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## Nature and Occurrence of Herbicide-Resistant Wild Oat and Green Foxtail Across Saskatchewan Ecoregions

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Abstract. A survey conducted in 1996 indicated that one in nine fields has Group 1 -resistant (R) wild oat and one in twenty fields has Group 1 -R green foxtail in Saskatchewan. However in the Parkland region, one in six fields has R wild oat and one in eleven fields has R green foxtail. One in five Group 1-R wild oat populations exhibits Group-2 resistance; these multiple-R populations greatly restrict chemical control options for producers. Results from this survey should alert producers to be more proactive in preventing, delaying or managing R weeds, by practicing herbicide-group rotation and integrated weed management.

### A Decade of Herbicide Resistance in Western Canada

Two grass and seven broadleaf weed species have demonstrated resistance to herbicides belonging to one or more groups (defined by mode of action) in western Canada over the past decade (Table 1). Green foxtail and wild oat are the two most abundant weeds in Saskatchewan, occurring in 53 and 67% of fields, respectively (Thomas et al. 1996). Green foxtail has been reported to be resistant to herbicides belonging to Group 1 (aryloxyphenoxy propionates [APP] and cyclohexanediones [CHD]) or Group 3 (dinitroanilines) (Table 2). Group-1, -2 (imidazolinones), -8 or -25 resistance in wild oat have been reported. Some populations of green foxtail and wild oat exhibit multiple resistance: green foxtail to herbicides belonging to Groups 1 *and* 3, and wild oat to herbicides in Groups 1.2 *and* 25 (Morrison et al. 1995). A population of cleavers in Alberta has been reported to be resistant to Group-2

Table 1. Herbicide-resistant weeds in western Canada: 1988- 1997

Weed	First report	Herbicide group(s)	Rank in SK (relative abundance)
Green foxtail	1988	3	1
	1991	1	
	1992	1,3	
Wild oat	1989	8	2
	1990	1	
	1994	1,2,25	
Chickweed	1988	2	23
Kochia	1988	2	13
Russian thistle	1989	2	8
Wild mustard	1991	4	9
	1992	2	
	1994	5	
Hemp-nettle	1996	2	22
Cleavers	1996	2,4	16
Annual sow-thistle	1997	2	45

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Table 2. Grass herbicides registered for use on canola and wheat in Saskatchewan\*

		Canola			Wheat				
Gp	Type <sup>2</sup>	Product	Common name <sup>3</sup>	Year ®	Product	Common name	Year ®		
1	POST	Hoe-grass	diclofop-methyl	1976	Hoe-grass	diclofop-methyl	1976		
		Poast	sethoxydim	1983	Laser(gf) <sup>4</sup>	fenoxaprop-ethyl	1989		
		Venture	fluazifop-butyl	1984	Puma	fenoxaprop-ethyl	1989		
		Assure	quizalofop-ethyl	1991	Triumph plus	fenoxaprop-ethyl	1990		
		Fusion	fenoxaprop-ethyl/	1992	Achieve/Affirm	tralkoxydim	1992		
			fluazifop-butyl		Prevail	tralkoxydim	1993		
		Select	clethodim	1992	Horizon	clodinafop-propargyl	1995		
		2	POST			Assert(wo)	imazamethabenz	1989	
		3	PRE	Treflan	trifluralin <sup>5</sup>	1970	Treflan	trifluralin	1970
				Edge	ethalfluralin	1988			
4	POST			Accord(gf)	quinclorac	1997			
7	POST			Stampede(gf)	propanil	1977			
8	PRE	Avadex( wo)	triallate	1961	Avadex(wo)	triallate	1961		
	POST			Avenge(wo)	difenzoquat	1974			
3/8	PRE	Fortress	triallate/trifluralin	1986	Fortress	triallate/trifluralin	1986		
25	POST			Mataven( wo)	flamprop-methyl	1978			
<u>Herbicide-resistant canola:</u>									
2	POST	Pursuit	imazethapyr	1996					
		Odyssey	imazethapyr/ imazamox	1997					
9	POST	Roundup	glyphosate	1996					
10	POST	Liberty	glufosinate	1996					
			ammonium						

<sup>1</sup>This table lists all grass herbicides registered for other annual crops as well, except Champion Plus (fenoxaprop-ethyl) registered for use on barley.

\*POST: postemergence; PRE: preemergence application.

<sup>3</sup>Products may contain additional ingredients with activity on broadleaf weeds.

<sup>4</sup>Gf: green foxtail; wo: wild oat.

<sup>5</sup>Other trifluralin products subsequently registered include Advance, Bonanza, Heritage and Rival.

and -4 herbicides. Clearly, this type of resistance can greatly restrict herbicide options.

Group 1-R wild oat and Group 3-R green foxtail have constituted the majority of reported cases. Group 3-R green foxtail develops to noticeable levels after 8-12 herbicide treatments (Morrison et al. 1989; Heap et al. 1993), whereas Group 1 -R green foxtail and wild oat typically develop after 5-10 applications (Bourgeois and Morrison 1997). Group 3-R green foxtail is estimated to occur in one of every four fields in SW Manitoba (Goodwin 1994). Group 1-R wild oat is estimated to occur in one of every five fields in Manitoba, where Group-1 herbicides were applied at a frequency of 50% or greater (Morrison et al. 1995). In 1993, one-half of cropped fields in Manitoba received a Group- 1 application.

To ascertain the extent of herbicide resistance in grass weeds in Saskatchewan, a survey was conducted in 1996 to determine the nature, distribution and abundance of R wild oat and green foxtail across four ecoregions, defined by climate, natural vegetation and soils.

## Survey of Resistant Wild Oat and Green Foxtail Across Saskatchewan Ecoregions

### Methods

Information from the 1995 Saskatchewan weed survey (Thomas et al. 1996) was used to identify fields at high risk for R wild oat or green foxtail, based on: 1) 250% frequency of herbicide-group use from 1990 to 1995; 2) high weed density (295th percentile) following grass-herbicide application; and 3) producer's suspicion of resistance. Herbicide-use histories indicated that 15% of fields were at high risk for Group- 1, 0.4% for Group-2 (imidazolinones), 7% for Group-3, and 3% for Group-S resistance.

The 64-ha (quarter-section) fields were surveyed in late summer, prior to crop harvest. Of the fields surveyed, 50% were cropped to wheat, 19% to barley, 11% to canola, 8% to oats, 6% to pulses, 5% to flax and 1% to rye or specialty crops. Fields were surveyed using the inverted W-pattern (Thomas et al. 1996). Wild oat or green foxtail patches visible from the transect were sampled separately (Heap 1994). Wild oat was tested for Group-1, -2, -3 and -8 resistance, and green foxtail for Group-1 and -3 resistance.

### Results and Discussion

Group-1 resistance in wild oat. Results from the resistance questionnaire indicated a high frequency of use of Group- 1 herbicides in 1996 (Table 3), particularly in the Parkland region (Aspen Parkland and Boreal Transition ecoregions). This level of use confirms the dominance of Group-1 products in the grass-herbicide market, and indicates that many producers are not following the '1 -in-3' recommendation, whereby herbicides from a group should not be used in a field more than once every 3 years (i.e., 33% frequency threshold). Of the 203 fields surveyed, one-half had Group 1-R wild oat (Table 4). This compares with 67% of fields with Group 1-R wild oat in a high-risk township in Manitoba (Bourgeois 1997). Only 5% of producers had suspected Group 1-R wild oat. Sixty-eight percent of fields with R wild oat were located in the Parkland region, reflecting past and present Group 1-herbicide use in predominantly continuous cropping systems. Resistance was confirmed in 71% of fields classified as high risk for resistance, based on herbicide-use history. Based on the percentage of fields in the 1995 survey at high risk for Group- 1 resistance (15%) and the proportion of those with R wild oat (0.71), *one in nine* fields in Saskatchewan is estimated to have Group 1 -R wild oat. In the Parkland region, where 21% of fields are at high risk for Group- 1 resistance and 76% of those have resistance, *one in six* fields is estimated to have R wild oat.

Group-1 resistance in green foxtail. Of the 107 fields surveyed for green foxtail, 18% had Group-1 resistance (Table 5). Sixty-eight percent of fields with R green foxtail were located in

Table 3. Frequency of Group 1-herbicide use in Saskatchewan in 1996

Ecoregion (corresponding soil zone)	Group 1 -herbicide use
	(% of fields)
Mixed Grassland (Brown soil zone)	38
Moist Mixed Grassland (Dark Brown soil zone)	55
Aspen Parkland (Black soil zone)	61
Boreal Transition (Gray soil zone)	64
<i>Average</i>	<i>56</i>

Table 4. Group 1-resistant wild oat, according to ecoregion

Ecoregion	Fields surveyed	Fields with R wild oat	
		(no.)	(%)
Mixed Grassland	31	15	48
Moist Mixed Grassland	49	18	37
Aspen Parkland	79	38	48
Boreal Transition	44	32	73
<i>Total</i>	<i>203</i>	<i>103</i>	<i>51</i>

the Aspen Parkland ecoregion, reflecting the relatively large number of high-risk fields (based on herbicide-use history and producer's suspicion) in this ecoregion. Group 1-R green foxtail is estimated to occur in one *in twenty* fields in Saskatchewan. In the Aspen Parkland ecoregion, where 21% of fields are at high risk for Group-1 resistance and 43% of those have R green foxtail, one *in eleven* fields is estimated to have R green foxtail. A total of 10 fields had both Group I-R wild oat and green foxtail; 70% of these were located in the Aspen Parkland ecoregion.

Group-2 resistance in wild oat. Group 1-R wild oat populations were tested for Group-2 (imazamethabenz) resistance. Eighteen percent of fields had Group 2-R wild oat, even though imazamethabenz had been applied infrequently in these fields. Frequency of use of Group-2 grass herbicides averaged 5% of fields across ecoregions. Seventy-eight percent of these multiple-R wild oat populations were located in the Parkland region (Table 6). Based on the frequency of occurrence of Group 1 -R wild oat and the proportion of fields with Group-2 resistance (0.18), one *in 50* fields in Saskatchewan is estimated to have multiple-R wild oat. (one *in thirty* fields in the Parkland region). Based on reported cases of multiple-R wild oat in Manitoba, these populations likely are resistant to flumetypic-methyl (Group 25) as well. Remaining grass-herbicide options for producers are Group-3 and -8 products, and Group-9 and -10 products registered for use on herbicide-resistant canolas (Table 2).

Group-3 resistance in wild oat. Forty-two of the fields surveyed for wild oat were at high risk for Group-3 resistance based on herbicide-use history, whereas 20 fields were suspected by the producer of Group 3-R wild oat. However, wild oat from all of these fields were

Table 5. Group 1-resistant green foxtail, according to ecoregion

Ecoregion	Fields surveyed	Fields with R green foxtail	
		(no.)	(%)
Mixed Grassland	15	2	13
Moist Mixed Grassland	37	4	11
Aspen Parkland	44	13	30
Boreal Transition	11	0	0
<i>Total</i>	<i>107</i>	<i>19</i>	<i>18</i>

Table 6. Multiple-resistant (Groups 1 and 2) wild oat, according to ecoregion

Ecoregion	GR-1+2 R	GR-1 R	GR 1+2/GR1
	(no.)	(no.)	(%)
Mixed Grassland	3	15	20
Moist Mixed Grassland	1	18	6
Aspen Parkland	8	38	21
Boreal Transition	6	32	19
<i>Total</i>	<i>18</i>	<i>103</i>	<i>18</i>

susceptible. There is no apparent reason for lack of resistance in wild oat to Group-3 herbicides. Perhaps the frequency of natural gene mutation in populations, conferring resistance to dinitroanilines, is exceedingly rare. Many producers mistakenly concluded resistance as the cause of poor wild oat control.

Group-3 resistance in green foxtail. Twelve of the fields (11%) had Group 3-R green foxtail (Table 7). Of these fields, 67% were located in the Aspen Parkland ecoregion, similar to Group 1 -R green foxtail. One field in the Moist Mixed Grassland ecoregion had multiple-R green foxtail (resistance to both Group-1 and -3 herbicides). Overall, 30 fields (28%) had Group 1- or 3-R green foxtail. Based on the percentage of fields surveyed in 1995 that were classified as high risk for Group-3 resistance and the number of fields with verified resistance, Group 3-R green foxtail is estimated to be present in less than 5% of fields where annual crops are grown. This incidence may be conservative, however, if good control by postemergence herbicides, such as those in Group 1, precluded seed collection. Frequency of use of Group-3 herbicides averaged 19% of fields across ecoregions.

Group-8 resistance in wild oat. Only one field, in the Moist Mixed Grassland ecoregion, had Group 8-R wild oat. Frequency of use of Group-8 herbicides averaged 6% of fields across ecoregions.

### Management of Resistance

Questionnaire data from this survey and the 1995 general weed survey were subject to multiway frequency analysis to examine the relationship between wild oat resistance and Group 1 -herbicide use. As expected, risk of wild oat resistance to Group- 1 herbicides was

Table 7. Group 3-resistant green foxtail, according to ecoregion.

Ecoregion	Fields sampled	Fields with R green foxtail	
	(no.)	(no.)	(%)
Mixed Grassland	15	0	0
Moist Mixed Grassland	37	2	5
Aspen Parkland	44	8	18
Boreal Transition	11	2	18
<i>Total</i>	<i>107</i>	<i>12</i>	<i>11</i>

related to frequency of Group 1 -herbicide use. However, although risk of Group- 1 resistance in wild oat was related to frequency of APP use, risk of Group-1 resistance was *not* related to frequency of CHD use. This may suggest that risk of Group-1 resistance is lower for one or more CHD than APP herbicides. Risk of wild oat resistance to APP was not related to rate of application, whereas risk of wild oat resistance to CHD was higher in fields where lower than recommended rates had been applied.

Results of this survey indicate that producers need to be more proactive in preventing, delaying or managing R weeds, by practicing herbicide-group rotation and integrated weed management. Results from survey questionnaires indicated that producers who reported only partial attention to sanitation, such as using weed-free seed, cleaning equipment between fields, covering transported seed or screenings, and spraying or mowing the edges of fields, were more likely to have R weeds than those who paid more careful attention. If R weeds are suspected, avoid spreading crop seed, weed seed, or crop residues from the affected area. Note the location of R weed patches and monitor their spread. If possible, prevent weed seed production by herbicides, tillage or cutting, before or at flowering. Managing R weeds will be more effective and successful if detected early. Therefore, routine field scouting to monitor the occurrence of R-weed patches is strongly recommended.

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