"Lessons to be drawn from a herbicide trial programme in regard to Annual Ryegrass *Lolium rigidum* resistance".

J.M. Swain[1], W. Roy[2], G.S. Gill[3] and P.J. O'Connell[1]

1. Ciba-Geigy Australia Ltd., Pendle Hill, NSW
2. Agricultural Consulting & Research Services Pty. Ltd., York, Western Australia
3. Western Australia Dept. of Agriculture, Perth, Western Australia

Abstract

The paper outlines the effect of crop rotations and herbicide use patterns on the development of resistance and gives the results obtained with different herbicide groups against biotypes whose resistance status was determined in a glasshouse bioassay.

Introduction

It was reported in 1982[2] that biotypes of Annual Ryegrass, *Lolium rigidum* Gaud. resistant to diclofop-methyl had been detected in South Australia. Subsequent studies[1] showed that these biotypes were also resistant to other unrelated herbicides including the ALS (Acetolactate synthase) inhibitors of which the sulfonylureas are members.

It was postulated that this occurred because of selection resulting from the regular use of diclofop-methyl and thus the potential seriousness of this problem to the Australian Agriculture industry became obvious.

The sulfonylurea herbicides which are active against Annual Ryegrass were introduced into Australia with the registration of chlorsulfuron in 1982 and in 1989 of triasulfuron. Because of their activity against both Annual Ryegrass and other important broadleaf weeds they became, particularly in Western Australia, an important part of the herbicide programme used by wheat farmers.

Neither the extent throughout the cereal areas of the presence of cross resistant biotypes nor its effect on the level of weed control obtained with the herbicides in question was known because all evaluations to determine whether the biotypes were resistant or not, had been determined using a glasshouse bioassay.

A series of four trials was initiated in 1990 with the objective of examining cross-resistance patterns and their effect on the performance of the sulfonylurea herbicides in controlling Annual Ryegrass.

Methodology

Field Trials

Four sites were selected in the Central Eastern wheatbelt region of Western Australia. Sulfonylurea herbicides had not previously been applied at any of these sites. In all cases they had been part of a wheat/lupin rotation for the previous 8-10 years, with regular use of diclofop-methyl, sethoxydim and simazine, the latter 2 being used during the lupin phase.

Two of the sites (Trials 1 and 2) had biotypes of Annual Ryegrass which had not been controlled by the previous commercial application of diclofop-methyl[5]. They were selected in order to determine whether these biotypes exhibited cross resistance to the sulfonylureas, and if so, what effect this had on herbicide performance. The other 2 sites (Trials 3 and 4) were selected initially to compare the performance of pre-plant incorporated applications of the sulfonylurea herbicides with the early post-emergent applications of diclofop-methyl.

In Trials 1 and 2, triasulfuron and chlorsulfuron were applied pre-plant incorporated by sowing, at the registered rates, plus one higher rate of triasulfuron with a sequential application of diclofop-methyl being applied post emergent, to one treatment each of triasulfuron and chlorsulfuron. These were compared with the registered rate of diclofop-methyl applied as an early post-emergent application.

In Trials 3 and 4 triasulfuron and chlorsulfuron were applied pre-plant incorporated by sowing, with and without post-emergence applications of Diuron and MCPA (Trial 3) and metsulfuron-methyl (Trial 4) at registered rates. Diclofop-methyl and bromoxynil + MCPA (Trials 3 and 4) and diclofop-methyl plus chlorsulfuron (Trial 4) were applied early post-emergent.

See Tables 1, 2, 3 and 4 for the treatments applied.

Evaluations including wheat yield and Annual Ryegrass biomass, plant numbers and panicles per square metre were taken.

At harvest time seed head samples, collected from selected treatments (see Table 5), were sent to the Western Australian Department of Agriculture to determine, using a bioassay, their resistance status to diclofop-methyl, triasulfuron, sethoxydim and simazine.

Glasshouse Bioassay

The bioassay was conducted using pots sown with both a susceptible biotype and the biotype under investigation.

Seeds (caryopses) of ryegrass populations were vernalized at 4°C for 7 days which was found to promote rapid and even germination of ryegrass. These vernalized seeds of ryegrass were planted in pots filled with a sandy loam soil. The pots were sealed at the bottom to prevent herbicides from leaching out of the root zone. The experiments were carried out in an air-conditioned glasshouse set to maintain day/night temperature at 22/17°C (± 2°C). The pots were watered regularly to maintain the soil near field capacity.

A small plot manual sprayer was used to spray the pots with herbicides. The sprayer delivered output equivalent to 200 L/ha at a pressure of 200 kPa. Triasulfuron and simazine were sprayed on to the moist soil surface on the day of planting. Preliminary tests showed that in small sealed pots incorporating herbicide in to the soil did not enhance its performance. A non-ionic wetting agent, BS 1000 at 0.25% (vol./vol.) was added to diclofop-methyl and Ulvapron(R) at 2 L/ha to sethoxydim. These post-emergence herbicides were sprayed at the Z12-13 stage of ryegrass.

All the herbicides were sprayed at two rates, the registered label rate and double the label rate. Therefore, triasulfuron was sprayed at 25 and 50 g a.i./ha, simazine at 750 and 1500 g a.i./ha, diclofop-methyl at 562.5 and 1125 g a.i./ha and sethoxydim at 50 and 100 g a.i./ha.

Experiments were terminated 3 weeks after the application of post-emergence herbicides (5 weeks after planting), the time when differences between the susceptible and resistant samples were absolutely clear cut. At this time, healthy ryegrass survivors were counted and cut at the ground level to determine their fresh weight.

Results and Discussion

In Trials 1 and 2 which were known diclofop-methyl resistant sites, the field results (Tables 1 and 2) and the bioassay (Table 5) confirmed that there was resistance to diclofop-methyl and cross resistance to the sulfonylureas. The use of the sulfonylureas at the registered rates still produced a significant yield increase when compared with the untreated and diclofop-methyl treatments. Of concern was the high number of Annual Ryegrass panicles per square metre remaining which will increase the seedbank reserves with resistant seeds.

In Trial 3 the results from the field (Table 3) indicated the presence of a biotype resistant to diclofop-methyl and cross resistant to the sulfonylureas. However, the results from the bioassay (Table 5) confirmed resistance to diclofop-methyl, but not to the sulfonylureas.

A yield increase in the order of 70% compared to both diclofop-methyl and untreated resulted from the use of the sulfonylureas. As with Trials 1 and 2 the number of Annual Ryegrass panicles remaining in the sulfonylurea treatments is of concern.

The consistency between treatments in regard to herbicide performance supports the presence of resistant biotypes.

In Trial 4, whilst the field results (Table 4) indicated the presence of biotypes resistant to both diclofop-methyl and the sulfonylureas this was not borne out by the bioassay results (Table 5).

As for Trial 3, the consistency between treatments in regard to herbicide performance supports the presence of resistant biotypes. However, the field data are for only one season and the possibility of interaction between the herbicide and environmental factors cannot be ruled out.

As before significant yield increases were obtained with all basic pre-emergent treatments except chlorsulfuron followed by metsulfuron-methyl. An adverse crop effect is considered to be the factor contributing to the reduced yield obtained with this treatment.

In none of the trials was there any indication of resistance to simazine despite reported field failures following its application over the past years when it was applied during the Lupin phase. Only in Trial 2 was cross resistance to sethoxydim confirmed.

Conclusions

The lessons to be drawn from this set of trials.

1. If sulfonylureas have not previously been used on a population known or suspected as being resistant to diclofop-methyl then it appears likely that cross resistance to them could be present.
2. Sulfonylureas can still be used when cross resistance is present to produce a commercially viable crop. Because of the high numbers of panicles remaining this would indicate that this practice should not be continued for more than 1 or 2 seasons and, in fact, should only be used when a pasture phase cannot be introduced into the rotation.
3. Selection by diclofop-methyl does not appear to produce cross resistance to simazine.
4. The bioassay did not agree with the field results from Trial 4 for both diclofop-methyl and triasulfuron and for triasulfuron in Trial 3. The reasons for this require further study as this technique is a useful aid to determining programs to manage resistance and it is essential that the technique reflects accurately what is happening in the field. To detect low levels of partial resistance, it may be necessary to screen ryegrass populations at lower herbicide rates in the glasshouse bioassay.
5. Results of a small scale survey conducted jointly by Ciba-Geigy Australia and the Western Australian Department of Agriculture[3,4] in 1990/91 suggest that cross resistance to the sulfonylureas is more widespread than perhaps previously thought and thus a survey to determine the precursors and extent of resistance is warranted.

References:

1. Heap I., and Knight R., 1986. The occurrence of herbicide cross resistance in a population of Lolium rigidum resistant to diclofop-methyl. Aust. J. Agric. Res. 37:149-150.

2. Heap J., and Knight R., 1982. A population of ryegrass tolerant to the herbicide diclofop-methyl. J. Aust. Inst. Ag. Sci. 48:56-153.

3. Gill G.S., 1991. Personal Communication.

4. O'Connell 1991. Personal Communication.

5. Roy W., 1990. Personal Communication.

Table 1 Trial 1 - To evaluate cross resistance to sulfonylurea herbicides of a Lolium rigidum population known to be resistant to the label rates of diclofop-methyl.

TR	PRODUCT NAME/CODE	GAC PER HA	DATE 27/7 Rye /sqm	15/8 RB 0-5	9/10 RP /sqm	15/11 WH t/ha
1	Triasulfuron	17.9	99	3.3	428	1.69 a
2	Triasulfuron	25	73	3.4	310	1.70 a
3	Triasulfuron	32.1	83	3.3	320	1.79 a
4	Triasulfuron fb diclofop-methyl	25 fb 563	84	3.3	383	1.64 ab
5	Chlorsulfuron	15	70	2.6	260	1.83 a
6	Chlorsulfuron fb diclofop-methyl	15 fb 563	58	2.4	278	1.88 a
7	Diclofop-methyl	563	116	4.1	413	1.38 bc
8	Untreated control	-	167	5.0	520	1.27 c
		Significance	0.1%	0.1%	5%	1%
		LSD 5%	31	0.8	162	0.28
		LSD 1%	43	1.0	na	0.38
		LSD 0.1%	58	1.4	na	na

Triasulfuron and Chlorsulfuron applied on 20.5.90 and incorporated by seeding.

Diclofop-methyl applied as an epe treatment on 22.6.90 when ryegrass was Z12-21 and wheat Z12-Z21.

Rye = Ryegrass plants per sqm
RB = Ryegrass biomass score
RP = Ryegrass panicles per sqm
WH = Wheat yield

Duncans Test Result provided at 5% level of significance

Table 2 Trial 2 - To evaluate cross resistance to sulfonylurea herbicides of a Lolium rigidum population known to be resistant to label rates of diclofop-methyl.

TR	PRODUCT NAME/CODE	GAC PER HA	DATE 30/7 Rye /sqm	11/10 RP /sqm	15/11 WH t/ha
1	Triasulfuron	17.9	49	469	1.98 abc
2	Triasulfuron	25	26	431	2.06 ab
3	Triasulfuron	32.1	19	331	2.16 a
4	Triasulfuron fb diclofop-methyl	25 fb 563	26	388	2.17 a
5	Chlorsulfuron	15	33	481	1.82 c
6	Chlorsulfuron fb diclofop-methyl	15 fb 563	21	444	1.95 bc
7	Diclofop-methyl	563	128	1188	1.37 d
8	Untreated control	-	143	1175	1.49 d
		Significance	0.1%	0.1%	0.1%
		LSD 5%	16	148	0.17
		LSD 1%	22	201	0.23
		LSD 0.1%	29	271	0.3

Triasulfuron and Chlorsulfuron applied on 23.5.90 and incorporated by seeding.

Diclofop-methyl applied as an epe treatment on 6.7.90 when ryegrass was Z11-12 and wheat Z13.

RP = Ryegrass panicles per sqm
WH = Wheat yield
Rye = Ryegrass plants per sqm

Duncans test results provided at 5% level of significance

Table 3 Trial 3 - To compare the performance of sulfonylureas applied as pre em treatments with that of diclofop-methyl applied epe in tank mixture with herbicides for broadleaved weed control.

TR	PRODUCT NAME/CODE	GAC PER HA	DATE	27/7 Rye /sqm	15/8 RB 0-5	9/10 RP /sqm	14/11 WH t/ha
1	Triasulfuron	21.4		91	3.8	869	0.91 a
2	Triasulfuron	25		82	3.4	838	0.97 a
3	Chlorsulfuron	11.3		76	2.4	675	0.97 a
4	Triasulfuron fb Diuron/MCPA	25/175/200		81	3.5	894	0.94 a
5	Chlorsulfuron fb Diuron/MCPA	11.3/175/200		73	2.6	813	0.95 a
6	Diclofop-methyl/ Bromoxynil/MCPA	375 + 200		134	4.8	1338	0.57 b
7	Diclofop-methyl/ Bromoxynil/MCPA	263 + 120		146	5.0	1263	0.53 b
8	Untreated control	-		158	4.9	1288	0.61 b
		Significance		0.1%	0.1%	1%	0.1%
		LSD 5%		28	0.5	317	0.16
		LSD 1%		38	0.6	432	0.22
		LSD 0.1%		51	0.9	na	0.33

Triasulfuron and Chlorsulfuron applied on 20.5.90 and incorporated by seeding.

Diclofop-methyl/bromoxynil/MCPA and diuron/MCPA applied as epe treatments on 22.6.90 when ryegrass was Z12-21 and wheat Z12-Z13.21.

RP = Ryegrass panicles per sqm

Wh = Wheat yield - t/ha

Rye = Surviving ryegrass plants per sqm

RB = Ryegrass biomass score

Duncans test results provided at 5% level of significance

Table 4 Trial 4 - To compare the performance of sulfonylureas applied as pre em treatments with that of diclofop-methyl applied epe in tank mixture with herbicides for broadleaved weed control.

TR	PRODUCT NAME/CODE	GAC PER HA	DATE	31/7 RB 0-5	23/8 RYE /sqm	17/10 RP /sqm	27/11 WH t/ha
1	Triasulfuron	21.4		3.1	61	469	1.72 a
2	Triasulfuron	25		2.4	58	350	1.81 a
3	Chlorsulfuron	11.3		2.5	52	306	1.80 a
4	Triasulfuron fb metsulfuron-methyl	25 fb 3		2.0	57	325	1.83 a
5	Chlorsulfuron fb metsulfuron-methyl	11.3 fb 3		1.8	39	275	1.69 ab
6	Diclofop-methyl/ Bromoxynil/MCPA	375 + 200/200		2.9	648	4568	1.70 a
7	Diclofop-methyl/ Chlorsulfuron	263 + 3.75		2.5	53	388	1.79 a
8	Untreated control	-		5.0	125	813	1.32 b
		Significance		0.1%	0.1%	0.1%	5%
		LSD 5%		0.9	26	167	0.31
		LSD 1%		1.2	35	227	na
		LSD 0.1%		1.7	48	307	na

Triasulfuron and Chlorsulfuron applied on 24.5.90 and incorporated by seeding.

Diclofop-methyl/bromoxynil/MCPA, diclofop-methyl/chlorsulfuron and metsulfuron-methyl applied as epe treatments on 27.6.90 when ryegrass was Z12-21 and wheat Z12-Z13.21.

RB = Ryegrass biomass score

Wh = Wheat yield - t/ha

Rye = Surviving ryegrass plants per sqm

RB = Ryegrass biomass score

Duncans test results provided at 5% level of significance

Table 5 Results of pot bioassay test.

TREATMENT	GAC/HA*	TRIASULFURON	DICLOFOP-METHYL	SETHOXYDIM	SIMAZINE
Trial 1					
Triasulfuron	25	PR (37.7)a	R (80.9)	S (0)	S (0)
Diclofop-methyl	375	PR (26.1)	R (62.5)	S (0)	S (0)
Untreated	-	PR (42.2)	R (78.5)	S (0)	S (0)
Trial 2					
Triasulfuron	25	PR (60.8)	R (64.6)	R (6.7)	S (0)
Diclofop-methyl	375	PR (23.4)	R (82.6)	R (15.5)	S (0)
Untreated	-	PR (24.9)	R (100.0)	R (47.6)	S (0)
Trial 3					
Triasulfuron	25	S (6.4)	R (100.0)	S (0)	S (0)
Diclofop-methyl/ Bromoxynil/MCPA	375 + 200/200	S =	R (100.0)	S (0)	S (0)
Untreated	-	S (2.4)	R (87.8)	S (0)	S (0)
Trial 4					
Triasulfuron	25	S (2.2)	S** (8.1)	S (0)	S (0)
Diclofop-methyl/ Bromoxynil/MCPA	375 + 200/200	S (3.2)	S** (10.0)	S (0)	S (0)
Untreated	-	S (5.1)	S** (6.7)	S (0)	S (0)

* = Field rates of herbicides used in 1990
R = Resistant
PR = Partially resistant
S = Susceptible

** Shoot growth inhibition ranged from 90-93% as compared to 100% for the susceptible population. Possibility of partial resistance to diclofop-methyl which may show up better at lower herbicide rates, needs to be investigated further.

a Figures in parentheses are the shoot fresh weights expressed as a percentage of the unsprayed controls.

= Low seed viability.

JMS1a/mz
13.02.92