HERBICIDE RESISTANT WEEDS FROM THE NORTH-EAST GRAIN REGION OF AUSTRALIA

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Summary Herbicide resistant weeds are increasing throughout the world. Recently, weeds resistant to sulfonylurea herbicides have been discovered in Australia and in the north-east grain region. In order to find populations of winter and summer weeds which are resistant to various herbicides a survey was commenced. Seed were collected and screened against the herbicide to which resistance was suspected and results were recorded. At some sites the winter weeds, *Fallopia convolvulus* (L.) A. Love, *Sisymbrium orientale* L. *Sisymbrium thellungii* O. Schultz and *Sonchus oleraceus* L. had individuals resistant to chlorsulfruon. The summer weed *Urochloa panicoides* Beauv. was shown to have individuals resistant to atrazine. However some populations of *U. panicoides* with no previous history of atrazine use had individuals with resistance to atrazine. This survey has shown that resistance of weeds to herbicides is widespread throughout the north-east grain region.

INTRODUCTION

Herbicide are being used more frequently for weed control in many countries. However, an adverse consequence of persistent use has been the emergence of weed populations resistant to herbicides (Jutsum and Graham 1995). Most cases have appeared in the northern hemisphere and involve resistance to the triazine herbicides. Some of the weeds resistant to atrazine include *Amaranthus* sp. and *Echinichloa crus-galli* (L.) Beauv., but there are no reports of resistance to triazine herbicides in Australia (Le Baron 1991). However, in recent times resistance of weeds to ALS-inhibitor herbicides has become evident in Australia. The weed, *Lolium rigidum* has most widespread resistance to ALS-inhibitor herbicides (Saari *et al*. 1994). Boutsalis and Powles (1995) reported a resistant biotype of Indian hedge mustard (*Sisymbrium orientale* L.) was located near North Star in northern New South Wales and a resistant biotype of common sowthistle (*Sonchus* oleraceus L.) was located near Goondiwindi in southern Queensland. Saari *et al.*(1994) reported that there was at least 13 weed species resistant to ALS-inhibitor herbicides.

The north-east grain region is a major producer of summer and winter crops. In wheat and barley crops chlorsulfuron has been mainly used to control parodoxa grass (*Phalaris paradoxa* L.) and broadleaf weeds. In sorghum (*Sorghum bicolor* (L.) Moench) crops atrazine has been used to control broadleaf weeds and some grasses.

In 1993, reports were made that some weeds that had easily been controlled in earlier years were becoming harder to control. Since little was known about the extent of herbicide resistance in this part of Australia, the present study was initiated.

The aim of the research was to determine the sites where weeds had evolved resistance and the types of weeds which have developed resistance. For the purposes of this paper our work on weeds tested against chlorsulfuron and atrazine is reported.

MATERIALS AND METHODS

Plant materials Seed from sites within a 100 km radius of Goondiwindi, Queensland were collected in October 1993 and 1995. One population of African turnip weed was collected from near Roma, Queensland. The majority of weeds were collected from sites where chlorsulfuron had been applied at rates of 10 to 15 g a.i. ha^{-1} for between 6 and 10 years. Other seed samples were collected from sites in the region which had never or only occasionally been treated with ALS-inhibiting herbicide, including chlorsulfuron. Each site was systematically traversed, seed taken from surviving plants to form the sample to be tested.

Seed from summer weed populations was collected in an identical way to that described above, from several sites within 100 km west, south and south-east of Toowoomba, Queensland in March, 1994 and 1995. At the majority of sites atrazine had been applied at rates of 1.8 kg a.i. ha^{-1} for between 2 and 15 years. Other seed samples were collected from sites in the region which had never or only occasionally been treated with triazine herbicides, including atrazine.

Whole plant screen A whole plant screening technique, using a single discriminating herbicide dose and an untreated control, was used for detection of herbicide resistance (Moss 1995). Where seed numbers allowed this was replicated three times.

Equivalent numbers of non dormant seed were sprinkled onto the soil surface and covered with an additional layer of soil (0.5 cm) to create a level seed bed. The soil was a sterilized light brown loam (pH = 5.7, <1% organic carbon) and was contained within plastic germination trays (34.7 × 28.5 × 5 cm). The seedbed was watered to field capacity and the plastic trays placed at random on a series of glasshouse benches during the winter season of 1994, 1995 and 1996 (about March–July for winter weeds) or summer season of 1994/95 and 1995/96 (about November–March for summer weeds).

Herbicide was applied immediately after planting (in the case of chlorsulfuron) or prior to planting (in the case of atrazine). Herbicide was delivered by a sprayer positioned 43 cm above soil surface delivering 110 L ha^{-1} (250 kPa) through flat-fan nozzles (Tee-jet 001).

Each population was tested against the appropriate herbicide; chlorsulfuron (Glean®) and atrazine (Gesaprim®). After herbicide application, the plastic trays were randomized on a glasshouse bench and rewatered to field capacity. After visible herbicide effects were no longer pronounced in the remaining plants (about 30 days later) the number of survivors were recorded. Then remaining plants were cut at ground level

Table 1. A comparison of populations of *Sisymbrium orientale*, survival (%) and dry weight reduction (%) as a result of application of 15 g a.i. ha^{-1} chlorsulfuron with an indication of history of herbicide use (years).

Population	Survival %	Dry weight reduction %	Herbicide use history (years)
A	0	0	2
B	0	0	6
C	0	0	10
D	6	<1	10
E	7	<1	5
F	9	22	7
G	49	24	3
H	57	81	10
I	63	101	6
J	72	78	9
K	112	48	5
L	128	115	6

Table 2. A comparison of populations of *Sisymbrium thellungii*, survival (%) and dry weight reduction (%) as a result of application of 15 g a.i. ha^{-1} chlorsulfuron with an indication of history of herbicide use (years).

Population	Survival %	Dry weight reduction %	Herbicide use history (years)
A	0	0	6
B	0	0	10
C	62	49	6
D	117	56	5

and dry weight obtained following treatment at 60°C for 48 h. Results are expressed as survival percentage (number of live seedlings in treated trays/number of live seedlings in untreated trays) and dry weight reduction percentage (dry weight of treated survivors/dry weight of untreated seedlings).

Since herbicide resistance was determined by a single dose assay, the degree of herbicide resistance for each population was not able to be quantified (Moss 1995). However a population was considered to have resistant individuals if any weed survived the herbicide application and the dry weight of survivors was at least 40% of the untreated seedlings.

RESULTS

Resistance of *Sisymbrium orientale* Seven populations with resistant individuals (Table 1, F-L) of *S. orientale* were discovered from seed collected in 1993 and 1995. These populations were collected from wheat fields where chlorsulfuron had been applied for a minimum of six years. Five other populations where chlorsulfuron had been used for 2–10 years were shown to be sensitive to chlorsulfuron.

Resistance of *Sisymbrium thellungii* Two populations with resistant individuals (Table 2, C and D) of *S. thellungii* were discovered from seed collected from wheat fields in 1995 where chlorsulfuron had been applied for a minimum of five years. Two other populations where chlorsulfuron had been applied for six years (A) and for 10 years (B) were susceptible to chlorsulfruon.

Resistance of *Sonchus oleraceus* Eleven populations with resistant individuals (Table 3, D-N) of *S. oleraceus* were isolated from different wheat paddocks near Goondiwindi, Queensland in 1993 and 1995. These populations were growing on continuously cropped wheat sites where chlorsulfuron had been used once a year for between six and ten years. Three other populations from locations where chlorsulfuron had never been used (C), used for three years (D) and ten years (A) were shown to be sensitive to chlorsulfuron.

Resistance of *Fallopia convolvulus* Three populations with resistant individuals of *F. convolvulus* (Table 4, E, F and G) was isolated in 1993 from a wheat paddock near Goondiwindi, Queensland. This population was growing on a continuously cropped wheat site where chlorsulfuron had been used once a year for between 5 and 10 years. Four other populations were susceptible to chlorsulfuron.

Resistance of *Urochloa panicoides* Six populations with resistant individuals of *U. panicoides* (Table 5,

Table 3. A comparison of populations of *Sonchus oleraceus*, survival (%) and dry weight reduction (%) as a result of application of 15 g a.i. ha^{-1} chlorsulfuron with an indication of history of herbicide use (years).

Population	Survival %	Dry weight reduction %	Herbicide use history (years)
A	0	0	10
B	11	2	3
C	17	2	0
D	50	30	10
E	75	40	10
F	78	91	6
G	83	52	10
H	83	117	10
I	85	103	5
J	87	119	4
K	87	89	10
L	118	101	6
M	136	115	5
N	173	214	6

Table 4. A comparison of populations of *Fallopia convolvulus*, survival (%) and dry weight reduction (%) as a result of application of 15 g a.i. ha^{-1} chlorsulfuron with an indication of history of herbicide use (years).

Population	Survival %	Dry weight reduction %	Herbicide use history (years)
A	0	0	0
B	0	0	10
C	0	0	5
D	0	0	5
E	8	44	5
F	20	10	5
G	118	169	10

Table 5. A comparison of populations of *Urochloa panicoides*, survival (%) and dry weight reduction (%) as a result of application of 2.25 kg a.i. ha^{-1} atrazine with an indication of history of herbicide use (years).

Population	Survival %	Dry weight reduction %	Herbicide use history (years)
A	0	0	9
B	0	0	5
C	9	6	2
D	58	79	2
E	60	170	7
F	68	67	5
G	75	36	10
H	79	82	0

C-H) was isolated in 1995 from sorghum paddocks south and south-east of Toowoomba where atrazine had been in use for between 0 and 10 years. Two other populations which had a nine and five year history of atrazine application were susceptible to atrazine. The farmer with population E commented that control of *U. panicoides* was successful but after about three years of atrazine application, control of this weed was poor.

Susceptible weeds Seed samples from surviving plants of the other major weed species were also collected after winter in 1993 and 1995 and after summer in 1994 and 1995. Of the winter weeds *Phalaris paradoxa* L. *Brassica tournefortii* Gouan., *Sisymbrium irio* L. and *Emex australis* Steinh. showed no resistance to chlorsulfuron. The summer weed species *Echinochloa colona* (L.) Link, *Amaranthus viridus* L., *Hibiscus trionum* L. and *Salvia reflexa* Hornem. showed no resistance to atrazine.

DISCUSSION

Currently there appears to be four dicotyledonous weeds with an acquired resistance to chlorsulfuron. One grass weed (*U. panicoides*) also shows a resistance to atrazine. It has been reported that there are a number of naturally occurring biotypes with resistance to atrazine (Anon. 1995). This is confirmed in this research as population H (Table 5) showed resistance to atrazine despite having no history of atrazine use. However, the farmer with population E commented that control of *U. panicoides* was successful when he first used atrazine but, after about three years the level of control of this weed using atrazine was reduced. The anecdotal evidence indicates a number of resistant individuals were already present in the population.

The current research indicates that in addition to the already reported resistance of S. *orientale* and S. *oleraceus* (Boutsalis and Powles 1995) *Sisymbrium thellungii* and *Fallopia convolvulus* are resistant to chlorsulfuron. Further trials have indicated that one of the populations of *F. convolvulus* is resistant to other sulfonylurea herbicides (trisulfuron and trifensulfuron methyl/metsulfuron methyl) but susceptible to picloram/ 2,4-D (Tordon 75-D®), fluroxypyr (Starane 200®) and bromoxynil (Buctril 200®) (Adkins unpublished data). An investigation is proceeding into the degree of resistance of *S. thellungii* to other sulfonylureas and herbicides from different mode of action groups.

The survey of the north-east grain region has revealed that there are many sites with weeds resistant to chlorsulfuron. Most prevalent is the resistance of S. *oleraceus* where only two sites surveyed with a history of chlorsulfuron use have not developed resistance. The sites where resistance of *F. convulvulus* to chlorsulfuron has been found is in a location north-west of Goondiwindi within 10 km of each other. However, resistance has been found to *S. thellungii* near Goondiwindi, Queensland and 350 km north-west at Roma, Queensland.

Clearly the appearance of these weeds resistant to chlorsulfuron and atrazine is a concern to the chemical companies and farmers. The strategy to avoid herbicide resistance is to increase the use of non chemical control methods and when chemical weed control is required select herbicides from different mode of action groups to what has been used previously (Herbicide Resistance Action Committee).

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