CURRENT STATUS OF HERBICIDE RESISTANCE IN NEW ZEALAND WEEDS

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Summary. In New Zealand the first case of true weed resistance was that of *Chenopodium album* to triazine herbicides reported in 1982. Since then *Polygonum persicaria* has been added to the list of triazine-resistant weeds. In pastures differential tolerance of MCPA has been established in different biotypes of *Rananculus acris* and *Carduus nutans* at a few sites as a result of herbicide selection pressure. In *C. nutans* cross resistance has also been demonstrated between 2,4-D, MCPA and MCPB. Research is continuing on some other suspected tolerance problems and further weed species could be added to this list.

INTRODUCTION

Over the past five decades that modern herbicides have been developed and extensively used, there have been several cases of differential tolerance within various weed species. The development of true herbicide resistance though was not confirmed until the discovery of triazine-resistant common groundsel, *Senecio vulgaris*, in the late 1960's. Although weeds have taken longer to evolve resistance compared to insect pests, an increasing number of resistant weeds have been identified world-wide. The most recent survey shows a total of 100 herbicide-resistant weed biotypes reported from USA, Canada and 26 other countries. This includes 55 biotypes (40 broad-leaved and 15 grass weeds) resistant to triazine herbicides and 45 weed biotypes (29 broad-leaves and 16 grasses) which have evolved resistance to 14 other classes of herbicides (13).

World-wide probably the most serious problems have arisen with the s-triazine herbicides. In almost all cases, resistance to triazines has occurred mostly in areas where these herbicides have been used repeatedly for several years, and especially where little or no tillage has been used (2, 6). Studies have shown that the triazine resistance in weeds was due to non-binding of the herbicide to plastids and not due to the degradation of the herbicide, as occurs in resistant varieties of maize (1). A summary of what is known about the problem, and how to identify and prevent it can be found in Le Baron and Gressel (14).

The development of triazine resistance has been of great interest and concern because of the importance and extensive use of this group of herbicides. It is likely that if other single target site residual herbicides (e.g. diuron) were used as extensively and continuously as the triazines, they would have also resulted in resistant weed biotypes (13). In addition to some of the common types of herbicide resistance discovered around the world, both Australia and New Zealand have developed some specific herbicide resistance problems as a result of their prevalent agricultural systems. This paper reviews the present status of herbicide resistance in weeds in New Zealand.

CURRENT SITUATION IN NEW ZEALAND

The subject of herbicide-resistant weeds in New Zealand was reviewed by Rahman in 1982 (18). At that time he noted that the only case of herbicide resistance in New Zealand was that of fathen, *Chenopodium album*, in some maize fields. However, since then at least three more New Zealand weed species have been confirmed as showing biotype variation in herbicide tolerance. Some of the interesting and novel herbicide resistance problems in New Zealand are associated with applications to perennial pasture. The appearance of these problems is probably not a coincidence but, as discussed later, related to the permanence of some pastoral systems and the very early manufacture and use of chlorophenoxy herbicides in this country.

Fathen (*Chenopodium album*). The tolerance of fathen to atrazine was first suspected in the 1979-80 maize growing season in some maize fields where atrazine was applied for several years in succession. Limited laboratory and glasshouse work suggested that these plants could tolerate between 35 and 60 kg/ha of atrazine. This confirmed that the strong selective pressure of repeated treatments with atrazine in continuous maize production had resulted in a biotype with remarkable tolerance to this herbicide.

Two field trials conducted by Rahman *et al* (19) confirmed the presence of atrazine-resistant fathen and also led to the conclusion that much of the fathen population surviving after atrazine treatments in the maize fields had developed resistance to this herbicide. The competitive ability of the fathen plants and their detrimental effect recorded on the maize grain yield indicated strongly that this biotype may become a problem weed in most maize fields of New Zealand and it may limit the usefulness of s-triazine herbicides. However, a number of post-emergence herbicides provided promising control of this weed in maize.

Glasshouse studies showed that there was no difference in physical appearance between the resistant and susceptible biotypes and separation of the two without exposure to triazine herbicides was impossible. However, when growing together, the resistant plants were often found to be smaller with less seedling dry weight than their susceptible counterparts. There was no difference between susceptible and resistant biotypes in their tolerance to 2,4-D, dicamba, bentazone and bromophenoxim (19).

In the last few years the resistant fathen biotype has also appeared in some asparagus fields which have been treated with triazine herbicides. Many of these fields were previously in maize crops.

Willow weed (*Polygonum persicaria*). A biotype of willow weed resistant to atrazine was first discovered in 1980 in a field which had been in successive maize crops since 1970 and sprayed annually with a mixture of grass herbicide and atrazine. Between 1981 and 1984 dicamba was included in the annual spray programme, but the problem was still present in 1985, confirming the conclusion of Le Baron (12) that seeds from herbicide resistant plants which develop and infest an area are often difficult to eradicate, even though the plants can be controlled by other means.

Glasshouse studies with seeds from this biotype showed that the resulting plants could tolerate up to 20 kg/ha of atrazine, with no apparent damage or growth reduction. Further experiments established that these resistant biotypes were also resistant to 12 other triazine herbicides tested (20). As was the case with fathen, there was no marked difference in physical appearance between the resistant and susceptible biotypes. In some cases the resistant plants had slightly narrower leaves than the susceptible biotypes.

Fortunately, so far this resistant biotype of willow weed is restricted to just a few maize and asparagus fields and has not spread into other crops or other regions.

Nodding thistle (*Carduus nutans*). Nodding thistle is a biennial weed occurring mainly in sheep pastures under low rainfall and is most common in summer-dry high-fertility areas of both islands of New Zealand. Resistance to MCPA in a population of nodding thistle was demonstrated by Harrington and Popay in 1987 (8). When seed collected from these plants was sown under glasshouse conditions, the resulting plants required between 5 and 30 times more herbicide than the susceptible plants to achieve adequate control. Under field conditions, a 6-fold increase in the rate of MCPA was required for adequate control of the resistant biotype (9).

Although the resistance detected in nodding thistle was to MCPA, correlations with spraying history suggested that the selection pressure had been applied by 2,4-D on almost all farms (4). Subsequent cross resistance studies by Harrington (7) showed that the biotype resistant to MCPA was also tolerant to MCPB and 2,4-D, but not to mecoprop, clopyralid, dicamba, picloram, paraquat or glyphosate. An unexpected result was a slight but significant level of tolerance to the sulfonylurea herbicide DPX-L5300. Unfortunately the recommended rates of herbicides which adequately controlled the resistant biotype are too damaging to pasture species to be used for selective control (7).

Seeds were collected in 1988 from a number of farms where problems were experienced in controlling nodding thistle with MCPA or 2,4-D. Subsequent investigations with resulting plants in the glasshouse confirmed the presence of at least 12 other sites where this weed showed tolerance to MCPA (7). However farmers at some of these sites where tolerance was detected have still managed to get reasonable levels of nodding thistle control using the phenoxy herbicides. They applied them when the plants were very young and either used higher than recommended application rates or added clopyralid for increased phytotoxicity.

Giant buttercup (*Ranunculus acris*). Giant buttercup occurs throughout New Zealand and is a serious weed of dairy pastures receiving high annual rainfall (17). Bourdot and Hurrell (3) identified an MCPA-resistant biotype of this weed that required five times as much MCPA as a susceptible biotype to achieve the same level of control. The resistant and susceptible populations came from sites only 1 km apart. Both sites supported permanent pastures rotationally grazed by dairy cattle and there appeared to be no managerial or environmental differences between them. The histories of the two biotypes revealed that the susceptible population has had no MCPA treatment for at least 20 years, whilst the resistant population had been treated every one, two or three years for over 30 years.

In earlier studies Popay *et al* (17) had found that the level of control of giant buttercup was highly variable between sites. The finding by Bourdot and Hurrell (3) suggests a probability that difficulties in controlling this weed on some North Island farms may also be explained by the existence of resistant biotypes. Confirmation of the wider existence of resistant biotypes of giant buttercup arising from past use of MCPA awaits comparative studies under uniform conditions.

Recent work by Bourdot *et al* (5) showed that the LD_{50} of seedling progeny of the MCPA-tolerant biotype was reduced by 24 - 68% by addition of an organo-silicone co-polymer surfactant, Silwet M, to MCPA. Despite a considerable variation in the biological effects of adding surfactants to MCPA, increased effectiveness was recorded in each case.

DISCUSSION

It is known that herbicide resistance in general develops more slowly than corresponding resistance to other pesticide groups. This is usually attributed to differences in generation times for target organisms. This does not diminish the herbicide resistance problem, rather it suggests that increasing numbers of examples will become evident in the future. Forecasting the magnitude of herbicide resistance problems in any country is impossible, although it is clear that the number of cases is most likely to increase. One major factor that may contribute to herbicide resistance is the use of soil-acting herbicides which have long persistence in the soil.

As mentioned above, there are limited examples of herbicide resistance in New Zealand at this stage. This is probably linked to the absence of crop monocultures and the traditional forms of mixed farming in this country. The expansion in the number of horticultural enterprises in recent years will no doubt contribute some new problems, particularly associated with perennial crops.

Perhaps the most interesting herbicide resistance problems in New Zealand are associated with perennial pasture. Both nodding thistle and giant buttercup have shown resistance to chlorophenoxy herbicides. These resistances seem to have developed due to selection pressure exerted by phenoxy herbicides since for both species, the susceptibility of populations was correlated with their historical exposure to phenoxys. The 5 to 7-fold differences found in susceptibility between the two biotypes of both pasture weeds are not large compared to those reported for triazine herbicides (14). They are large enough, however, to render the least susceptible biotypes of nodding thistle and giant buttercrup resistant to MCPA applied at the normal application rate of 1.0 kg/ha (4).

Over recent years, a number of weed species in other countries have been shown to have biotypes with varying tolerance to phenoxy herbicides (e.g. 10, 11, 15). Most of these cases involve biotypes which are morphologically distinguishable, suggesting that differences in physical characteristics such as cuticle thickness, pubescence, erectness of growth habit, small sized seedlings, hardiness, long term seed dormancy, etc may provide the mechanisms for the differences in tolerance (10, 14). By contrast, there are no consistent morphological differences between the resistant and susceptible biotypes of the two New Zealand pasture weeds discussed here. The resistance mechanism may therefore be biochemical in nature, possibly concerning the metabolic breakdown of MCPA. Lutman and Snow (16) reported that differences in herbicide uptake and translocation were unlikely to be the cause of chickweed, *Stellaria media*, resistance to mecoprop. Since the difference in resistance of New Zealand weeds to MCPA has been recorded under uniform environmental conditions, it is also possible that, the difference is genetically based. If this was the case, the selection pressure provided by repeated phenoxy treatment could be expected to `produce' a resistant biotype by favouring resistant genotypes. As the repeated use of phenoxy herbicides appears to be the cause of resistance build up in nodding thistle and giant buttercup, it is reasonable to expect that resistance to phenoxys may appear in other pasture weeds in New Zealand.

Although herbicide resistance has been confirmed only in the two pasture weeds listed above, there are a number of other pasture weed species which sometimes have proved difficult to control in the field. It is possible that at least partial tolerance to phenoxy herbicides has also developed in biotypes of *Carduus pycnocephalus*, *Carduus tenuiflorus*, *Cirsium arvense*, *Rubus fruticosus* and *Silybum marianum*. However, this has yet to be confirmed.

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