Assessment of the

Economic and Related Benefits to Canada of Phenoxy Herbicides

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Prepared for:

Industry Research Task Forces for Phenoxy Herbicides (MCPA, 2,4-D, mecoprop-p)

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Acronyms, Abbreviations and Chemical Names

AAFC	Agriculture and Agri-Food Canada
CS	Consumers' surplus
CGSA	Canadian Golf Superintendents' Association
CLC	CropLife Canada
FERC	Federal Energy Regulatory Commission (United States)
GDP	Gross domestic product
IPM	Integrated pest management
NAPIAP	National Agricultural Pesticide Impact Assessment Program
NPV	Net present value
OECD	Organization for Economic Co-operation and Development
OMAFRA	Ontario Ministry of Agriculture and Food and Rural Affairs
PACR	Proposed Acceptability for Continuing Registration
PMRA	Pest Management Regulatory Agency (Canada)
RCGA	Royal Canadian Golf Association
RDD	Re-evaluation decision document
RED	Registration Eligibility Decision
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGA	United States Golf Association
USGAGS	United States Golf Association Green Section
WHO	World Health Organization

Chemical Names

2,4-D	2,4-dichlorophenoxyacetic acid
MCPA	2-methyl-4-chlorophenoxyacetic acid
MCPP-p	2-(4-chloro-2-methylphenoxy propionic acid [also named mecoprop-p]
Banvel®	dicamba
Baseline®	floroxypyr + talkoxydim
Buctril®	bromoxynil
Brigade®	florasulam + clodinafop
Dyvel®	dicamba + MCPA
Dyvel® DS	2,4-D + mecoprop-p + dicamba
Express®	tribenuron methyl
Frontline*	florasulam + MCPA * Trademark of Dow AgroSciences
Mextrol®	bromoxynil
Refine® Extra	thifensulfuron methyl + tribenuron methyl
Sword®	MCPA + mecoprop-p + dicamba
Target®	MCPA + mecoprop-p + dicamba
Tracker®	MCPA + mecoprop-p + dicamba
Trophy®	fluroxypyr + MCPA

Executive Summary

The pesticide industry has formed a number of task forces to fund the new research required by both the US Environmental Protection Agency (USEPA) and the Health Canada Pest Management Regulatory Agency (PMRA) under current pesticide re-registration/re-evaluation programs. The three major task forces for the phenoxy herbicides are the Industry Task Force II on 2,4-D Research Data, the MCPA Task Force Three and the MCPP-p Task Force.

In Canada, the PMRA is re-evaluating various uses of the herbicides 2,4-D and MCPA. A third important phenoxy herbicide, mecoprop has been phased out and replaced by mecoprop-p, which is used at half the rate of the old mecoprop active ingredient. mecoprop-p is registered under a modern database. It is not under re-evaluation.

The task forces commissioned the preparation of this benefits report for all the interested parties, including those using phenoxy herbicides and the regulatory authorities in the Canadian federal, provincial and other levels of government. The report identifies and quantifies, where possible, the economic, financial, environmental, health and other benefits that accrue to Canadians from the use of the three phenoxy herbicides. It estimates the benefits of usage of the phenoxy herbicides as the increased costs producers and consumers would incur if phenoxy herbicides were withdrawn from the market.

The task forces requested that this report focus on:

- the wheat and barley markets in the Western Provinces and Ontario, because the agriculture sector is the largest user group of the phenoxy herbicides;
- the non-crop industrial sector as an example of a business sector that uses phenoxy herbicides to manage harmful vegetation; and
- the lawn and turf sector as examples of the uses made of phenoxy herbicides by individual Canadians and businesses for private investment, aesthetic and recreational purposes.

These sectors represent the very large percentage of all usages of phenoxy herbicides in Canada, likely over 90%. For each sector, the report identifies and values, whenever possible, the benefits that accrue to Canadians from the use of phenoxy herbicides. It does not scale these estimates to overall Canadian usage, because the uses are so different. The results should be interpreted as examples of the type and scale of benefits that would likely emerge if other uses were also examined.

The Three Phenoxy Herbicides

2,4-D, MCPP-p and MCPA are chlorophenoxy acids developed in the 1940s and 1950s as growth-regulating herbicides for use against broadleaf weeds. Since its introduction into Canada in the 1940s, 2,4-D has become one of the most widely used and studied herbicides for use in agriculture, forestry, non-crop vegetation management and lawn care. MCPA was introduced into Canada in 1952. MCPA and 2,4-D now account for most of the phenoxy herbicide expenditures in the agriculture sector. MCPP was introduced into Canada in 1960 and the mixed isomer version, MCPP, was replaced in 2004 by the single isomer version, MCPP-p. For lawn and turf, 2,4-D and MCPP-p are used in over 95% of the turf herbicide products available.

The Agriculture Sector - Wheat and Barley

These three phenoxy herbicides accounted for 69% of the expenditures in 2005 on post-emergent broadleaf herbicides for wheat and barley in the western provinces. In Ontario, 2,4-D and MCPA account for just over 50% of all herbicides used on Ontario grain farms. All three phenoxy herbicides are used, but 2,4-D and MCPA are the most important to producers. Currently, producers spend about twice as much on MCPA as on 2,4-D. These two phenoxy herbicides are used on their own and in combination with other herbicides as part of sound integrated pest management (IPM) to broaden the list of weeds controlled and delay onset of resistance to the non-phenoxy herbicide. (See Figure (i).

Total current phenoxy herbicide costs to wheat and barley producers are estimated to be $170 million, split out as $55 million for 2,4-D and $115 million for MCPA. Wheat treatment costs are $114 million, barley $57 million. The costs of mecoprop-p are contained within those estimates, because mecoprop-p is overwhelmingly offered as a mix with one of the other two phenoxy herbicides.

It should be noted that while shown as a separate line item in the following table, the costs of mecoprop-p are also contained within the 2,4-D and MCPA cost estimates, because mecoprop-p is offered as a mix with one of the other two phenoxy herbicides. For this reason, “All phenoxy herbicides” is the sum of only the first two of the three preceding rows.

Current Annual Treatment Costs ($ millions) – see Figure (ii)

	Wheat $	Barley $	Total $
2,4-D	41.6	13.6	55.2
MCPA	72.1	43.2	115.3
MCPP-p (included within 2,4-D and MCPA above)	[9.3]	[1.4]	[10.7]
All phenoxy herbicides	113.7	56.8	170.5

Note:
Calculated using 2005 usage patterns and costs for each of the phenoxy herbicides on the two cereal crops.

Figure (i)

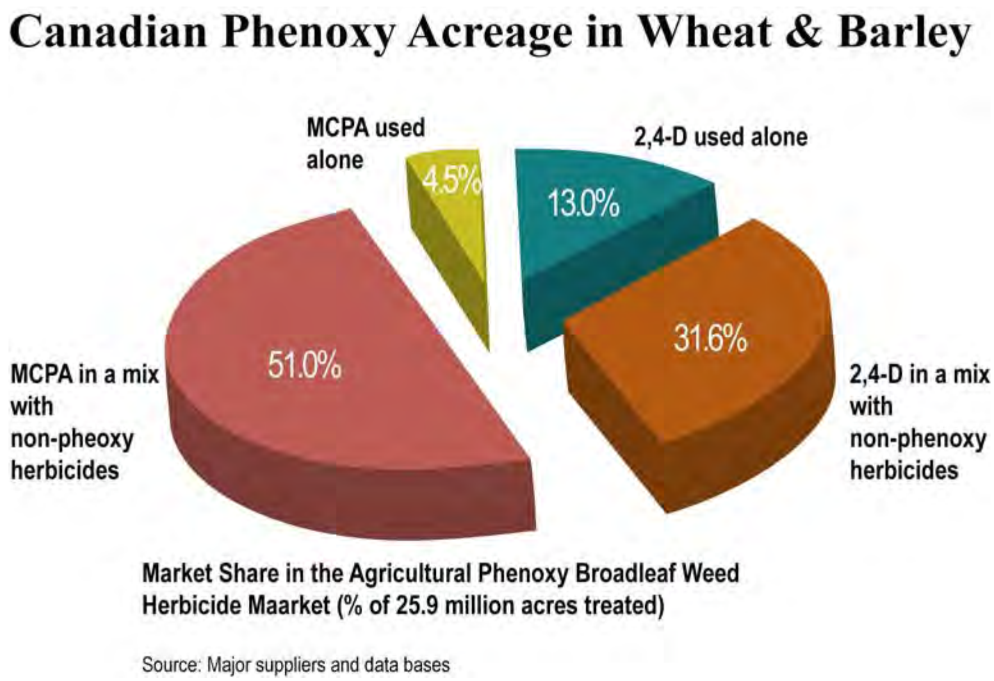
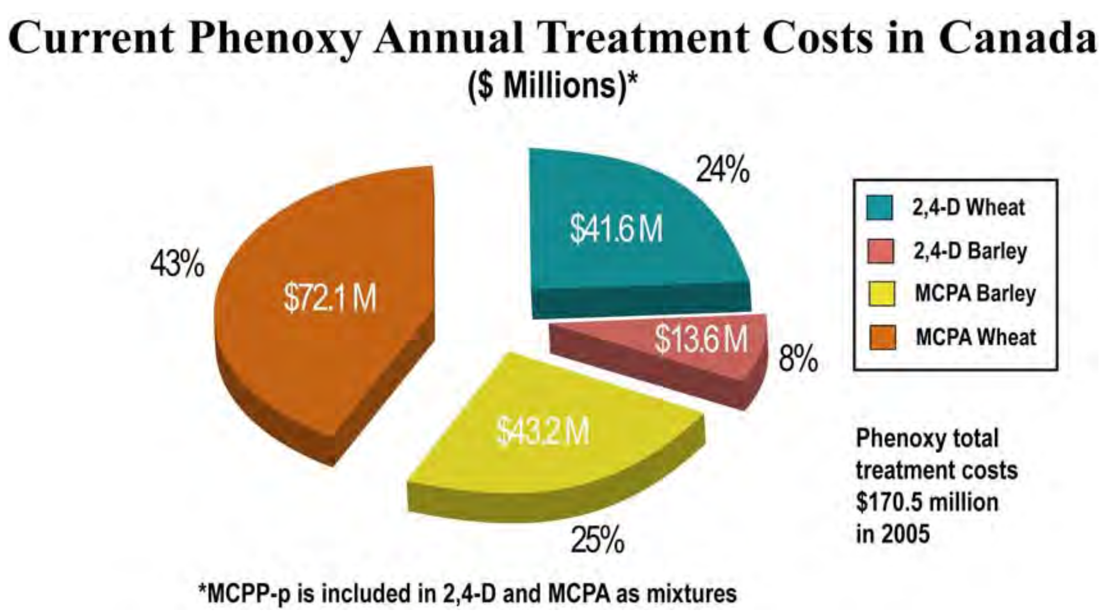


Figure (ii)



Agriculture producers would attempt to preserve both the yield and quality of their cereal crops if the phenoxy herbicides were withdrawn. The cheapest and most effective alternative is the increased use of other, more expensive, less effective herbicides. Other crop management practices, such as increased tillage, are considerably more expensive and less effective.

The incremental (additional) annual costs to farmers if these phenoxy herbcides were not available are shown in the next table. Each row summarizes the incremental costs of the specific alternative herbicide treatments that would result from the loss of each of 2,4-D, MCPA and MCPP-p, and then the loss of all three phenoxy herbicides together. If all three phenoxy herbicides were removed, producers would experience $227 million in additional annual weed-control costs, a 133% increase over the current costs of treatment with the three phenoxy herbicides.

Estimated Incremental Annual Costs of Broadleaf Weed Control ($ million and percent increase over current costs) – See Figure (iii)

	Wheat	Barley	Total
If 2,4-D were not available	$41.5 - 100%	$14.3 - 105%	$55.9 - 101%
If MCPA were not available	$47.3 - 66%	$8.2 - 19%	$55.5 - 48%
If MCPP-p were not available	$4.7 - 50%	$1.5 - 112%	$6.2 - 58%
If all phenoxy herbicides were not available	$168.9 - 148%	$55.1 - 97%	$224.0 - 131%

Notes:
The incremental costs from the loss of all three phenoxy herbicides is not the summation of the three preceding rows. When one phenoxy is lost, in some cases the other is a reasonable alternative treatment, at much less cost than the non-phenoxy alternatives. When all phenoxy herbicides are lost, the incremental costs of alternative herbicide treatment are much higher.

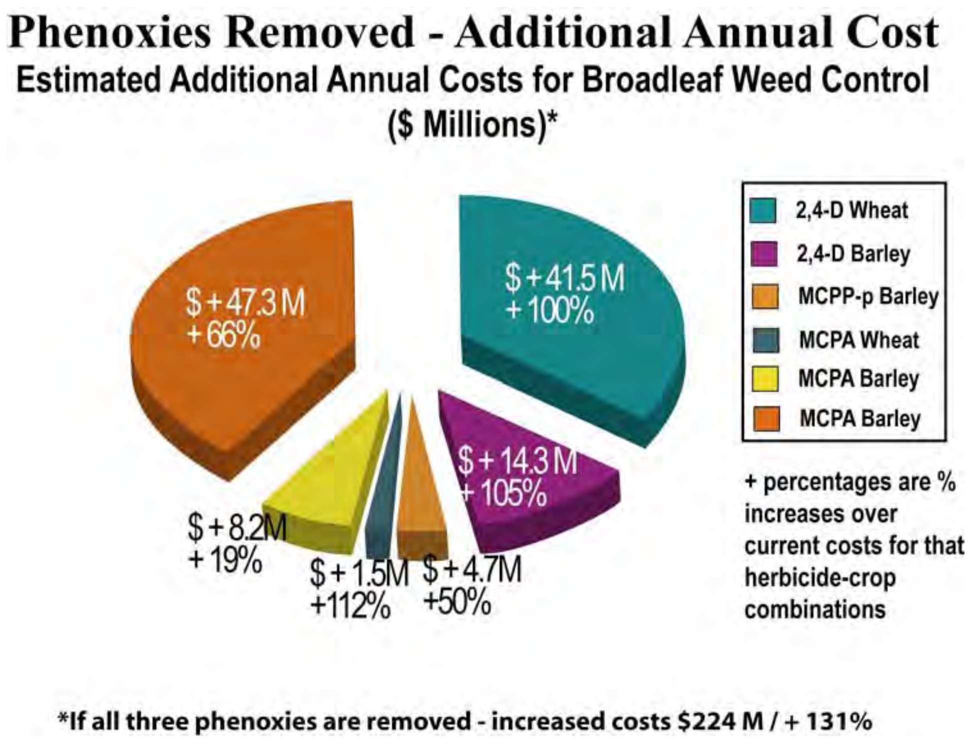
The percentage increase in costs for each current phenoxy treatment is the incremental cost divided by current treatment cost (e.g., for MCPA wheat: $47.3 / $72.1 = 66%).

The next table presents the incremental cost for wheat and barley farmers of the loss of each phenoxy as a percentage of total current phenoxy costs for each of wheat and barley. For example, for MCPA wheat: $47.3 / $113.7 = 42%.

Percentage Increase over Total Current Costs of Phenoxy Herbicides

	Wheat %	Barley %	Total %
If 2,4-D were not available	37	25	33
If MCPA were not available	42	14	33
If MCPP-p were not available	4	3	4
If all phenoxy herbicides were not available	148	97	131

Figure (iii)



Overall Economic Effects

Despite increases in treatment costs, producers believe weed control would decline. There would be yield losses and possibly quality degradation. To estimate the overall economic impacts on the agriculture sector, a low estimate of yield losses (0.5% to 3.5%) was used, although other studies have estimated yield losses as high as 15% to 37%. The revenue losses from the drop in yields if all three phenoxy herbicides were withdrawn would be about $114 million, with wheat accounting for $76 million and barley the remaining $38 million.

Farmers would bear all the direct incremental costs of the alternative treatments, (i.e., the $224 million). Opinions differ about who would bear the costs of the drop in yields. Industry representatives believe Canada is a price taker in international cereal markets and a drop in Canadian yield would have no effect on market prices. In this situation, farmers would bear also the loss in revenue from the drop in yields, for a total cost burden of $338 million. However, some well-recognized Canadian academics and government agencies believe a drop in Canadian yield would cause some domestic prices to rise, thus transferring some of the cost increase to Canadian consumers. Using the results of their research, consumers would bear about 15% of the cost incurred by the drop in yields, with producers picking up the remaining 85%. In either scenario, the minimum incremental cost to producers is $321 million. Even this minimum incremental cost represents 22% of the total net farm income in 2005 for Manitoba, Saskatchewan and Alberta.

If all three phenoxy herbicides were withdrawn, manufacturers of other herbicides would probably show a revenue gain. The alternative herbicides are more expensive, and more expensive products generally carry higher profit margins. This study has not assumed any increase in the prices of these already-more expensive herbicides as a result of this increased demand. Industry representatives identified three other impacts of a withdrawal of the phenoxy herbicides: a reversion of Canadian farm practices to the 1940s, the spread of broadleaf weeds as the weaknesses in the alternatives became evident and increased resistance to the alternative herbicides.

The most comprehensive previous study of the economic impacts of 2,4-D, conducted in 1988 for Agriculture and Agri-Food Canada, estimated net losses of $58 million to $82 million in the agricultural sector from the loss of 2,4-D, and a net loss to agriculture of $328 - $365 million from the loss of all phenoxy herbicides. While the results from the 1988 study appear similar to the results reported in this study, this study identifies a number of important differences in the methodologies used. The comparison of the two sets of results suggests the economic impacts estimated in this study should be considered conservative.

Preventing and Delaying the Onset of Resistance in Target Weeds

Target weeds can develop resistance to a herbicide; eventually, the herbicide fails to control sufficiently. Then, new herbicides are required and the cycle begins again. New herbicides are expensive (up to US$180 million to bring to market), and can take a decade before coming to market. A Canadian weed science researcher suggests that existing herbicides be viewed as non-renewable resources. The phenoxy herbicides play a special role in managing resistance, because they have the lowest risk of fostering the development of resistance. The phenoxy herbicides are often mixed with resistance-prone broadleaf herbicides or used in rotations to delay resistance. Weeds that survive the non-phenoxy herbicide through resistance are controlled by the phenoxy. Postponement of resistance by the phenoxy herbicides lengthens the time before the resistance-prone herbicide becomes truly non-renewable.

This report does not attempt to estimate the economic significance of this ability of the phenoxy herbicides to prevent and delay the emergence of resistance, but some industry observers suggest that its value could overshadow all the other economic benefits identified in this study. Herbicide expenditures by farmers and downstream agricultural commodity prices would probably have to support the increased and recurring development of new herbicides.

Lawn and Turf Sector

The sector includes turfgrass farms, lawns and landscaping around homes and institutions, municipal parks, golf courses and sports fields. Although a multi-billion dollar industry in Canada, reliable statistics on it are scarce despite considerable public debate. Two activities were selected (residential lawns/landscaping and golf courses) to examine the benefits that might result from the phenoxy herbicides. This study made extensive use of panels of specialists and experts to estimate parameters that were required to identify and value the economic benefits of phenoxy herbicides.

Many phenoxy-based herbicide products are available for use on turfgrass. About 95% of the products contain a mix of 2,4-D and mecoprop-p. No products containing MCPA are currently approved for domestic use in Canada. Thus, withdrawing either 2,4-D or MCPA is, de facto, a withdrawal of both phenoxy herbicides from the market. Industry and the PMRA agree that there are no herbicide alternatives available to the lawn/turf sector in the event of the withdrawal of one or both 2,4-D and mecoprop-p. The only alternative with the same degree of safety and efficacy testing as the phenoxy herbicides is a combination of hand weeding and re-sodding.

Residential Lawns/Landscaping

Good lawns and landscaping translate into an increase in market value of homes. Buyers pay a premium for those attributes, and they represent a good investment by homeowners. Recent work done at Université Laval in Quebec demonstrated a mean premium of 7.7% across all landscape attributes and all values of houses. Since broadleaf weeds are the most unsightly of the weed problems in turfgrass, they are a major concern. The only alternative to the phenoxy herbicides that has undergone comparable safety and efficacy testing is a combination of hand weeding and periodic re-sodding. On a net present value basis, the cost of maintaining consistently high turf quality using these alternatives is about 60 times higher than the net present value of current costs using herbicides. There are herbicides that could be as effective as the phenoxy herbicides, but they are not approved for lawn/turf uses in Canada.

Golf Courses

Golf is big business. A recent study estimated the value of the golf economy (goods and services) in the United States to be in excess of $62 billion for the year 2000, translating roughly into a $6 billion industry in Canada. One in five Canadians over the age of 12 plays golf. There are about 2,000 18-hole equivalent golf courses in the country and competition for golfers is strong among the courses. Key to bringing the best golf clients to a course and attracting the international stars is the quality of the course. Canadian cities and courses compete for these tournaments, because of the economic benefits that result.

A three-year controlled experiment by independent researchers on a US public golf course demonstrated that there are no alternatives available to golf courses that would preserve course quality, if herbicides are withdrawn. Canadian golf representatives agree. Herbicide treatment costs at golf courses would increase eightfold (from about C$3 million to about C$26 million) if the phenoxy herbicides were to be withdrawn, but without maintaining course quality. The decline in quality could cost Canadian courses both their regular customers and the high-profile competitions that bring the benefits to their communities.

The Environmental and Health Benefits of Weed Management in Turfgrass

Many diverse groups recognize the following environmental and health benefits of turfgrass.

Environmental: Soil erosion control, water conservation (e.g., ground water recharge), storm water runoff and flood control, soil enrichment and organic chemicals decomposer.

Health: Temperature moderation, pollutant filter for water quality, oxygen release, pollen allergy control, noise abatement (glare reduction) and recreational activities.

A key requirement of the turfgrass growth to achieve these benefits is dense ground cover with a high shoot density and root mass. Broadleaf weeds act directly against the requirement of a healthy grass environment. Weeds cover much of the ground, destroying the shoot density. The presence of broadleaf weeds reduces the environmental and health benefits of turfgrass. A withdrawal of the phenoxy herbicides would significantly weaken the control of broadleaf weeds.

Non-Crop Industrial

Also known as industrial vegetation management, this industry carries out the control, removal or alteration of vegetation to achieve the objectives of land users. The main users of vegetation management services are utilities, such as electrical distribution and pipeline companies, railways, highway maintenance agencies and those charged with fighting invasive/noxious vegetation. This last point is a relatively recent one. The World Conservation Union identified invasive alien species as the second most significant threat to biodiversity, after habitat loss. Also, a growing concern is assuring the security of this infrastructure. The August 2003 blackout in eastern Canada and the United States showed the damage that can result from improperly maintained rights-of-way.

The vegetation management industry in Canada does about $50 million in business a year, about $20 million of that being for herbicides and $30 million for the cost of applying the herbicides and the other vegetation management methods, such as hand trimming, mowing, etc. 2,4-D is the most common phenoxy used in this sector, either alone or, more frequently, as a tank mix partner. Industry representatives suggest there would be two immediate effects of a withdrawal of 2,4-D and a more important follow-on effect. The immediate effects would be an increase in the costs of industrial vegetation management estimated to be 150% (i.e., from about $7.0 million to about $17.5 million) along with a decrease in the effectiveness of weed control and brush management.

The follow-on effect would be an increase in the events that industrial vegetation management is intended to prevent (i.e., power outages through brush contact with transmission lines, the inability to access facilities quickly for maintenance or in response to an emergency/failure, reduced visibility at crossroads and the loss of even more land to invasive species). Ensuring infrastructure security is also a growing concern.

Summary of Benefits in Terms of Increased Costs

Sector/Issue	Costs if the Phenoxy Herbicides Withdrawn from Market	Estimation
Agriculture – wheat and barley	Increased annual weed control costs to farmers of 131%	Current annual costs $170 million. Incremental annual cost of withdrawing all phenoxy herbicides: $224 million
	Drop in yield, because weeds not controlled as well	Minimum additional annual cost of $114 million due to decreased yields, shared between farmers and consumers Minimum annual incremental total cost to farmers: $321 million, which is 22% of total net farm income (2005) for all three Prairie provinces
Lawn/turf	No herbicide alternatives to this sector if the phenoxy herbicides were to be withdrawn. Only option: hand weeding and re-sodding	
Residential lawns and landscaping	Increased costs, reduction of weed control	NPV of weed control costs rises by a factor of 60 for households that chose to maintain consistent high quality of turf
Golf	No alternative to preserve course quality	Weed control costs rise from about $3.2 million to about $26 million annually. Course quality declines, leading to loss of big-name players and competitions
	Environmental and health benefits of turfgrass are recognized. Turf must have dense ground cover and high shoot density to achieve those benefits Broadleaf weeds act against grass shoot density and cause benefits to decline	Not estimated
Non-crop industrial	Increase in weed control costs of 150%	From about $7.5 million to about $17.5 million
	Reduction in weed control leading to increase in preventable events (power failures, etc.)	Not estimated
	Reduction in security maintenance	Not estimated
Prevention and delay of herbicide resistance	The phenoxy herbicides delay and prevent the emergence of resistance to some other herbicides, prolonging the life of these other herbicides and reducing the need to replace them with new herbicides	Not estimated; some believe this value alone would be much larger than all other benefits identified

1) Background, Purpose and Format of This Report

2,4-D, MCPA and mecoprop-p (MCPP-p) are herbicides in the chlorophenoxy acid family used post-emergence for selective control of broadleaf weeds. They are registered for use on a variety of food/feed sites including field, fruit, vegetable crops and for use on turf, lawns, rights-of-way, and aquatic and forestry applications. Residential homeowners also use 2,4-D and MCPP-p on lawns.

The phenoxy herbicides come in multiple chemical forms and are found in numerous end-use products intended for a wide range of use patterns. They are ingredients in hundreds of agricultural and home use products, as sole active ingredients and in conjunction with other active ingredients.

The industry task forces for the phenoxy herbicides (one for each phenoxy herbicide) were formed to fund the new research required by both the US Environmental Protection Agency (USEPA) and the Canadian Pest Management Regulatory Agency (PMRA) under current pesticide re-registration/re-evaluation programs in each jurisdiction.

In Canada, the PMRA is conducting a re-evaluation of lawn and turf uses of the herbicide 2,4-D and MCPA as part of the PMRA's commitment to review the most common lawn and turf chemicals used in Canada. The PMRA issued a Proposed Acceptability for Continuing Registration document for lawn and turf uses (PACR2006-05) in February 2005 and a Re-evaluation Note (REV2006-11) on August 16, 2006 (PMRA, 2006). The PACR for agricultural uses has not yet been issued. The USEPA Registration Eligibility Decision (RED) for MCPA was issued in September 2004 (USEPA 2004) and for 2,4-D was issued in June 2005 (USEPA, 2005).

MCPP-p was granted temporary registration in 2004 by PMRA subject to the registrants submitting additional non-core safety data commonly required during the re-evaluation process. MCPP-p has been registered in USA since 1995 and the RED for MCPP-p is expected to be issued in 2007.

All three phenoxy herbicides, 2,4-D, MCPA and MCPP-p have successfully completed their European evaluation through the 91/414 EU review of active ingredients and are listed on Annex I, the list of approved active ingredients. So far, only 61 active ingredients from the more than 1000 registered at the start of the EU review process have been listed on Annex I.

The task forces recognized that an important part of the pesticide re-registration process in all jurisdictions is the identification and valuation of the economic, environmental, health and other benefits of the pesticide being reviewed. In the United States, the National Agricultural Pesticide Impact Assessment Program (NAPIAP) Task Force commissioned in 1996 a report entitled *Biologic and Economic Assessment of Benefits* *from Use of Phenoxy Herbicides in the United States* (USDA, 1996). The PMRA has a regulatory directive, Dir 93-17, that provides a recommended table of contents for assessing the economic benefits of a pesticide. Generally, this report follows the principles of that directive.

The three task forces commissioned the preparation of this Canadian benefits report, to be provided to all interested parties, including those using the three phenoxy herbicides and the regulatory authorities in the Canadian federal, provincial and other levels of government.

This report identifies and quantifies, where possible, the economic, financial, environmental, health and other benefits that accrue to Canadians from the use of the three phenoxy herbicides. Because of the high degree of integration of Canadian and US economies and the re-registration processes of Canada and the United States, this benefits assessment was to be similar generally to one published in the United States in 1996, as part of the NAPIAP.

The remainder of this report consists of eight sections.

2. History of Use of 2,4-D, mecoprop-p and MCPA in Canada, describing the history of these phenoxy herbicides in Canada.

3. Key Methodology and Scope Issues, identifying the main issues in methodology and approach that arose.

4. Canadian Markets for the Phenoxy Herbicides, describing the size of the market and how the phenoxy herbicides get from manufacturers to the end users.

5. Phenoxy Herbicides in the Canadian Agriculture Sector, presenting the current uses of phenoxy herbicides in the wheat and barley sectors for Western Canada and Ontario, and the estimated costs to these producers and the Canadian economy if the phenoxy herbicides were to be withdrawn.

6. Managing Resistance to Herbicides, describing a particular benefit of 2,4-D that reduces significantly the demand for the introduction of more herbicides to counter the resistance to herbicides that often develops within target weeds.

7. The Lawn and Turf Sector, a review of the roles 2,4-D and mecoprop-p play in this sector and the contributions they make to the environmental benefits that result from healthy turf.

8. Non-Crop Industrial, describing the use and value of phenoxy herbicides in the vegetation management sector;

9. Summary: Estimates of the Benefits to Canada of Phenoxy Herbicides, presenting the economic, environmental and health benefits that accrue in Canada from the use of these herbicides and providing a summary of the benefits identified in the selected sectors.

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2) History of Use of 2,4-D, mecoprop-p and MCPA in Canada

2,4-D and MCPA are chlorophenoxyacetic acids developed in the 1940s as hormone (i.e., growth regulating) herbicides for use against unwanted weeds (Troyer, 2001). mecoprop-p (MCPP-p) is a related herbicide also used in weed control. These herbicides are ideal for use in cereal crops and turfgrasses due to their selectivity against broadleaf weeds. Broadleaf weeds, due to increased surface area, absorb more of the herbicide. 2,4-D is applied post-emergence (i.e., once plants have already germinated) and is rapidly absorbed (within four to six hours) and distributed within the plant (WHO, 1984). Once absorbed, these herbicides mimic plant growth-regulating hormones called auxins (e.g., indole-3-acetic acid) and over-stimulate plant cells causing abnormal plant growth and death (Mullison, 1987; PMRA, 2006). Plant metabolism, which includes transportation of nutrients within the plant, is also affected (Mullison, 1987). Both 2,4-D and MCPA have similar efficacy on weeds, such as wild carrot, chickweed, dandelion, ground ivy, round-leaved mallow, black medick and plantain (PMRA, 2006). On cereals, MCPP-p used alone or in combination with dicamba or MCPA is effective against black medic, buttercup, chickweed, cleavers, corn spurry, ground ivy, lamb's quarters, plantain, volunteer clover and wild mustard (Alberta, 2001).

Since its registration in Canada in 1946 and labelling for use on lawn and turf in the 1960s, 2,4-D is one of the most widely used and studied herbicides in Canada. 2,4-D is intended for use on several crops including alfalfa, apple, apricot, asparagus, barley, blueberry, cereals, cherry, clover, corn, cranberry, flax, grasses, maple, millet, oyster beds, peach, pear, plum, raspberry, rye, sorghum, strawberry and wheat (PMRA, 2005). As early as the mid-1940s, the US Golf Association Green Section published articles discussing the use of 2,4-D on turf (USGAGS, 1944; 1945). In 1988, an Agriculture and Agri-Food Canada (Agri-Food 1988) report estimated that 342,000 kg of 2,4-D active ingredients were used on turf in Canada per year, which was about 7% of the total estimated 2,4-D use in Canada (PMRA, 2005). Since that report, due to recent registration of alternatives to 2,4-D in the agriculture market and the increased adoption of integrated pest management (IMP) practices, it was estimated that total 2,4-D use in Canada has decreased 30% (PMRA, 2005). Market sales data from the United States in 2001 show that 2,4-D is the most commonly used pesticide in the home and garden sector (8 million to 11 million pounds of active ingredient used) and in other non-agricultural sectors (e.g., industrial and non-crop uses; 16 million to 18 million pounds of active ingredient used) (USEPA, 2004). In the US agricultural sector, 2,4-D is the fourth most commonly used herbicide (28 million to 33 million pounds of active ingredient used) behind glyphosate, atrazine and acetochlor (USEPA, 2004).

When used for turfgrasses, 2,4-D is often used in combination with other synthetic auxin herbicides; one of the most common combinations is 2,4-D/MCPP-p/dicamba, first registered for use in 1965 (PMRA, 2005). A total of 69 2,4-D products are registered for fine turf use in Canada under the *Pest Control Products Act*; of these, 35 are co-formulations with MCPP-p and/or dicamba (PMRA, 2005). Numerous fertilizer/herbicide products containing 2,4-D and mcpp-p are registered for use in Canada under the *Fertilizers Act* (PMRA, 2005).

MCPP was first registered for use in Canada in 1960 and is intended for use on food and feed crops (e.g., wheat, rye, oats, barley and corn) and residential lawns and turf (PMRA, 2004). Conversion to the single isomer version, MCPP-p, which is used at 50% of the rate of MCPP (with the same level of control), was implemented in 2004. Market sales data from the United States in 2001 show that MCPP-p is the fourth most commonly used herbicide in the home and garden sector (four million to six million pounds of active ingredient used) behind 2,4-D, glyphosate and pendimethalin (USEPA, 2004).

MCPA was first registered for use in Canada in 1951 and its major uses are on field crops (e.g., wheat, barley, oats, rye, flax, peas, corn,), sweet corn, turf, established legumes, pasture and rangeland grasses (PMRA, 2006). There are also MCPA product combinations, such as those mentioned above for 2,4-D in turf, currently registered for use on field crops in Canada . The total value of MCPA treatments on agricultural crops in Canada is about double that of 2,4-D. MCPA is registered for use on turf (except for domestic uses). Very little is used on turf and accounts for 5% or less of the amount of 2,4-D and MCPP-p sold for use on turf in Canada (PMRA, 2006).

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3) Key Methodology and Scope Issues

3.1) Selected Sectors

The scope and timing of this research necessitated a focus on selected sectors of the Canadian economy, specifically:

- the agriculture sector, as the single largest use sector of the phenoxy herbicides and, in particular, on the wheat and barley markets in the Western provinces and Ontario;
- the non-crop industrial sector, also called industrial vegetation management, as an example of another sector that uses the phenoxy herbicides to support their business activities; and
- the lawn and turf sector, to provide examples of the uses made of phenoxy herbicides by individual Canadians for private investment, aesthetic and recreational purposes.

The task forces requested that this report focus on these sectors. While they represent the very large percentage of all usages of the phenoxy herbicides in Canada, there are some uses that are not captured in this report.

3.2) Data

The report uses available literature and other sources of readily available information. It does not use any confidential business information held by firms in the herbicide industry sector, nor was this even sought. All the data for this research are available to the public, either free of charge or through subscription to the services of the data/information provider:

- original Canadian data collected and analyzed by recognized agencies, such as Statistics Canada, Agriculture and Agri-Food Canada, Health Canada-Pest Management Regulatory Agency (PMRA), and provincial ministries of agriculture and environment;
- previous Canadian, US and Organization for Economic Co-operation and Development (OECD)-member sponsored studies on related topics to provide comparisons and context;
- relevant research published by the US Department of Agriculture (USDA) and the US Environment Protection Agency (USEPA);
- contract research by independent firms and research conducted by university professors and staff;
- Canadian sector associations such as Landscape Ontario, CropLife Canada, Vegetation Management Canada, the Royal Canadian Golf Association and others;
- publications (including information available over the web) of firms that are active in the fields, at all stages of the value chain from manufacture to end-use; and
- interviews with representatives of firms and users within the selected sectors.

Some reports prepared by private market research firms were made available under confidentiality restrictions that have been respected. However, all the data/information in those private market reports is available to subscribers of that company's services.

The lawn and turf sector posed especially difficult challenges in terms of the required data. This study used panels of experts and specialists to estimate the required parameters when no publicly available and reliable estimates existed.

3.3) Scope of the Benefits Estimated

For each selected sector, the study identifies and values, whenever possible, the economic, financial and environmental benefits attributable to the uses of the phenoxy herbicides within that sector. Various options to take the results from the selected sectors and scale them up to the overall Canadian economy were examined, but no specific method was found to be reliable and informative across all the sectors. Thus, these results should be viewed as examples of the benefits that could be found if other sectors were examined at a similar level of detail. However, the selected sectors account for the large majority of the phenoxy usages in Canada.

3.4) Expert Review

Expert, peer review took place of the materials incorporated into the research and review of drafts of this report. In some cases, the experts were retained to contribute to the research; in other cases, the experts, especially those from universities and government agencies, contributed their time and knowledge freely. However, any errors of omission or commission in this report are the responsibility of the authors.

3.5) Economic and Related Benefits Only

This report considers only the economic and related benefits of use of the three phenoxy herbicides. Readers wishing to explore other aspects of the usage of these herbicides are invited to visit the web site of Canada's federal pesticide regulatory agency, the PMRA at www.pmra-arla.gc.ca or various other studies and resources.

4) Canadian Markets for Phenoxy Herbicides

4.1) Sales of Herbicides/Phenoxy Herbicides in Canada

The trade association, CropLife Canada (CLC), represents the manufacturers, developers and distributors of plant science innovations — pest control products and plant biotechnology — for use in agriculture, urban and public health settings. It is a member of CropLife International, a global network that represents the plant science industry and supports a network of regional and national associations and their member companies worldwide. All the major companies involved in the Canadian plant chemistry industry are members of CLC.

CropLife Canada publishes within its annual report a "state of the industry" snapshot of sales by dollar value, measured at the stage in the value chain of transfers between manufacturers and distributors. This is not a retail sales value. Table 4.1 presents the sales data provided by CLC annual reports for the last three years (CLC 2004/2005, 2003/2004, 2002/2003).

Table 4.1 Annual Pesticide Sales in C$ Billions (current dollars)

Category of Sales	2004	2003	2002
All pest control products ($)	1.33	1.31	1.27
Herbicides	76% - $1.02	77% - $1.01	80% - $1.02
Fungicides	10% - $0.13	9% - $0.12	8% - $0.10
Insecticides	6% - $0.08	8% - $0.10	5% - $0.06
Specialty products	8% - $0.11	6% - $0.08	7% - $0.09

In 1996, CLC showed a total of C$1.2 billion in annual sales. Clearly, growth in this sector has been moderate; in constant dollars, sales have probably declined. Across all products, CLC data show that Western Canada (British Columbia, Alberta, Saskatchewan and Manitoba) accounts for about 75% of all member sales. The remainder (25%) is sold in Eastern Canada (Ontario, Quebec and Atlantic Canada).

Globally, Canada represents about 3% of pesticide sales. (Environment Canada, 2005). In its submission to a House of Commons standing committee in the year 2000, the Urban Pest Management Council of Canada (UPMC-2000) estimated that the agricultural sector accounted for 91% of pesticide sales, while non-agricultural pest management products represent 9% of sales (1997 figures). Of this 9% of non-agricultural pest management products, domestic products accounted for 56.5% of the sales value. That is, domestic products accounted for just over 5% (56.5% of 9%) of total pesticide sales. Industry experts generally agree that this assessment remains valid and that a further distinguishing feature of the Canadian market is that it is primarily an herbicide market.

Over 7,000 pesticide products are registered for use in Canada. However, many of these contain the same active ingredients. It is difficult to identify reliable and publicly available national sales data based on active ingredients, but industry analysts and experts agree generally that the largest volume of herbicide sales are glyphosate, 2,4-D and MCPA.

4.2) How Phenoxy Herbicides Get to Canadian Consumers

McEwan and Deen (1997) presented a good description of the Canadian pesticide industry: the main pesticide manufacturing firms in Canada are subsidiaries of global firms. Industry observers agree that research and development in Canada is predominantly limited to testing products developed elsewhere for their suitability in Canadian conditions. As with most pesticides, no manufacturing of the phenoxy herbicides takes place in Canada although formulation of end-use products does occur in Canada.

In the case of phenoxy herbicides, typically, the parent companies (predominately in the United States, Europe and Australia) provide their Canadian subsidiaries and distributors with active ingredients or formulated products that contain the active ingredient. The Canadian subsidiary/distributor then either resells the active ingredient to a domestic distributor/wholesaler or formulator that, in turn sells at the retail level; or formulates its own products and sells them to a distributor/wholesaler that delivers the product to the retail outlets. Some companies do both at the same time, that is, they sell an active ingredient to a formulator that then markets a product competing with the formulated product of the Canadian subsidiary.

This type of supply chain is described as a two- or three-step system, and distributors play an important role. In Canada, the distributors can be either independent wholesalers and serve independent retailers, or be part of what McEwan and Deen (1997) referred to as "line companies." These line companies that distribute pesticides usually have a full complement of services that they offer to farmers, including farm supplies, fertilizers, transportation, grain handling and consulting.

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5) Phenoxy Herbicides in the Agriculture Sector

The agriculture and agri-food system[1] in Canada plays an important role in the national and provincial economies: the sector accounts for one in eight jobs, and 8.3% of the total gross domestic product (GDP). The agriculture and agri-food system grew at about 2% annually in the period 1991-2003. Value-added processing leads the growth (at 3.3%), while primary agriculture has remained relatively static. The significance of the primary agriculture sub-sector varies across the country. East of Manitoba, processing accounts for the majority of the sector's share of provincial GDP. In the Prairies, primary agriculture plays the more important role.

International markets are critical to the success of this sector. Canada is the fourth-largest agriculture and agri-food exporter, and the fifth-largest importer. Grains and oilseeds account for over one third of the value of all exports (mainly wheat and barley), while rice and corn comprise most of Canadian grain imports. Export sales to the United States have nearly tripled since 1990, while those to Mexico have increased nine-fold. In 2001, 23% of farm production was exported directly and 44% went to processing (some of which was also exported).

This has been a highly productive sector. Labour productivity growth in primary agriculture production[2] from 1997 to 2003 was at an annual rate of 4.8%, exceeding the business sector average of 2.1% for labour productivity. Despite these gains, real net farm income in Canada fell over this period. Rising input costs are given as the main contributing factor. For the average Canadian, food has become increasingly affordable, even as real net farm income dropped.

5.1) Wheat and Barley in Western Canada and Ontario

These small grain cereals in Alberta, Saskatchewan, Manitoba and Ontario are major components of their respective agricultural sectors. In the west (Alberta, Saskatchewan, Manitoba), just over 40% of the total seeded acreage is wheat (winter and spring) and barley, for both 2003 and 2004. Wheat accounts for about 25% of the total seeded acreage, and barley the remaining 15% (Statistics Canada). Western farmers generated approximately $2.67 billion in farm cash receipts from wheat and barley in 2005.

In Ontario, wheat and barley account for about 14% of the province's field crop acreage and just short of $200 million in farm cash receipts in 2004 (OMAFRA 2004-2005).

[1] Most of this overview material is abstracted from, Agriculture and Agri-Food Canada (2005b).
[2] Includes forestry, fishing and hunting.

Overall, wheat and barley represent 7.7%[3] of total farm cash receipts in Canada and account for 28%[4] of all agricultural exports.

5.2) Current Control of Broadleaf Weeds in These Crops

Pests have been a major problem for farmers for at least as long as recorded history, and it is safe to assume that this concern even predates the written word. A recent report prepared for CropLife Canada (CropLife Canada 2005) noted that ancient texts listed various remedies against pests, including prayers and sacrifices, and materials such as salt, nitrates, olive dregs, vinegar and urine. The number and variety of pesticides approved for weed control in these crops and the estimates of the drop in yield that can be expected if the weeds are not controlled demonstrate the significance of weed control to the final yield and quality of cereal crops. For example, the Saskatchewan Department of Agriculture, Food and Rural Revitalization (2005) identified 37 pesticides approved for control of weeds in barley and 45 for weed control in spring wheat . Ontario's Ministry of Agriculture and Food (OMAFRA, 2004-2005: 99) has a four-page list of pesticides approved for spring wheat (and other crops), for post-emergent grass herbicides, post-emergent broadleaf weeds, etc. This long list of herbicides registered for broadleaf control in small grains indicates the importance of weeds, the dependence of growers on herbicides for weed management and the diversity of weeds in these crops across Canada.

The economic threat is real. Farmers stand to suffer significant financial losses if weeds in wheat and barley are not controlled. The immediate loss is in the yield of the crop planted. Weeds crowd out the crop, absorb soil moisture and take up crop nutrients, resulting in dramatically lower yields. Estimating the possible damage to crop yields from the removal of pesticides can be difficult. It involves creating "what if" scenarios and using various methods to determine the likely implications on crop yields. Three general approaches are used: partial budget models based on agronomic projections, combinations of budget and market models, and econometric models.[5]

The Saskatchewan publication referred to above gives an example of the threat of weeds, specifically yield losses to wheat caused by wild oats. The expected losses are a function of the density of the weed infestation and the relative growth stages of the weed and the crop. The losses range from a high of 37% (high infestation density and the weed is one leaf stage ahead of the crop), to a low of 3% to 5% for lower infestation densities and a crop that is one leaf stage ahead of the weed (Saskatchewan, 2005: 20). The original Canadian study on 2,4-D economics considered a variety of approaches for estimating yield losses and concluded that all were consistent with a central estimate of yield loss of

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[3] Statistics Canada. Farm Cash Receipts - Agriculture Economic Statistics Catalogue no.: 21-011-XWE May 2006, vol. 5 no.1
[4] Statistics Canada, Trade Data Online
[5] For a good overview of these methods and the strengths/drawbacks of each, see the US National Research Council (2000: 15 ff).

10%, with wide variation according to the method used, the crop considered and other factors (Krystynak, 1983).

The US Department of Agriculture, National Agriculture Pesticide Impact Assessment Program (USDA NAPIAP) confirmed these threats in the United States. Potential losses in wheat range from 20% to 56%, depending on the specific broadleaf weeds and other factors, such as soil fertility, moisture and temperature (USDA, 1996: 128). A report prepared by the US National Research Council (USNRC, 2000) surveyed the literature on the impact of pesticides on agricultural yields and found that the yields of many crops could decrease by as much as 50% without crop protection and that removing pesticides from US agriculture would cause crop production to decline by 24% to 57% and that cultivated acreage would increase by 10% to compensate for yield losses.

A caveat to many of these studies is that they use the partial-budget approach that has been found to over-estimate the consequences, especially the longer-term consequences, of a regulatory change. Typically, the partial-budget approach assumes only a limited set of responses by farmers to, for example, the withdrawal of the pesticide and does not consider longer-term adaptations, such as crop changes or new technologies. A counterpoint to this concern, however, is that farmers can benefit from the less-threatening long-term environment only if they can survive the short-term adjustment costs predicted by the partial-budget approach.

While much of this research has focused on estimating the drop in yields that would result from a resurgence of broadleaf weeds, another impact on crops is a drop in quality of the final, reduced, crop. Krsytynak (1983) explained a number of factors that affect grain quality, including increased dockage[6] if phenoxy herbicides were not used. The presence of broadleaf weed material within the cropped grain can result in a downgrading of the quality of the grain (reduced grade). One outcome of a quality downgrade is a reduction in price. Another potential outcome is the inability to sell the grain into the preferred markets.

The most notable effect on grain quality estimated by Krystynak involved loss of protein content. Krystynak estimated a $4 million loss in the 1979 value of wheat in Canada due to lower protein levels if 2,4-D were not used to control broadleaf weeds.

What is indisputable from the research is that weed infestations can make the difference for a farmer between profit and loss. Given the current economics of agriculture in Canada, any financial loss could be devastating.

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[6] Dockage refers to "foreign material contained in harvested grain, which can be removed with approved cleaning equipment. This foreign material includes broken grains, weed seeds, chaff, huffs, dirt and other foreign materials" (Krystynak, 1983: 20). Dockage also includes high moisture grain that requires drying. Often the weed seeds, etc., will raise the moisture content of the tested sample as well as the grain.

The Problem Weeds - Western Canada - Wheat and Barley

The main annual and perennial broadleaf weeds that presented a threat to Western growers in 2005 are listed in order of decreasing percentage of the total seeded acreage treated for that weed in Table 5.1.

Table 5.1 Western Weeds

Perennial Broadleaf (% of treated acreage for respective weed)	Annual Broadleaf (% of treated acreage for respective weed)
Canadian thistle (23%) Sow thistle (7%) Dandelion (6%) (and 10 others)	Wild buckwheat (28%) Stinkweed (24%) Kochia (21%) Mustard (14%) Pigweed (11%) and 18 others

Note:
Numbers add to more than 100%, because of multiple weeds in the same acreage.
Source: Stratus (2005).

Producers added that volunteer canola in small grains is considered a weed. MCPA and 2,4-D combat all of these weeds identified by Western farmers to be of the most concern.

Ontario - Wheat and Barley

The OMAFRA listed the main weeds of concern to Ontario cereal crop farmers, as shown in Table 5.2.

Table 5.2 Ontario Weeds

Perennial weeds:			Annual broadleaf:	
Field bindweed	*Convolvulus arvensis*		Wild buckwheat	*Polygonum convolvulus*
			Stinkweed	*Thlaspi arvense*
Dandelion	*Taraxacum officinale*		Cocklebur	*Xanthium strumarium*
Curled dock	*Rumex crispus*		Mustards	*Brassica, sp., Sinapis arversis*
Ground-ivy	*Glechoma hederacea*		Pigweeds	*Amaranthus hybridus*
Horsestail	*Equisetum arvense*		Chickweed, common	*Stellaria media*
Mallow	*Malva neglecta*		Corn spurry	*Spergula arvensis*
Milkweed	*Asclepias syriaca*		Canada fleabane	*Conyza canadensis* or *Erigeron canadensis*
Nutsedge	*Cyperus, sp.*		Hempnettle, common	*Galeopsis tetrahit*
Plantain	*Plantago, sp.*		Ladysthumb	*Polygonum persicaria*
Quackgrass	*Elytrigia repens*		Lambsquarters	*Chenopodium album*
Sow-thistle	*Sonchus, sp.*		Common ragweed	*Ambrosia artemisiifolia*
Canada thistle	*Cirsium arvense*		Giant ragweed	*Ambrosia trifida*
Vetches	*Vicia, sp.*		Shepherd's purse	*Capsella bursa-pastoris*
			Velvetleaf	*Abutilon theophrasti*

Source:
OMAFRA (2004-2005).

This OMAFRA workbook indicated that MCPA labels specifically target 12 of the 16 annual broadleaf weeds, and none of the perennial weeds; 2,4-D targets 11 of the 16 annual broadleaf weeds and 6 of the 14 perennial weeds.

Current Control Methods for Broadleaf Weeds in These Crops

Small grains are seeded in rows, less than one foot apart. Thus, cultivation during the growing season is not feasible. As well, reducing tillage has been recognized as a benefit to producers, from both a financial and environmental perspective. Hand weeding in small grains was a common practice before the introduction of the phenoxy herbicides in 1945. However, current labour costs and the large acreage planted make hand pulling in small grains financially impossible. Hand hoeing for broadleaf weed control in these grains is difficult and unacceptable, because of labour costs, large acerage and potential damage to the crop from both the hoe and the labourer. Additionally, weeds growing within the crop row could not be destroyed by hoeing; yield and quality losses would still occur.

These practicalities make selective herbicides the most appropriate method for controlling broadleaf weeds and minimizing the farmer’s financial risk. Even the most sophisticated approach to integrated pest management recognizes that herbicides have a role to play in broadleaf control. Both the literature and practical experience of farmers around the world are clear on this point.

Of the 34.7 million acres seeded to wheat and barley in Western Canada, just over 90% were treated with herbicides one or more times during 2005. This percentage increased from 86.7% in 2003. Note that the absolute number of acres treated one or more times did not change significantly over this period; while the total number of seeded acres declined, the percentage treated increased. Of the three uses of herbicides for small grains (fall post-harvest, spring pre-seed and post-emergent), post-emergent is by far the most common in both Western Canada and Ontario by almost any measure used. (Stratus, 2005).

5.3) Phenoxy Herbicides in Broadleaf Weed Management for Wheat and Barley

All three phenoxy herbicides (2,4-D, MCPA and mecoprop-p) are registered for broadleaf weed control in wheat, barley, corn and many other agricultural crops. By far, the two most important phenoxy herbicides to producers are 2,4-D and MCPA. mecoprop-p is used primarily as a second or third herbicide in formulated products applied for weed control. It is formulated with either 2,4-D or MCPA (along with dicamba) in three products, only one of which has significant sales, at about 4% of the brand acres in 2005. mecoprop-p is not among the 20 most common current herbicide treatments used by grain and barley producers. Its importance in this analysis lies in that it is in two of the alternatives available to some producers in the event of the withdrawal of either 2,4-D or MCPA. Note that the withdrawal of 2,4-D and MCPA from the market essentially implies the withdrawal of mecoprop-p since mecoprop-p is often available only in combination with 2,4-D and MCPA. While this discussion of the agriculture sector and herbicides focuses on 2,4-D and MCPA, mecoprop-p is discussed with the costs of alternatives.

It is particularly important to note that these two phenoxy herbicides are used both on their own, and in combination with other herbicides from the Group 4 set and from other herbicide groups.[7] Combined herbicides are used as part of sound integrated pest management practices by farmers to broaden the list of weeds controlled by the resultant mix and delay any onset of resistance to the non-phenoxy herbicide. This point about the phenoxy herbicides, especially 2,4-D, delaying the onset of resistance to the non-phenoxy herbicides is so important that it is discussed separately in Chapter 6.

The importance of the phenoxy herbicides to wheat and barley in Western Canada is demonstrated by the following facts.

- Just over 80% of the Western “brand-acres”[8] that received post-emergent herbicide treatment in 2005 had as an active ingredient either 2,4-D (32%) or MCPA (44%) or mecoprop-p (5.5%) (Stratus, 2005: 32-33).

- Of the ten major brands that account for most of the market for broadleaf weed control in Western wheat and barley in 2005, seven had either 2,4-D or MCPA as an active ingredient. One of the remaining three is used to some degree tank-mixed with one of the phenoxy herbicides (Stratus, 2005: 34). These ten brands belong to the four major companies that account for about 82%, by dollar value, of the market for herbicides.

- The brand herbicides with a phenoxy as the active ingredient accounted for 69% of the total expenditures in 2005 on post-emergent herbicides for Western wheat and barley (Stratus, 2005).

- Of 37 brands of broadleaf herbicides available for wheat, 2,4-D was the cheapest on a per/acre basis; MCPA was the third-lowest price. Barley presented the same picture (Stratus, 2005).

In Ontario, the two phenoxy herbicides 2,4-D and MCPA, account for just over 50% of all herbicides used in Ontario grain farms (includes wheat, oats, barley, mixed grain and rye). Ontario grain farms also account for about 89% of the total provincial usage of these two phenoxy herbicides (OMAFRA, 2004-2005).

5.4) Economic Consequences of Withdrawing Phenoxy Herbicides

As noted earlier, it is useful to identify three main approaches for estimating the economic impacts of a regulatory change to farming practices.

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[7] Herbicides are grouped based on target sites and modes of action. For more information, see PMRA (1999).

[8] A measure used in the industry to deal with the fact that some treatments involve multiple brands on the same acreage.

- The **partial-budget** approach estimates the productivity effects of changes in pesticide use by constructing alternative production scenarios, each of which consists of a set of input usages (pesticides, fertilizers, labour, energy, etc.) and corresponding crop yields. The current crop production budgets and the scenarios are constructed from real-world experience and the opinions of agricultural experts. The scenarios describe what is likely to happen under various assumptions about the timing of the withdrawal of the pesticides, the availability of alternatives, the response of consumers and many other factors. Likely changes in yields and quality are estimated either from field trials or expert opinions. Input and output prices are then used to turn the various scenarios into financial impacts on the primary producers and, sometimes, on their suppliers in the value chain.

  The partial-budget approach has been used widely over the years to estimate the impacts of a wide range of regulatory changes, including the case of pesticides. The original Canadian economic study of 2,4-D (Krystynak, 1983) used this approach, as have many other regulatory impact assessments carried out in Organization for Economic Co-operation and Development (OECD) nations in the intervening years. However, this approach can over-estimate the actual impacts of a regulatory change. The most significant cause for this potential over-estimation is that the approach usually considers only a subset of all possible adaptations by affected producers. In particular, the approach usually considers only the short-run substitutions. Longer-run adaptations, such as changes in land allocations and new technologies, are not included in the analysis.

- The **combined budget-market models** take the results of the partial-budget approach and then use econometric models to predict likely changes in output prices and consumption for agricultural goods affected by the withdrawal of the pesticides.

  The combined budget-market approach builds on the results of the partial-budget approach by estimating the likely flow-through impacts on market prices and consumption patterns for the affected products. This approach has the same caveat as the partial-budget approach, but it presents a deeper analysis of the potential implications of the regulatory change.

- The **econometric models** take a different route and estimate directly the productivity effects of pesticides (i.e., the effects on crop yield and quality) by using statistical methods to model the links between agricultural inputs (pesticides, fertilizers, crop rotation, etc.) and crop yields. The econometric models approach, while potentially interesting, requires a great deal of complex data.

This study used the combined budget-market models approach. It is consistent with the original Canadian study and the more-recent USDA NAPIAP, and was feasible within the time and budget constraints of this analysis. A recent in-depth review of economic impact assessment approaches conducted for Agriculture and Agri-Food Canada (2006 a) recommended an approach that is similar to this combined budget-market models approach. The caveat about potential over-estimation of impacts is addressed by taking a conservative approach to the estimation of all factors in the analysis, and by using ranges for particularly sensitive factors.

How will wheat and barley producers maintain yield and quality if the phenoxy herbicides are withdrawn? This is the first question to be asked in the partial-budget approach. Typically, farmers will take different actions that vary according to local conditions and personal preferences. Then the cost implications of these actions are determined and a variety of market models used to estimate the broader, economic implications of these changes in production costs.

There are two possible reactions, not mutually exclusive, by farmers to maintain crop yield and quality.

- Use other weed management practices, including herbicides, to maintain, to the greatest extent feasible and affordable, the same crop quality and yield.

- Cultivate more land, in conjunction with the above approach, to maintain quality and yield. However, this approach is not practical in most cases.

As noted earlier, the use of herbicides is the preferred approach in small grains. The choice of replacement herbicide or other management practices will be an individual one, influenced by:

- the predominant weed species present;
- the local environmental conditions (soil, temperature, moisture) that influence the time of emergence of weeds relative to that of the crop;
- the costs of the alternative herbicide treatments; and
- the best fit with the management practices on individual fields and farms (e.g., tank mixability with graminicides, the desire for herbicide rotations, presence of specific herbicide resistant weed populations, crop rotations, any crop/herbicide interactions that affect crop rotation decisions, water sources, equipment availability, flexibility to accommodate weather-influenced delays to herbicide application and personal experience).

These complex decisions take place at the farm level, and are extremely difficult to estimate with certainty. Where possible, the variables used in the models are drawn from detailed farm practice surveys, such as the comprehensive USDA NAPIAP study. In other instances, the academic literature and industry sector experts in the field were used to provide insight into potential changes in farm weed management practices.

The Direct Costs of Controlling Broadleaf Weeds in Wheat and Barley without Phenoxy Herbicides

Manufacturers and distributors of herbicide formulations sell their products under various price structures. There can be price discounts for volume purchases, for the purchase of multiple products and price changes in response to short-term fluctuations in supply and changes in corporate marketing strategies. The details of these market changes are closely guarded corporate strategies. The issue was to identify accessible prices that would present a consistent picture across the phenoxy herbicides, and for the herbicides that would be considered as alternatives that would not violate corporate confidentiality restrictions. Ideally, the price data should be available publicly so this work could be reviewed.

The major corporate sponsors of this research all subscribe to the market reports of a private company called Stratus Agri-marketing Inc. of Guelph, Ontario. Stratus has been publishing market research data on herbicide use for many years and has a consistent database on herbicide costs to farmers, application rates, co-formulations and many other farming practices. Portions of the Stratus data for 2005 were made available for this study only. Access to this database ensured consistency of the cost used in estimating, first, the baseline costs of current herbicide practices and, second, the costs of the alternatives. The Stratus database is available to subscribers.

The Current Cost of Treating with 2,4-D and MCPA

Industry sector experts identified the current treatments using the phenoxy herbicides that are being applied to wheat and barley. Because the treatments and alternatives are similar, Western Canada and Ontario acreages for the cereals are aggregated. Tables 5.3 and 5.4 present current usage patterns and costs, for each of the two phenoxy herbicides on the two cereal crops.

Table 5.3 Direct Farm Management Cost Model for Wheat in Western Canada and Ontario

Current 2,4-D Usages and Costs for Wheat	Total		
Treatment	Treated Acres (millions)	Average Cost per Acre ($/acre)	Total Treatment Cost ($ millions)
Treatment 1 2,4-D applied alone	2.48	2.22	5.50
Treatment 2 2,4-D mixed with bromoxynil (proprietary broadleaf herbicides)	2.17	5.78	12.51
Treatment 3 2,4-D mixed with dichlorprop* (commodity broadleaf herbicides)	1.06	5.45	5.76
Treatment 4 2,4-D mixed with florasulam or fluroxypyr (proprietary broadleaf herbicides)	1.26	6.96	8.80
Treatment 5 2,4-D mixed** with dicamba, imazamox, tribenuron	0.90	7.81	7.07
Treatment 6 2,4-D mixed with glyphosate	0.87	2.25	1.96
Totals	8.74		41.60

Note:
* Dichlorprop is 2,4-DP.

Current MCPA Usages and Costs for Wheat		Total	
Treatment	Treated Acres (millions)	Average Cost per Acre ($/acre)	Total Treatment Cost ($ millions)
Treatment 1 MCPA applied alone	0.62	3.42	2.11
Treatment 2 MCPA mixed with bromoxynil (proprietary broadleaf herbicides)	4.15	8.67	35.97
Treatment 3 MCPA mixed with florasulam, floroxypyr, clopyralid (proprietary broadleaf herbicides)	2.71	7.79	21.11
Treatment 4 MCPA mixed** with dicamba	2.33	5.57	12.97
Totals	9.81		72.16

Note:
**includes mecoprop-p (in Dyvel DS, Sword or Target).

Table 5.4 Direct Farm Management Cost Model for Barley in Western Canada

Current 2,4-D Usages and Costs for Barley	Total		
Treatment	Treated Acres (millions)	Average Cost per Acre ($/acre)	TotalTreatment Cost ($ millions)
Treatment 1 2,4-D applied alone	0.885	2.58	2.28
Treatment 2 2,4-D mixed with bromoxynil (proprietary broadleaf herbicides)	0.538	5.89	3.17
Treatment 3 2,4-D mixed with dichlorprop (commodity broadleaf herbicides)	0.273	5.41	1.48
Treatment 4 2,4-D mixed with florasulam or fluroxypyr (proprietary broadleaf herbicides)	0.729	7.52	5.48
Treatment 5 2,4-D mixed* with dicamba, imazamox, tribenuron	0.106	4.56	0.48
Treatment 6 2,4-D mixed with glyphosate	0.301	2.46	0.74
Totals	2.832		13.63

Note:
* Includes mecoprop-p (in Dyvel DS, Sword or Target).

Current MCPA Usages and Costs for Barley		Total	
Treatment	Treated Acres (millions)	Average Cost per Acre ($/acre)	TotalTreatment Cost ($ millions)
Treatment 1 MCPA applied alone	0.562	3.25	1.83
Treatment 2 MCPA mixed with bromoxynil (proprietary broadleaf herbicides)	2.409	11.77	28.35
Treatment 3 MCPA mixed with florasulam, floroxypyr, clopyralid (proprietary broadleaf herbicides)	1.349	8.49	11.45
Treatment 4 MCPA mixed* with dicamba	0.253	6.11	1.55
Totals	4.573		43.18

Note:
* Includes mecoprop-p (in Dyvel DS, Sword or Target).

Estimated Direct Costs of Withdrawing 2,4-D, MCPA and mecoprop-p

For each of the above current treatments, a panel of industry experts identified the most likely treatment alternatives that would be used by the affected producers in four scenarios:

- 2,4-D alone withdrawn from the market;
- mecoprop-p withdrawn from the market;
- MCPA withdrawn from the market; and
- both 2,4-D and MCPA (and therefore mecoprop-p) withdrawn from the market (i.e., the withdrawal of all three phenoxy herbicides).

Industry experts identified two classes of alternatives to the current uses of the phenoxy herbicides: the use of other herbicides, and, the use of a variety of other practical farm management techniques, such as increased tillage, referred to as "iron in the field". It became apparent quickly that the “iron” alternatives would be more expensive, less effective and more labour intensive than the herbicide alternatives.[9] In the interest of ensuring that this economic analysis was a conservative one, only the alternative herbicide treatments were considered.

For each alternative, advantages and disadvantages were identified along with any changes in costs of the herbicides being used and to herbicide application techniques, such as frequency, other cost impacts, such as the requirement for additional spraying, and any required changes to application intensity. Any expected changes in yield of the crop were identified. The goal in describing each alternative was to preserve crop yield and quality, to the greatest extent possible.

Table 5.5 is an example of the treatment alternatives and their direct farm management costs identified for one current use of 2,4-D and MCPA. Similar tables were developed for the other uses. Direct farm management costs means the direct costs producers would experience in trying to maintain the yield and quality of their cereal crops using alternative herbicides. Direct farm management costs do not cover two other categories of costs:

- any farm revenue losses that result from a decline in yields; and
- indirect farm management costs.

Industry representatives believe that, no matter how rigorously producers apply the alternatives, the results will not be as effective as current farm management practices involving use of phenoxy herbicides. In some cases, these representatives believe that Canadian cereal producers will be thrust back into weed control practices of the early 1940s.

[9] For detailed information on the relative costs of chemical and iron or tillage weed control, see Gianessi and Reigner (2006).

Table 5.5 Example of Alternative Treatments to the Use of 2,4-D Alone on Wheat

Alternatives	% of Treatment Area*	Average Cost per Acre [10] ($/acre)	Incremental Cost (+/- $/acre)	Other Cost Impacts [11] ($ millions)	Total Cost Impact ($ millions)**
MCPA alone	5	3.42	1.20	-	0.15
Express®	5	4.31	2.09	-	0.26
Refine® Extra	10	4.39	2.17	-	0.54
Buctril® Mextrol®	20	5.97	3.75	-	1.86
Banvel	5	3.05	0.83	-	0.10
Dyvel®	15	5.20	2.98	-	1.11
Target® Tracker® Sword®	10	5.84	3.62	-	0.90
Frontline* *Trademark of Dow AgroSciences	10	6.72	4.50	-	1.11
Brigade®	10	22.00	19.78	-	4.90
Trophy®	5	10.12	7.90	-	0.98
Baseline®	5	22.50	20.28	-	2.51
Additional costs				8.20	8.20
Total	100	8.04			22.62

Notes:
* Based on 2.48 million acres treated with 2,4-D alone (from Table 5.3).
** Total cost impact is calculated as the % of treatment area for the alternative treatment x acres treated with 2,4-D alone x incremental cost of the alternative treatment (e.g., for the MCPA alone alternative, 5% x 2.48 x $1.20 = $0.149M).

Annual Direct Cost Impacts on Farmers

An estimate of the total direct farm management costs to wheat and barley producers under the four scenarios are presented in the following tables. Tables 5.6 through 5.8 show the current phenoxy treatment costs, estimated cost increases and the percentage change in weed control costs for farmers by crop for the four scenarios if phenoxy herbicides were lost as weed management tools in Canadian agriculture.

Table 5.6 provides a summary of all current treatment costs to treat wheat and barley in Canada with phenoxy herbicides using 2005 usage patterns and costs for each of the phenoxy herbicides on the two cereal crops. In 2005, farmers spent over $170 million on the phenoxy herbicides on wheat and barley. It should be noted that while shown as a

[10] From Stratus (2005). The total is the weighted average cost/acre for the alternative treatments.
[11] Calculated as the weighted average cost/acre for the alternative treatments plus $3 per acre in additional application costs, applied to 20% of treated acres once per year, plus "doubling-up" of the alternative treatments on 10% of treated acres once per year, in an effort to minimize yield loss if the phenoxy herbicides were not available.

separate line item in Table 5.6, the costs of mecoprop-p are also contained within the 2,4-D and MCPA cost estimates because mecoprop-p is often offered as a mix with one of the other two phenoxy herbicides. For this reason, the row "All phenoxy herbicides" is not the sum of the three preceding rows.

Table 5.6 Summary of Current Treatment Costs ($ millions)

	Wheat $	Barley $	Total $
2,4-D	41.6	13.6	55.2
MCPA	72.1	43.2	115.3
MCPP-p (included within 2,4-D and MCPA above)	[9.3]	[1.4]	[10.7]
All phenoxy herbicides	113.7	56.8	170.6

The incremental (additional) cost to farmers if these phenoxy herbcides were not available is shown in Table 5.7. Each row summarizes the incremental costs of the specific alternative herbicide treatments that would result from the loss of 2,4-D, MCPA, MCPP-p and all phenoxy herbicides. Again, it should be noted that the incremental costs from the loss of all phenoxy herbicides (bottom row in the table) is not the summation of the three preceding rows. This is due to the fact that when one phenoxy is lost, in some cases the other is a reasonable alternative treatment, at much less cost than the non-phenoxy alternatives. When all phenoxy herbicides are lost, the incremental costs of alternative herbicide treatment are much higher.

Table 5.7 also presents the percentage increase in costs for each current phenoxy treatment (estimated incremental cost divided by current treatment cost, e.g., for MCPA wheat: $47.3 / $72.1 = 66%).

If all three phenoxy herbicides were removed, producers would experience **$224 million** in additional annual weed-control costs, a 131% increase.

Table 5.7 Estimated Incremental Costs for Broadleaf Weed Control ($ million and percentage increase over current costs)

	Wheat	Barley	Total
If 2,4-D were not available	$41.5 - 100%	$14.3 - 105%	$55.9 - 101%
If MCPA were not available	$47.3 - 66%	$8.2 - 19%	$55.5 - 48%
If MCPP-p were not available	$4.7 - 50%	$1.5 - 112%	$6.2 - 58%
If all phenoxy herbicides were not available	$168.9 - 148%	$55.1 - 97%	$224.0 - 131%

Table 5.8 presents the incremental cost for farmers of the loss of each phenoxy as a percentage of total current phenoxy costs (e.g., for MCPA wheat: $47.3 / $113.7 = 42%).

Table 5.8 Percentage Increase Over Total Current Costs of Phenoxy Herbicides

	Wheat %	Barley %	Total %
If 2,4-D were not available	37	25	33
If MCPA were not available	42	14	33
If MCPP-p were not available	4	3	4
If all phenoxy herbicides were not available	148	97	131

The estimated cost impacts in wheat would be significant. Farmers would face a 100% increase in weed-control costs on acres currently treated with 2,4-D, a 66% increase on those acres currently treated with MCPA and a 148% increase on all 2,4-D and MCPA treated acres if both phenoxy herbicides were lost. For barley, the cost impacts are also significant, at 97% if the three phenoxy herbicides were lost. Overall, if both 2,4-D and MCPA were removed from the Canadian marketplace, agriculture would experience over $224 million in additional annual weed-control costs, or a 131% increase.

As noted earlier, the above costs do not include any changes to farm revenues that result from the reduction in yields. The issue of whether Canadian crop prices would change in response to changes in yields of Canadian producers is critically important in deciding which sectors of the Canadian economy would, ultimately, bear the consequences of these cost increases. However, there are differing opinions on this point.

The Economic Consequences of These Cost Increases and Income Effects

The cost impacts on farmers are combined with estimates of potential yield reductions and changes in the price of wheat and barley resulting from lower production, to calculate both economic efficiency and income distribution effects in the economy.[12] Potential "upstream" effects on the suppliers of 2,4-D and MCPA, as well as potential "downstream" effects on food and feed markets for wheat and barley are also discussed.

Impact on Producers' Surplus, Consumer Surplus and Social Welfare

Economic efficiency and income distribution effects are estimated in terms of changes in the producer's surplus, consumer's surplus and social welfare. Producer's surplus is the difference between income and costs of production. Income is the product of output price and yield per acre. A pest-control strategy can affect revenues by reducing crop damage, increasing yield or increasing product quality and its price. Assessment of yield and quality effects is essential for quantitatively estimating the impacts of a pest-control strategy.

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[12] This is a welfare economics approach whereby micro-economic techniques are used to determine simultaneously the allocational efficiency and the income distribution consequences of a particular change in the economy (in this case, a loss of 2,4-D and MCPA as inputs to production). Economic efficiency deals with the "size of the pie." Income distribution deals with "dividing up the pie."

Costs include pest control costs, such as application, material and other costs per acre associated with pesticide use. Non-pest-control costs include preparation, fertilizer, harvesting and non-pest-control post-harvesting costs. Pest control and non-pest-control costs cannot always be separated. For example, when cultivation practices (such as crop rotation) are a major element of the pest-control effort.

Increases in costs of production for farmers can lead to a decrease in producer surplus, depending on how prices change for wheat and barley in response to the changes in supply (i.e., a reduction in wheat and barley production). This involves a concept in economics called the price elasticity of demand. Price elasticity of demand is normally expressed in terms of the percentage change in quantity demanded that occurs in response to a percentage change in price. For example, if, in response to a 10% fall in the price of a good, the quantity demanded increases by 20%, the price elasticity of demand would be 20%/ (−10%) = −2.[13]

Price elasticity of demand also determines how prices change in response to a change in quantity (which, in this case, results from an upward shift in the supply curves for wheat and barley due to a combination of higher costs of inputs and lower yields). From the above example, a price elasticity of demand of –2 means that for every 1% reduction in supply, prices would increase by 0.5% (i.e., the reciprocal of the price elasticity).
The overall elasticity of demand for wheat and barley is regarded as highly inelastic. When the price elasticity of demand for a good is inelastic (i.e., less than 1), the percentage change in quantity is smaller than that in price.

Is Canada a Price Taker in Wheat and Barley Markets or Would Reduced Yield Affect Crop Prices?

There are two divergent opinions within the Canadian agriculture sector as to whether a reduction in Canadian production (i.e., yield) would have any effect on the market prices of wheat and barley. One opinion holds that Canada is a marginal player in both markets, and thus Canadian producers and consumers must accept whatever the global market prices are. An attempt by Canadian producers to demand more for their products in response to a decline in their domestic yield would just cause their Canadian clients to buy their grains offshore at the lower international price. Thus, this view is that the price elasticity of Canadian demand is “zero.” A reduction in yield will have no effect whatsoever on the prices for grains. Industry representatives are, generally, of this opinion.

However, some well-recognized Canadian academics as well as some government agencies believe empirical evidence suggests that Canadian prices for wheat and barley would change in response to changes in Canadian yields. Prices to Canadian producers would rise in response to reduced supply from declining yields, thus softening somewhat the financial loss incurred by the producers. This view holds, further, that there is

[13] Price elasticity of demand is calculated as follows: (% change in quantity demanded of product X) / (% change in price of product X).

empirical evidence to suggest that the price changes would vary across the Canadian markets for the two cereals (i.e., that the price change for barley used in brewing would be different than the price change for barley used in, say, feed). Of course, it is the Canadian processors and consumers who would then incur a loss brought about by the increased prices. This report analyzes both viewpoints.

In the case of Canada being a price taker in both wheat and barley markets, it is the farmer who would bear the direct farm management costs, plus the drop in revenue that resulted from the drop in yields. Yield loss estimates were based on results from the USDA (1996) study, the Canadian study by Krystynak (1983) and other expert opinions.

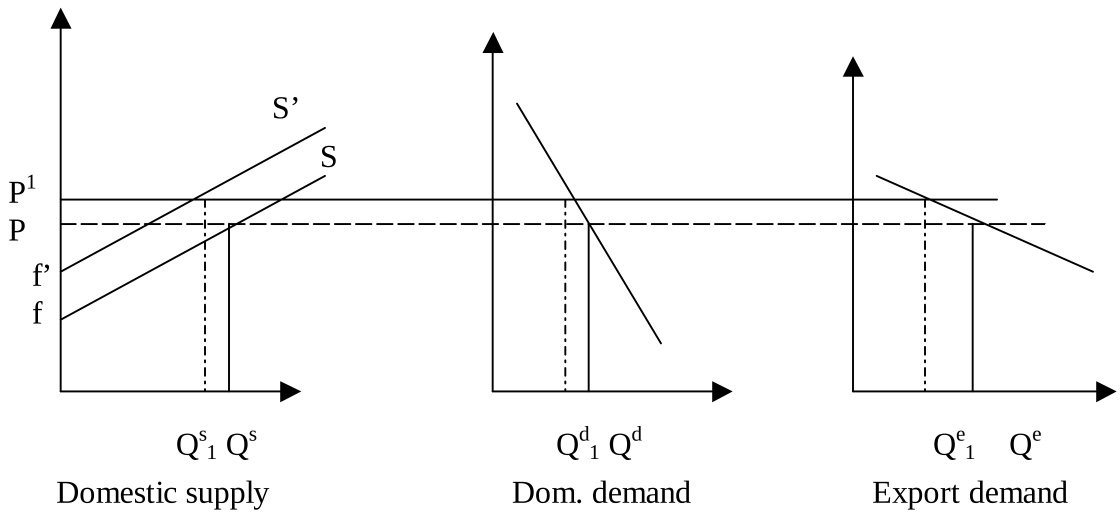
For the other viewpoint, the same yield loss estimates were combined with price elasticities of demand according to the literature and expert opinion, as described in tables 5.9 and 5.10.

Table 5.9 Potential Yield and Price Effects from Loss of Phenoxy Herbicides in Canada

Market	Estimated Yield Loss in U.S. (USDA, 1996) %	Estimated Yield Loss in Canada (Krystynak, 1983) %	Yield Loss Applied in This Study %	Canadian Price Elasticities	Sources
Potential Yield and Price Effects from Loss of 2,4-D					
Wheat					
Domestic feed use	0.9	7.5 -10	1.0	-1.08	Canada, 2006b
Domestic food and ind use				-0.06	
Exports				-15	Alston et al., 1994: 239 Furtan, 2006
Barley					
Domestic feed use	2.1	7.5 -10	2.0	-0.53	Schmitz et al., 1997
Domestic malting use				-0.5	Furtan (2006)
Exports				-20	Schmitz et al., 1997
Potential Yield and Price Effects From Loss of MCPA					
Wheat					
Domestic feed use	n/a	n/a	0.5	-1.08	Canada, 2006b
Domestic food and ind use				-0.06	
Exports				-15	Alston et al., 1994: 239 Furtan, 2006
Barley					
Domestic feed use	n/a	n/a	1.0	-0.53	Schmitz et al., 1997
Domestic malting use				-0.5	Furtan (2006)
Exports				-20	Schmitz et al., 1997
Potential Yield and Price Effects from Loss of 2,4-D and MCPA					
Wheat					
Domestic feed use	2.2	7.5 -10	2.0	-1.08	Canada, 2006b
Domestic food and ind use				-0.06	
Exports				-15	Alston et al., 1994: 239 Furtan, 2006
Barley					
Domestic feed use	3.8	7.5 -10	3.5	-0.53	Schmitz et al., 1997
Domestic malting use				-0.5	Furtan (2006)
Exports				-20	Schmitz et al., 1997

The supply and demand for Canada's wheat and barley production is characterized in Figure 5.1.

Figure 5.1 Supply and Demand for Canadian Wheat and Barley



Source:
Dr. Hartley Furtan, University of Saskatchewan.

Dr. Furtan went on to explain his diagram.

> Here we have two markets: 1) the domestic demand, and 2) the export demand. We have one supply curve **S.** Because the export demand is an excess demand we get the world price in Canada as **P.** Other countries' supply and demand curves are not shown, but their net effects are included in the above diagram. We get the allocation of the supplied quantity in Canada $\mathbf{Q^s}$ to the two markets $\mathbf{Q^d}$ and $\mathbf{Q^e}$. The excess demand (which is the export demand curve) is much more elastic than the domestic demand curve.
>
> Now the supply curve is shifted to the left to **S'** and the quantity produced in Canada is reduced. The reduction is quantity is allocated to the markets so as to maximize returns with $\mathbf{Q^d_1}$ and $\mathbf{Q^e_1}$ respectively. Given the respective elasticities this raises the world price to $\mathbf{P^1}$**.** In the real world markets this increase in price would be very small" (Furtan, 2006).

Table 5.10 shows the linear demand functions calculated as per the discussion above for the various markets.

Table 5.10 Linear Demand Functions by Market

Market	Linear Demand Functions
Wheat	
Domestic feed use	P = 370 - 0.053Q
Domestic food and ind use	P = 3394 - 1.542Q
Exports	P = 205 - 0.0013Q
Barley	
Domestic feed use	P = 323 - 0.038Q
Domestic malting use	P = 336 - 1.402Q
Exports	P = 118 - 0.005Q

Solving these demand equations for the change in supply from reduced yields due to a loss of phenoxy herbicides results in the market clearing prices for Canadian wheat and barley shown in Table 5.11.

Table 5.11 Market Clearing Prices

	Loss of Production (tonnes)	New Market Clearing Price ($/tonne)	% Change in Price
Wheat			
If 2,4-D were not available	154,000	192.30	0.1
If MCPA were not available	77,000	192.21	0.05
If MCPP-p were not available*	0	no change	no change
If all phenoxy herbicides were not available	308,000	192.49	0.2
Barley			
If 2,4-D were not available	137,000	112.60	0.54
If MCPA were not available	69,000	112.30	0.27
If MCPP-p were not available*	--	--	--
If all phenoxy herbicides were not available	240,000	113.06	0.95

Note:
* Assumes that current 2,4-D and MCPA treatments containing mecoprop-p (Dyvel DS, Sword and Target) would be replaced with equally effective alternatives, with no changes in yield.

Consumers' Surplus

Consumers' surplus (CS) is a measure of consumer welfare, defined as the difference between the amount consumers are willing to pay for a quantity of product and the amount they actually do pay. The magnitude of CS also depends on demand elasticities. For products with inelastic demands, where changes in quantity can substantially affect price, the impact of reductions in supply on CS can be substantial, because of potential price increases. The CS effect could be substantial when pest-control strategies change for producers of agricultural commodities that have a significant market share and products with inelastic demand. For example, NAPIAP determined that CS could reduce significantly if 2,4-D or all phenoxy herbicides were banned for use on wheat and barley in the United States.

Social Welfare

Total change in social welfare is the sum of the changes in producer and consumer surplus.

5.5) Summary of Economic Impacts

Economic Impacts on Wheat and Barley Producers if They are Price Takers

As described above, the assumption that Canadian producers are price takers in these two markets means that Canadian producers would bear the full impacts of both the direct farm management costs and the drop in revenues caused by the drop in yields. Table 5.12 presents these annual total costs to the producers for wheat and barley.

Table 5.12 Overall Annual Economic Impact on Farmers if No Price Change

	Estimated Direct Cost Impacts ($000)	Lost Revenues ($000)	Total Economic Impact on Farmers ($000)
Wheat			
If 2,4-D were not available	41,531	37,794	-79,325
If MCPA were not available	47,304	18,897	-66,201
If MCPP-p were not available	4,710	0	-4,710
If all phenoxy herbicides were not available	168,915	75,589	-244,503
Barley			
If 2,4-D were not available	14,327	21,855	-36,182
If MCPA were not available	8,160	10,928	-19,088
If MCPP-p were not available	1,520	--	-1,520
If all phenoxy herbicides were not available	55,126	38,247	-93,373
Totals			
If 2,4-D were not available	55,859	59,650	-115,508
If MCPA were not available	55,464	29,825	-85,289
If MCPP-p were not available	6,230	--	-6,230
If all phenoxy herbicides were not available	224,041	113,836	-337,876

Table 5.12 shows that Canadian wheat and barley farmers could suffer $115.5 million in losses (direct costs plus lost revenues) per year if 2,4-D were withdrawn, $85.3 million if MCPA were withdrawn, $6.2 million if mecoprop-p were withdrawn and about $338

million per year if all three phenoxy herbicides were withdrawn. This represents 24% of the entire net farm income in 2005 for Manitoba, Saskatchewan and Alberta[14]. The losses across the entire agriculture sector would be even larger.

Comparison with Previous Studies

The most comprehensive previous study of the economic impacts of 2,4-D was conducted by Stemeroff et al. (1988) for Agriculture and Agri-Food Canada. The study estimated net losses of $58 million to $82 million in the agricultural sector from loss of 2,4-D, and a net loss to agriculture of $328 million to $365 million from the loss of all phenoxy herbicides. While the results from the 1988 study appear similar to the results reported in this study, it is important to note a number of important differences.

- Results for both studies are reported in current dollar terms. Expressed in 2005 dollars, the 1988 results would be significantly higher.

- Different approaches were taken to assess potential farm-level responses to the loss of phenoxy herbicides. Stemeroff et al. used fewer existing and alternative treatment options in their assessment. Based on input from a number of industry experts, this study used a broader range of current and alternative treatment options considering issues, such as soil type, region, weed spectrum and resistance, to build the farm-level impact scenarios.

- The 1988 study estimated crop production losses of 5% to 10% in the short term, and up to 35% in the longer term, due to crop acres being left untreated with the loss of phenoxy herbicides. This study assumed that farmers would use alternative herbicide treatments to minimize production loss. As a result, the production loss estimates in this study are significantly lower than the 1988 study.

- Also in the 1988 study, prices of non-phenoxy herbicides were anticipated to increase by 10% to 16%, increasing the treatment costs to farmers. This study did not assume any price increases for non-phenoxy herbicides in response to their loss from the Canadian marketplace.

- Stemeroff et al. estimated the extent to which agricultural stabilization programs would offset losses for farmers. This study did not estimate the impact of agricultural support programs in offsetting losses for farmers, since this would essentially represent a transfer of consumer surplus to producer surplus, with no change in overall societal effects (subject to some efficiency loss in the system).

The above comparison is not intended to imply that one study is methodologically superior to the other. Rather, the comparison suggests that the results in this study should be considered conservative.

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[14] http://dsp-psd.pwgsc.gc.ca//Collection/statcan/21-010-XIE.html

Economic Impacts on Canadian Consumers and Agriculture Producers if Prices Do Change in Response to Drops in Yields

Table 5.13 summarizes the annual changes in producer's surplus, consumer's surplus and overall social welfare if 2,4-D and MPCA were no longer available for use in the production of wheat and barley in Canada.

Table 5.13 Overall Annual Economic Effects

	Change in Producer Surplus ($000)	Change in Consumer Surplus ($000)	Change in Social Welfare ($000)
Wheat			
If 2,4-D were not available	-75,625	-3,701	-79,326
If MCPA were not available	-64,439	-1,762	-66,201
If MCPP-p were not available	-4,710	0	-4,710
If all phenoxy herbicides were not available	-237,177	-7,326	-244,503
Barley			
If 2,4-D were not available	-30,446	-5,737	-36,183
If MCPA were not available	-16,190	-2,898	-19,088
If MCPP-p were not available	-1,520	0	-1,520
If all phenoxy herbicides were not available	-83,393	-9,980	-93,373
Totals			
If 2,4-D were not available	-106,071	-9,438	-115,509
If MCPA were not available	-80,629	-4,660	-85,289
If MCPP-p were not available	-6,230	0	-6,230
If all phenoxy herbicides were not available	-320,570	-17,306	-337,876

Table 5.13 shows that the overall welfare loss to the Canadian economy from loss of phenoxy herbicides in wheat and barley would be about $338 million per year. Based on the methods employed in this study, that estimate should be considered conservative.

The wheat market would be the hardest hit, with costs to wheat farmers, production losses and price increases accounting for almost $245 million, or about 72%, of the total welfare loss.

These cost impact estimates do not cover the entire Canadian agriculture sector. For example, about five million acres of oats grown in Canada are treated with phenoxy herbicides. As well, producers have pointed out the importance of the phenoxies to managing range and pasture lands.

5.6) Economic Consequences of Withdrawal of Phenoxy Herbicides

Due to the very modest price changes that might occur, farmers would bear the brunt of the overall economic impacts. Consumers could bear about $17 million or 5.1% of the total burden. Loss of 2,4-D would place a relatively higher share of the financial burden on consumers (8.2%) than would the loss of MCPA (5.5%) or loss of all phenoxy herbicides (5.1%).

Upstream

If all phenoxy herbicides were withdrawn, some manufacturers could expect to gain through increased sales of non-phenoxy herbicides. The phenoxy herbicides are not manufactured in Canada so there would be no domestic change at the beginning of the value chain. The large majority of the alternative herbicides are more expensive than the phenoxy herbicides that would be replaced. In general, products that are more expensive carry higher profit margins so the herbicide manufacturing industry could expect to show higher profitability from the sales of the more expensive products. A similar effect would probably be evident throughout the entire herbicide value chain, as distributors and formulators accrued more profitable margins from the more expensive herbicides.

Downstream

Changes in production and quality would affect a number of downstream industries. Wheat and barley are used as inputs to the production of a wide range of food products. Wheat is produced primarily for the domestic and export food market but a significant proportion is also used for feed. Although some barley is selected for the production of malt, about 85% of production is generally used in the feed market.

Wheat is normally used as a feed ingredient by the hog and poultry industries. In a normal year, only about 5% to 10% of the western wheat crop is of feed quality (AAFC, 2005a: 1). Table 5.13 shows that the downstream industries would face almost $10 million in extra costs for barley, and over $7 million for wheat.

Other Impacts

There are other consequences of withdrawing these important products from the market.

- Induced Changes to Farming Practices: Various pest-control strategies affect directly and indirectly the resources used in agricultural activities. For example, changes in pest-control strategies that decrease yield per acre could increase agricultural land and water use relative to an initial benchmark. Such increases in land use could reduce environmental benefits as habitat for wildlife-preservation activities. Expanding the area cultivated would bring its own problems in the form of lost species habitat and increased levels of erosion. Finally, cultivation practices would have to return to the more intensive use of plows, discs and harrows, all of which require increased outlays on tractor fuel and increased soil compaction.

- A number of industry representatives believe Canadian producers would find themselves reverting to practices that were the standards in the 1940s before the introduction of 2,4-D. They question whether Canadian producers could ever compete in such an environment.

- Spread of Broadleaf Weeds: Note that these alternatives are not as effective as 2,4-D and MCPA even with increased application rates and number of applications. Thus, a further impact would be the increase in the spread of the target weeds, and that the economic loss values presented are considered conservative.

- Increased Threat of Weed Resistance: Weeds have been found to exhibit resistance to newer alternative herbicides, and a greater use of these alternatives can be expected to lead to a greater incidence of resistance. The anti-resistance properties of the phenoxy herbicides, and the broad spectrum activity of 2,4-D in particular, are so significant to the agriculture industry that it is discussed separately in Chapter 6.

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6) Managing Resistance to Herbicides

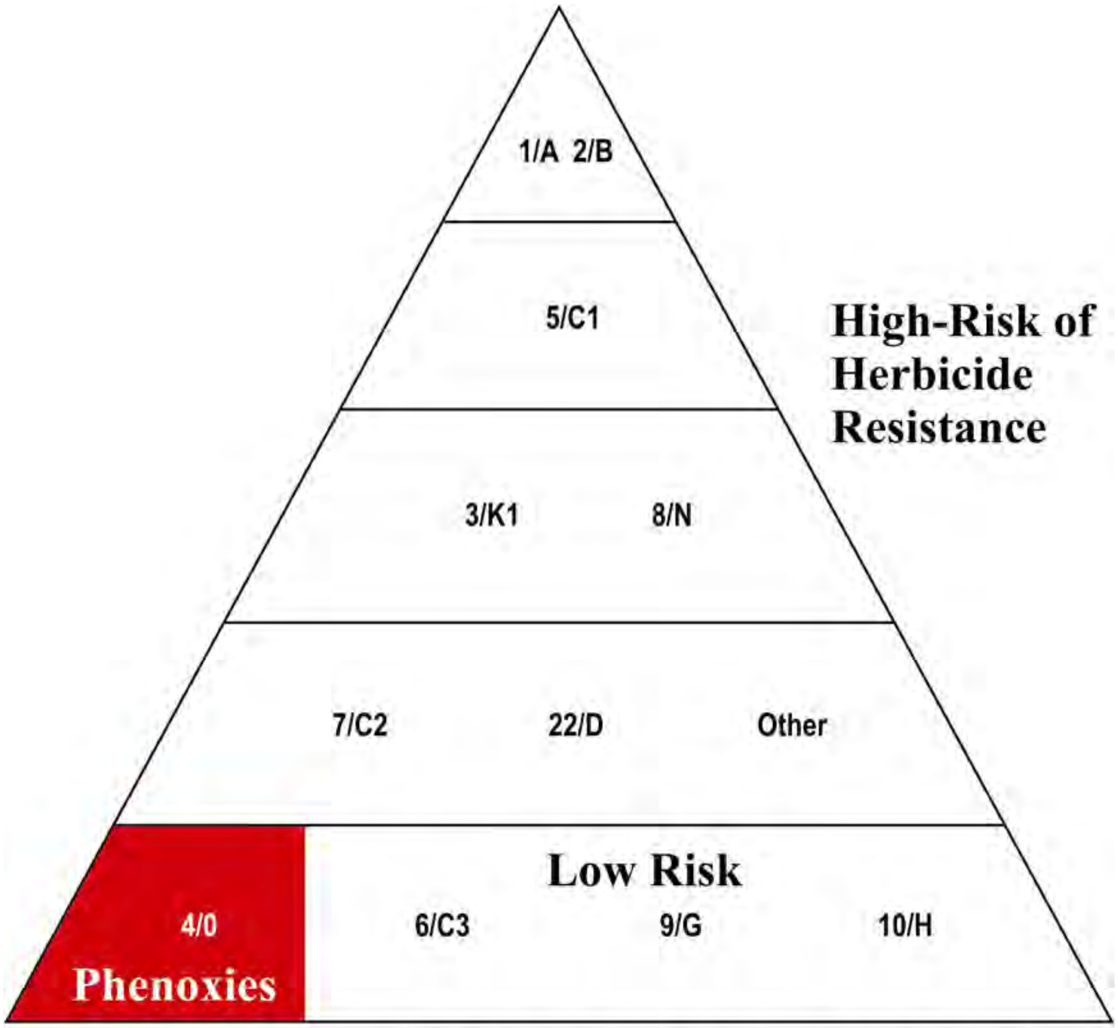
Some herbicides do not continue to be effective forever against all their target weeds. Their target weeds develop resistance to the herbicide and eventually the herbicide fails to control sufficiently. Crop yields begin to drop because of crowding out by the weeds, and farmers must look for different ways to control the target weeds and restore yields. Estimates of crop losses (up to 37%) and the detailed recommendations on the herbicide labels to assist farmers to use application and monitoring techniques that minimize the likelihood of resistance developing demonstrate the significance of this problem. A recent paper by Dr. H.J. Beckie (2006) of the Saskatoon Research Centre of Agriculture and Agri-Food Canada (AAFC) pointed out that many farmers are reluctant to manage weeds proactively to prevent or delay the onset of herbicide resistance. He suggested that this reluctance may be due, in part, to the lack of alternative herbicide groups to control the target weeds as well as expectations that new herbicide technologies will come to the rescue. Dr. Beckie cautioned that this latter belief is unrealistic and suggested that herbicides be viewed as a non-renewable resource (i.e., one that is consumed over time and will be difficult or impossible to replace).

The phenoxy herbicides, and 2,4-D in particular, play a special role in managing the development of herbicide resistance. This special role comes from the fact that 2,4-D has proven to be one of the herbicides with the lowest risk of fostering the development of resistance.

Figure 6.1, taken from Dr. Beckie’s paper, classifies the risk of developing target-site resistance according to the herbicide’s site of action. The phenoxy herbicides, the 4/O point on the figure, are one of the herbicide groups with the lowest risk. Other groups are also low risk, but many are higher risk.

Figure 6.1 The Risk of Target - Site Resistance for Herbicide Groups

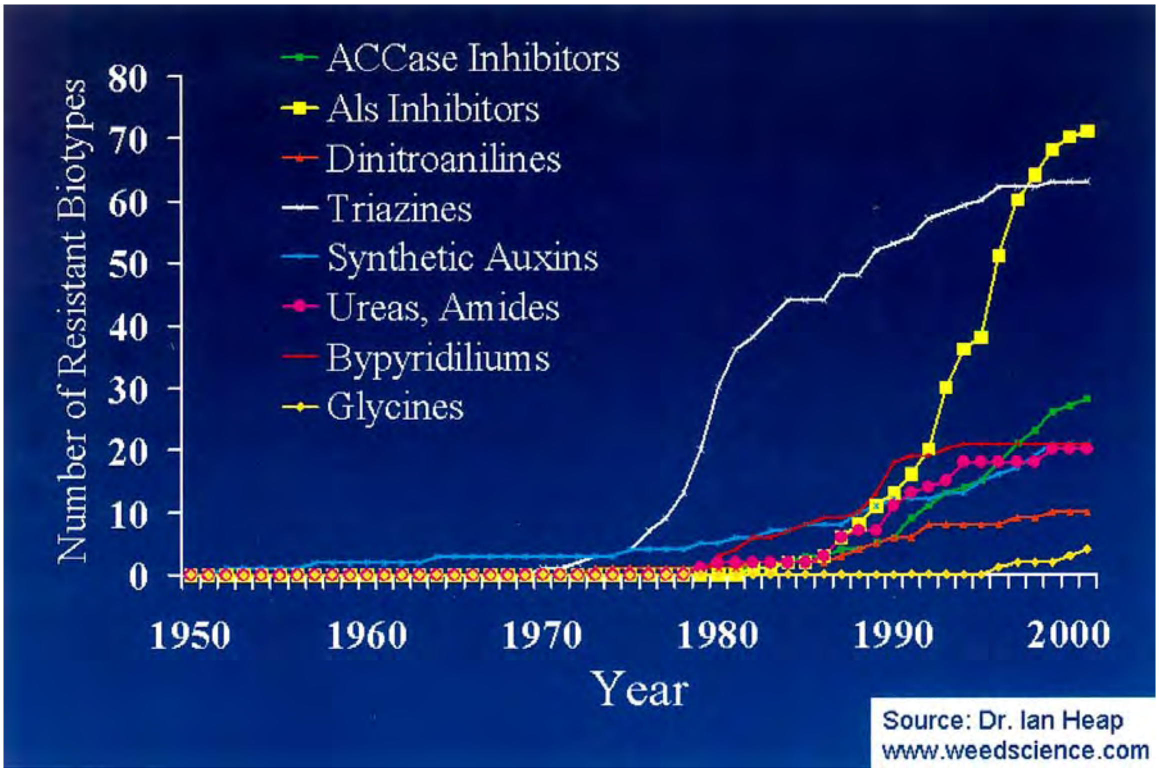
(taken from Beckie, 2006)



Classification of herbicide site of action by risk of selection for target-site resistance (high≤ 10; moderate = 11-20; low > 20 applications (H. Beckie and L. Hall, unpublished data); "Other": insufficient information to definitively categorize as low or moderate risk. Numberical (Weed Science Society of America) and alphabetical (Herbicide Resistance Action Committee) herbicide groups are referenced in (Beckie, 2006). The phenoxy herbicides are at point 4/0, highlighted.

Exhibit 1, downloaded from <www.weedscience.com>,[15] shows the chronological increase in weed resistance. Weed resistance to the synthetic auxins had an early start in Canada (1957) but has increased slowly, despite being used since 1946.

Exhibit 1



[15] Weedscience.org is the authoritative source for compiling cases of weed resistance worldwide. Researchers such as Dr. Beckie contribute new cases to the web site continually.

To date, 304 unique herbicide resistant biotypes have been identified, as shown in Exhibit 2. Of this total, only 8% (24) are resistant to the synthetic auxins, despite the 60-year history of use of 2,4-D.

Exhibit 2

Home | Resistant Weeds | Researchers | Herbicides | Add Case | Weed Photos | Contact

HERBICIDE RESISTANT WEEDS SUMMARY TABLE
Thursday, June 15, 2006

Herbicide Group Click for details	Mode of Action	HRAC Group	Example Herbicide	Total
ALS inhibitors	Inhibition of acetolactate synthase ALS (acetohydroxyacid synthase AHAS)	B	Chlorsulfuron	95
Photosystem II inhibitors	Inhibition of photosynthesis at photosystem II	C1	Atrazine	65
ACCase inhibitors	Inhibition of acetyl CoA carboxylase (ACCase)	A	Diclofop-methyl	35
Synthetic Auxins	Synthetic auxins (action like indoleacetic acid)	O	2,4-D	24
Bipyridiliums	Photosystem-I-electron diversion	D	Paraquat	23
Ureas and amides	Inhibition of photosynthesis at photosystem II	C2	Chlorotoluron	21
Dinitroanilines and others	Microtubule assembly inhibition	K1	Trifluralin	10
Glycines	Inhibition of EPSP synthase	G	Glyphosate	8
Thiocarbamates and others	Inhibition of lipid synthesis - not ACCase inhibition	N	Triallate	8
Triazoles, ureas, isoxazolidiones	Bleaching: Inhibition of carotenoid biosynthesis (unknown target)	F3	Amitrole	4
PPO inhibitors	Inhibition of protoporphyrinogen oxidase (PPO)	E	Oxyfluorfen	3
Carotenoid biosynthesis inhibitors	Bleaching: Inhibition of carotenoid biosynthesis at the phytoene desaturase step (PDS)	F1	Flurtamone	2
Chloroacetamides and others	Inhibition of cell division (Inhibition of very long chain fatty acids)	K3	Butachlor	2
Arylaminopropionic acids	Unknown	Z	Flamprop-methyl	2
Nitriles and others	Inhibition of photosynthesis at photosystem II	C3	Bromoxynil	1
Mitosis inhibitors	Inhibition of mitosis / microtubule polymerization inhibitor	K2	Propham	1
Cellulose inhibitors	Inhibition of cell wall (cellulose) synthesis	L	Dichlobenil	1
Organoarsenicals	Unknown	Z	MSMA	1
Pyrazoliums	Unknown	Z	Difenzoquat	1
Total Number of Unique Herbicide Resistant Biotypes				**307**

The 24 resistant weeds are listed in Exhibit 3, where it can be seen that four of the resistant weeds were identified in Canada with a further four in the continental United States. The first Canadian case was in 1957 (wild carrot along a roadside in Ontario), the most recent in 1998.

Exhibit 3

Home | Resistant Weeds | Researchers | Herbicides | Add Case | Weed Photos | Contact

SYNTHETIC AUXINS (O/4) RESISTANT WEEDS by species and country

#	Species	Country (Click for Details)	Year
1.	***Carduus nutans*** Musk Thistle	1981 - New Zealand	**1981**
2.	***Carduus pycnocephalus*** Italian Thistle	1997 - New Zealand	**1997**
3.	***Centaurea solstitialis*** Yellow Starthistle	1988 - USA (Washington)	**1988**
4.	***Cirsium arvense*** Canada thistle	1979 - Sweden 1985 - Hungary	**1979**
5.	***Commelina diffusa*** Spreading Dayflower	1957 - USA (Hawaii)	**1957**
6.	***Convolvulus arvensis*** Field Bindweed	1964 - USA (Kansas)	**1964**
7.	***Daucus carota*** Wild Carrot	1952 - Canada (Ontario) 1993 - USA (Michigan) 1994 - USA (Ohio)	**1952**
8.	***Digitaria ischaemum*** Smooth Crabgrass	2002 - USA (California)	**2002**
9.	***Echinochloa colona*** Junglerice	2000 - Colombia	**2000**
10.	***Echinochloa crus-galli*** Barnyardgrass	1998 - USA (Louisiana) 1999 - Brazil 1999 - USA (Arkansas) *Multiple - 2 MOA's	**1998**
11.	***Echinochloa crus-pavonis*** Gulf Cockspur	1999 - Brazil	**1999**
12.	***Fimbristylis miliacea*** Globe Fringerush	1989 - Malaysia	**1989**
13.	***Galeopsis tetrahit*** Common Hempnettle	1998 - Canada (Alberta)	**1998**
14.	***Galium spurium*** False Cleavers	1996 - Canada (Alberta) *Multiple - 2 MOA's	**1996**

15.	***Kochia scoparia*** Kochia	1995 - USA (Montana) 1995 - USA (North Dakota) 1997 - USA (Idaho)	**1995**
16.	***Limnocharis flava*** Yellow bur-head	1995 - Indonesia 1998 - Malaysia *Multiple - 2 MOA's	**1995**
17.	***Limnophila erecta*** Marshweed	2002 - Malaysia *Multiple - 2 MOA's	**2002**
18.	***Matricaria perforata*** Scentless Chamomile	1975 - France 1975 - United Kingdom	**1975**
19.	***Papaver rhoeas*** Corn Poppy	1993 - Spain *Multiple - 2 MOA's	**1993**
20.	***Ranunculus acris*** Tall Buttercup	1988 - New Zealand	**1988**
21.	***Sinapis arvensis*** Wild Mustard	1990 - Canada (Manitoba)	**1990**
22.	***Soliva sessilis*** Carpet Burweed	1999 - New Zealand	**1999**
23.	***Sphenoclea zeylanica*** Gooseweed	1983 - Philippines 1995 - Malaysia 2000 - Thailand	**1983**
24.	***Stellaria media*** Common Chickweed	1985 - United Kingdom	**1985**

In practice, the phenoxy herbicides are frequently mixed with resistance-prone broadleaf herbicides such as Group 2 (appearing at the top, that is, high risk, of Figure 6.1), or used in herbicide rotations to delay or manage the emergence of broadleaf weed resistance. Such mixtures are important in delaying resistance to the resistance-prone herbicide when both the phenoxy herbicides and the resistance-prone herbicide control the same weed species. Plants that survive the non-phenoxy herbicide through the development of resistance are destroyed by the phenoxy component. Postponement of resistance gives farmers more options to control the weeds, and the phenoxy herbicides lengthen the time before the resistance-prone herbicide becomes truly non-renewable. (Beckie, 2006).

The time and cost involved in developing and marketing new herbicides demonstrates their non-renewable characteristics. Dr. Beckie quoted costs of US$150 million to US$180 million to develop new products. A report by Ridgetown College quoted a figure of US$70 million to US$100 million (McEwan and Deen, 2003). A major study on pesticides in US agriculture noted that the development phase for a new product can begin only after a compound has been identified with the efficacy needed to control the pest and with minimal impacts on the environment and non-target organisms. The development, testing and registration can typically take eight to twelve years and cost over US$50 million for each new product (National Academy Press 2000, page 179). The Ridgetown College study noted that, in Canada, it can take four to five years and cost at least C$2 million to secure the approval of a new pesticide, assuming that it has already been approved for use in the United States or other Organization for Economic Co-operation and Development (OECD) country. About 80% of the data required for approval in Canada are core tests that would have been used to register the product in other countries. Efficacy trials are completed in Canada and supplemented with field research carried out in northern US states that is accepted by Health Canada PMRA. Minimal pesticide research is conducted by industry in Canada because of the relatively small scale of the Canadian market. However, if the registration is for field crops (i.e., wheat), significant crop residue research is required in Canada for Canadian conditions. The proliferation of resistance can lead to a treadmill in which the two responses are, first, increased application of the less-effective herbicide leading to even greater resistance plus collateral damage to other organisms, followed by the introduction of new herbicides until either the pest meets a resistance-proof pesticide or until no new pesticides are available. Ultimately, the pest wins.

The withdrawal of the phenoxy herbicides from the Canadian market would significantly reduce the tools available to manage the development of broadleaf weed resistance. Dr. Beckie concluded that "the phenoxy herbicides are critical for proactive and reactive broadleaf weed resistance management." (Beckie, Dr. H - personal correspondence, summer 2006).

Some industry observers suggest that the economic significance of this ability of the phenoxy herbicides to prevent and delay the emergence of resistance could overshadow all the other economic benefits identified in this study to specific sectors, such as agriculture. Herbicide expenditures by farmers and downstream agricultural commodity prices would probably have to support increased and recurring development of new herbicides.

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7) The Lawn and Turf Sector

Despite the considerable recent public debate in Canada around pesticides in this sector, there are few reliable statistics available to assist in economic benefits research. Indeed, data are scarce for this sector. To overcome this difficulty, this research project used groups of industry experts and specialists drawn from the manufacturing, distribution, retailing and end-use sectors to produce estimates of specific parameters required to identify and value the benefits derived from the phenoxy herbicides. In each such case, the assumptions used and the conclusions reached are identified in this report. Whenever possible, the report also examines the implications of such assumptions.

7.1) The Turfgrass-Growing Industry

Turfgrass is a multi-billion dollar industry in Canada. This sector consists of the planting, growing, and maintaining of turfgrass principally in the following locations:

- turfgrass farms;
- home lawns and landscaping;
- lawns and landscaping around institutions;
- municipal parks;
- landscaping of office and multi-unit residential buildings;
- cemeteries;
- golf courses; and
- sports fields.

For such a large industry, there are few reliable statistics available. The following information is abstracted from a Statistics Canada (2005) report, but industry participants are skeptical about many of the numbers.

- Just over 21,300 hectares (52,700 acres) were owned and devoted to sod growing in Canada in 2005, down about 2% from the area in 2004, 21,800 hectares (53,870 acres). Including land rented and used, growing sod would bring the 2005 number up to about 24,500 hectares (60,540 acres) (Statistics Canada, 2005).

- The sod-growing industries are concentrated in Ontario and Quebec, accounting for 50% and 28% respectively of the total sod growing area in Canada.

- The value of sod sold in 2005 was about C$104 million, down about 1% from 2004.

7.2) Current Control of Broadleaf Weeds in Turfgrass

The common weeds that invade Canadian landscapes share a similar characteristic — their ability to adapt and thrive in human-influenced habitats. Main features of weed adaptability include:

- the ability to survive in cultivated soil;
- competitive ability;
- an ability to tolerate unfavourable habitats; and
- the ability to withstand repeated cutting or

Almost any broadleaf weed species can be found in turfgrass, but dandelion, chickweed, plantains and ground ivy are the main species of broadleaf weeds that infest turfgrass.

Methods for Controlling Weeds in Turfgrass

Annual broadleaf weeds are found commonly in turfgrass, but many of them are suppressed by mowing the turfgrass. Perennial species are not suppressed effectively by mowing, and it is these species that are treated by herbicides.

No one herbicide will control all the broadleaf weed species and still be selective to the turf.[16] Many annual weed species can be controlled by pre-emergence herbicides, but annual weeds that are established, or perennial weeds, can be controlled generally only with post-emergence herbicides. Pre-emergence herbicides are not available to control the entire weed species currently found in turfgrass. The principal weed species listed above are controlled by post-emergence application of 2,4-D and mecoprop-p, but are less sensitive to MCPA and other non-phenoxy herbicides.

Turf species of grass vary in their susceptibility to herbicides. Most turfgrass species grown in Canada are tolerant of the phenoxy herbicides, as well as newer non-phenoxy herbicides.

Turfgrass specialists agree that the best deterrent to weeds is a vigorously growing turfgrass that is adapted to the site. However, perennial weeds, once established, usually require a herbicide treatment for effective control. Most weeds in turfgrass can be controlled selectively with herbicides. Although complete eradication of weeds is not usually possible, control usually is adequate for the turfgrass to crowd out the remaining weeds. In the US Department of Agriculture National Agricultural Pesticide Impact Assessment Program (USDA NAPIAP) study, (1996: 108) weed control was a major part of the costs of turfgrass maintenance. Only mowing and fertilization accounted for similar portions of the total maintenance costs.

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[16] See, for example, Ontario Ministry of Agriculture and Food (Guide to Weed Control: Table 4.1 or Table 17-1).

Post-emergence herbicides represent the main method for controlling broadleaf weeds in turfgrass. The phenoxy herbicides are the main products. Formulations of the phenoxy herbicides are available in many different forms to suit different markets and uses. The most common are liquid formulations that are mixed with water and sprayed. Concentrated forms are used by commercial turfgrass managers and the lawn care industry. Lower-concentration formulations are used by homeowners. Another common practice is to mix the herbicide with a fertilizer. Homeowners and lawn care managers, such as golf course superintendents, may use more than one formulation during a season. Note that the phenoxy herbicides are used most commonly in mixtures, rather than alone. The most common mixing partner of 2,4-D and mecoprop-p is dicamba a non-phenoxy broadleaf herbicide. Weed scientists believe these mixes are the most effective (and cost effective) way to control a broad spectrum of broadleaf weeds. For example: a three-way combination of 2,4-D, mecoprop-p and dicamba is estimated to control many more weeds than 2,4-D alone yet with a 33% reduction in 2,4-D loading and only a 4% increase in total herbicide loading (Latter, 2006). The USDA NAPIAP (1996:109) noted that 2,4-D was used on 18% of all turfgrass acreage in 1992, alone or, more frequently, in combination with one or more other herbicides. MCPA was sometimes used as a substitute, on 2.5% of turfgrass.

7.3) Phenoxy Products in the Canadian Lawn and Turf Sector

Total herbicide sales in Canada in 2004 were estimated by CropLife Canada to be $1.0 billion, measured at the stage in the value chain of transfers between manufacturers and distributors. This is not a retail sales value. That association reports that about 1% of total pesticide sales went to lawn/turf/ornamental uses. Using the same proportion, estimated herbicide sales into this lawn/turf sector were about $10 million in 2004. Industry experts believe that the very large majority of these herbicide sales would be of the phenoxy herbicides. However, there are no publicly available reliable estimates of the total acreage treated with phenoxy herbicides in the lawn and turf sector. A group of industry specialists proposed the following calculation to provide a rough approximation of the total acreage treated:

- (Dollar value of sales as per CropLife reports)/(representative price per litre)= number of litres sold
- (Number of litres sold)/(representative application rate per hectare)=number of hectares treated.

Representative prices that were appropriate to the value-chain stage of the CropLife estimates, and application rates representative of the wide variety of products that were available to this sector were provided by industry specialists:

- price per litre: $5
- application rate per hectare = 5.43 l/hectare (2.2 l/acre)

This led to the following estimate of acres treated with phenoxy herbicides:

- ($10 million sales)/($5 per litre) = 2 million litres sold
- 2 million litres/5.43 litres per hectare = 368,300 hectares (909,000 acres) treated with herbicides in the lawn and turf sector

It must be stressed that this is an approximation only. Other estimation approaches were considered but either required confidential business data or were not believed to be any more reliable than the one presented here.

7.4) Alternatives for Controlling Broadleaf Weeds in Turfgrass

A wide range of phenoxy-based products are available for the Canadian turf market. 2,4-D and mecoprop-p are combined in about 95% of the products, either alone or along with dicamba. The remaining 5% of products contain only one of 2,4-D or mecoprop-p. Used alone, these herbicides have a much narrower spectrum of weed control. The practical implication of this fact is that withdrawal of one of the two phenoxy herbicides (2,4-D and mecoprop-p) from domestic usages in the lawn/turf sector is a de facto withdrawal of the other. No products containing MCPA are approved for domestic use on turf in Canada.

Weed industry experts agree that the situation for commercial users would be the same. Three-way mixtures (2,4-D, mecoprop-p and dicamba) are the most biologically and cost-effective way to handle broadleaf weeds. MCPA plays only a minor role in the commercial parts of the lawn/turf sector.

Experts agree that the withdrawal of mecoprop-p would lead to a 50% increase in loading of 2,4-D and the loss of control of the weeds black medick, chickweed, clover, ground ivy and knotweed. The withdrawal of 2,4-D would not lead to an increase in application of mecoprop-p, but it would increase treatment costs and lead to the loss or reduced control of the dominant weeds, dandelion and plantain. Neither approach would be satisfactory. Thus, as in the domestic sector, the withdrawal of one of the two phenoxy herbicides (2,4-D and mecoprop-p) from commercial usage in the lawn/turf sector is also a de facto withdrawal of the other phenoxy.

The conclusion is that there are no herbicide alternatives available to the lawn/turf sector in the event of the withdrawal of one or both of 2,4-D and mecoprop-p.

Other, more “natural” alternatives for controlling broadleaf weeds have been proposed in recent years, as part of the re-evaluation of pesticides. However, to do a fair comparison would require a selection of only those alternatives that have gone though the same degree of efficacy and safety testing as have the phenoxy herbicides. At least one provincial web site (Quebec) points out that a product that is “natural” does not always mean it is safe.

Some natural pesticides are more toxic than the synthetic pesticides currently in use.[17] The efficacy of some of the natural herbicides is also unproven.[18]

The PMRA web site on healthy lawns[19] and various provincial manuals on turfgrass management offer only integrated pest management (IPM) as an alternative. Even the reduced-risks pesticides on the PMRA web site are not herbicides for lawn/turf use. The only "turf" use on that list is for an insecticide. On close reading, IPM boils down to lawn care, (i.e., judicious use of the appropriate pesticide plus ensuring a good quality and depth of soil, mowing according to strict specifications, careful watering and draining, avoiding compaction, over-seeding, fertilization according to rigid specifications, hand weeding as required, and turf replacement if required). Thus, according to the criteria of equivalent safety and efficacy in maintaining a consistent high quality of turf, the practical alternative to the phenoxy herbicides considered here is a combination of hand weeding, top dressing, extensive watering and re-sodding when required.

7.5) The Costs of Re-Sodding and Hand Weeding

Weed management experts agree that hand weeding alone could not be completely effective in maintaining high turf quality. The weeds win out, eventually, and re-sodding is required. Top dressing, extensive watering, and other activities are also required to postpone the day when the weeds prevail.

Hand weeding is the removal of the weed from the turf by pulling or digging manually at the weed. If even a part of the root is left in the soil, the weed can be back in place as soon as the next day. That is why hand weeding can never completely eliminate weeds. The time until the weeds dominate the turf depends on several factors.

- If neighbouring properties are weed free, then there will be less weed growth from blowing seeds.

- Irrigation and feeding of the turf results in a thick turf that crowds out weeds for a while. Careful fertilizing and watering can help maintain turf shoot density.
- Weather conditions for the growing season affect turf growth and condition.

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[17] <www.mddep.gouv.qc.ca/pesticides/permis-en/code-geste-en/index.htm>.
[18] For example, corn gluten has been marketed to homeowners seeking an organic way to control weeds. Scientists at the University of Maryland have noted "corn gluten is not effective against mature weeds and provides only limited pre-emergence control for a few weed species." They also pointed out: "At the rates required for weed suppression, this product can be very expensive." They also comment on soap-based herbicides: "Soap-based herbicides control perennial weeds poorly. The PMRA Regulatory Note on two corn gluten meal products states that both could be "mildly irritating to the eyes if both products conform to the mycotoxin guidelines established by the Canadian Food Inspection Agency" The mycotoxin guidelines were established for animal feed applications. The PMRA adds that "hypersensitivity from contact with corn by dermal and inhalation routes may be of concern," and requires that a precautionary warning be added to the label and that "personal protective equipment recommendations be made for applicators"
[19] www.healthylawns.net/english-e.html

A group of weed and turf management specialists drawn from the fields of landscaping, IPM, turf growing and end users developed a method for calculating the costs of this alternative to the phenoxy herbicides. The specialists agreed that, on average, hand weeding, watering, top dressing, etc. could keep a parcel of land relatively weed free for up to three years. By the end of the fourth year, they believed that the weeds would have taken control of the land. However, what would likely happen at the end of the fourth year was more difficult to predict. The specialists believed that the only way to re-establish the original quality of the turf would be to re-sod the land. Whether a business or residential proprietor would do so would be a function of the cost, the benefits of re-establishing the turf quality and of personal taste. The specialists calculated the following estimates. These are used later in this report to examine potential cost implications of withdrawing the phenoxy herbicides from the market.

- Number of weeds picked per minute: 8 (under ideal conditions, but this pace could not be maintained for a full 8-hour day).
- Typical costs per acre of re-sodding: delivery charge of about $7,000, installation cost of about $5,000, plus taxes, for a total of about $13,000 ($32,120/hectare).
- Typical herbicide spray time per acre by a retail user: 30 minutes, once per year.
- Assuming a threshold of 8 weeds per 100 square feet (roughly comparable with government agency recommendations on when to spray for high quality turf) and a minimum wage of $7/hour, the cost to a business, such as a golf course or office building of hand weeding one acre is just over $50[20] ($124/hectare) per treatment. This is the cost for a new turf area. The cost rises as the turf ages because, as noted above, hand weeding does not eliminate weeds and increasing effort is required to attempt to control them. Of course, the hand weeding would have to be repeated throughout the season, estimated conservatively at once per week to maintain quality. Assuming 12 sessions of hand weeding, the annual costs start at $600 per acre ($1,483/hectare) and rise as the turf quality degrades. For a homeowner who values leisure time at a rate higher than the minimum wage, the annual cost is proportionately higher.

Note that this alternative to the phenoxy herbicides assumes that turf growers would be able to supply weed-free turf when required for re-sodding. In fact, this is problematic, given that there is no completely effective approach, absent the phenoxy herbicides.

7.6) The Economic Benefits of Broadleaf Weed Control

To value the economic benefits that result from the control of broadleaf weeds in turfgrass, this report examines two sectors: residential landscaping and golf courses.

[20] $(43{,}560\ ft^2/acre \div 100) * (8\ weeds/100ft^2 \div 8 weeds/min) \div (60 mins/hr) * \$7/hr$

Residential Landscaping Including Lawns

Good landscaping is a good investment decision. A branch of economics known as hedonic pricing has developed methods for investigating the extent to which particular features of an asset, such as a house, play a role in determining the market price of that asset. The most common example of the hedonic pricing method is the housing market. The price of a property is determined by the characteristics of the house (size, appearance, features, condition) as well as the characteristics of the surrounding neighbourhood (accessibility to schools and shopping, level of water and air pollution, value of other homes, etc.). The hedonic pricing model is used to estimate the extent to which each factor affects the price.[21] This type of analysis requires large amounts of data and careful, sophisticated analysis.

Much of the original hedonic pricing work was done in the United States. A literature review by the US National Turfgrass Institute (2003: 5) noted that landscaping can add up to 15% to the value of a residential property, as evidenced by increased values for properties close to parks and individual house prices. A 1999 study in South Carolina found that homes with excellent landscaping sell four to five percentage points higher, and that homes with poor landscaping in neighborhoods with excellent landscaping sold for 8% to 10% less (Henry, 1999). One study demonstrated that home value increased from 5% to 11% with a good landscape. The Urban Institute (Urban Institute 2004) noted in studies of three neighbourhoods in Colorado that property values decreased by $4.20 for each foot away from a greenbelt. A report funded by the US Department of Agriculture and the Forestry Service (Hall et al., 2005) concluded that well-landscaped homes have a 7% to 11% premium in value over similar properties without such amenities.

One of the most sophisticated hedonic pricing analyses by Canadians at Université Laval (des Rosiers et al., 2002) won the Real Estate Valuation manuscript prize presented at the 2001 American Real Estate Society Annual Meeting. This hedonic study investigated the effect of landscaping on house values, based on a detailed survey of 760 single-family homes sold between 1993 and 2000 within the greater Québec City area. Information on the individual homes included 31 landscaping attributes of both the houses and their immediate locale, that is, the neighbourhood visible from the properties. The landscaping attributes included trees, ground cover with and without trees, flower arrangements, hedges, landscaped curbs and density of visible vegetation. Property types included bungalows, cottages, multi-storey (both detached and semis) and row houses. Average selling price was $112,000, from a minimum of $50,000 to a maximum of $435,000.

The researchers found the following.

- Trees are valued most by potential homeowners, across all property types. Each percentage point of positive differential between a property's tree cover and that of its neighbours translates into a 0.2% increase in house value.

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[21] See, for example, Jenkins and Kuo (2006).

- For bungalows and cottages, however, it is ground cover (lawns, etc.) on the property that adds the most value. Each percentage point of ground cover adds about 0.2% to the market value of the house, the same as for trees across all property types.

- Landscaped curbs can add about 4.4% to the value of the house.

- Assuming mean values for each landscaping-related variable, the presence of a hedge results in a 7.7% market premium for either a typical bungalow or cottage. This result is consistent with the findings of earlier work in the hedonic pricing research.

At an average selling price of $112,000, the ground cover premium (assuming 10% ground cover) translates into a gain of roughly $2,240. Counting all the landscaping-related variables produces a market gain of just over $8,600. These are significant economic returns to homeowners who have landscaped their properties.

It is interesting to note that these economic returns are available not just to high-end large properties. At an average selling price of $112,000, the subject properties were more typical of the average Canadian's homes. Also, it is worth noting that many Canadian municipalities gain a tax benefit from this increased valuation. For those with market-value assessment as the basis of determining the residential tax bill, the actual market value of the house is one determinant. The gain in the selling price of the house translates into increased municipal taxes.

Statistics Canada estimates that about 66% of Canadian households live in single-detached or single-attached housing, the housing types that are most likely to have lawns and landscaping. This market-place benefit of landscaping is available to two thirds of all Canadians.

Research demonstrates that the benefits of landscaping apply to rental properties also. A study by Prof. Joel Goldsteen determined that landscape amenities had the highest correlation with occupancies of any other architectural and urban design variables evaluated. He concluded that "landscaping amenities pay back the developer as evidenced by the higher occupancies (and rents) clearly justifying the investment."[22]

The conclusion is that investment in a well-cared for landscape surrounding a home makes good economic sense. Willing buyers pay a premium for this amenity. This return on investment is available to all Canadian homeowners, with the follow-on benefits accruing to the host municipalities also. Control of noxious weeds is an integral part of this investment decision. Since broadleaf weeds are the most unsightly of the weed problems in turfgrass, much of the concern is for the control of these weeds.

[22] As quoted in Money Magazine (2003).

There would be no impact on the residential sector with MCPA withdrawal, because no MCPA-based products are registered for domestic uses. Reliance on 2,4-D and mecoprop-p would continue. However, if 2,4-D and mecoprop-p were also taken off the market, hand weeding and re-sodding would be the only theoretically feasible alternative to the homeowner to maintain the goal of consistent high-quality lawn around the residence. The following parameters were used to estimate the economic costs of replacing the use of the phenoxy herbicides with the alternative of hand weeding and re-sodding.

- The **time of a homeowner** is valued at $16/hour. This is the average wage in the Canadian service sector and is a more realistic estimate of the opportunity cost that a homeowner would ascribe to the use of leisure time than the minimum wage of about $7 per hour.

- **Time taken by a homeowner to apply** a phenoxy herbicide is twice as long as that of a professional (i.e., 60 minutes rather than 30 minutes).

- **Annual cost of $600 ($1,483/hectare)** per acre to do the hand weeding remains constant over time, rather than increasing as turf quality decreases, and the homeowner hires a labourer to do the hand weeding at the lower cost of $7/hour.

- **Representative cost of the homeowner's phenoxy herbicide** is $18 per litre. Note that this is a retail price, and not comparable to other prices used previously in this section that were taken at earlier stages of the value chain.

- **Representative application rate of the herbicide by the homeowner** is 2.2 litres per acre, (5.43l/hectare) the same value used earlier to estimate the total acreage treated by phenoxy herbicides in Canada.

- **Net present value (NPV)** is used as the basis of cost comparison for the two alternatives, over a time horizon of 20 years with a discount rate of 5%. The NPV is a measure of the value today of a stream of payments over time. In effect, the NPV represents the amount that would have to be invested at the assumed interest rate at the beginning of the period of payments, such that, with accumulated interest, it would be just adequate to meet all the payments as they fell due. Thus the NPV of a stream of annual payments, such as in these weed management scenarios, is the amount that would have to be invested today at the assumed interest rate to make the annual weed management costs required for each option and scenario. The NPV accounts for the time value of money by expressing future cash flows in terms of their value today. It recognizes that money has a cost (interest), so a homeowner would prefer to have $1 today to having $1 a year from now. If the homeowner earns 10% interest on invested money, $1 today will be worth $1.10 a year from now ($1.00*1.1). Or, turning that around, the present value of $1.00 one year out is $0.909 now ($1.00/1.1), because $0.909 invested now at 10% will produce $1 in one year's time. The NPV is the method most commonly used to compare investment alternatives in financial analysis in business and commerce. In financial analysis for commercial banking and investment, a high positive NPV is desired, because it means the cash inflows exceed the costs. For the cost comparison analysis presented in this report, the NPVs are all negative in that they are all costs and so a high NPV is the least desirable option.

- **No inflation or cost escalation factors** are built into the analysis, because the values used in this analysis are indicative only.

- **The frequency of re-sodding.** The cost of re-sodding is so high that the critical issue in the comparison of costs of alternatives is the frequency with which the homeowner elects to re-sod to re-establish the original turf quality. Sector specialists produced different estimates of this parameter, ranging from once or twice over the 20-year period to a maximum of five times (i.e., once every four years over the 20-year period). This report presents the cost comparison under various assumptions about the frequency of re-sodding.

Weed Control Costs per Acre to a Homeowner Using Herbicides: Annual costs of: (one hour at $16/hour) + herbicide costs of $18/litre*application rate of 2.2 litres/acre= $55.60 per acre ($137.39/hectare).

A 20-year stream of fixed annual costs of $55.60, discounted at 5%, produces an NPV of $692 per acre ($1,710/hectare) as demonstrated below.

Weed Control Costs per Acre to a Homeowner Using Hand Weeding, Re-Sodding: This set of weed management alternatives consists of the following sequence of costs:

- annual costs of $600 per acre;
- interspersed with periodic re-sodding costs of $13,000 per acre, with the period of re-sodding depending on the individual homeowner.

Three re-sodding scenarios were considered.

1. No re-sodding (i.e., annual costs of $600/per acre for each of the 20 years).

2. Two re-soddings, at the end of year 10 and year 20, with annual costs of $600 in between these events.

3. Five re-soddings (i.e., one at the end of each fourth year in the 20-year cycle) interspersed with annual costs of $600 as in the above two scenarios.

The results of the NPV analysis of the herbicide and hand-weeding alternatives for weed control are presented in Table 7.1. Costs per acre are used in this table because acre is still the common measure of land area.

Table 7.1 NPV Comparison of Weed Control Alternatives per Acre

Year	Herbicide Option Costs $	Hand Weeding Costs: Scenario #1 $	Hand Weeding Costs Scenario #2 $	Hand Weeding Costs: Scenario #3 $
1	55.60	600.00	600.00	600.00
2	55.60	600.00	600.00	600.00
3	55.60	600.00	600.00	600.00
4	55.60	600.00	600.00	13,000.00
5	55.60	600.00	600.00	600.00
6	55.60	600.00	600.00	600.00
7	55.60	600.00	600.00	600.00
8	55.60	600.00	600.00	13,000.00
9	55.60	600.00	600.00	600.00
10	55.60	600.00	13,000.00	600.00
11	55.60	600.00	600.00	600.00
12	55.60	600.00	600.00	13,000.00
13	55.60	600.00	600.00	$600.00
14	55.60	600.00	600.00	$600.00
15	55.60	600.00	600.00	$600.00
16	55.60	600.00	600.00	13,000.00
17	55.60	600.00	600.00	$600.00
18	55.60	600.00	600.00	$600.00
19	55.60	600.00	600.00	$600.00
20	55.60	600.00	13,000.00	13,000.00
NPV	$692.90	$7,477.33	$19,763.28	$43,330.44

The weed control and lawn-care specialists estimated that the average Canadian lawn is about 3,000 square feet, or about 7% of one acre. The above NPV cost results for the average Canadian homeowner thus are as follows.

Table 7.2 NPV Comparison of Weed Control Alternatives for Average Canadian Lawn

	Herbicide Option	Hand Weeding: Scenario #1	Hand Weeding: Scenario #2	Hand Weeding: Scenario #3
NPV	$48	$524	$1,383	$3,033

The NPV per acre of the simplest hand-weeding scenario (#1) is over 10 times that of the herbicide option. The most expensive hand-weeding scenario (#3) has an NPV of over 60 times that of the herbicide option. Recall, though, that the specialists were of the view that the turf quality resulting from these alternatives would not be the same. Their view was that only the third hand-weeding scenario would lead to retention of the high-quality turf. Under this assumption, a homeowner wishing to retain a consistent high quality of turf but with only the hand-weeding option available, over the 20-year period would incur an NPV of costs that would be more than 60 times higher than that of the herbicide option.

Golf Sector

Golf is big business in Canada. The Royal Canadian Golf Association (RCGA) reported the following statistics

- One in five Canadians aged 12+ plays golf (4.9 million), both seriously and occasionally as a hobby.
- Canadians average about 13 rounds of golf per year (in 2001).
- Canada enjoys one of the highest golf participation rates in the world.
- There are bout 2,500 golf courses in Canada.
- A recent study (SRI International, 2002) estimated the value of the golf economy (goods and services) in the United States to be in excess of $62 billion for the year 2000. While no comparable study of the Canadian golf economy exists, using the 1 to 10 rule of thumb when comparing Canada to the United States suggests the Canadian golf industry has an estimated value of more than $6 billion.

The economic impact of this activity is significant. The RCGA estimated the following economic impact on host communities for its major competitions.

Table 7.3 Examples of Incremental Expenditures Due to Major Golf Events

Golf Event	Economic Benefits ($ millions)[a]	
	To the city	To the region/province
Niagara Falls- CN Canadian Women's Open 2004	8.9	11.3
Halifax- Canadian Women's Open 2005	13.3	17.9
Hamilton- Men's Canadian Open	23.3	30.8

Notes:
Counts capital as well as spectator and participant expenditures.
[a] Estimates produced by the Sport Tourism Economic Assessment Model (STEAM), developed by the Canadian Sport Tourism Alliance, provided to the authors by the RCGA.

The British Columbia Golf Association recently carried out an economic impact assessment of the game on the provincial economy. Here are some highlights from that report (CounterPoint Consulting. Provided by the BCGA.).

- One in five British Columbians plays golf at least once a year.
- Golfers in British Columbia spent $983 million in the activity. These expenditures added $437 million to provincial gross domestic product (GDP), accounting for 0.3 percent of provincial GDP.

- Golf in British Columbia created 12,520 jobs, making the golf sector a bigger employer than its paper manufacturing industry. British Columbians employed in the golf sector brought home $308 million in household income during 2004.

- The golf sector in British Columbia paid $87 million in taxes: $37 million to the federal government, $32 million to the provincial government and $18 million to municipal governments.

- In 2004, the sport of golf generated total economic impacts of $1.53 billion in British Columbia as measured by total sales revenues of businesses. This translated into $692 million or 0.48 percent of provincial GDP.

- Golf-related direct and indirect employment created 17,515 jobs in British Columbia.

- Tourism BC reported that 1.12 million visitors from the United States went to British Columbia to golf over a two-year period.

- In 2005, the Bell Canadian Open was held in Vancouver. According to the RCGA, the Open generated $68 million in total sales revenues and added $32 million in GDP and 800 jobs to the provincial economy.

- In 2004, golf tournaments and the courses that hosted them raised $10.4 million for charities in British Columbia.

The quality of the turf is critically important to golfers. GOLF 20/20 is a strategic alliance of the American golf industry that addresses the issues of growth, participation and interest. Among the presentations at a recent conference was a detailed look (Last, 2005) at the key factors that affect participation by golf's best customers — those defined as avid and core golfers. (Avid golfers play 25 or more rounds a year, core golfers play 8 to 24 rounds.)

Among those factors, the condition of the course was most important. When asked, "Do you generally prefer to play a course that is 'very challenging, not top condition' or one that is 'challenging but in very good condition'?" 88 percent of respondents said they'd choose the course in very good condition. Golfers were also asked to rank conditioning against course design in a decision to pay 25% higher green fees. The key groups selected "better course conditioning" twice as often as "better architectures and layout." Finally, golf's best customers ranked the factors (course, their own performance, fellow players, etc.) that drive their enjoyment of the game on a scale from 1 to 7. The conditions of the course received the highest ranking.

- Well maintained greens and bunkers: 6.34.
- Well maintained fairways and tees: 6.28.

Canadian representatives of golf agencies believe the situation in Canada is similar. The best customers want to play on well-maintained courses and will avoid a course that does not meet their standards.

Pesticides and golf turf quality. Many golf courses today rely on IPM strategies to establish and maintain the quality of their fairways, roughs and greens. As a generalization, IPM calls for the selection of the option (including the use of appropriate pesticides) that is most cost effective and least intrusive to deal with a problem of turf quality.

The Canadian Golf Superintendents' Association (CGSA) surveys its members annually on the pests affecting their turf areas and the IPM measures they adopt to manage the pests. A summary of findings in 2004 and 2005 includes the following points.

- Of the three classes of pesticides (fungicides, insecticides and herbicides), fungicides are by far the most significant in terms of costs. The total cost of fungicides in 2005 to CGSA members was just over $13.8 millions, up from $10 millions in 2004. Herbicides cost about $1.6 million in 2005, down slightly from $1.74 million in 2004.[23] Insecticide costs are comparable to those of herbicides.

- The most troublesome weeds are dandelion, clover and plantain on the course tees, fairways and rough turf areas. Herbicides are used less frequently on the greens.

- 2,4-D was the herbicide of choice, either alone or in a mix. The mix (2,4-D + mecoprop-p) accounted for most of the applications. Glyphosate was used by some courses, but in multiple applications. It is noteworthy that glyphosate does not selectively control broadleaf weeds in turf; weeds must be treated individually since glyphosate would kill the turfgrasses when applied at a rate that controls weeds. mecoprop-p alone also figured prominently in the IPM activities of some courses. None of the courses reported using MCPA.

- Both spot spray and full spray approaches are used by the course turf managers.

Alternatives to the phenoxy herbicides available to golf course managers. The US Golf Association (USGA) sponsored a research project to address the question of whether one part of the golf course, the putting green, could be managed effectively without pesticides. The strategic importance of this work to the golf industry is evidenced by the high priority, reported above, attached by golfers to the condition of the greens. The research was carried out by Dr. Frank Rossi, turfgrass scientist and Dr. Jennifer Grant, environmental biologist from Cornell University.
An 18-hole golf course in Long Island, NY, was divided into six groups of three holes each. The study consisted of six separate turf treatments, each of which was replicated three times. The core of the six treatments consisted of:

[23] Both estimates obtained from extrapolations from CGSA survey data.

- unrestricted chemical usage;
- IPM (including chemical usage when appropriate); or
- no chemical usage.

A summary of the main conclusions of this controlled experiment follows.[24]

- Successful turfgrass management that produces even reasonable playability was not possible without pesticides. Acceptable quality could be maintained until mid-August of each of the three years, but quality declined drastically after that point.

- Mature courses forced to forego the use of pesticides may have to re-grass large turf areas to take advantage of more recent turfgrasses.

- Current industry standards cannot be maintained without the use of pesticides. Reduced golfer expectations are a necessity if courses are to reduce or forego the use of pesticides.

- More staff is required for the no- or low-pesticide approach. Monitoring and spot treating are the most significant new activities. Even with this extra cost, the researchers could not compensate for the lack of pesticides.

- Course owners foregoing pesticides run the risk of a significant drop in playability and even widespread turf loss, plus the risk that golfers may choose to go elsewhere to play.

- Integrated pest management treatment achieved a 28% average reduction in pesticide use when compared to the unrestricted pesticide use greens, with no reduction in turf quality.

Conclusions: Golf is not only a leisure sport, it is also a huge business in Canada. The spin-off benefits from this activity are significant. Competition for golfers is strong among the courses. The key to bringing the best golf clients to a course, and attracting the international stars and sponsors to competitions, is the quality of the course.

Integrated pest management is a useful approach to course quality being adopted by Canadian golf course superintendents, and it offers the potential to reduce the use of pesticides. But, there are no effective alternatives to the periodic use of herbicides for control of broadleaf weeds on the courses. As noted earlier, the per acre costs of hand weeding on new turf start at $600 and then rise as the turf ages and the weeds begin to gain ground. These manual alternatives are expensive but, more importantly, they do not achieve the required turf quality.

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[24] Available at <www.usga.org/turf/green_section_record/2004/may_june/research.html>.

There would be no impact on the golf sector of MCPA withdrawal, because this phenoxy is not a significant part of current IPM approaches. Reliance on 2,4-D and mecoprop-p would continue. However, because 2,4-D and/or mecoprop-p are combined in such a high percentage of the products, the withdrawal of one or both of these phenoxy herbicides would effectively pull the other from the market also. The only remaining herbicide would be MCPA, and some golf course managers may use it although no golf courses report using it currently. The cost increases would be approximately 10% due to increased prices, and a further 10% due to application costs. However, full weed control would not be maintained and the labour-intensive activities of weeding, re-sodding, etc. would also be required.

Lawn care industry experts have done their market research on the golf sector. On average, each 18-hole golf course in Canada has about 42 acres treated with pesticides but only about 22 acres that are treated with the phenoxy herbicides, because of sensitivities of the grass types. At the per-acre manual treatment costs estimated to be $600 annually, the new annual cost to the average course would be $13,200, but with a loss in weed control and a decline over time in turf quality.

The total cost of all herbicides used by all golf courses in Canada in 2005 was $1.6 million. A rule of thumb to count total application costs (material and application) is to double the material cost. Thus, current costs of herbicide usage would be roughly $3.2 million. For the 2,000 golf courses in Canada, the costs of broadleaf weed control would increase from $3.2 million to $26.4 million, an increase of over eightfold.

If all phenoxy herbicides were withdrawn, Canadian golf course superintendents and turf industry experts agree that there is no alternative. The quality of Canadian golf course turf would begin to decline, even if the expensive activities of hand weeding, etc. were to be undertaken. The question is asked sometimes, “Would the game be affected if all golf courses faced the same conditions, or would golfers just learn to play in a poorer quality of turf?” Competitive markets don’t work in such a simple way. It is more likely that the courses with the poorer turf quality (due either to weak financial position or inadequate technical skill) would begin to lose market share first, as golfers shifted to the courses that deteriorated less quickly. These weaker courses would fail first but eventually the deteriorating turf would affect even the remaining courses. Canadian courses would also begin to lose their status as a location for the high-profile competitions that bring economic benefits to the host communities and promote interest in the sport. The best players that draw the crowds and the sponsors will not come to sub-quality courses.

7.7) The Environmental, Health and Other Benefits of Weed Management in Turfgrass

The environmental and health benefits of turfgrass are recognized by many diverse groups.

Environmental

- **Soil erosion control, water conservation — ground water recharge.** Healthy lawns absorb rainfall and reduce runoff up to 80 times more efficiently than impervious surfaces. Runoff water from agriculture and urban areas account for 64% and 5% of non-point surface water pollution affecting US rivers, and 57% and 12% of non-point water pollution affecting US lakes. Research has shown that "quality turfgrass stands modify the overland flow process so that runoff is insignificant except in the most intensive rainfall events." Good turf had runoff of 5% to 25% of bare soil (various studies as reported in Beard and Green, 1994).

- **Storm water runoff and flood control.** This is a critical issue in Canadian and US rural and urban municipalities, especially those with combined sewer outflows, which can cause sewage facilities to overflow in heavy rain events. The issue is so important that storm water utilities have been established in the United States (only studies, so far, in Canada) to charge for runoff from properties. The charge structures usually offer an incentive to reduce runoff. Properties with good ground cover would pay less than those without. This is another market-price recognition of the value of good ground cover.

- **Soil enrichment.** This takes place through carbon storage.

- **Discourages nuisance pests.** Well-maintained lawns discourage nuisance pests.

- **Organic chemicals decomposer.** Bacterial populations in a thick turf community offer one of the most active biological systems for the degradation of trapped organic chemicals (Beard and Green, 1994).

- **Phosphorus runoff.** Research at the University of Wisconsin O.J. Noer Turfgrass Research Center confirms that poorly kept, unfertilized lawns contribute 40% more phosphorus than fertilized lawns. The reason is that phosphorus binds to soil; and soil runoff carries phosphorus with it. A healthy, well-kept, properly fertilized lawn filters rainwater and holds soil in place, preventing runoff — and phosphorus pollution (Kussow, 2004).

Health

- **Temperature moderation.** The average-sized front lawns of eight homes have the same cooling effect as about 70 tons of air conditioning.[25] Lawns cool hot summers. Healthy, well-maintained lawns will reduce surface temperatures by 18 to 24 degrees Celsius in comparison to bare soil, and 10 to 15 degrees Celsius in comparison to natural vegetation or poorly managed grass.

- **Pollutant filter for water quality.**

- **Oxygen release.** 2,500 square feet (232 sq. meters) of lawn releases enough oxygen for a family of four.[26]

- **Pollen allergy control.** About 15% to 20% of the population has hay fever or allergic reactions to plant pollen, dust and other airborne particles. Ragweed is the major cause of the problem. Hay fever is most common among 24 to 44 year olds, and the economic impact of their diminished productivity is substantial. For many individuals, high pollen counts trigger asthma attacks, and may promote the development of the condition. Dense lawns typically are free of the many weedy species that produce allergy-related pollens.

- **Noise abatement/glare reduction.** Good turf also makes life a bit quieter. It effectively absorbs and deflects sound. When combined with trees and other landscaping, grass can reduce noise levels by 20% to 30%.

- **Recreational activities.**

- **Natural beauty and aesthetic benefits.**

The Role of Broadleaf Herbicides in Achieving Those Benefits

To achieve these benefits requires dense ground cover with a high shoot density and root mass for surface soil stabilization (See, for example, Beard and Green, 1994). Broadleaf weeds act directly against that requirement by covering much of the ground with their leaves, destroying the turf shoot density necessary to achieve the environmental and health benefits. If broadleaf weeds are present, then the environmental and health benefits of turfgrass are reduced accordingly. Control of broadleaf weeds is essential if these environmental and health benefits are to be realized.

[25] as reported by Landscape Ontario at www.lawnfacts.ca/article-0018.shtml
[26] op.cit

7.8) The Consequences of Withdrawing Phenoxy Herbicides

Withdrawal of either or both of the phenoxy herbicides would have the following effects:

- a change in the use patterns of herbicide, including a shift to herbicides that are less effective and that pose a greater risk to landscape shrubs and trees;
- a large increase in the costs of controlling broadleaf weeds but without achieving the same control over the weeds;
- an increase in the spread of broadleaf weeds throughout turfgrass;
- increased risk of resistance in the target weeds; and
- the loss of the significant environmental and health benefits.

Change in Use Patterns

The most likely replacement herbicide would depend on the area being treated. MCPA would be the main replacement to 2,4-D in some mixtures, with an increased rate and number of applications per year. mecoprop-p and dicamba could be added for the majority of turfgrass applications, but dicamba can be hazardous to trees and shrubs if applied to exposed or shallow roots. Experience has shown that this mixture is not as effective as 2,4-D in controlling dandelions, the most common weed in turf. A higher application rate or more applications of MCPA would be required to match the broadleaf control of 2,4-D.

If MCPA were withdrawn also, then the options would be even more limited and even less effective. North American experts believe there are herbicides available that would be almost as effective but at 10 to 15 times the cost. Neither of these expensive alternatives would be available to this Canadian sector.

Increased Costs

Here are several views on the likely increase of costs if one, or both, of the phenoxy herbicides 2,4-D and mecoprop-p were to be withdrawn.

- **The USDA NAPIAP.** This study showed that replacement of 2,4-D by MCPA and other herbicides would lead to a 60% (USDA 1996, pg. 111) increase in total herbicide use over the 2,4-D volume used because of the need for higher application rates, more applications or both. The price tags for these new herbicides would be 82% higher than for the current uses of 2,4-D, and the application costs would increase by 49% (USDA 1996, tables 5 and 6). The total incremental cost of using the alternatives to 2,4-D was estimated to be just over $232 million (1992 US dollars). If MCPA were to be banned also, this cost rose to $367 million. However, this analysis is 14 years old at the time this study was prepared and the herbicide situation has changed.

- **Current cost analyses.** Another perspective on the costs of alternatives to the phenoxy herbicides is provided by the current work of Mr. Ron Calhoun at Michigan State University. He is a research/extension specialist with the Department of Crop and Soil

Sciences, Michigan State University and has studied broadleaf weeds, herbicides and turfgrass since 1992. Mr. Calhoun has done trials on a wide range of commercial and consumer herbicides and points out that 2,4-D is always the gold standard in such trials. It is by far the cheapest of comparable herbicides and is effective on about 80% of the target weed species in lawns, rising to about 90% based on frequency of weed occurrence. As an example, he quoted typical 2,4-D single active ingredient treatments costing about $6/acre versus $25-$35/acre for comparable single product herbicides, using current 2006 costs. Cost comparisons for two- and three-way mixes get more complicated, but 2,4-D is still the cheapest, usually by a significant margin (R. Calhoun, personal correspondence, summer 2006).

If only 2,4-D were withdrawn from the market, Calhoun believes that MCPA would be the first option and would be almost as effective as 2,4-D, in those situations for which registered products were available. The cost would be slightly higher, because of the need for a slight increase in concentration. A typical cost increase for a commercially available product that replaced 2,4-D with MCPA would be from about $13.75/acre to about $15.75/acre, about 10%. Withdrawing MCPA from the market would pose a more formidable challenge, according to Calhoun.

There are herbicides, such as triclopyr, that could be almost as effective as 2,4-D, but at much greater concentrations. The per-acre cost of 2,4-D treatment of $6 would rise to approximately $25, if both phenoxy herbicides were to be withdrawn. And, control of key broadleaf weeds like dandelion would not be as effective. Some alternatives, like quinclorac, have excellent activity on dandelion but cost $80 to $90/acre, (R. Calhoun, personal correspondence, summer 2006) compared to the cost of $6/acre for 2,4-D. However, even these prohibitively expensive options would not be available to Canadians, because there are no registered products for lawn/turf uses that contain either triclopyr or quinclorac. Two end-use quinclorac products are registered in Canada, but for agricultural uses only in the Prairie Provinces and the Peace River Region of British Columbia.

- **Residential lawns**. The cost of residential weed control would increase significantly. The increased costs could prevent householders from benefiting from the higher value that the market place puts on well-cared for lawns and landscaping.

Spread of Broadleaf Weeds

Without 2,4-D and MCPA not only do costs go up but turf quality declines significantly. The herbicide alternatives are not as effective as 2,4-D and MCPA, even with increased application rates and number of applications. Thus, a further impact would be the increase in the spread of the target weeds. Though it may be exceedingly expensive, hand weeding may be necessary on some fine turfgrass areas to achieve the required control. Even these laborious, expensive measures will not be completely effective and the golf courses, public parks, athletic fields, building landscapes and lawns will become weedier.
The USGA controlled experiment demonstrated that it is highly unlikely that the current approach to IPM would be effective in the absence of the phenoxy herbicides. An

important component of IPM is reliance on the specific activity, including the application of the herbicides that are the most appropriate to the then current situation of the turf area. Without the periodic use of the most effective herbicides, the evidence suggests that the remaining IPM activities would not be effective in controlling broadleaf weeds to the expected quality level. The weeds would spread.

Increased Threat of Weed Resistance

Noted earlier in this report was the role 2,4-D plays in reducing and delaying the threat of resistance to herbicides developing among the target weeds. There is little resistance to 2,4-D on the part of weeds in turfgrass, even after over 60 years of use. Weeds have been found to exhibit resistance to some of the newer alternative herbicides, and a greater use of these alternatives can be expected to lead to a greater incidence of resistance.

Loss of Environmental and Health Benefits

As noted earlier, it is not well appreciated that the environmental and health benefits attributed legitimately to well-maintained turfgrass require a high shoot density of the turf. The presence of broadleaf weeds acts directly against high shoot density. The environmental and health benefits would decline, as weed populations increased.

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8) Non-Crop Industrial

Also known as industrial vegetation management, this industry sector carries out the control, removal or alteration of a vegetation community to achieve the objectives of the landowners and users. Vegetation can be manipulated in various ways, including mechanical, chemical, cultural and biological.

8.1) Utility Company Rights of Way

Pipelines and electrical distribution utilities are the main examples of this sector. For electric utilities to provide a safe and reliable supply of electricity to customers, they must manage their systems to minimize the number and length of interruptions. Vegetation management, both on and off the power line corridor, is a major component of a utility's effort to ensure this reliable and safe supply of energy. The August 2003 blackout in the eastern part of both Canada and the United States showed the damage that can result from improperly maintained rights-of-way. The US Federal Energy Regulatory Commission (FERC) concluded that the blackout would never have occurred if tree branches had not come into contact with 345-kv transmission lines. It also determined that there were no consistent vegetation management standards for utilities to follow. During routine maintenance and repair, crews have to access substations, power lines, poles and towers easily and safely. Safety remains another problem when trees touch transmission and distribution lines. Finally, well-maintained rights-of-way offer aesthetic value to the community and provide beneficial wildlife habitat. Pipelines have similar requirements. A clear sight line remains important for proper pipeline maintenance. During regular inspections conducted from aircraft or ground vehicles, crews can spot leaks or problems. Even routine maintenance becomes difficult if crews can't easily access pumps, gates and valves. Vegetation management also positively affects the safety of work crews that must access pipelines. Both electrical utilities and pipeline companies have legal responsibilities to maintain rights of way to ensure safety; vegetation management is a significant component of achieving that goal. As is the case with electric utilities, aesthetics and wildlife habitat also play a role in managing a well-maintained pipeline right-of-way. An emerging issue is security. Clear visibility and access are vital to ensure that the security of this infrastructure is not threatened.

8.2) Roadsides

Safety is paramount along highways and roads. Vegetation management helps ensure motorist safety by controlling encroaching weeds and brush that can conceal road signs and affect driver visibility. Since weeds and brush offer animals an ideal hiding spot, wildlife can dart into the road, increasing the potential for vehicular accidents. Eliminating heavy, tall vegetation bordering roadways prevents shading and allows the sun to melt ice or snow on pavement. It also eliminates snow that may be trapped in vegetation and lead to hazardous drifting across roadways. In addition, vegetation management stops weeds and brush roots that crack and buckle road surfaces.

8.3) Railroads

With more than 51,000 km of railroad track crisscrossing Canada, effective vegetation management on and along railways is critically important. Safety is essential for railroads, because heavy equipment moves at high speeds along the rails. Left unchecked, weeds and brush can reduce train traction during starts and stops, can hide damaged equipment and other hazards, and can cause rail ballast to rot prematurely. At crossings, dense foliage limits motorist sight lines. Again, railways have a legal responsibility to safety and vegetation management.

8.4) Industrial Bare Ground

Safety and productivity requirements often dictate that certain areas on industrial sites, around enclosed warehouses and exposed stockpiles and warehouses, utility substations, highways, railways and runways be kept completely weed free. This reduces fire hazards and ensures that maintenance and emergency equipment can access freely the sites and facilities.

8.5) Invasive/Noxious Vegetation

Invasive, noxious and exotic weeds can threaten existing natural ecosystems and severely damage agricultural products. The World Conservation Union identified invasive alien species as the second most significant threat to biodiversity, after habitat loss.[27] More than simply "plants out of place," as many weeds are referred to, these invaders are more far-reaching in their impacts.

Invasive alien plants are species introduced deliberately or unintentionally outside of their natural habitats. In this new environment, free from their natural enemies, non-native plants have an advantage that allows them to out-compete native plants and agricultural crops for space, moisture and nutrients. An example of this threat is the weed known as wild carrot (*Daucus carota*), also known as Queen Anne's lace, and widely distributed in North America, Europe and Asia. A problem in perennial cropping systems, such as grass seed production, pasture and hay fields, and Christmas tree production, it is an especially serious threat where cultivated carrot seed is produced. Wild carrot hybridizes with the domestic crop and ruins crop seed.[28]

As native plants are replaced by invasives, biodiversity declines and habitats change. These impacts are like a ripple on a pond, affecting wildlife, ecosystem functions, natural resources, recreation and industry. Industry representatives note that they receive an increasing number of calls from the general public, inquiring about practical ways to prevent the spread of invasive species.

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[27] As reported by the Alberta Invasive Plants Council (nd).
[28] Pacific Northwest Extension Publication (2003).

8.6) Canadian Service Contractors

About four large contractors in Canada provide vegetation management services to rail, roadside, utility and industry customers. In addition, dozens of small private operations service local utilities and industrial customers. The large majority of vegetation management services are outsourced to contractors. The business has grown slightly in recent years but essentially is stable year to year indicating the ongoing need for vegetation management. Hydro One is believed by industry analysts to be the single largest Canadian user of industrial vegetation management. The total areas treated by Hydro One with brush control programs include 11,472 hectares of transmission rights of way and 8,606 hectares of distribution rights of way (five year averages) (Hydro One, personal correspondence, summer 2006).

8.7) Phenoxy Herbicides in Industrial Vegetation Management

Statistics are hard to come by for this sector. Channel representatives suggest that annual product sales are in the range of $20 million, measured as the selling price to the client contracting for the vegetation management services. Hydro One reports its cost of product purchased in 2005 as $2,300,000 (Hydro One, personal correspondence, summer 2006). The same channel representatives estimate that the total value of vegetation management work completed annually in Canada is about $50 million, $30 million being spent on mechanical cutting and the cost of the services provided. Hydro One reported its total annual vegetation management program costs, averaged over the last five years, at $33 million for both transmission and distribution rights of way. This Hydro One cost figure is for rights of way floor vegetation management activities only, and does not count the management of trees along the edge or off the side of the rights of way. Hydro One estimates that this costs about 30% to 33% of its total vegetation management costs (Hydro One, personal correspondence, summer 2006).

Overall, the value of phenoxy product used in industrial vegetation management is estimated to be about $3.5 million or 17% of the total herbicide expenditures. 2,4-D is, by far, the most common phenoxy used in this sector, either alone or, more frequently, as a tank mix partner or as part of a three-way mix. The other two phenoxy herbicides (MCPA and mecoprop-p) do not play a significant role. Hydro One reported the following herbicides used in its vegetation management programs, listed in decreasing order of volume of product:

- triclopyr products;
- picloram and 2,4-D;
- glyphosate products;
- other 2,4-D products; and
- imazapyr.

As noted earlier, 2,4-D as a partner broadens the spectrum of weeds controlled and is a very important addition when mixed with products aimed at specific, difficult to control weeds. For example: Table 8.1 lists the weeds controlled by one particular vegetation management herbicide, Aminopyralid Herbicide, a Group 4 herbicide marketed by Dow AgroSciences, when it is used alone and when it is mixed with 2,4-D. The list represents one concentration of each of the two herbicides. Stronger concentrations control even more weeds.[29]

Table 8.1 Weeds Controlled by Aminopyralid Herbicide

Tank Mix	Weeds Controlled
Aminopyralid Herbicide 0.29 L/ha (70 g ai/ha)	Canada thistle, spotted Knapweed, Canada goldenrod, scentless chamomile
Aminopyralid Herbicide 0.29 L/ha (70 g ai/ha) with 2,4-D Amine 840 g ae/ha	Control of annual sow thistle, blue bur, burdock (<4 leaf), cocklebur, common plantain, flixweed, goat's beard, prickly lettuce, ragweeds, stinging nettle, sweet clover, curled dock (<4 leaf), hawkweed, peppergrass, season long control of Canada thistle, spotted knapweed, scentless chamomile, Canada goldenrod, and top growth control of blue lettuce, bull thistle, buttercup, gum weed, hoary cress, perennial sowthistle

Industrial vegetation management markets differ markedly in the west and east of Canada. In the west, the focus is on weed control. The focus in the east is more on control of woody brush and bare ground. British Columbia has both issues, with a growing concern over invasive species.

About 60% to 65% of the total expenditure on herbicides is for woody brush control, with the rest being spent on bare ground herbicides such as glyphosate. 2,4-D is not used widely in areas where bare ground is required, such as at electrical sub-stations or on railway ballast, but it is sometimes added to speed up the process whereby the target weeds are eliminated. Two products, one each from Dow AgroSciences and NuFarm, are believed to account for about 40% of the woody brush control herbicides used in this sector. Both contain 2,4-D. Other herbicides used include triclopyr and glyphosate.

A major advantage of herbicides for brush control is that they remove vegetation to the root, rather than just the above-ground portion of the brush. Removal right down to the root can add years to the vegetation control cycle, whereas superficial mowing has to be repeated at least annually, and sometimes more often. Selective herbicides, such as 2,4-D, in combination with other herbicides such as picloram, do not remove grasses that can then proliferate after the removal of brush. The proliferation of grasses further reduces the potential of woody re-growth and provides the required right of way condition (i.e., low-growing species that are selected to be compatible with the specific objectives of the vegetation management program). Hydro One representatives confirm these gains from the use of herbicides (Hydro One, personal correspondence, summer 2006).

[29] Taken from the label available at <www.dowagro.com/ca/prod/Milestone.htm>.

8.8) Implications of the Withdrawal of Phenoxy Herbicides

Withdrawal of the phenoxy herbicide 2,4-D, from the market would be the most disruptive. Industry representatives believe there would be two immediate effects of such a withdrawal and a follow-on effect they believe would probably be the most significant. The immediate effects would be an increase in the costs of industrial vegetation management; along with a decrease in the effectiveness of weed control and brush management. The follow-on effect would be an increase in the events that industrial vegetation management is intended to prevent (i.e., power outages through brush contact with transmission lines, inability to access facilities quickly for maintenance or in response to an emergency/failure, reduced visibility at crossroads and the loss of even more land to invasive species). Infrastructure security in the future may even be a greater concern.

Costs and Loss of Weed Control

If 2,4-D were removed, most brush control herbicides without the 2,4-D tank mix partner would be very ineffective. Most registered herbicides would have to be used in higher concentrations and would still lose much of their spectrum and capacity to control weeds and brush. Preliminary estimates are that herbicide costs would at least double as customers applied more of the higher-cost herbicides in an attempt to retain some degree of vegetation management. Mechanical removal of the remaining weeds would have to be carried out on a more frequent basis, and that would further increase the costs.

Conifer control would be particularly challenging. Basal bark method with higher cost products and very expensive application costs could be an alternative as could straight mechanical removal.

TransAlta Utilities prepared a report in 1991, *Why Does TransAlta Use Herbicides?* (as reported in Dow AgroSciences, undated), in which it compared the costs of vegetation management with herbicides to the costs using mechanical or hand methods. While the absolute value of the costs of each method will have changed over the intervening 15 years, industry representatives believe that the relative cost advantage of herbicides over the other methods remains about the same. That is, hand cutting can be up to 27 times as expensive as the herbicide option and mowing up to four times as expensive.

Those cost estimates were done based on long-term costs, which is the preferred perspective. TransAlta reported that, over time, the costs of vegetation management programs that used herbicides, and the amount of herbicide used, actually went down. Herbicides, by removing vegetation to the roots, minimize re-growth, which can occur only by way of seeding-in from outside sources or from roots of bordering vegetation, such as brush on the border of the right of way. Low-growing grasses begin to spread, reducing the potential for woody brush to revive, thus reducing the amount of herbicide required and increasing the time interval between maintenance operations. On the other hand, reliance on mechanical methods means the vegetation managers cannot abandon the vegetation practices for very long, because the roots of the mechanically cut brush can continue to sprout for up to two years (Dow AgroSciences, undated).

A preliminary calculation of the likely cost increase, were 2,4-D to be withdrawn, is as follows, using the conservative estimates from the industry studies and the following assumptions.

- Current cost of 2,4-D: $3.5 million.
- Application costs of 2,4-D: Estimated to be equal to the cost of the herbicides, a rule of thumb offered by vegetation management contractors (i.e., $3.5 million).
- Total current cost of 2,4-D: $7.0 million purchase and application cost.

Table 8.2 Estimated Costs of Vegetation Management if 2,4-D Were Withdrawn

Incremental Cost Element	Calculation Method	Value ($million)
Cost of greater volume of more expensive replacement herbicides	At least 100% of the cost of the withdrawn 2,4-D	3.5
Costs of mowing, etc. to control remaining weeds	Four times the cost of applying herbicides (i.e. 4*$3.5 million)	14
Total cost		$17.50

This calculation suggests the vegetation management industry could expect a 150% increase in costs (i.e., from $7 million to $17.5 million) if 2,4-D were to be withdrawn from the Canadian market. These findings are consistent with those of NAPIAP (1996: 167) that estimated cost increases ranging from 50% to 1,500%, depending on the particular type of right of way. Electrical lines were expected to incur the largest cost increases.

Sector experts add that weed and woody brush control would not be as effective as currently, even with this large increase in costs. They also point to the reduced control over invasive species, a growing concern throughout the country. This points to the second, follow-on, impact that they anticipate.

An Increase in the Preventable Events

The reduction in the efficacy of weed and woody brush control that industry representatives believe would result from the withdrawal of 2,4-D would lead, over time, to an increase in the events that vegetation management is intended to prevent. It is not possible, in this research, to estimate the likely timing and severity of such incidents, but industry experts point to recent experiences with power failures in North America.

Another industry concern is that the growing emphasis on security of the North American industrial infrastructure could be compromised.

8.9) Herbicides and Biodiversity: A Side Benefit

A major research project on herbicides and rights-of-way has been in process for just over 50 years now in Pennsylvania. The project is now the longest continuous study documenting the effects of mechanical and herbicidal maintenance on wildlife and plants along utility rights-of-way. Its conclusions have led to dramatic changes in how these rights-of-way are designed and in the recognition of the environmental and ecological benefits that can flow from well-maintained rights-of-way (Dow AgroSciences, 2003).

The project began as a result of concerns by hunters, particularly rabbit hunters, who thought that herbicide use by the line-clearance companies was disturbing wildlife. The line-clearance and chemical companies also had an interest in eliminating any concern their utility customers might have. The original objectives of the research, which have not changed in the intervening period, were to:

- determine the relative effects of chemical and mechanical brush control on game food and cover;
- study wildlife use of treated areas;
- determine herbicide efficacy; and
- develop a low, stable plant cover that would resist woody plant (especially trees) invasion.

The researchers who started the work in 1953 were a university professor, Dr. W. Bramble, and his then assistant, now Dr. W. Byrnes. The controlled experiment consisted of six treatments that changed slightly in 1987 and include hand cutting with no herbicides, mowing plus herbicide treatment and a variety of herbicidal application methods. 2,4-D was one of the original herbicides tested. The research led to the development of the “wire zone-border zone” concept of rights-of-way vegetation management. In this approach, the rights-of-way are divided into two areas: the wire zone that is directly under the power lines, and the border zone that fringes the wire zone for at least 20 feet on each side. The wire zone consists of a community of grass, forbs and low shrubs, bordered by low- to medium-sized shrubs in the border zone. Low trees grow on the outer edge of the rights-of-way, where the border zone meets the natural forest. The researchers found that a careful selection of herbicides and application techniques would let them control the pattern of vegetation development in the two zones, keeping the growth of high trees to a minimum where they posed a risk to the transmission lines. It was also determined that the two zones were hospitable to a wide range of fauna, hence the “biodiversity” benefit. Birds found nesting cover in the border zone’s shrubs, while ground-nesting birds found cover in the wire zone. Deer used the shrubs in the border zone for shade and heavy vegetation to bed down their fawns. Grouse and turkeys foraged on the wire zone’s low-growing plants.

Many of these benefits would be very difficult, if not impossible, to deliver without the use of phenoxy herbicides.

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9) Summary: Estimates of the Benefits to Canada of Phenoxy Herbicides

This report has examined three sectors as representative of the major uses of phenoxy herbicides in Canada:

- wheat and barley production in Alberta, Saskatchewan, Manitoba and Ontario;
- the lawn and turf sector, in particular residential landscaping and lawns, and the golf industry; and
- non-crop industrial uses, also referred to as industrial vegetation management.

It is believed that these three sectors account for over 90% of phenoxy use in Canada, with the first (agriculture) accounting for about 80%. The report estimated benefits of usage as the increase in costs that would be incurred if the phenoxy herbicides were to be withdrawn from the Canadian market and considered options to take the results from the selected sectors and expand them to the overall Canadian economy. However, a reliable and informative method for this extrapolation could not be found; the uses are too different. Thus, these results should be interpreted as examples of the benefits that could be found if other use sectors were examined.

9.1) Agriculture Sector: Wheat and Barley

Total current phenoxy herbicide costs to wheat and barley producers are estimated to be $170 million: $55 million for 2,4-D and $115 million for MCPA. Wheat treatment costs are $114 million, barley $57 million. The costs of mecoprop-p are contained within those estimates, because mecoprop-p is available only as a mix with one of the other two herbicides.

Agriculture producers would attempt to preserve both the yield and quality of their crops if the phenoxy herbicides were withdrawn. The cheapest, most effective alternatives are the increased use of other, more expensive, less effective herbicides. Other crop management practices such as increased tillage are considerably more expensive and less effective.

If all three phenoxy herbicides were removed, producers would experience $224 million in additional annual weed-control costs, a 131% increase. Producers believe there would still be yield losses and possibly quality degradation. This study estimated low yield losses (0.5% to 3.5%), although other studies have estimated yield losses as high as 15% to 37%. The revenue losses from the drop in yields would be about $114 million, with wheat accounting for $76 million and barley the remaining $38 million.

Farmers would bear all the direct costs of the alternative treatments (i.e., the $224 million). Opinions differ about who would bear the costs of the drop in yields. Industry representatives believe Canada is a price taker in international cereal markets and a drop in Canadian yield would have no effect on market prices. In this situation, farmers would also bear the loss in revenue from the drop in yields, for a total cost burden of $338 million. However, some well-recognized Canadian academics and government agencies believe a drop in Canadian yield would cause some domestic prices to rise, thus transferring some of the cost increase to Canadian consumers. In this case, consumers would bear about 15% of the cost incurred by the drop in yields, with producers picking up the remaining 85%. In either scenario, the minimum incremental cost to the agriculture producers would be $321 million.

Other Canadian agriculture products benefit from the use of the phenoxy herbicides, but have not been counted in this analysis. For example, there are five million acres of oats grown in Canada that also rely on the phenoxy herbicides for broadleaf weed control.

The most comprehensive previous study of the economic impacts of 2,4-D was conducted by Stemeroff et al. (1988) for Agriculture and Agri-Food Canada. The 1988 study estimated net losses of $58 million to $82 million in the agricultural sector from the loss of 2,4-D, and a net loss to agriculture of $328 million to $365 million from the loss of all phenoxy herbicides. While the results from the 1988 study appear similar to the results reported in this study, this study identifies a number of important differences in the methodologies used. The comparison of the two sets of results suggests the economic impacts estimated in this study should be considered conservative.

9.2) Prevention and Delay of the Onset of Resistance

Some target weeds develop resistance to certain chemical classes of herbicides. Crop yields drop and farmers must find new methods to control the weeds. A Canadian resistance expert has noted that farmers don’t always follow the manufacturers’ recommendations for preventing the development of resistance, in part because farmers believe new herbicides will come to their rescue. He suggested that this attitude is unrealistic, and herbicides should be viewed as non-renewable resources. It is so expensive (up to $180 million) and time consuming (up to a decade) to get new herbicides approved that there may be few new products entering the market to aid the producers.

The phenoxy herbicides, and 2,4-D in particular, play a special role in managing the emergence of herbicide resistance. Over its 60-year history, 2,4-D has proven to have one of the lowest risks of fostering resistance in weeds. The phenoxy herbicides are frequently mixed with resistance-prone broadleaf herbicides, or used in herbicide rotations. Plants that survive the non-phenoxy herbicide through the development of resistance are killed by the phenoxy. The withdrawal of the phenoxy herbicides from the Canadian market would significantly reduce producers’ ability to manage the emergence of broadleaf weed resistance.

The immediate consequences of this would be a drop in yield. Producers would attempt to maintain yield and quality by using more of the remaining herbicides. The concern is that this would lead to a proliferation of resistance, exacerbating the problem. The Canadian expert concludes that phenoxy herbicides are critical for managing the resistance of broadleaf weeds.

This study has not attempted to estimate the economic significance of this ability of the phenoxy herbicides to prevent and delay the emergence of resistance, but some industry observers suggest that its value could overshadow all the other economic benefits identified in this study. Herbicide expenditures by farmers and downstream agricultural commodity prices would clearly have to support the increased and recurring development of new herbicides.

9.3) Lawn and Turf Sector

This sector represents the use of phenoxy herbicides by individual Canadians and businesses for aesthetic, recreational and investment purposes. Turfgrass is a multi-billion industry in Canada, but reliable statistics on it are scarce despite the considerable recent public discussion of the sector. This study used groups of specialists and experts to estimate the required parameters when reliable estimates were not available.

The sector consists of turfgrass farms, home lawns and landscaping around institutions, municipal parks, cemeteries, golf courses and sports fields. Annual sales of the phenoxy herbicides in this sector are estimated at about $10 million, as measured at the point of transfer from manufacturer to distributor. Retail sales values would be higher. A wide range of products are available, with 2,4-D and mecoprop-p combined in about 95% of the products. The remaining 5% contain only one of 2,4-D and mecoprop-p. No products containing MCPA are in domestic use in Canada. Thus, the withdrawal of either 2,4-D or mecoprop-p from the market would be a withdrawal of both. Industry experts and the Canadian Pest Management Regulatory Agency agree that no herbicide alternatives are available to the lawn/turf sector in the event of the withdrawal of one or both of 2,4-D and mecoprop-p.

Residential Landscaping Including Lawns

The results of academic research, including recent work in Canada confirm that investing in a well-cared for landscape surrounding a home is a good economic investment that is valued in the market place. Willing buyers pay a premium for this amenity, estimated in the Canadian research to average 7.7%. This return on investment is available to all homeowners, not just those who have large and expensive grounds. Control of noxious weeds is an integral part of that investment decision. 2,4-D and mecoprop-p are the main herbicides used in this sector. The only alternatives to herbicides that have undergone the same tests of safety and efficacy of weed control are hand weeding and periodic re-sodding. On a net present value basis, the cost of maintaining consistent high turf quality using these manual alternatives is about 60 times higher than the net present value of current costs using herbicides. There are herbicides that could be as effective as the phenoxy herbicides, but they are not approved for lawn/turf uses in Canada. Other impacts of the withdrawal would be a spread of broadleaf weeds, an increased threat of weed resistance, and a loss of some of the environmental and health benefits associated with turfgrass.

The Golf Industry

One in five Canadians over the age of 12 plays golf, either seriously or recreationally. The spin-off benefits from this business are significant. A recent US study valued the industry at US$62 billion annually, or about $6 billion for the Canadian industry. Competition for golfers and for the high-visibility international competitions is strong among the courses and municipalities. One of the most significant features that bring golfers and competitions to a course is the quality of the course, including its landscaping. A three-year controlled experiment at a public golf course in the United States demonstrated that there are no alternatives that will maintain golf course quality if phenoxy herbicides are withdrawn. Integrated pest management is a useful approach that can reduce herbicide usage, but there are no effective alternatives. The costs of herbicide treatment at Canadian courses would increase eightfold (from about $3 million to about $26 million), but would not maintain the required turf quality. Over time, Canadian courses could lose their ability to attract the big-name competitors that draw the viewers and the sponsors.

The Environmental and Health Benefits of Turfgrass

Many diverse groups recognize the environmental and health benefits of turfgrass. Soil erosion control, water conservation, storm water runoff and flood control, organic chemicals decomposer, pollutant filter for water quality, oxygen release, pollen allergy control — these and other benefits have been documented and quantified as part of “green” strategies. However, a key requirement of the turfgrass growth to achieve these benefits is dense ground cover with a high shoot density and root mass. Broadleaf weeds act directly against that requirement. They cover much of the ground, destroying the shoot density. The presence of broadleaf weeds reduces the environmental and health benefits of turfgrass. A withdrawal of the phenoxy herbicides would significantly weaken the control of broadleaf weeds.

9.4) Non-Crop Industrial

The industrial vegetation management industry carries out the control, removal or alteration of a vegetation community to achieve the objectives of the landowners and users. Statistics are hard to come by for this sector, but sector representatives suggest that about $3.5 million is spent annually on the phenoxy herbicides, about 17% of total herbicide expenditures in vegetation management. 2,4-D is by far the most common phenoxy used; MCPA and mecoprop-p do not play significant roles. As in the other sectors, 2.4-D is especially important as a tank mix partner, especially when added to products aimed at specific, difficult-to-control weeds.

The estimated costs that would accrue from the withdrawal of 2,4-D are as follows:

- an immediate incremental increase of about 150% in the costs of industrial vegetation management, from about $7 million per year to $17.5 million per year;
- a loss of control over weeds, as the alternatives are not as effective as current practices involving 2,4-D;
- the reduced ability to respond to the threat of invasive and noxious species; and
- an increase in preventable events, such as outages and accidents caused by overgrowth of vegetation.

A growing concern is the ability to ensure the physical security of the infrastructure if both visibility and ease of access are impaired. 2,4-D plays an important role in these objectives.

Table 9.1 Summary of Benefits in Terms of Increased Costs

Sector/Issue	Costs if Phenoxy Herbicides Withdrawn from Market	Estimation
Agriculture – wheat and barley	Increased weed control costs to farmers of 131% annually Drop in yield because weeds not controlled as well	Current annual costs: $170 million Incremental annual cost of withdrawing all phenoxy herbicides: $224 million Minimum additional annual cost of $114 million, shared between farmers and consumers Minimum total cost to farmers: $321 million, 22% of total net farm income (2005) for all three Prairie provinces
Lawn/turf	No herbicide alternatives to this sector if the phenoxy herbicides were to be withdrawn. Only option: hand weeding and re-sodding	
Residential lawns and landscaping	Increased costs, reduction of weed control	Weed control costs rise by a factor of 60 for individual households that want to maintain turf quality
Golf	No alternative to preserve course quality	Weed control costs rise from about $3.2 million to about $26 million annually. Course quality declines, leading to loss of big-name players and competitions
	Environmental and health benefits of turfgrass are recognized. But the turf must have dense ground cover and high shoot density to achieve those benefits Broadleaf weeds act against grass shoot density and cause benefits to decline	Not estimated
Non-crop industrial	Increase in weed control costs of 150% Reduction in weed control leading to increase in preventable events (power failures, etc.) Reduction in security maintenance	From about $7.5 million to about $17.5 million Not estimated Not estimated
Prevention and delay of herbicide resistance	The phenoxy herbicides delay and prevent the emergence of resistance to some other herbicides, prolonging the life of these other herbicides and reducing the need to replace them with new herbicides	Not estimated; some believe that this value alone would be much larger than all other benefits identified