HERBICIDE RESISTANT AQUATIC WEEDS, A PROBLEM IN NEW SOUTH WALES RICE CROPS

R.J. Graham, J.E. Pratley, P.D. Slater and P.R. Baines
Farrer Centre, Charles Sturt University, PO Box 588, Wagga Wagga, New South Wales 2678, Australia

Summary A survey was conducted of New South Wales (NSW) rice farms where bensulfuron had been extensively used. Seeds of the aquatic weed species, starfruit (*Damasonium minus* R.Br. Buch.), dirty dora (*Cyperus difformis*) and arrowhead (*Saggitaria montevidensis* Cham. & Schlechter) were collected and screened in pots for resistance to bensulfuron. Resistance was detected in all three species.

Two of the five *D. minus* samples screened in the survey exhibited resistance. Only one of the 17 *C. difformis* samples analysed was clearly susceptible whilst two of the six *S. montevidensis* samples examined were resistant. Many additional samples of these three species, obtained subsequent to this survey and processed by the resistance testing service at Charles Sturt University (CSU) have also proven to be resistant. These findings have widespread and serious implications for the rice industry. The current lack of aquatic weed management options means that Riverina rice farmers are being confronted with a problem which currently has few viable solutions.

INTRODUCTION

Herbicide resistance is an ever increasing problem in Australia and elsewhere. Its occurrence here has been documented by people such as Powles and Howat (1990) who at this time suggested five terrestrial species had been detected as being resistant. This number has increased significantly since this time and now includes weed species which have developed resistance to chemicals in lower risk categories. This paper however outlines the occurrence of three aquatic weeds, *Damasonium minus, Cyperus difformis* and *Saggitaria montevidensis*, which have developed resistance to bensulfuron a higher risk sulfonylurea Group B chemical.

Given that resistance to sulfonylurea herbicides has occurred extensively in dryland cropping situations in Australia, it is not surprising that these species have developed resistance under the current rice farming system. Bensulfuron has been used extensively and almost exclusively on NSW rice crops for around ten years, as the only form of aquatic weed control. The issue here however is that, unlike terrestrial crops where there are numerous management options to overcome the problem of herbicide resistance, very few management tools are currently available to overcome this potentially explosive problem in rice in the Riverina environment.

This paper reports on the findings of a survey of the three aquatic rice weeds as well as subsequent screenings conducted at CSU over recent seasons and examines the implications of such findings.

MATERIALS AND METHODS

Farm survey Seed samples for all three species, *D. minus*, *C. difformis* and *S. montevidensis*, were obtained from crops across the rice growing areas of south western NSW, where crops had received three or more applications of bensulfuron. The collection was conducted in early 1993 with samples stored unthreshed until testing occurred.

The *C. difformis* and *S. montevidensis* experiments were carried out between December 1993 and February 1994 under glasshouse conditions whilst the *D. minus* experiment was conducted between May and June 1994 in a growth room set at 25°C 14 hour day and 12°C 10 hour night.

Resistance screening for each experiment was conducted as follows. Aluminium trays were used as pots containing 450 g of a screened clay loam soil. Trays were sown with 0.2 g of their respective seed sprinkled on top of pre-saturated soil. A known susceptible sample was used in each experiment. For the *D. minus* experiment soil pre-saturation was achieved by applying 170 mL of a 150 µg mL^{-1} ethephon solution which was used to enhance germinations. Soil saturation was maintained for between 14 and 24 days after sowing when water levels were raised to 3 cm where they remained for the duration of the experiments. Bensulfuron was applied when plants were between the one and three leaf stages.

Four rates of bensulfuron (0, 25.5, 51 and 102 g a.i. ha^{-1}) were applied by injecting 10 mL of the appropriate dilution into each of the flooded trays. All treatments were replicated three times and arranged in a randomized block design.

Copper, present as mixed copper chelates, was used at regular intervals to control algal growth within trays at rates up to 428 g a.i. ha^{-1}. At times physical removal of algal mats was also required to supplement chemical control. The equivalent of 50 kg N ha^{-1} in the form of urea was applied to the trays 10 to 15 days after treatment (DAT).

Recordings in the form of growth scores across the experiment, between zero and ten, were conducted 23 and 24 DAT for the *S. montevidensis* and *D. minus* experiments respectively. Whole plant harvests were conducted 20 DAT by wet sieving the contents of each tray through a 2 mm screen for the *C. difformis* experiment, and dry weights obtained.

Data analysis was conducted by way of a binomial analysis of variance in which dry weights and scores (after arcsin transformation) were expressed as proportions of their untreated controls. Having identified seed type in each experiment as a significant source of variance, least significant differences ($P<0.05$) were then calculated and used to compare the binomial mean estimates for each type in the three experiments. The variation in bensulfuron tolerance between seed types for each experiment was then determined. Three categories, susceptible (S), moderate resistance (MR) and highly resistant (HR), based on statistical analysis, were then used to classify seed types in each experiment.

CSU screenings Subsequently a screening service for farmers was provided using methods described above for the seasons 1993–94 and 1994–95.

RESULTS AND DISCUSSION

The effectiveness of control by bensulfuron on survey samples and CSU screening service samples is shown in Tables 1 and 2 respectively. Using the above criteria as indicating resistance, the data show 94% of the 17 *C. difformis* samples screened in the farm survey as being statistically different from the susceptible seed type. Of these, ten (59%) are categorized as HR and a commercial result would not be achieved on these weeds. A visual assessment of the six samples found within the MR category indicates that four would not produce a commercially acceptable level of control by bensulfuron applied at the recommended rate of 51 g a.i. ha^{-1}. The other two samples in this category, although significantly different from the known susceptible would probably give a commercially acceptable result. However, continuing bensulfuron applications as their only form of control would enhance the build-up of resistance in succeeding years.

Of the six *S. montevidensis* samples screened in the farm survey the data show two as being resistant and four (66%) being susceptible. Although the number of resistant samples (two) was lower for this species it was alarming to note that one sample, upon visual assessment, showed no reduction in growth at twice the recommended rate (102 g a.i. ha^{-1}) of bensulfuron.

Five *D. minus* samples were screened in the farm survey and of these two were shown to be resistant. One sample showed little reduction in growth at all the four bensulfuron rates. The paddock from which the sample was obtained had only received two bensulfuron applications and this is cause for concern.

Table 1. Aquatic weed survey results for seed samples collected from farms in early 1993.

Weed species	Region	S	MR	HR
C. difformis	MIA	1	3	5
	CIA	0	3	3
	MV	0	0	2
S. montevidensis	MIA	3	0	1
	CIA	1	0	1
	MV	0	0	0
D. minus	MIA	1	0	1
	CIA	2	0	0
	MV	0	0	1

Note: Figures exclude the known susceptible sample for each experiment. Regions as follows, Murrumbidgee Irrigation Area (MIA), Coleambally Irrigation Area (CIA) and Murray Valley Irrigation Districts (MV).

Table 2. CSU aquatic weed resistance (bensulfuron) screening results summary for the 1993–4 and 1994–5 rice seasons.

Weed species	S	R
C. difformis	8	34
S. montevidensis	0	1
D. minus	0	4

An examination of the above data appears to show no correlation between the incidence of herbicide resistance and the regions in which it occurs. Actual numbers may be higher in some regions however due to the small sample size and the fact that more farms were visited in the MIA and CIA than the MV, it is difficult to draw any real conclusions.

The CSU screening service test results are presented in Table 2 above and indicate that resistance is widespread and of increasing significance. Although both the farm survey and the testing service results are biassed samples these results are likely to represent a more general trend across the regions as most rice farmers practise similar farming methods. Therefore, these findings have potentially serious implications for the rice industry especially since farmers have very few alternative aquatic weed control strategies.

Over 90% of Riverina farmers aerially sow their rice into flooded bays, for reasons of simplicity, timeliness and also due to soil characteristics in southern areas.

Therefore they are more likely to predispose themselves to aquatic weed problems. McIntyre *et al*. (1991) suggest that the establishment of *C. difformis* and *D. minus* is favoured by aerial sowing conditions and thus their occurrence is now widespread. This management system allows such weeds to germinate often prior to the rice crop being sown, and with their high growth rates, often have a competitive edge over the crop. The introduction of bensulfuron in the latter half of the 1980s provided effective control of these infestations.

The identification of bensulfuron resistance has led the NSW rice industry to search for alternative aquatic weed control measures. To date few have been identified and these that have either limited application or have deleterious side effects. Alternative establishment techniques such as sod sowing are currently being promoted but they have limited appeal for reasons of increased workload and potential establishment problems. Herbicide alternatives are few. MCPA can pose water management and drift problems, while thiobencarb is used only on *C. difformis* and has a narrow application window.

Weed control strategies are currently inadequate as they rely almost exclusively on herbicides. If the NSW rice industry is to sustainably manage its weeds other options need to be found. A diverse, more complex farming system, embracing integrated pest management principles, based upon an understanding of the biology and ecology of the weeds present, including dormancy, germination and seed production characteristics needs to be adopted. Options such as biological control, cultural manipulations, allelopathy and improved hygiene measures need to be explored.

Herbicide resistance increases the risk of large infestations by aquatic weeds. Such a situation will result in yield loss and thus income reduction and if not addressed it could undermine the attempts of some NSW rice farms to grow rice.

ACKNOWLEDGMENTS

We wish to thank farmer and industry personnel for their assistance in the conduct of this work. We also wish to acknowledge the foresight of Mr. Don Pollock and Assoc. Prof. Steve Powles in bringing this issue to the attention of the industry thus provided the impetus for this project. The financial support of the Department of Employment, Education, Training and Youth Affairs and Du Pont (Australia) Ltd. is very much appreciated.

REFERENCES

McIntyre, S., Finlayson, C.M., Ladiges, P.Y. and Mitchell, D.S. (1991). Weed community composition and rice husbandry practices in New South Wales, Australia. *Agriculture, Ecosystems and Environment* 35, 27-45.

Powles, S.B. and Howat, P.D. (1990). A review of weeds in Australia resistant to herbicides. *Weed Technology* 4, 178-85.