PS&C
Prairie Soils & Crops Journal

The history of herbicide use for weed management on the prairies

F.A. (Rick) Holm[1] and Eric N. Johnson[2].
[1]Dept. of Plant Sciences, University of Saskatchewan, [2]Agriculture and Agri-Food Canada Research Farm, Scott, SK.

Summary
For the past 60 years, herbicides have played a vital role in crop production in western Canada. Their use has allowed for significant diversification in crop types and has triggered a major shift towards more soil- and water-conserving and energy-efficient farming systems. Many new herbicides were discovered and developed in the 1960s and 1970s, but the herbicide "golden era" appears to be over. In recent years, dramatically fewer new herbicide registrations and ever-increasing numbers of herbicide-resistant weeds make the herbicide tools we already have increasingly valuable. All players (herbicide manufacturers, researchers, farm advisors and farmers) will need to work together closely to develop integrated strategies to ensure that effective weed control can be achieved on a sustainable basis for the future.

Introduction
Throughout the history of agriculture, more time, energy and money have been devoted to weed control than to any other agricultural activity. While there are records of ancient civilizations using chemicals such as common salt and wood ashes to control unwanted vegetation, the widespread use of herbicides is a very recent phenomenon that did not become a significant factor in crop production until the 1950s[1, 6].

As illustrated in Table 1, the 1960s and 1970s were the golden age of herbicide development. More than half of the modes of action currently used in western Canada were introduced during that period. Since that time, the rate of herbicide discovery and their introduction has slowed substantially, not only in western Canada but throughout the world. This is due, in large part, to three main reasons: 1. The herbicide market is relatively mature and so new products must be substantially better than currently registered products in terms of efficacy and environmental and health impacts in order to win significant market share. 2. The cost of herbicide research and development continues to escalate as health and environmental issues attract closer scrutiny from the general public and the regulatory agencies. 3. The global dominance of glyphosate has reduced the incentive for manufacturers to attempt to compete with this herbicide.

In recent years, herbicide sales in Canada have accounted for approximately 80% of total pesticide sales; about 75% of those sales are in western Canada. Thus, in 2006, farmers in western Canada spent approximately $800 million on herbicides[2, 3]. The intensive use of herbicides over the past six decades has resulted in the evolution of a significant number of cases of herbicide resistance in weeds. While this has not yet resulted in a decline in herbicide use, it has certainly reduced the efficacy of some herbicides on many farms. Herbicide resistant weeds are a good reminder of the weakness inherent in the over-reliance on one weed control method and this problem is spurring renewed interest in the development of cost-effective integrated weed management systems.

Table 1. Introduction of Herbicide Mode of Action Groups Currently Used in Western Canada by Decade.

Decade	Mode of Action Groups Introduced*	Decade total
1940s	4	1
1950s	8, 11	2
1960s	3, 5, 6, 7, 22	5
1970s	1, 9, 20, 25, 27	5
1980s	2	1
1990s	10, 14, 15	3
2000s	28	1

The Early Days (prior to 1945)

Non-Selective Control of Persistent Perennial Weeds

Early attempts at controlling persistent perennial weeds with herbicides involved the application of high rates of inorganic compounds such as sodium chlorate and sodium arsenite (registered in 1929 and 1933, respectively). Recommended application rates were in the range of 488-1,708 kg/ha. In some cases a second treatment one month after the first was suggested and control lasting for two years was the expectation[1, 10, 12, 14]. Other compounds such as sodium metaborate tetrahydrate were also used for this purpose[11]. These treatments were quite expensive and rendered the soil unsuitable for crop production. Thus, their use was limited to preventing the spread of small weed patches.

Early attempts at selective weed control

One of the earliest reported instances of selective weed control in field crops was in Germany in the mid-19th century and involved sulphuric acid and iron sulphate[15]. There are accounts of the use of iron sulphate to control wild mustard *(Sinapis arvensis L.)* and stinkweed *(Thlaspi arvense L.)* in wheat *(Triticum aestivum* L.) near Winnipeg in 1908[7]. By the 1930s, considerable research was being conducted into the use of a number of inorganic compounds (sulphuric acid, copper nitrate, copper sulphate, iron sulphate, sodium chloride, sodium dichromate, sodium chlorate, ammonium thiocyanate and ammonium bisulphate) for the selective control of annual broad-leaved weeds in field crops. Based on four years of testing throughout the prairies, Godel (1933) reported that only copper nitrate, copper sulphate and sulphuric acid provided selective control of weeds. A 4% solution of sulphuric acid applied at 842-1,123 L/ha controlled wild mustard, Indian mustard (*Brassica juncea* (L.) Czern.), stinkweed, wild radish (*Raphanus raphanistrum* L.), false flax (*Camelina microcarpa* Andrz. ex DC), tumbling mustard (*Sisymbrium altissimum* L.) and wild buckwheat (*Polygonum convolvulus* L.). Sulphuric acid provided broader spectrum weed control than the copper compounds but the latter resulted in less crop injury and greater yield responses. Wheat and oats (*Avena sativa* L.) were tolerant to sulphuric acid but barley (*Hordeum vulgare* L.) and rye (*Secale cereale* L.) were not. In spite of considerable research, none of the compounds tested provided an attractive combination of efficacy, crop safety, user safety and low cost[8].

In the 1930's attention turned to the evaluation of organic compounds for selective weed control. Phenol compounds such as Sinox® (*sodium dinitro-o-cresylate*) were introduced in France in 1933 and somewhat later in North America. It was rapidly adopted for control of broad-leaved weeds in cereals, field pea (*Pisum sativum* L.), corn (*Zea mays* L.), flax *(Linum usitatissimum* L.), garlic (*Allium sativum* L.) and onion (*Allium cepa* L.). Where weed pressure was heavy, crop yield increases were sometimes spectacular (7,200% in wheat, 445% in flax and 244% in barley). Additional benefits over inorganic herbicides included improved crop safety, non-corrosiveness, and much lower mammalian toxicity[13, 18]. Sinox ® was introduced to Western Canada in 1944 for use on cereals and flax (Figure 1). Applied in 660-880 L of water/ha, it provided excellent control of wild mustard, stinkweed, lamb's quarters (*Chenopodium album* L.) and suppressed wild buckwheat[18].

The Modern Weed Control Era (1945 to Present)

For convenience, herbicides will be grouped according to their mode of action (MOA) and their use in western Canada will be described briefly. The order of presentation will be by the date of introduction of the first member of the MOA group. MOA group designations are as in the Weed Science Society of America Herbicide Handbook, 9th ed. 2007[16]. Registration dates were obtained from the Pest Management Regulatory Agency (PMRA) web-site[4] or were provided by Iulia Popa of the PMRA (personal communication). Some active ingredients have multiple commercial trade names; however, only the most familiar names are listed for illustrative purposes.

Figure 1. Applying Sinox® in west-central Saskatchewan for selective broadleaf weed control, 1948. (Photo: Courtesy of AAFC).

Auxin Mimics (or Synthetic Growth Regulators) - Group 4

The face of chemical weed control changed dramatically with the introduction of the first Group 4 herbicide (Table 2) in 1945 (Figure 2). In 1946, Wood and Olson reported that wild mustard, lamb's quarters, stinkweed, chickweed (*Stellaria media* (L.) Vill.), cocklebur (*Xanthium strumarium* L.) and false ragweed (*Iva xanthifolia Nutt.*) were susceptible to 2,4-D but that wild buckwheat and portulaca (*Portulaca oleracea* L.) were resistant. They also indicated variable results on perennial weeds such as Canada thistle (*Cirsum arvense* (L.) Scop.), leafy spurge (Euphorbia esula L), field bindweed (*Convolvulus arvensis* L.) and poison ivy (*Toxicodendron radicans* (L.) Kuntze) and excellent control of hedge bindweed (*Calystegia sepium* (L.) R. Br.)[19]. By 1948, many common annual, biennial and perennial weeds had been categorized as Generally Susceptible, Moderately Susceptible or Resistant[20]. The popularity and rapid adoption of 2,4-D is illustrated by the fact that approximately 40 ha were sprayed with the product in western Canada on a research/demonstration basis in 1946. In 1947, 200,000 ha were treated and in 1949, approximately 3.2 million ha were treated. By 1962, the area treated with 2,4-D had grown to over 10 million ha[6, 7].

While 2,4-D controlled a wide spectrum of broad-leaved weeds and rapidly became very widely used, some species such as wild buckwheat and many pasture and rangeland weeds were not well controlled. In addition, crop tolerance was marginal in oat, field pea, alfalfa (*Medicago sativa* L.) and other legumes. These weaknesses were quickly addressed by the introduction of other related compounds such as MCPA, 2,4-DB, MCPB, mecoprop, dichlorprop and 2,4,5-T. Dicamba, introduced in the 1960s, is still widely used in cereal crops in combination with 2,4-D or MCPA. Picloram and clopyralid, two members of the picolinic acid family, were introduced in the 1970s and 1980s, respectively. Picloram was withdrawn for use in cereal crops due to soil persistence concerns, but clopyralid remains popular for controlling Canada thistle and many annual broadleaved weeds. 2,4,5-T was introduced in the 1950s and was used in a 1:1 mix with 2,4-D for brush control. This mixture gained notoriety as "Agent Orange" in the Vietnam War. By 1980, all uses of 2,4,5-T in Canada had been suspended. Benazolin® was used briefly for control of wild mustard in rapeseed (canola) (*Brassica napus* L., *Brassica campestris* L.); however, its value was limited due to variable control, crop safety concerns and cost.

Fluroxypyr, registered in 1997, is not sold as a stand-alone product, but is used as a component of some broadleaf herbicide mixtures to enhance and broaden weed control. Quinclorac is currently being added to a Group 2 herbicide to enhance cleavers control.

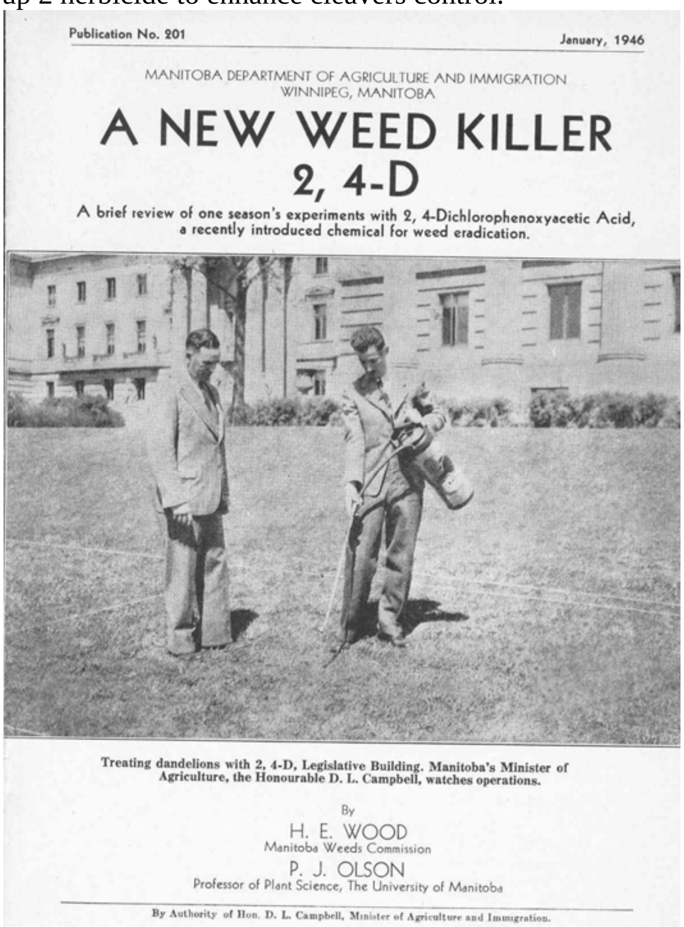
Publication No. 201 January, 1946
MANITOBA DEPARTMENT OF AGRICULTURE AND IMMIGRATION
WINNIPEG, MANITOBA
A NEW WEED KILLER
2, 4-D
A brief review of one season's experiments with 2, 4-Dichlorophenoxyacetic Acid, a recently introduced chemical for weed eradication.
Treating dandelions with 2, 4-D, Legislative Building. Manitoba's Minister of Agriculture, the Honourable D. L. Campbell, watches operations.
By
H. E. WOOD
Manitoba Weeds Commission
P. J. OLSON
Professor of Plant Science, The University of Manitoba
By Authority of Hon. D. L. Campbell, Minister of Agriculture and Immigration.

Figure 2. The introduction of 2,4-D in the mid-1940's marked the beginning of the modern herbicide era.

Table 2. Group 4 Herbicides

Active Ingredient (AI)	Typical Trade Name	AI First Registered
2,4-D	2,4-D	1945
MCPA	MCPA	1952
MCPB	Tropotox®	1956
2,4-DB	Embutox®	1958
Mecoprop	Mecoprop®	1960
Dicamba	Banvel®	1964
Picloram	Tordon®	1964
Benazolin	Benazolin®	1970
Dichlorprop	Estaprop®	1978
Clopyralid	Lontrel®	1984
Trichlopyr	Remedy®	1989
Fluroxypyr	Attain® & others	1997
Quinclorac (broadleaves)	Accord®	1997
Aminopyralid	Restore®	2006

Fatty Acid Inhibitors - Group 8

EPTC was the first product introduced in this group for control of grassy and broadleaved weeds in corn, flax and a number of horticultural crops (Table 3). Its requirement for immediate and deep soil incorporation limited its use in the semi-arid prairies. Ethofumesate was a very specialized product for use in sugarbeets (*Beta vulgaris (saccharifera*) L.) and so saw very little overall use. The products in this group that had a major impact on western Canadian agriculture were diallate and triallate as the first widely used wild oat (*Avena fatua* L.) herbicides in cereals, oilseeds, pulses and forages. Triallate quickly became the product of choice because of its greater crop safety for barley and wheat but its use declined in the mid- to late-'70s as the Group 1 post-emergent wild oat herbicides gained popularity. However, interest in this compound is being renewed as Group 1 resistant wild oat has become a serious concern on many farms.

Table 3. Group 8 Herbicides

Active Ingredient (AI)	Typical Trade Name	AI First Registered
EPTC	Eptam®	1959
Diallate	Avadex®	1960
Triallate	Avadex BW®	1962
Ethofumesate	Nortron®	1978

Pigment Inhibitors - Group 11

This group contains only one active ingredient, amitrole (Amitro 240®), which was introduced in 1959 and is still in limited use today. It is a non-selective, highly translocated, herbicide that controls a wide range of annual and perennial broadleaved and grassy weeds. Prior to the mid-'70s, its use was limited due to high cost and because typical application rates resulted in soil residues that restricted cropping choices. Its use all but stopped following the introduction of glyphosate in the mid- '70s but new use patterns for control of hard-to-kill weeds in direct seeding systems have rekindled some limited interest in this herbicide.

Cell Membrane Disruptors - Group 22

Diquat (Reglone®) and paraquat (Gramoxone®) are very fast-acting, non-selective, non-translocated, non-residual herbicides that were registered in 1960 and 1963, respectively. Diquat is more commonly used as a desiccant in pulse crops, canola, mustard (*Brassica juncea* L.; *Sinapis alba* L.), potatoes (*Solanum tuberosum* L.), flax (*Linum usitatissimum* L.), sunflowers (*Helianthus annuus* L.) and forage legumes. A special formulation (Reglone A®) is used for aquatic weed control in ponds and dugouts. Paraquat use is much more limited. It is registered for stale seedbed treatment prior to seeding many horticultural crops, for weed control in established alfalfa and bird's foot trefoil (*Lotus corniculatus* L.) and for burndown weed control prior to emergence of many field crops. These products have very little effect on perennial weeds because they cause rapid leaf tissue damage and are not translocated within the plant.

Photosynthesis Inhibitors - Group 5

All of the herbicides in this group have soil activity and some are very persistent and are thus used as soil sterilants (simazine, bromacil, hexazinone) (Table 4). Simazine and atrazine are used for shorter term residual control of weeds in crops such as established alfalfa, bird's foot trefoil, corn and shelterbelts. Atrazine, used for weed control in corn, was not widely used in western Canada, even though it was one of the most popular herbicides in the world during the '70s and '80s. Cyanazine was used for a brief time for post-emergent control of hard-to-kill annual broadleaved weeds in cereals, especially in the black soil zone. In western Canada, metribuzin is the most widely used product in this group; it can be used for post-emergent control of annual broadleaved weeds in a wide variety of pulse crops, cereals, potatoes and soybeans (*Glycine max* (L.) Merr.). The use of cyanazine and metribuzin expanded in the mid-80s with the introduction of triazine-tolerant canola; however, these cultivars were quickly replaced with cultivars that carried the Roundup Ready, Liberty Link, or Clearfield trait.

Table 4. Group 5 Herbicides

Active Ingredient (AI)	Typical Trade Name	AI First Registered
Simazine	Simazine®	1963
Bromacil	Hyvar®	1963
Cyanazine	Bladex®	1970
Atrazine	Atrazine®	1971
Metribuzin	Sencor®	1971
Hexazinone	Velpar®	1977

Cell Division Inhibitors - Group 3

The introduction of trifluralin in 1965, followed by ethalfluralin in 1987, had a profound impact on rapeseed and canola production in western Canada as they provided the first means of controlling both grass weeds and a wide range of annual broadleaved weeds (Table 5). In fact, it is doubtful that those crops would have become such significant contributors to the agricultural economy of western Canada without these two herbicides. Both products were also widely used in flax and pulse crops, cereal crops, in summerfallow and in many horticultural crops. In the past 10-15 years their use has declined significantly due to their need for soil incorporation, the reduction in summerfallow, the availability of alternative products for pulse crops and, most importantly, the current domination of herbicide-resistant canola cultivars. Dinitramine had a relatively short life as a rapeseed/canola herbicide due its marginal crop safety.

Pronamide is a specialty product used to a very limited extent for control of foxtail barley (*Hordeum jubatum* L.) in forage legumes and seeded grass pastures.

Table 5. Group 3 Herbicides

Active Ingredient (AI)	Typical Trade Name	AI First Registered
Trifluralin	Treflan®	1965
Pronamide	Kerb®	1972
Dinitramine	Cobex®	1973
Ethalfluralin	Edge®	1987

Photosynthesis Inhibitors - Group 7

Diuron and tebuthiuron are specialty products for long-term vegetation control and so have seen very limited use (Table 6). Propanil had a relatively short life as a product for green foxtail (*Setatia viridis* L.) control in cereals from the late -'70s to the mid-'80s. Linuron has been used for control of some hard-to-kill weeds in cereals in the black soil zone and for broadleaf weed control in coriander (*Coriandrum sativum* L.), caraway (*Carum carvi* L.), dill (*Anethum graveolens* L.), and in shelterbelts.

Table 6. Group 7 Herbicides

Active Ingredient (AI)	Typical Trade Name	AI First Registered
Diuron	Krovar®	1965
Tebuthiuron	Spike®	1973
Propanil	Stampede®	1977
Linuron	Lorox®	1979

Photosynthesis Inhibitors - Group 6

Bromoxynil, first registered in 1966, has been very widely used for the past four decades and remains a very popular herbicide for controlling annual broadleaved weeds in cereals, flax, canaryseed (*Phalaris canariensis* L.), corn and a number of forage crops. It is sometimes used alone (Pardner®), but most often, it is used in combination with MCPA ester (Buctril M®) to enhance control of mustard family weeds Its popularity is due in large part to its effectiveness, relatively good crop safety and its compatibility in mixtures with many other herbicides. Bentazon (Basagran®) was registered in 1973 and is used on a wide variety of field and forage crops but sees limited use due primarily to its relatively high cost.

Unknown MOA - Group 25

Benzoylprop-ethyl (Endaven®) and flamprop-methyl (Mataven®) were registered in 1972 and 1977, respectively, and were used for post-emergent wild oat control in wheat. Their major weaknesses were: they could not be used in other major crops, they were not good tank-mix partners and they did not control green foxtail or other annual grass weeds. These weaknesses led to their rapid replacement when Group 1 herbicides became available in western Canada.

Cellulose Inhibitors - Group 20

Diclobenil (Casaron®), registered in 1973, is a soil-applied herbicide that is used on a very limited basis for control of annual and perennial grasses and broadleaved weeds in several shelterbelt species and in nursery stock and orchards.

Potential Nucleic Acid Inhibitors or Non-descript MOA - Group 27

Difenzoquat (Avenge®) is a post-emergent wild oat herbicide that was registered in 1973 and is used in barley, canaryseed, some varieties of wheat, fall rye, triticale (× *Triticosecale* Wittm. ex A. Camus) and many legume and grass forage crops. It can be tank-mixed with a number of herbicides that control broadleaved weeds; however, its inability to control other grass weeds has limited its popularity. The Group 1 resistant wild oat problem could result in increased use of this product in future. Quinclorac (Accord®), generally considered a Group 4 product due to the symptoms it produces on broadleaved weeds, is also placed in Group 27 due to its effect on grasses such as green foxtail.

Fatty acid Inhibitors - Group 1

The introduction of the Group 1 herbicides for control of wild oat and other annual and perennial grass weeds marked the transition from a predominantly pre-emergent (triallate and trifluralin / ethalfluralin) to a post-emergent weed control strategy (Table 7). These herbicides are effective and can be mixed with a wide variety of broadleaf herbicides allowing for "once over" weed control in all the major field crops. Their frequent and wide-spread use resulted in the fairly rapid selection of Group 1 resistant wild oat biotypes. It is estimated that Group 1 herbicides were used on 41% to 59% of grain crop fields in western Canada in 2001 and that about one in six fields contained Group 1 resistant wild oat biotypes[5]. The proportion of Group 1 herbicide use and Group 1 resistant wild oat was highest in the moister areas of the prairies where wild oat pressure is highest. Group 1 resistant biotypes of two other annual grasses (green foxtail and Persian darnel (*Lolium persicum* Boiss. & Hohen. ex Boiss.)) are also confirmed in western Canada[9]. In spite of the high frequency of wild oat resistance to this group of herbicides, product sales remain high.

Table 7. Group 1 Herbicides

Active Ingredient (AI)	Typical Trade Name	AI First Registered	Crop Use
Diclofop	Hoe-Grass®	1976	Grasses & Broadleaved
Sethoxydim	Poast®	1983	Broadleaved
Fluazifop	Venture®	1984	Broadleaved
Fenoxaprop	Puma120 Super®	1991	Grasses
Tralkoxydim	Achieve®	1992	Grasses
Clethodim	Select®	1992	Broadleaved
Clodinafop	Horizon®	1995	Grasses
Quizalofop	Assure®	1998	Broadleaved
Tepraloxydim	Equinox®	2004	Broadleaved
Pinoxaden	Axial®	2007	Grasses

Amino Acid Inhibitors - Group 9

Glyphosate, the only herbicide in this group, (Roundup® and many others) is a non-selective, non-residual, highly translocated herbicide that is effective on a wide range of grass and broadleaved weeds. It was introduced in western Canada in 1976, primarily as a product used at high rates in summerfallow and after harvest for control of perennial weeds such as quackgrass (*Elymus repens* (L.) Gould) and Canada thistle. Initially, it was expensive ($65 to $130 per hectare) and its use was limited mainly to fields that had literally been overrun with perennial weeds. Subsequent research and development resulted in the registration of lower rates for controlling annual and winter annual weeds prior to crop emergence and to pre-harvest and post-harvest applications for perennial weed control. These use patterns, combined with a significant price reduction facilitated the development of direct-seeding technology which is now the dominant production system on the prairies (Figure 3). The mid -‘90s saw the introduction of Roundup Ready® canola cultivars which have been widely adopted and now account for over 40% of the canola acreage in western Canada. Because glyphosate is the only herbicide in this MOA group, it is critical to the continuing success of our current no-till production systems of crop management. Thus, the possible appearance of resistant weed bioytpes is a constant concern. While at least 15 weed species have evolved resistance to glyphosate on a global basis, to date no resistant biotypes have been identified in Canada[9].

Figure 3. Pre-seed application of glyphosate forms the basis of modern direct-seeding systems which have revolutionized crop production in western Canada. (Photo credit: F.A. Holm)

Amino Acid Inhibitors - Group 2

The Group 2 herbicides were introduced to western Canada in the early-'80s and are currently used on approximately 30% of field crop acres in the region[5] (Table 8). This class of compounds is typified by extremely low application rates and, in some cases, long lasting soil residues which can impose significant re-cropping restrictions. Many of these compounds control only broadleaved species but several are used to control both broadleaved and grass weeds. Their widespread use combined with their very specific mode of action and, in some cases, their persistence in soil has resulted in the fairly rapid evolution of resistance in a number of broadleaved species and in wild oats. This problem is most widespread in kochia (*Kochia scoparia* (L.) Schrad.) which has evolved Group 2 resistance throughout the prairies. As growers have become more reliant on Group 2 products in response to the development of Group 1 resistant wild oats, the evolution of Group 2 resistant wild oats and, in some cases, the evolution of wild oat biotypes resistant to both Group 1 and Group 2 herbicides has become more of a problem.

Table 8. Group 2 Herbicides

Active Ingredient (AI)	Typical Trade Name	AI First Registered
Chlorsulfuron	Glean®	1982
Metsulfuron	Ally®	1987
Imazamethabenz	Assert®	1988
Thifensulfuron	Refine®	1989
Ethametsulfuron	Muster®	1990
Imazethapyr	Pursuit®	1990
Tribenuron	Express®	1991
Triasulfuron	Unity®	1992
Nicosulfuron	Ultim®	1994
Rimsulfuron	Prism®	1994
Imazamox	Odyssey®	1997
Sulfosulfuron	Sundance®	1999
Flucarbazone	Everest®	2000
Florasulam	Frontline®	2001
Foramsulfuron	Option®	2003
Pyroxsulam	Simplicity®	2008

Cell Division Inhibitors - Group 15

Metolachlor (Dual®) is a pre-plant incorporated or pre-emergence herbicide registered in 1990 for control of a variety of annual grass and broadleaved weeds in corn, dry bean (*Phaesolus* spp.), potatoe (*Solanum tuberosum* L.), soybean and sweet white lupin (*Lupinus albus*). It can also be used early post-emergence in corn. Dimethanamid (Frontier®) is used pre-plant incorporated or pre-emergence for green foxtail control in field corn and dry beans. It was registered in 1994. Because of their crop and weed spectrum they, are not widely used in western Canada.

Glutamine Synthetase Inhibitor - Group 10

Glufosinate (Liberty®), the only active ingredient in this group, was registered in 1993 and is a fast-acting, non-selective, non-residual, post-emergent herbicide for control of annual weeds in Liberty Link® canola and corn. Over 40% of the western Canadian canola crop is seeded to Liberty Link® varieties each year.

Protox (Cell Membrane) Disruptors - Group 14

Fomesafen is registered under the User Requested Minor Use Registration Program for annual broadleaved weed control in dry beans in the Red River Valley of Manitoba (Table 9). Carfentrazone is a foliar-absorbed, fast-acting herbicide that is registered for tank-mixing with glyphosate as a burn-down treatment prior to seeding a variety of field crops, primarily for the control of Roundup Ready® canola volunteers and for enhanced control of some other broadleaved weed species not particularly well-controlled by low rates of glyphosate. Sulfentrazone was conditionally registered in May of 2008 for pre-emergence control of broadleaved weeds in chickpea (*Cicer arietinum* L). Its strength is control of kochia including Group 2 resistant biotypes. Further potential registrations for both carfentrazone and sulfentrazone may result in their more widespread use in the future.

Table 9. Group 14 Herbicides

Active Ingredient (AI)	Typical Trade Name	AI First Registered
Fomesafen	Reflex®	1997
Carfentrazone	CleanStart®	2006
Sulfentrazone	Authority®	2008

HPPD (Pigment) Inhibitors - Group 28

Currently only one active ingredient from Group 28, pyrasulfotole is registered for use in western Canada. It was registered in 2007 and is marketed in combination with bromoxynil (Group 6) as Infinity® for control of annual broadleaved weeds and suppression of some broadleaved perennials in wheat, barley, triticale and timothy (*Phleum pratense* L.). Pyrasulfotole is the first herbicide with a new mode of action for broadleaved weed control in western Canada in approximately two decades.

Significant but now obsolete herbicides

A few significant early selective herbicides that are no longer in use should be mentioned. TCA® (registered in 1947) and Dalapon ® (registered in 1955) are Group 26 herbicides that were used at relatively low rates to control green foxtail and at higher rates to control perennial grasses such as quackgrass. Low rates of TCA® could be used in cereals but Dalapon® use was restricted to broadleaved crops. Crop tolerance in cereals was marginal and green foxtail control was quite variable. Dinoseb® (a Group 24 herbicide registered in 1947) was a pre-emergence and contact herbicide that was sometimes used to control small annual broadleaved weeds in cereals but most often as a potato top killer and for other horticultural uses. It was highly toxic to humans and other animals and its use was discontinued in the 1980s. Barban (Carbyne® – Group 23) was the first major post-emergent wild oat herbicide that could be used in wheat and barley. It was also used in a number of broadleaved crops including mustard, rapeseed and sunflowers. It was registered in 1960 and remained a significant product until it was displaced by triallate, trifluralin and the Group1 wild oat herbicides. A very narrow growth-stage window of application for both weed control and crop safety, a lack of activity on other grass weeds and limited possibilities for tank-mixing with herbicides for broadleaved weed control were significant weaknesses. Asulam (Asulox F®) was used for control of wild oats and suppression of some annual broadleaved weeds in flax in the '70s. As with several other products of this era, its popularity was limited by marginal weed control and crop safety concerns.

Conclusions

Herbicides have been used extensively in western Canada for more than half a century and have contributed substantially to increased and more stable crop yields, and improved crop quality. Their use has also resulted in a marked reduction in the amount of tillage required to produce annual crops and this has contributed to significant reductions in summerfallow acreage and soil erosion throughout the prairies. However, early hopes that they would bring an end to weed problems on the prairies were dashed long ago. In spite of the effectiveness of herbicides and their widespread use, weeds continue to be a major threat to successful crop production. Weed populations have changed and evolve in response to herbicide use as tolerant or resistant species fill the void left by more susceptible species. The appearance of herbicide resistant biotypes of several weed species is a constant reminder that over reliance on any one weed control method is ultimately doomed to failure. While herbicides will likely remain an important component of weed management on the prairies for many decades to come, their on-going utility can only be assured if they are used judiciously within well-designed, integrated systems that utilize a wide variety of weed management techniques.

References:

1. Anonymous, 1942. Weed Control. In: Guide to Farm Practice in Saskatchewan, 1942. Department of Extension, University of Saskatchewan, Saskatoon, SK. pp 81-88.
2. Anonymous, 2005. Annual Report, 2004-05. CropLife Canada, Etobicoke, ON. 23 pp.
3. Anonymous, 2007. Annual Report, 2006-07. CropLife Canada, Etobicoke, ON. 28 pp.
4. Anonymous, 2008. Public Registry of Pesticides. Online. Internet. August 20, 2008. Available at: http://www.pmra-arla.gc.ca/english
5. Beckie, H. J., J. Y. Leeson, A. G. Thomas, L. M. Hall, C. A. Brenzil, T. Andrews, K. R. Brown and R. C. Van Acker, 2007. Prairie Weed Survey: Herbicide Resistant Wild Oat 2001 to 2003. Weed Survey Series Publication 06-02. Agriculture and Agri-Food Canada Research Centre, Saskatoon, SK.
6. Coupland, R. T., 1957. New herbicides for weed control. In: Addresses and Proceedings, Farm and Home Week, 1957. University of Saskatchewan, Saskatoon, SK. pp 84-90.
7. Friesen, G., 1963. Recent advances in chemical control of weeds. In: Addresses and Proceedings, Farm and Home Week, 1963. University of Saskatchewan, Saskatoon, SK. pp 16-22.
8. Godel, G. L., 1933. The chemical control of annual weeds in growing crops. Proceedings, World's Grain Exposition and Conference. Canada, 1933.
9. Heap, I. The International Survey of Herbicide Resistant Weeds. Online. Internet. August 20, 2008. Available at www.weedscience.com
10. Kephart, L. W. 1931. Quack Grass. Farmers' Bulletin No. 1307. U.S. Dept. of Agriculture, Washington, DC. 30 pp.
11. Klingman, G. C., 1961. Weed Control as a Science. John Wiley & Sons, Inc. New York, NY. 421 pp.
12. McRostie, G. P., L. E. Kirk, G. Godel, W. G. Smith and J. M. Mason, 1932. Weeds and their control. Report No. 27. The Assocociate Committee on Weed Control, National Research Council of Canada. Ottawa, ON. 15 pp.
13. Norman, A. G, C. E. Minarik and R. L. Weintraub, 1950. Herbicides. Ann. Rev. Plant Physiol. 1:141-168.
14. Sexsmith, JJ. 1942. Weed control experiments conducted by the Dominion Experimental Station, Lethbridge. In: The Weed Problem in Alberta. Agricultural Extension Service, Alberta Department of Agriculture. 48 pp.

15. Timmons, F. L., 1970. A history of weed control in the United States and Canada. Weed Sci. 18:294-307.
16. WSSA Herbicide Handbook, 9th ed. 2007. Weed Science Society of America, Lawrence, KS.
17. Westgate, W. A. and R. N. Raynor, 1940. A new selective spray for the control of certain weeds. Bulletin No. 634, University of California, College of Agriculture, Agricultural Experiment Station, Berkeley, CA. 36 pp.
18. Wood, H. E., 1949. Chemical weed control in the prairie provinces. In: Agricultural Institute Review, Agricultural Institute of Canada, Ottawa, ON. March, 1949. pp 133-135.
19. Wood, H. E. and P. J. Olson, 1946. A new weed killer, 2,4-D. Pub. No. 201. Manitoba Dept. of Agriculture and Immigration. Winnipeg, MB. 8 pp.
20. Wood, H. E. and P. J. Olson, 1948. 2,4-D and its use. Pub. No. 216. Manitoba Dept. of Agriculture and Immigration. Winnipeg, MB. 15 pp.