Herbicides: Past, Present, and Future

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The following is a summary of a peer-reviewed paper that is available on the Internet:

Holm, F.A. and Johnson, E.N. 2009. The history of herbicide use for weed management on the prairies. Prairie Soils and Crops: 2. [Online] Available: http://www.prairiesoilsandcrops.ca/display_article.html?id=26.

Introduction

Throughout the history of agriculture, more time, energy and money have been devoted to weed control than any other agricultural activity. The widespread use of herbicides is a recent phenomenon and has become a significant input in crop production since the 1960s. Herbicides account for approximately 80% of total pesticide sales in Canada with about 75% of those sales in western Canada.

Early Days (1920 to 1945): The focus was on controlling persistent perennial weeds such as thistles, and quackgrass with inorganic compounds such as sodium chlorate, sodium arsenite, and sodium metaborate tetrahydrate. High rates, high cost, and re-cropping issues limited their use to small patches.

Early attempts at selective weed control:
1908 – Iron sulfate was evaluated for wild mustard control.
1930 – Inorganic compounds such as copper nitrate, copper sulfate and sulfuric acid were evaluated for selective control in cereals. Sulfuric acid (4% solution) applied at 840-1,120 L per ha controlled mustards, stinkweed, and other broadleaf weeds. Copper compounds were less efficacious than sulfuric acid but provided less crop damage and greater yield increases.
1940s – Attention turned to organic compounds. Sodium dinitro-o-cresylate (Sinox) was introduced in 1944 for control of wild mustard, stinkweed, and lamb's quarters in cereals and flax. It was applied in 420 – 560 L of water/ha.

1945-2010

Synthetic Auxins (Group 4)

"Modern Selective Herbicide Era" began in 1945 with introduction of 2,4-D which provided selective control of many annual broadleaf weeds. The product was rapidly adopted by producers. In1946, 40 ha were treated for research and demonstration purposes. In 1947 and 1949, 200,000 and 3,200,000 ha were treated with 2.4-D, respectively. By 1962, over 10,000,000 ha were treated with 2,4-D. Other products introduced in this group were (year of registration in brackets): 2,4,5-T (1948), MCPA (1952), MCPB (1956), 2,4-DB (1958), mecoprop (1960), dicamba, picloram (1964), dichlorprop (1978), clopyralid (1984), fluroxypyr, quinclorac (1997), and aminopyralid (2006).

Fatty Acid Inhibitors (Group 8):

This group had a major impact on wild oat control. Products included EPTC (1959), diallate (1960), triallate (1962), and ethofumesate (1978). Soil incorporation was required so their use declined with the introduction of post-emergence Group 1 graminicides. There is renewed interest in triallate due to Group 1 and Group 2 resistant wild oat.

Cell Division Inhibitors (Group 3):
Trifluralin (1956) & ethalfluralin (1987) provided annual broadleaf & grass weeds in rapeseed and canola. Soil incorporation was required which was a poor fit with no-till. There has been a major decline in their use due to the introduction of HR canolas in 1996. Others in this group include: pronamide (1972) dinitramine (1973).

Photosynthetic Inhibitors (Group 6)
Bromoxynil (1966) was introduced for “hard to kill” annual broadleaf weeds and remains very popular. The use of bentazon (1973**)** is increasing in field pea for control of Group 2 resistant broadleaf weeds.

Potential Nucleic Acid Inhibitors / Non-descript MOA (Group 27)
Difenzoquat was introduced in 1973 for post-emergence wild oat control in wheat, barley, and canaryseed. Group 1 & 2 resistant wild oat could re-kindle interest. Quinclorac (1997) is included in this group for green foxtail control; however it is considered a Group 4 herbicide for broadleaf weeds.

Fatty Acid Inhibitors (Group 1)
These herbicides provide annual grass control in a wide range of monocot and dicot crops. They were rapidly adopted and marked the transition from pre-emergence to post-emergence wild oat control. Currently, they occupy about 60% share of the wild oat herbicide market. There are widely used in spite of widespread wild oat resistance (1 in 5 fields). Products include: diclofop (19760, sethoxydim (1983), fluazifop (1984), fenoxaprop (1991), tralkoxydim (1992), clethodim (1992), clodinafop (1995), quizalofop (1980), tepraloxydim (2004), pinoxaden (2007)

Amino Acid Inhibitors (Group 9)
Glyphosate (1976) transformed agriculture in western Canada with chemfallow, conservation tillage, Roundup ready crops, and pre-harvest control of perennial weeds. To date, resistant weeds have not been an issue in Western Canada.

Amino Acid Inhibitors (Group 2)
This group of herbicides provides annual grass and broadleaved weed control in many crops. They are widely used (30% of crop area treated annually) and there are several resistant weed biotypes. Products in this group include: chlorsulfuron (1982), metasulfuron (1987), imazamethabenz (1988), thifensulfluron (1989), ethametsulfuron, imazethapyr (1990), tribenuron (1991), pyroxasulam (2008), and thiencarbenzone (2009).

Amino Acid Inhibitors (Group 10)
Glufosinate (1993) is a fast-acting, non-selective herbicide for control of monocot & dicot weeds. The product is selective in Liberty Link canola, which currently occupies about 40% of canola acreage. There are no resistant weed issues to date.

Other important herbicides and their modes of action are listed in Table 1.

Table 1: Use pattern, date of introduction and mode of action of various products used in western Canadian crop production over the past 60 years.

MOA (Group)	Product(s)	Use	Date(s)
Photosynthesis inhibition (5)	bromacil, hexazinone	soil sterilant	1963, 1977
	simazine, atrazine	corn, forages	1963, 1971
	cyanazine	broadleaf weeeds in cereals	1970
	metribuzin	pulse, cereal, potato	1971
Photosynthesis Inhibition (7)	diuron, tebuthiuron	soil sterilant	1965, 1973
	Propanil	green foxtail – cereals	1977
	linuron	hoerticulture, shelterbelts	1979
Pigment Inhibition (11)	amitrole	mono & dicot weeds	1959
Cell Membrane Disruption (14)	fomesafen	dry beans	1997
	carfentrazone	pre-seed burn-off	2006
	sulfentrazone	broadleaf weeds – chickpea	2008
Cell Division Inhibition (15)	metolachlor	corn, bean, potato, soy	1990
	dimethanamid	corn, bean	1994
Cellulose Inhibition (20)	dichlobenil	soil sterilant	1973
Cell Membrane Disruption (22)	diquat	crop dessicant, aquatic weeds	1960
	paraquat	weed control on horticulture	1963
Cell Division Inhibition (23)	barban	wild oat control in field crops	1960
Unknown (cell elongation) (25)	benzoylprop, flamprop	wild oat control in wheat	1972, 1977
FA & Lipid Inhibition (26)	TCA, dalapan	grass control	1847, 1955
HPPD (pigment) inhibition (28)	pyrasulfotole	ann. broadleaf weeds in cereals	2007

Herbicide Development: Thirteen modes of action were introduced into Western Canada prior to 1980. Since 1980, only six new modes of action have been introduced with only one new mode of action introduced in the past decade.

Sulfentrazone registration: Sulfentrazone, a Group 14 herbicide, has been recently granted full registration in chickpea, field pea, flax, and sunflower in the Prairie Provinces. Full label details are not available yet. Label rates may not provide adequate weed control in soils with greater than 6% organic matter due to product adsorption. Further information on the effect of soil organic matter and clay content on sulfentrazone activity is available in the following manuscript:

Szmigielski, A.M., Schoenau, J.J., Johnson, E.N., Holm, F.A., Sapsford, K.L., and Liu, J. (2009). "Development of a Laboratory Bioassay and Effect of Soil Properties on Sulfentrazone Phytotoxicity in Soil.", Weed Technology, 23(3), pp. 486−491.

More recent work by the same authors has found that sulfentrazone activity increases as soil pH increases. Application of the high label rate is recommended on soils with a pH lower than 7.0.

Summary
Herbicides have played a vital role in western Canadian crop production in the past 60 years, allowing for significant crop diversification and adoption of conservation tillage; however, introduction of new modes of action has declined dramatically over the past 20 years. Rapid evolution of herbicide resistance indicates a need for judicious use of existing herbicides integrated with cultural practices in order to maintain their utility in Prairie agriculture.