant increase in management. As one interviewee lamented, 'science in the government labs used to be driven quite heavily by the scientists, but

somewhere a decision was made that you need managers … consequently, Canada has a lot of bureaucratic inertia, and a lot of it has to do with the fact that the people in charge are general managers, not specialists, so they can't decide—they need committees, so you get all this gridlock'.[6]

While changes to policy instruments surrounding approvals detracted from the consistency and expediency of the policy process, these changes arguably bolstered legitimacy. Although canola policy was contested by environmental groups, organic producers, and marginal farmer associations, opponents have thus far been unsuccessful in challenging the policy in either political or judicial forums. This suggests Canadian canola policy is sufficiently consistent with accepted norms to prevent reform via normal institutional channels. Moreover, although government has been criticized by some for permitting the industry to lead the sector with public backing, collaboration led by a durable coalition of stakeholders arguably encouraged adaptability and innovation (cf. Kneen, 1992; Pitsula and Rasmussen, 1990). In the words of a veteran member of the policy community:

> *There are about ten of us who meet monthly to discuss what's hot, what's emerging, and what's not working … Nobody's there because they're assigned by their company. They're there because they're part of this community. It's membership by merit, rather than membership by authority. I don't think anybody's there because they have a job. They're there because they have a vocation.*[7]

Programmatic Success

At the program level, success has similarly been resilient. Recall that the 1983 National Biotechnology Strategy identified agriculture, energy, and forestry as target sectors. Yet, energy and forestry were dropped early on by the Allelix public-private partnership, as was its work on corn and potatoes, when the company reoriented its focus towards canola. Although such programmatic alterations may be interpreted as failures, the ability to 'fail fast' may be virtuous if it frees up resources to pursue more promising projects.

Regarding biotechnology specifically related to canola, although undoubtedly successful overall, several 'programmatic failures' can be identified. Research and development related to triazine and bromoxynil tolerance, high-laurate canola, and *Brassica juncea* did not yield high returns. Moreover, the IPPM and distancing systems designed to prevent contamination of organic and other non-transgenic varieties fell short of their objectives to maintain access to overseas markets, where many transgenic varieties remain uncertified. Yet, to the previous point, programmatic failure is considered by many to be a necessary evil of innovation, as

[6] Confidential telephone interview conducted by the author, 2 October 2018.
[7] Confidential telephone interview conducted by the author, 22 November 2018.

achieving success almost inevitably requires some incidence of failure (Alchian, 1950). Had government required industry actors to sustain programs that were failing, the cost of programmatic failure could have been much greater.

Political Success

Although policy towards canola has been criticized in some quarters, disenchantment has not been sufficient to mobilize serious political opposition. Every major Canadian political party has presided over canola policy at either the provincial or federal level, and none has implemented major reforms. The general thrust in favour of hybrids and transgenic varieties has proven resilient. This feature of Canadian public policy contrasts with the experience in Europe and Asia, where moratoria on transgenic crops and their accompanying herbicides have been issued under the aegis of the 'precautionary principle', which states that a product need not be demonstrably unsafe for regulators to deny its certification. Although sources indicate that progress is being made in a liberalizing direction in these markets, it is reported to be taking place 'at glacial speed'.[8]

Interviews with former politicians and bureaucrats suggest that opposition to agricultural biotechnology was not anticipated initially. Rather, political backing was premised on the assumption that investment in biotechnology would pay off, even if it was unclear at the outset what would be produced. In the words of one interviewee 'the early biotech strategies were pretty nebulous and undifferentiated; they were saying "this is important technology … we're not quite sure how it is going to be used, but there are about a thousand different ways it could change the world, so we're going to support it" '.[9] This is not to say that government actors were naïve in their enthrallment with the emerging technology. On the contrary, Grant Devine, the premier of Saskatchewan who presided over the third stage of canola development, was an agricultural economist familiar with Keith Downey's research on canola and the advances being made at Agriculture Canada's Ottawa and Saskatoon labs.

Accounting for Policy Success

What explains Canada's amenability to agricultural biotechnology? According to Hall and Soskice (2001), Canada and other liberal countries possess a 'comparative institutional advantage' when it comes to the commercialization of

[8] Confidential telephone interview conducted by the author, 28 May 2021.
[9] Confidential telephone interview conducted by the author, 2 January 2017.

radically-innovative technologies, like biotech. Indeed, Canadian institutions governing both public and corporate policy permit decision-makers to pursue high-risk, high-return ventures unencumbered by opposing forces in society, such as coalition partners, strong unions, and shareholders. On the political side, Canada's first-past-the-post electoral system tends to produce both centrist parties and one-party governments capable of pursuing policy objectives without compromise (Duverger, 1954; Savoie, 1999). On the business side, corporate law in North America permits executives to quickly adapt corporate strategy by facilitating stock trading, mergers, and acquisitions (Whitley, 2007).

As stated by McConnell (2010, 357) 'striving for success in one realm can mean sacrificing, intentionally or through lack of foresight, success in another… such trade-offs and tensions are at the heart of the dynamics of public policy.' While it is true that liberal institutions permit decision-makers to externalize costs and risk onto unwilling segments of society, in this case, co-production and private regulation served to internalize much of the cost and risk associated with Canadian canola policy within the beneficiary group.

For instance, the IPPM system put in place to segregate transgenic and non-transgenic varieties was financed almost entirely by industry. Government, industry, universities, producer associations, the Prairie Pools, and United Grain Growers also cultivated mutually-beneficial collaborative schemes, which gave private interests with valuable capital access to university and government research, as well as the marketing networks controlled by the Prairie Pool cooperatives and United Grain Growers. As but one example, Agriculture Canada worked with Hoechst-AgrEvo to develop the first transgenic herbicide-tolerant system, *Liberty Link,* which was marketed through the Prairie Pools. Yet, access to marketing networks was not always sufficient to elicit private investment. Allelix began as a private-public partnership, after all, which worked with University of Guelph scientists to develop the hybrids that eventually led to its buyout by Pioneer Hi-Bred. Government and university scientists were also the ones to develop triazine-tolerant canola, the precursor to canola tolerant to the imidazolinone-based *Pursuit* herbicide.

Although some criticized the focus on hybrids in the 1980s, it was not until the fourth phase (1990–present) that opposition to Canadian canola policy garnered much attention (cf. Kneen, 1992). Even so, the use of public money to attract private firms to Canada did not draw much fire, which may be explained by the fact that many such investments were scrutinized by arms-length entities like Ag-West Biotech, major banks, CIC, and SEDCO. By resisting the temptation to externalize excessive costs and risk onto the public, Canadian governments avoided political liabilities at a time when fiscal discipline was a major priority among Canadian voters (MacKinnon, 2003). To be clear, not all costs associated with canola development were internalized by its beneficiaries. Rather, the level of cost

internalization was arguably sufficient to prompt wise investments and avoid waste that might otherwise have galvanized greater opposition to government policy towards canola.

Social and environmental costs cannot be so easily internalized in a liberal system, however. Consequently, opponents like Greenpeace, the National Farmers Union, the Saskatchewan Organic Directorate, and other litigants against agrochemical companies are incentivized to seek out venues in which their gripes may be heard (Baumgartner and Jones, 1991). Besides provoking media attention, in Canada, opposition strategies typically involve recourse to the courts (Pralle, 2006). Although the Supreme Court of Canada has been dismissive of opposition claims to this point, support of the courts does little to undo the negative publicity that has coincided with litigation, as Bayer's shareholders can attest.

Insofar as liberal institutions are equated with free markets, it is important to keep in mind that unregulated markets do not lend themselves to providing public goods, the likes of which the success of Canadian canola policy depended upon. Nor do markets enshrine private property rights necessary for their proper functioning. Rather, governments must enforce competition policy and guarantee property rights, both tangible and intellectual. Likewise, governments or some other non-market entity must step in to provide public goods (Picciotto, 1995). Government, Pool cooperatives, producer associations, the Edible Oils Institute, and Ag-West Biotech are examples of non-market coordination in an otherwise liberal market economy, as was the alliance between Monsanto, AgrEvo, and the Canola Council of Canada to put in place the IPPM system required to differentiate canola destined for different markets. Although industrial policy can be very wasteful, encouraging rent-seeking and moral hazard on the part of recipients of government subsidies, the approach to co-production taken in the canola industry has largely checked such tendencies (cf. Atkinson and Coleman, 1989). As discussed above, financing via producer levies and repayable loans has had the effect of internalizing some of the costs and risk associated with canola development within the beneficiary group.

Whereas Canada's liberal institutions are largely entrenched, counterweights are not automatic. Rather, checks against negative aspects of liberal institutions must be consciously designed by entrepreneurial actors. Blood, sweat, and tears went into forging cooperative marketing networks, finding ways to analyse oil composition, implementing producer levies for research and development, and striking alliances between firms, cooperatives, producer associations, government labs, and universities. Moreover, to the extent that Canada's institutional comparative advantages were realized, it must be kept in mind that institutions constrain and enable actors by specifying rules; institutions cannot act themselves (Granovetter, 1985). Thus, although Canada's regulatory environment may have been conducive to agricultural biotechnology, agency was required on the part of entrepreneurial actors to see canola's development through to fruition.

Conclusion

The story of canola development is one of taking positive steps towards ensuring the core of the industry was located in Canada and that as much value as possible was captured within the country. The protagonists were a motley group consisting of government labs, private firms, associations, cooperatives, government ministries, and universities. Achievement of these actors' objectives was facilitated by Canada's liberal institutions, which permitted risk-taking necessary to develop, commercialize, and certify radically-innovative biotechnology. Yet, to the extent that Canada's liberal institutions encourage excessive risk-taking and cost-shifting, these tendencies were blunted by the implementation of co-production schemes that internalized much of the risk in the beneficiary group, while fostering coordination necessary to bring the industry to fruition.

Not all groups in society were on-side with Canadian policy towards canola, however, making the case a 'resilient' rather than a complete success. Environmental groups opposed to genetically-modified organisms used the Supreme Court case *Monsanto Canada Inc. vs. Schmeiser* to advertise a contrary position via media outlets. Although the Supreme Court of Canada ruled in favour of Monsanto in both the Schmeiser case and the following class action suit brought on by the Saskatchewan Organic Directorate, opposition to genetically-modified crops has not gone away. While Canadian policy has been steadfast in upholding certification for transgenic crops and the herbicides that complement them, moratoria abroad and legal challenges at home have damaged the share value of agricultural biotech companies.

Against the charge that corporate concentration would lead to farmer dependence on large multinational seed and chemical corporations, Canadian policy towards canola has been similarly resilient. Although marginal groups like the National Farmers Union have aired their concerns about corporate concentration following the privatization of the cooperatives in the late 1990s, they have been unsuccessful in prompting policy change. Indeed, every major political party has sustained the general direction of Canadian policy towards canola at either the federal or provincial level, despite having the means and opportunity to change it.

The previous point draws attention to the fact that, although institutions are important, institutions do not accomplish anything on their own. Rather, entrepreneurial actors must navigate institutional channels that specify constraints and opportunities in order to realize their objectives. Without the innovative ideas of entrepreneurial actors and their willingness to pursue them, there would be no canola industry in Canada. As we have seen, Canada's liberal institutions permitted entrepreneurial actors to pursue daring positive-sum projects unhindered by forces in society that would otherwise prevent them from doing so. At the same time, policy has been designed in such a way that society was spared from bearing excessive costs. Government's role was largely limited to supporting industry-led

development, which gave private actors incentive to adapt as circumstances warranted. The case serves as an example of successful innovation and industrial policy in a liberal setting. Although disaffected groups have also navigated the Canadian institutional environment to have their grievances heard, dissatisfaction has thus far been insufficient to reverse Canadian policy towards canola.

References

Alchian, A. A. 1950. "Uncertainty, Evolution, and Economic Theory." *Journal of Political Economy* 58 (3): pp. 211–221.

Arrow, K. J. 1962. "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, edited by R. Nelson, pp. 609–626. Princeton, NJ: Princeton University Press.

Atkinson, M. and W. Coleman. 1989. *The State, Business, and Industrial Change in Canada*. Toronto: University of Toronto Press.

Baumgartner, F. R. and B. D. Jones. 1991. "Agenda Dynamics and Policy Subsystems." *The Journal of Politics* 53 (4): pp. 1044–1074.

Belcher, K., J. Nolan, and P. Phillips. 2005. "Genetically Modified Crops and Agricultural Landscapes: Spatial Patterns of Contamination." *Ecological Economics* 53 (3): pp. 387–401.

Boulter, G. S. 1983. "The History and Marketing of Rapeseed Oil in Canada." In *High and Low Erucic Acid Rapeseed Oils*, edited by J. Kramer, F. Sauer, and W. Pigden, pp. 62–84. Don Mills: Academic Press.

Canada. 2008. *Growing Forward: A Federal-Provincial-Territorial framework Agreement on Agricultural, Agri-Food and Agri-Based Products Policy*. Ottawa: Agriculture and Agri-Food Canada.

Canada. 2018. Competition Bureau Statement regarding Bayer AG's Acquisition of Monsanto Company. Competition Bureau. 8 June. https://www.competitionbureau.gc.ca/eic/site/cb-bc.nsf/eng/04374.html

Canola Council of Canada. 2010. Estimated percentage of HT and conventional canola. https://www.canolacouncil.org/markets-stats/statistics/estimated-acreage-and-percentage/

Darcovich, W. 1973. *Rapeseed Potential in Western Canada: An Evaluation of a Research and Development Program*. Ottawa: Canada Department of Agriculture.

Duverger, M. 1954. *Political Parties: Their Organization and Activity in the Modern state*. London: Methuen.

Granovetter, M. 1985. "Economic Action and Social Structure: The Problem of Embeddedness." *American Journal of Sociology* 91 (3): pp. 481–510.

Gray, R., S. Malla, and P. Phillips. 2001. "Industrial Development and Collective Action ." In The *B*iotechnology *R*evolution in *Global Agriculture: Innovation, Invention and Investment in the Canola Industry,* edited by P. Phillips and G. Khachatourians, pp. 83–104. Wallingford: CABI Publishing.

Gray, R., S. Malla, and P. W. Phillips. 2006. "Product Innovation in the Canadian Canola Sector." *Supply Chain Management* 11 (1): pp. 65–74.

Hall, P. A. and D. W. Soskice (eds). 2001. *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage*. Oxford: Oxford University Press.

Kneen, B. 1992. *The Rape of Canola*. Toronto: NC Press.

MacKinnon, J. 2003. *Minding the Public Purse: The Fiscal Crisis, Political Trade-offs, and Canada's Future*. Montreal and Kingston: McGill-Queen's University Press.

McConnell, A. 2010. "Policy Success, Policy Failure and Grey Areas In-Between." *Journal of Public Policy* 30 (3): pp. 345–362.

McLeod, A. (ed.). 1974. *The Story of Rapeseed in Western Canada*. Saskatchewan Wheat Pool.

National Farmers Union. 2013. *Growing Forward 2: Accelerating Globalization, Stalling Food Sovereignty*. Guelph: National Farmers Union.

Nelson, R. R. 1959. "The Simple Economics of Basic Scientific Research." *Journal of Political Economy* 67 (3): pp. 297–306.

Phillips, P. 2001. "Regulating Discovery." In *The Biotechnology Revolution in Global Agriculture*, edited by P. Phillips and G. Khachatourian, pp. 197–212. Wallingford: CABI Publishing.

Phillips, P. 2018. "Private–Public R&D in the Development of the Canola Industry in Canada." In *From Agriscience to Agribusiness: Theories and Practices in Technology Transfer and commercialization*, edited by N. Kalaitzandonakes, E. G. Carayannis, E. Grigoroudis, and S. Rozakis, pp. 101–118. Switzerland: Springer.

Picciotto, R. 1995. *Putting Institutional Economics to Work: From Participation to Governance*. Washington, DC: World Bank.

Pitsula, J. M. and K. A. Rasmussen. 1990. *Privatizing a Province: The New Right in Saskatchewan*. Vancouver: New Star Books.

Pralle, S. 2006. "The 'Mouse That Roared': Agenda Setting in Canadian Pesticides Politics." *Policy Studies Journal* 34 (2): pp. 171–194.

Saskatchewan. 1992. *Partnership for Renewal: A Strategy for the Saskatchewan Economy*. Queen's Printer.

Savoie, D. 1999. *Governing from the Centre: The Concentration of Power in Canadian Politics*. Toronto: University of Toronto Press.

Smyth, S. and P. Phillips. 2002. "Product Differentiation Alternatives: Identity Preservation, Segregation, and Traceability." *AgBioForum 5* (2): pp. 30–42.

Smyth, S. and P. Phillips. 2001. "Competitors Co-operating: Establishing a Supply Chain to Manage Genetically Modified Canola." *The International Food and Agribusiness Management Review* 4 (1): pp. 51–66.

Smyth, S., P. Phillips, W. and C. Ryan. 2013. *Economic and Networking Impact Assessment for Ag-West Bio Inc: 1989-2012.* Saskatoon: Ag-West Bio Inc.

Whitley, R. 2007. *Business Systems and Organizational Capabilities: The Institutional Structuring of Competitive Competences*. Oxford: Oxford University Press.

World Health Organization. 2015. "Evaluation of Five Organophosphate Insecticides and Herbicides." *IARC Monographs*, *112*.