CARRYOVER EFFECTS OF RESIDUAL HERBICIDES AT THREE SITES IN NE SASKATCHEWAN

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The residual effects of three rates of picloram, chlorsulfuron, metsulfuron, metribuzin, and cyanazine, applied to a Wierdale loam (Meath Park), Melfort silty clay loam and Etomami clay (Somme) in 1985, were investigated on eight rotational crops. Picloram applied to cereals at the recommended rate of 0.024 kg/ha continued to suppress yields of lentils and field peas 2 years after application. Alfalfa, red clover and sweetclover were not affected, whereas canola yield increased due to the residual weed control provided by the herbicide. Chlorsulfuron residues adversely affected lentils, canola, red clover and sweetclover even at the lowest rate of 0.01 kg/ha but peas were not affected. Metsulfuron residues from the 0.006 kg/ha rate injured lentils, red clover and sweetclover. The recommended rates of metribuzin (0.41 kg/ha) and cyanazine (1.44 kg/ha) for TT-canola did not have any carryover effects, whereas the 2X rates injured lentils, peas and Tobin canola 2 years after application. Crested wheatgrass and smooth bromegrass were not affected by any of the herbicides tested even 1 year after application. In general, the risk of injury to rotational crops was greatest at Meath Park (pH = 7.8, o.m. = 5.6%) and least at Melfort (pH = 6.2, o.m. = 12%).

INTRODUCTION

In view of the increasing emphasis on crop diversification in northeast Saskatchewan, producers are often concerned about the potential injury of residual herbicides, used in cereals or triazine-tolerant canola, to forage and pulse crops grown in rotation. The sulfonylurea herbicides, chlorsulfuron and metsulfuron, which are widely used in cereal crops may persist for 1-3 years depending on soil and climatic factors and sensitivity of the rotational crops selected (2, 4, 6). Picloram, the residual constituent of Tordon 202C, often used for control of annual broadleaf weeds and suppression of Canada thistle and perennial sow-thistle in wheat and barley, may persist for up to 5 years (3, 6). Cyanazine, used in cereals and triazine-tolerant canola, and metribuzin, used in cereals, triazine- tolerant canola and some pulse crops, normally dissipate to undetectable levels by sensitive rotational crops within a year (6, 7). Although a wealth of information is now available on soil and climatic factors affecting the persistence of these herbicides (1, 3, 7), data on carryover effects on forage and pulse crops of importance to northeast Saskatchewan under local conditions are inadequate to provide guidelines to producers.

In response to increasing inquiries from area producers about the carryover effects of sulfonylurea herbicides, picloram and triazines on non-triazine-tolerant canola, pulses, and forage crops, experiments were established on black and grey wooded soils offering a range of soil types, organic matter and pH (Table 1).

MATERIALS AND METHODS

Randomized block design experiments with 2 x 10 m plots and 4 replicates were established at Melfort, Somme and Meath Park. A tractor-mounted driftless sprayer equipped with 2-m boom and 4 nozzles were used to spray the herbicides in 125 L/ha volume of water at 275 psi.

At Melfort Research Station, the herbicides were applied postemergence to wheat on 12 June 1985. The crop was harvested in the fall and the stubble was left standing until 2 May 1986 when the plots were lightly cultivated with a rotovator along the length of each plot (along the spray pattern) in order to minimize movement of the soil from plot to plot. Three rows each of Eston lentils, Victoria peas, Tobin canola, Beaver alfalfa, Altaswede red clover, Norgold sweetclover, Fairway crested wheatgrass, and Magna smooth bromegrass were seeded as parallel strips across the treated plots on 3 June 1986. Crop vigor ratings were recorded in July and samples for shoot (including pods) dry matter yield were harvested from 1 m^2 in September. In 1987, the rotational crops were seeded on 21 May after a light cultivation and samples for shoot dry matter were harvested in August.

At Somme, 20 km east of Porcupine Plain, the herbicides were applied to wheat on 26 June 1985. The plots were cultivated on 23 May 1986, as explained above, and rotational crops were seeded on 10 June 1986. Samples for shoot dry matter yield were obtained in September. In 1987, the experiment had to be terminated since the farmer cultivated the experimental site before rotational crops could be seeded.

The third experimental site was located near Meath Park. The herbicides were applied postemergence to wheat on 7 June 1985. The herbicide rates at this site were intended to be identical to those of other sites, however, due to an error in tractor speed, the amounts applied were 25% more than the desired rates. Therefore, the actual rates applied are listed in the tables. The following spring, the plots were cultivated on 21 May and rotational crops seeded on 4 June 1986. Samples for shoot dry matter yield were obtained in September. In 1987, the rotational crops were seeded 25 May.

RESULTS AND DISCUSSION

Carryover Effects 1-Year After Application.

1. **Melfort Silty Clay Loam.** Picloram applied at 0.048 kg/ha injured lentils, field peas and canola and reduced shoot dry matter yield of lentils to 36% of the untreated check (Table 2). Dry matter yields obtained higher than those of the respective check for each crop were due to residual weed

control and hence reduced weed competition. The highest rate of chlorsulfuron (0.04 kg/ha) injured lentils but did not affect its shoot dry matter yield. The same rate, however, reduced vigor and dry matter yield of sweetclover. Compared to all other crops, canola benefited from residual weed control the most since it yielded 259% of check even at the highest rate of chlorsulfuron. The lowest rate of metsulfuron was safe on all crops. The intermediate rate injured sweetclover and reduced its dry matter yield to 57% of the check. The highest rate of 0.024 kg/ha damaged the forage legumes but only sweetclover suffered a significant yield reduction. Once again, canola benefited the most from the residual weed control provided by all rates of metsulfuron since its shoot dry matter yield was three times that of the check even at the highest rate tested. None of the rotational crops were affected in plots where metribuzin was tested. A slight reduction observed in dry matter yield of lentils at 0.21 kg/ha was not due to metribuzin residues but due to weed competition since no residual weed control was observed where the herbicide was tested at the lowest rate. Cyanazine was also safe on all rotational crops.

Since crested wheatgrass and smooth bromegrass were not adversely affected by residues of any of the herbicides tested the preceding year, crop vigor and dry matter yield data obtained for these forage grasses will not be reported. In many instances where adequate residual weed control was evident at the intermediate or the highest rate of the herbicides, forage dry matter yields actually increased 2-3 times that of the untreated check.

2. **Etomami Clay.** Picloram tested at the lowest rate reduced dry matter yield of lentils, peas, and the forage legumes (Table 3). Crop vigor reductions observed at 0.024 and 0.048 kg/ha rates were significant for lentils, peas and red clover. Dry matter yields of lentils and peas were reduced to 23 and 18% of the check, respectively, at the highest rate. The lowest rate of chlorsulfuron damaged lentils, red clover and sweetclover. With the exception of the forage grasses, all other rotational crops were damaged at the 0.02 and 0.04 kg/ha rates of chlorsulfuron. The forage legumes were virtually killed at the highest rate. The lowest rate of metsulfuron damaged lentils and the forage legumes. The intermediate rate killed red clover and severely injured lentils, canola, alfalfa and sweetclover. The highest rate killed both red clover and sweetclover and severely injured the other crops. Canola dry matter yields were reduced to 67, 22 and 11% of the check when seeded in plots treated with 0.01, 0.02 and 0.04 kg/ha chlorsulfuron, respectively. Metribuzin tested at 0.21 and 0.42 kg/ha the preceding year did not have any adverse effect on any of the rotational crops. The highest rate of 0.84 kg/ha reduced vigor and dry matter yield of canola and red clover. Cyanazine did not have any adverse effects on any of the rotational crops when tested at 0.72 and 1.44 kg/ha. A slight reduction in dry matter yield of sweetclover was observed at the highest rate of 2.88 kg/ha.

3. **Wierdale Loam.** Field peas sustained severe injury even at 0.015 kg/ha of picloram. Both peas and lentils were killed at the highest rate of 0.06 kg/ha (Table 4). The poor lentil vigor observed at the lowest rate resulted from herbicide injury and weed competition since no residual weed control was evident at that rate. The highest rate of picloram reduced dry matter yields of canola, alfalfa and red clover. Chlorsulfuron residues from

the 0.012 kg/ha rate severely injured canola and alfalfa and virtually killed red clover and sweetclover. At the 0.025 and 0.05 kg/ha rates, with the exception of peas and forage grasses, all other crops were killed. Metsulfuron residues from the 0.0075 kg/ha rate severely damaged alfalfa and killed red clover and sweetclover. With the exception of peas and forage grasses, all other rotational crops were killed at 0.015 and 0.03 kg/ha rates of metsulfuron. The lowest rate of metribuzin did not have any adverse effect on any of the rotational crops. Dry matter yield reductions observed for lentils, peas, canola and sweetclover were not due to herbicide residues but caused by weed competition. Data recorded for the 0.52 and 1.05 kg/ha rate of metribuzin are not consistent with the extent of injury expected with doubling of the rate. Crop vigor and yield reductions were greater at the middle rate compared to the high rate for lentils, peas, canola and alfalfa. Crop vigor and dry matter yield reductions observed at the lowest rate of cyanazine were not caused by herbicide residues but by severe weed competition. The middle rate reduced dry matter yields of canola and red clover. The 3.6 kg/ha rate reduced dry matter yields of lentils, peas, and sweetclover.

Carryover Effects 2-Years After Application.

1. **Melfort Silty Clay Loam.** Lentils were severely injured by picloram residues from the 0.024 kg/ha rate and killed at the 0.048 kg/ha rate as indicated by shoot dry matter yield data obtained in 1987 (Table 5). The significant yield reduction observed on peas at the lowest rate of picloram was attributed to weed competitions, but that at the highest rate was caused by herbicide residues. Red clover also sustained some yield reductions where picloram had been tested in 1985. Canola, alfalfa, sweetclover and the forage grasses, however, were not affected. The forage legumes suffered significant yields reductions where chlorsulfuron had been tested at 0.01 kg/ha. At the intermediate rate, lentils, canola, alfalfa, red clover and sweetclover were severely injured. Residues from the higher rate of chlorsulfuron severely injured lentils and canola and killed the forage legumes. The lowest rate of metsulfuron reduced red clover and sweetclover dry matter yields but increased canola and alfalfa yields due to residual weed control. The middle rate killed red clover and reduced canola, alfalfa and sweetclover yields significantly. At the 0.024 kg/ha rate of metsulfuron, with the exception of peas and forage grasses, all other rotational crops suffered significant yield reductions. Only peas was adversely affected where metribuzin had been tested at 0.84 kg/ha rate. None of the rotational crops were affected where cyanazine had been applied 2-years ago.

2. **Wierdale Loam.** The lowest rate of picloram reduced dry matter yield of red clover (Table 6). The significant reduction in seed yield of field peas was attributed to weed competition. The 0.030 kg/ha rate reduced seed yield of peas and forage dry matter yields of red clover and sweetclover. At the highest rate, both shoot dry matter and seed yield of lentils, as well as seed yield of peas were reduced. The forage legumes also suffered significant yield reductions. As the rate of chlorsulfuron increased from 0.012 to 0.05 kg/ha, the shoot dry matter yield of lentils declined from 175 to 93% of the check, while the seed yield declined from 62 to 11% of the check. Field peas were not affected but canola seed yields were significantly reduced where chlorsulfuron had been tested at 0.025 and 0.05 kg/ha. The lowest rate of

metsulfuron did not have any adverse effects on rotational crops. A significant yield reduction observed on red clover was attributed to weed competition. The middle rate reduced seed yield of canola, whereas both canola and lentils suffered seed yield reductions at the highest rate of metsulfuron. The highest rate of metribuzin reduced shoot dry matter and seed yield of lentils and peas, respectively. The significant reduction in seed yield of canola at the lowest rate of cyanazine was attributed to weed competition. At the 1.8 and 3.6 kg/ha rates, seed yield of peas and dry matter yields of canola, red clover and sweetclover were reduced.

Herbicide Persistence Relative to Soil Characteristics.

Although persistence of the residual herbicides applied to Wierdale loam near Meath Park is not strictly comparable to those of the other two sites because the rates actually tested at Meath Park were 25% higher, some general comments can be made about the relative persistence of the five herbicides at the three sites. Without exception, carryover effects for each of the herbicides tested were least at Melfort and greatest at Meath Park. Since soil pH and organic matter have been well known to influence adsorption, and hence dissipation and bioavailability of sulfonylureas (1, 4), triazines (7) and picloram (3), it is expected that the risk of injury to sensitive rotational crops should increase as soil pH increases and organic matter decreases. Soil pH increased in the order Melfort silty clay loam (6.2) < Etomami clay (7.0) < Wierdale loam (7.8). Organic matter increased in the order Etomami clay (4.0%) < Wierdale loam (5.6%) < Melfort silty clay loam (12.0%). Exact measurements of mean soil temperature and precipitation are not available for Somme and Meath Park to establish a relationship between relative persistence and environmental factors.

At Melfort, chlorsulfuron appeared to be the most persistent herbicide, followed by metsulfuron. Field peas offered the only choice for a rotational crop 2-years after application of chlorsulfuron at 0.02 kg/ha. At Meath Park, picloram appeared to pose the greatest risk to rotational crops. Only canola was safe when seeded 2-years after application of picloram to cereals at 0.03 kg/ha.

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Table 1. Characteristics of soils at the three experimental sites in northeast Saskatchewan

	Melfort	Somme	Meath Park
Location	30-44-18 W2	13-42-8 W2	11-51-24 W2
Soil Zone	Black	Grey	Grey/Black
Association	Melfort	Etomami	Wierdale
Texture	Silty clay loam	Clay	Loam
Organic Matter	12.0%	4.0%	5.6%
pH	6.2	7.0	7.8

Table 2. Crop vigor ratings and shoot dry matter yield (% of check) of rotational crops seeded into Melfort silty clay loam, 1 year after application of residual herbicides to wheat

Treatment	Rate kg/ha	Lentils		Peas		Canola		Alfalfa		R. Clover		S. Clover	
		CV	DMY	CV	DMY	CV	DMY	CV	DMY	CV	DMY	CV	DMY
Picloram	0.012	7.0	77	7.5	116	7.6	264	8.5	184	8.5	211	9.0	188
Picloram	0.024	7.2	70	6.8	103	8.1	172	8.0	123	7.6	163	8.2	129
Picloram	0.048	5.9*	36	5.2*	95	5.5*	339	8.2	158	7.2	195	8.0	160
Chlorsulfuron	0.01	7.9	118	9.0	131	7.2	404	7.8	180	7.8	171	7.8	143
Chlorsulfuron	0.02	6.4	79	8.2	109	8.2	462	8.5	168	8.0	221	7.1	116
Chlorsulfuron	0.04	4.8*	104	8.0	106	7.0	259	7.2	120	5.2	81	3.0*	47
Metsulfuron	0.006	7.5	111	8.5	102	7.6	353	8.2	130	8.0	255	7.8	121
Metsulfuron	0.012	7.0	99	8.2	139	7.2	357	8.1	139	5.8	133	3.8*	57
Metsulfuron	0.024	6.0	70	8.5	110	6.8	310	5.8*	109	4.8*	142	3.5*	42
Metribuzin	0.21	7.8	73	8.8	94	6.2	93	7.5	126	8.2	158	7.9	140
Metribuzin	0.42	7.0	90	8.8	88	6.4	264	8.2	135	8.2	135	8.2	146
Metribuzin	0.84	7.8	125	9.0	131	8.0	276	8.5	174	8.0	197	8.2	187
Cyanazine	0.72	8.8	146	9.0	104	6.9	226	8.8	138	8.8	170	8.8	156
Cyanazine	1.44	7.8	126	8.8	98	6.8	180	8.0	142	8.2	127	8.0	120
Cyanazine	2.88	8.1	144	9.0	95	7.2	154	8.8	176	8.5	165	8.0	162
Check	-	8.0	100	9.0	100	6.6	100	7.5	100	6.5	100	7.5	100
LSD (0.05)		2.1		0.7		2.3		1.9		2.2		2.7	

CV = Crop vigor ratings based on scale of 0-9, where 9 = no herbicide effect, 0 = plants killed.
DMY = Dry matter yield expressed as percent of check.
* = Significantly lower than check ($P \leq 0.05$).

Table 3. Crop vigor ratings and shoot dry matter yield (% of check) of rotational crops seeded into Etomami clay at Somme, 1 year after application of residual herbicides to wheat

Treatment	Rate kg/ha	Lentils		Peas		Canola		Alfalfa		R. Clover		S. Clover	
		CV	DMY	CV	DMY	CV	DMY	CV	DMY	CV	DMY	CV	DMY
Picloram	0.012	6.8	61	7.0	55	6.2	110	6.0	49	5.2	54	7.8	49
Picloram	0.024	3.9*	102	4.6*	79	6.5	57	4.5	91	3.0*	112	5.6	105
Picloram	0.048	3.9*	23	2.6*	18	5.9	74	4.2	73	3.5*	108	6.2	127
Chlorsulfuron	0.01	5.4*	80	6.8	84	5.6	70	4.5	114	1.8*	45	3.2*	35
Chlorsulfuron	0.02	4.5*	55	5.2*	65	4.5*	38	3.0*	93	1.5*	52	0.5*	8
Chlorsulfuron	0.04	1.6*	11	6.0	82	2.5*	15	0.5*	61	0.0*	2	0.0*	4
Metsulfuron	0.006	5.6*	90	6.6	99	6.6	67	2.8*	70	1.2*	22	3.8*	25
Metsulfuron	0.012	4.5*	60	6.4	71	3.0*	22	2.2*	84	0.0*	6	1.0*	12
Metsulfuron	0.024	3.8*	77	5.8*	77	3.2*	11	1.5*	35	0.0*	6	1.0*	12
Metribuzin	0.21	7.1	136	7.4	102	6.9	62	6.4	120	6.5	128	7.0	81
Metribuzin	0.42	6.4	127	6.8	107	6.9	89	6.8	123	4.5	137	7.2	142
Metribuzin	0.84	6.0	75	7.1	84	4.8*	46	6.4	135	1.5*	19	6.8	78
Cyanazine	0.72	6.9	114	6.8	92	7.5	85	6.8	109	4.8	138	6.8	72
Cyanazine	1.44	8.0	156	7.5	105	7.8	130	6.9	98	6.2	158	6.9	92
Cyanazine	2.88	6.0	95	7.1	95	7.1	92	6.8	95	5.2	93	7.2	77
Check	-	7.4	100	7.6	100	8.0	100	6.4	100	5.8	100	7.2	100
LSD (0.05)		1.6		1.6		2.7		2.8		2.7		2.4	

CV = Crop vigor ratings based on scale of 0-9, where 9 = no herbicide effect, 0 = plants killed.
DMY = Dry matter yield expressed as percent of check.
* = Significantly lower than check ($P \leq 0.05$).

Table 4. Crop vigor ratings and shoot dry matter yield (% of check) of rotational crops seeded into Wierdale loam near Meath Park, 1 year after application of residual herbicides to wheat

Treatment	Rate kg/ha	Lentils		Peas		Canola		Alfalfa		R. Clover		S. Clover	
		CV	DMY	CV	DMY	CV	DMY	CV	DMY	CV	DMY	CV	DMY
Picloram	0.015	3.2*	4	3.2*	50	5.8	44	6.5	207	6.1	83	8.5	166
Picloram	0.030	4.2	12	2.2*	30	7.2	99	5.8	177	3.8	35	8.0	126
Picloram	0.060	0.5*	3	0.2*	11	6.0	61	4.8	57	4.5	34	8.0	151
Chlorsulfuron	0.012	4.0	31	4.5	66	2.0*	9	1.2*	8	0.5*	1	0.2*	2
Chlorsulfuron	0.025	1.2*	1	5.0	61	0.0*	0	0.0*	0	0.0*	0	0.0*	0
Chlorsulfuron	0.050	0.5*	1	4.0	45	0.0*	0	0.0*	0	0.0*	0	0.0*	0
Metsulfuron	0.008	5.8	44	8.8	147	5.8	18	1.5*	27	0.0*	3	0.0*	3
Metsulfuron	0.015	2.2*	7	5.0	85	0.0*	0	0.1*	0	0.0*	0	0.0*	0
Metsulfuron	0.030	1.0*	12	3.8	75	0.0*	0	0.0*	0	0.0*	0	0.0*	0
Metribuzin	0.26	6.5	71	6.8	73	5.5	59	3.2	120	3.2	109	4.6	69
Metribuzin	0.52	6.2	16	5.8	58	3.2*	35	4.5	190	4.4	73	6.2	83
Metribuzin	1.05	8.0	98	8.0	126	5.2	45	6.2	219	4.2	31	7.0	66
Cyanazine	0.90	3.2*	45	3.5*	62	5.5	31	4.2	48	2.0*	22	5.0	44
Cyanazine	1.80	7.5	85	7.0	80	5.8	39	4.8	130	4.2	43	7.4	112
Cyanazine	3.60	5.0	55	5.5	71	6.5	107	4.2	199	5.0	117	5.2	64
Check	-	5.8	100	6.2	100	5.8	100	5.5	100	4.8	100	6.5	100
LSD (0.05)		2.1		2.7		2.3		3.0		2.5		2.1	

CV = Crop vigor ratiangs based on scale of 0-9, where 9 = no herbicide effect, 0 = plants killed.
DMY = Dry matter yield expressed as percent of check.
* = Significantly lower than check ($P \leq 0.05$).

Table 5. Shoot dry matter yield (as % of check) of rotational crops seeded into Melfort silty clay loam in 1987, 2 years after application of residual herbicides to wheat

Treatment	Rate kg/ha	Lentils	Peas	Canola	Alfalfa	R. Clover	S. Clover
Picloram	0.012	76	36*	90	114	64	100
Picloram	0.024	26*	56	155	91	64	70
Picloram	0.048	1*	28*	97	91	70	110
Chlorsulfuron	0.01	62	67	87	41*	44*	24*
Chlorsulfuron	0.02	14*	116	41*	9*	16*	16*
Chlorsulfuron	0.04	11*	88	10*	0*	0*	0*
Metsulfuron	0.006	104	128	171	164	50*	36*
Metsulfuron	0.012	114	137	48*	54*	0*	16*
Metsulfuron	0.024	29*	119	17*	27*	10*	4*
Metribuzin	0.21	129	88	136	241	104	100
Metribuzin	0.42	178	59	94	132	64	70
Metribuzin	0.84	83	50*	71	127	100	90
Cyanazine	0.72	63	92	62	91	64	90
Cyanazine	1.44	112	68	94	132	80	76
Cyanazine	2.88	77	64	83	109	76	64
Check	-	100	100	100	100	100	100

*Yield reduction significant compared to check ($P \leq 0.05$).

Table 6. Shoot dry matter and seed yield (as % of check) of rotational crops seeded into Wierdale loam near Meath Park in 1987, 2 years after application of residual herbicides to wheat

Treatment	Rate kg/ha	Lentils		Peas		Canola		Alfalfa	R. Clover	S. Clove
		DMY	Seed	DMY	Seed	DMY	Seed	DMY	DMY	DMY
Picloram	0.015	120	103	92	36*	140	91	98	22*	71
Picloram	0.030	73	77	74	56	132	155	67	22*	38*
Picloram	0.069	64*	1*	83	28*	75	190	49*	30*	44*
Chlorsulfuron	0.012	175	62	114	66	120	87	147	244	244
Chlorsulfuron	0.025	124	13*	124	116	130	10*	236	183	221
Chlorsulfuron	0.050	93	11*	115	88	106	40*	74	100	162
Metsulfuron	0.008	86	104	99	128	74	172	104	56*	71
Metsulfuron	0.015	143	115	121	136	147	48*	151	213	200
Metsulfuron	0.030	98	30*	109	119	143	17*	149	343	74
Metribuzin	0.26	105	129	90	88	92	221	69	100	68
Metribuzin	0.52	141	179	79	79	119	189	133	113	109
Metribuzin	1.05	53*	83	119	50*	103	70	87	113	126
Cyanazine	0.90	78	64	100	91	84	48*	58	100	85
Cyanazine	1.90	88	113	93	67	52*	95	64	43*	56*
Cyanazine	3.60	98	78	101	65	66*	83	54*	30*	18*
Check	-	100	100	100	100	100	100	100	100	100

*Yield reduction significant compared to check ($P \leq 0.05$).