A REVIEW OF WEEDS IN AUSTRALIA RESISTANT TO HERBICIDES

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Summary. This review considers the appearance in Australia of weed biotypes resistant to herbicides. Biotypes of capeweed, *Arctotheca calendula*, and barley grass, *Hordeum glaucum* resistant to the bipyridyl herbicides paraquat and diquat have recently become evident. These resistant biotypes infest a small number of lucerne fields that have a long history of paraquat and diquat use. The resistant biotypes can be controlled by a range of alternative herbicides. A biotype of annual ryegrass, *Lolium rigidum*, has resistance to a broad-spectrum of herbicides. This resistant biotype appears at many locations in southern Australia and poses considerable problems for control by herbicides. Some populations of wild oats, *Avena fatua*, appear to have resistance to diclofop-methyl.

Tactics for the prevention of herbicide resistance are discussed.

INTRODUCTION

Agricultural crops are under constant attack by pests. The advent of modern organic chemicals has been very successful in gaining an advantage over pests, and chemical pesticides are a major part of agricultural technology throughout the developed world. However, as a consequence of widespread, persistant usage there have appeared populations of pests that are not controlled by particular pesticides. Resistance to pesticides is a global phenomenon and now exists for fungicides, bactericides, rodenticides, nematicides and herbicides (2).

Resistance of weeds to herbicides is a phenomenon that, until recently, had only been reported in the Northern Hemisphere (the term resistance is used to describe the inherited ability of a weed to tolerate doses of a herbicide that would prove lethal to a great majority of individuals in a normal population of that species). The first report of herbicide resistance was a population of *Senecio vulgaris* with resistance to the triazine herbicides (10). Since then triazine resistance has been reported in biotypes of at least 48 species and resistance has also appeared to biypyridyl herbicides, diclofop-methyl, diuron and trifluralin. At the present time herbicide resistance in the Northern Hemisphere has been documented in 60 weed species (6, 7). In Australia resistance of weeds to herbicides has appeared later than in the Northern Hemisphere. There are, at present, only four confirmed cases of herbicide resistance in biotypes of Australian weed species.

This review is confined to discussion of the appearance in Australia of weed populations resistant to herbicides.

BIPYRIDYL RESISTANT BARLEY GRASS

1. Occurrence. In response to farmer comments I.C.I. Australia tested barley grass, *Hordeum glaucum*, infesting a lucerne field on a farm "Edgarley" near Willaura in the Western District of Victoria and reported a biotype resistant to paraquat (13). This resistant biotype of *H. glaucum* was characterised in further studies and found to be 250 times less sensitive to paraquat and diquat than normal *H. glaucum* (8). The resistant biotype had become dominant in a lucerne field which had been sprayed annually since 1969. A total of 20 L/ha of bipyridyl herbicides (either paraquat alone or mixtures of paraquat

and diquat) had been applied to this field during the period 1969-1982. The resistant biotype was dominant on the lucerne field and yet could not be detected in adjoining fields which had not been treated with bipyridyl herbicides. A survey of lucerne fields with a history of bipyridyl herbicide usage was conducted in 1985 and 1986 throughout Victoria and South Australia. This survey revealed that the resistant biotype was present on nine lucerne fields on four separate farms, all within 100 km of Edgarley (11). There is no evidence that the resistant biotype was introduced from one farm to the other three farms, although the survey did reveal that in some cases the resistant biotype had been introduced to uninfested areas by the movement of lucerne hay or stock from an infested field (11). The common factors were the presence of the resistant biotype in lucerne fields that had been treated for a number of years with bipyridyl herbicides, without herbicide rotation or any cultivation. It cannot be distinguihsed whether the resistant biotype was present in the *H. glaucum* population prior to the commencement of herbicide usage, or is the result of a mutation under the selection pressure afforded by annual applications of bipyridyl herbicides.

Extensive ecological studies to characterise the resistant biotype in terms of its inter and intra-specific competitive ability and to assess its likely future persistance are in progress (Tucker and Powles, unpublished data). Studies to understand the physiological mechanism by which this biotype can withstand bipyridyl herbicides reveal that the leaves are able to bind substantial quantities of paraquat within the apoplast, thereby preventing paraquat from reaching its active site within the chloroplast (1, 9).

2. Control of the resistant biotype. The resistant biotype has only appeared on a small number of lucerne fields that have had a history of bipyridyl herbicide application. The resistant biotype has not been found as a weed of any other crops. Once it became known that paraquat was ineffective in controlling this resistant biotype then good control has been achieved by using a selective herbicide with a different mode of action to bipyridyl herbicides. Studies reveal that the resistance is specific for the bipyridyl herbicides and control is normally achieved with alternative herbicides with different modes of action (8). Therefore, both non-selective knock-down control and in-crop control of the resistant biotype has easily been achieved by the use of alternative herbicides. It should be noted however that control of the resistant biotype has involved extra costs to the grower.

BIPYRIDYL RESISTANT CAPEWEED

1. Occurrence. In 1985, a farmer at Elmshurt, near Ararat, Victoria reported that a double application of bipyridyl diquat herbicide was ineffective in controlling capeweed, *Arctotheca calendula* on one lucerne field. An experiment in this area in 1986 revealed that the *A. calendula* population on this field is resistant to diquat (Powles, *et al.* unpublished data). Studies to characterise the resistant *A. calendula* have commenced and some results are presented at this meeting (12). At the present time there is no information as to the current dispersion of the diquat resistant biotype. It is important to note that the lucerne field infested by the resistant *A. calendula* is also infested by bipyridyl resistant *H. glaucum* (11). This field has been sown to the perennial lucerne crop since 1962 and has not been cultivated or received any other herbicide than the bipyridyl type from 1963 to 1986. Throughout this period the field has been sprayed once annually with a total of 42 L/ha bipyridyl herbicide. Clearly the bipyridyl resistant *H. glaucum* and *A. calendula* have appeared in response to the consistent use of the same herbicide mixture.

2. Control of the resistant biotype. In 1986, following failure of bipyridyl herbicide, diuron was applied at 4 L/ha and this controlled the resistant *A. calendula*. Studies reveal that the resistant biotype can be controlled by diuron and a range of alternative herbicides (12). This suggests that control of the resistant biotype will be straightforward, as has been the case with the bipyridyl resistant *H. glaucum*.

DICLOFOP-METHYL RESISTANT WILD OATS

1. Occurrence. Very recently some populations of wild oats, *Avena fatua* from sites in W.A. have been found to be resistant to diclofop-methyl (T. Piper, pers. comm., 1986). Studies with these populations have just commenced and little information is yet available. Field experiments in 1986 and experiments with potted plants in 1987 confirm that 1.5 L/ha of diclofop-methyl has little effect on the resistant biotypes (T. Piper, unpublished data). The development of resistance to diclofop-methyl in *A. fatua* is of considerable importance and further research on this problem is justified. The distribution of the resistant biotype is not known.

2. Control of the resistant biotype. The diclofop-methyl resistant biotype does not appear to exhibit cross-resistance to the herbicides fluazifop or sethoxydim (T. Piper, unpublished data). This implies that alternative herbicides may control the resistant biotype. However, as diclofop-methyl is the major herbicide currently registered for post-emergence control of *A. fatua* in cereal crops then the appearance of a resistant biotype may pose some significant practical problems.

DICLOFOP-METHYL RESISTANT ANNUAL RYEGRASS

1. Occurrence. In 1980, a seed grower near Bordertown, S.A. advised that a population of annual ryegrass, *Lolium rigidum* was no longer being controlled by diclofop-methyl. Plants growing from seed of this population were tested and found to be resistant to diclofop-methyl (3). Subsequent studies have revealed that this resistant biotype is also resistant to three herbicides belonging to the same herbicide group, fluazifop, haloxyfop and sethoxydim (4). Such cross-resistance to a range of similar chemicals has been frequently observed in studies with pesticide resistant species (2). Of considerable scientific and practical importance was the observation that the diclofop-methyl resistant *L. rigidum* biotype was also resistant to the unrelated herbicides, chlorsulfuron and metsulfuron (4). Further experiments showing cross-resistance in the *L. rigidum* biotype are reported at this meeting (5).

The *L. rigidum* biotype with cross-resistance is apparently widespread throughout southern Australia. Samples from sites in N.S.W., Victoria, S.A. and W.A. have been found to be resistant (Heap and Knight, unpublished data). Extensive ecological and agronomic experiments are underway with the resistant biotype (Heap and Knight, unpublished data).

2. Control of the resistant biotype. The resistant *L. rigidum* biotype represents the first report world-wide of a weed species with cross-resistance to chemically dissimilar herbicides. Recently a biotype of the important grass weed *Alopecurus myosuroides* that has resistance to a number of unrelated herbicides has appeared in a cereal growing region of England (S. Moss, pers. comm., 1987). There are a number of insects and fungi exhibiting such cross-resistance (2). The appearance of weeds with cross-resistance is of considerable practical importance. The options for control of the *L. rigidum* biotype by herbicides have become very limited as diclofop-methyl and

chlorsulfuron are the only products registered for post-emergence control of *L. rigidum* in wheat and barley and the resistant biotype is not controlled by these herbicides. It is evident that control of this resistant biotype cannot simply be achieved by changing herbicides. A considerable research effort is underway to achieve a satisfactory method of control of this biotype. This work is being undertaken at the Waite Institute in Adelaide and in co-operation with field experiments commissioned by a herbicide resistance committee formed within the Agricultural and Veterinary Chemicals Association (AVCA). It is likely that some form of integrated weed management system, involving pasture-topping, cultivation and judicious choice of herbicides will be necessary to control the resistant biotype. The frequency and the length of a pasture phase in the rotation cycle may be important in the overall management of the resistant biotype.

TACTICS FOR THE PREVENTION OF HERBICIDE RESISTANCE

Research and experience with insecticide resistance has reached the point where an integrated approach to control (integrated pest management) is advocated (2). As herbicide resistant weeds have usually been well controlled by alternative herbicides, no such concerted strategy has been necessary for their control. Management factors, especially the choice and combination of herbicides can obviously be changed in response to the appearance of resistance to one herbicide. North American experience has been that alternative herbicides, or a combination of two or more herbicides with different modes of action, have meant that all cases of resistance have been adequately controlled (H.M. LeBaron, pers. comm., 1986). One response of herbicide resistance evident in the Northern Hermisphere is the introduction of herbicide mixtures of chemicals with different modes of action. As an example the Sandoz Crop Protection Company recently introduced the herbicide Marksman^R (mixture of triazine and dicamba herbicides) for use in areas of the United States infested with triazine resistant weeds. The triazine component of Marksman^R will control the majority of the weed population and the dicamba component controls those weeds resistant to triazine herbicide. It is likely that there will be a trend towards herbicide combinations, both to combat existing cases of resistance and to decrease the likelihood that resistance will develop.

As the resistant biotypes of *Arctotheca*, and *Hordeum* in Australia have resistance specific for a particular herbicide they can be controlled by herbicides with a different mode of action (this may be more expensive than incurred before resistance appeared). These resistant biotypes therefore pose no great problem and the situation appears similar to that observed in the Northern Hermisphere. However, the *Lolium* biotype exhibiting cross-resistance to a range of herbicides is potentially a much more significant problem. With this biotype it is likely that control will require an integrated approach, utilising cultivation, crop and pasture rotation and pasture-topping.

Clearly, the appearance of weed populations resistant to herbicides is of concern to various sectors of the agricultural industry. The occurrence of cross-resistance in *Lolium* in Australia and *Alopecurus* in England is of considerable concern. It is to be hoped that there will not be other such cases of cross-resistance, but should this phenomenon continue to occur then integrated weed management systems will be necessary.

REFERENCES

1. Bishop, T., Powles, S.B. and Cornic, G. 1987. Aust. J. Plant Physiol. (In press).
2. Georghiou, G.P. 1986. In: Pesticide Resistance: Strategies and Tactics for Management. (National Academy Press: Washington). pp. 14-43.
3. Heap, J. and Knight, R. 1982. J. Aust. Inst. Ag. Sci. 48, 156-157.
4. Heap, I. and Knight, R. 1986. Aust. J. Agric. Res. 37, 149-156.
5. Heap, I. and Knight, R. 1987. Proc. 8th Aust. Weeds Conf. (In press).
6. LeBaron, H.M. 1985. Proc. 1985 Calif. Weed Conf. pp. 38-49.
7. LeBaron, H.M and Gressel, J. 1982. Herbicide Resistance in Plants. (John Wiley and Sons: New York).
8. Powles, S.B. 1986. Weed Res. 26, 167-172.
9. Powles, S.B. and Cornic, G. 1987. Aust. J. Plant Physiol. 14. (In press).
10. Ryan, G.F. 1970. Weed Sci. 18, 614-616.
11. Tucker, E.S. and Powles, S.B. 1987. Plant Prot. Qrtly. (In press).
12. Van de Loo, F.J. and Powles, S.B. 1987. Proc. 8th Aust. Weeds Conf. (In press).
13. Warner, R.B. and Mackie, W.B.C. 1983. Aust. Weed Res. Newsletter 31, 16.