**THE EFFECTS OF HERBICIDES USED ON ASPARAGUS
ON THE GROWTH RATE OF THE EARTHWORM
*ALLOLOBOPHORA CALIGINOSA***

N.A. MARTIN

Entomology Division, DSIR, Private Bag, Auckland

SUMMARY

In the laboratory, mortality and growth of juvenile *Allolobophora caliginosa* (Oligochaeta: Lumbricidae) were measured in soil containing 1, 10 and 100 ppm of nineteen herbicides. Mortality was caused only by trifluralin which killed all worms at 100 ppm. The worms survived but lost weight in 100 ppm of oxadiazon, 2,4-D, prometryn, MCPB, metribuzin, terbacil, linuron and bromacil, while in 100 ppm aziprotryne, diuron, methabenzthiazuron, asulam and hexazinone the worms grew more slowly than those in untreated soil. Amitrole plus ammonium thiocyanate, 2,2-DPA, glyphosate, propazine and simazine had no consistent significant effect on worm growth. The use in asparagus crops of these nineteen herbicides is unlikely to reduce *A. caliginosa* populations, especially when applied at the end of picking.

INTRODUCTION

Earthworms are important for the maintenance of good structure in many soils where annual cultivation is not possible (Martin 1978). Although the soil above asparagus crowns can be cultivated, the zone around the crowns remains undisturbed. In soils liable to compaction, burrowing in this region by earthworms may be beneficial for the crop. In 1979, during a survey of earthworms in asparagus fields of Hawkes Bay, three species of earthworm, *Allolobophora caliginosa*, *A. rosea* and *Lumbricus rubellus* were found in crops but on one farm earthworms were absent from the crop though present in the grassed headlands. This suggested that the asparagus crop may have been treated with an earthworm-toxic substance. Herbicides were suspected and all herbicides approved for use on asparagus beds were screened in a laboratory test for toxicity to *A. caliginosa*, the commonest topsoil-mixing earthworm in New Zealand.

METHODS

The herbicides tested included seventeen listed for use in asparagus by Cox *et al* (1980) and two additional compounds suggested by a grower and a chemical company representative. The laboratory test used a soil-grass meal mixture in which juvenile earthworms grew well. Herbicides (or other chemicals) were mixed into the soil and the growth or mortality of the earthworms measured.

A Red Hill sand soil from a dairy farm in Mangere, Auckland was used. The topsoil under the turf was collected, air dried and sieved (opening 4 mm). Just before use 8.8 g of grass meal (commercial powdered grass leaves) was added to each kg of soil.

The moisture content of the mixture was determined by drying a sample at 105°C for 24h. The equivalent of 200 g of dry weight of a fresh mixture was placed into each of a number of plastic bags. Aqueous solutions of the commercial formulations of herbicides were added to different bags of soil to give concentrations of 1, 10 and 100 mg per kg of dry soil. Water was added to bring the moisture level to 25% (25 ml per 100 g of dry soil). The soil plus herbicide was thoroughly mixed in each plastic bag and then distributed between five 110 ml screw-topped jars. At each test five jars with untreated soil, and five jars of five concentrations of a standard, carbofuran, were similarly prepared. Carbofuran was used as a standard because of its known toxicity to

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earthworms and the data could be related to mortality caused in field experiments (Martin 1976, 1980). Four herbicides were tested at one time.

Four-week old juvenile *A. caliginosa*, which had been reared in a similar soil-grass meal medium were washed out of the medium and held in water. Each worm was gently blotted and weighed (± 0.1 mg) before a single worm was placed in each jar. The lids were loosely screwed on to retain the worms. Jars of each concentration of chemical were enclosed together in a plastic bag to retain moisture and toxic vapour and were kept in the dark at room temperature, about 20°C. After 7 days the worms were washed out of the soil and weighed.

The growth rate $\log_e \frac{(\text{weight day 7})}{(\text{weight day 0})}$ of the worms in each treatment and the untreated soil were calculated. Over a 7 day period under these experimental conditions, healthy juvenile *A. caliginosa* usually gained 0.5 mg for each 1 mg of the initial weight giving a $\log_e$ value of 0.41. In contrast a worm can lose over half its weight ($\log_e -0.69$) before dying (Martin unpublished data).

The growth of the worms in each treatment was compared with those in untreated soil by a one-sided t-test. The more detailed data obtained for carbofuran allowed the calculation of the concentration of this chemical that resulted in zero growth of the worms.

RESULTS

Table 1 shows the growth of juvenile *A. caliginosa* in the herbicide treated soil and the untreated soil and the concentration of carbofuran giving no growth. The herbicides are ranked in order of their effect on the worms at 100 ppm. Only trifluralin killed all the worms at 100 ppm, though eight other herbicides tested at this concentration caused the worms to lose weight and the worms in five other treatments grew at a significantly reduced rate.

TABLE 1: The effect of herbicides mixed into soil on the growth of juvenile *A. caliginosa*.

herbicide	growth in 7 days $\log_e \frac{(\text{weight day 7})}{(\text{weight day 0})}$				concentration (ppm) of carbofuran giving no growth
	100 ppm	10 ppm	1 ppm	control	
trifluralin	dead*	0.10	0.36	0.40	0.11
oxadiazon	-0.59*	0.29	0.35	0.40	0.11
2,4-D	-0.47*	0.26*	0.44	0.49	0.09
prometryn	-0.35*	0.30	0.27	0.40	0.11
MCPB	-0.25*	0.38	0.37	0.51	0.10
metribuzin	-0.21*	0.51	0.66	0.54	0.09
terbacil	-0.20*	0.39	0.42	0.45	0.11
linuron	-0.12*	0.26	0.48	0.37	0.05
bromacil	-0.11*	0.36	-	0.49	0.10
aziprotryne	0.05*	0.40*	0.45*	0.58	0.10
diuron	0.12*	0.40	-	0.49	0.10
methabenzthiazuron	0.17*	0.51	0.57	0.54	0.09
asulam	0.20*	0.39	0.35	0.40	0.11
amitrole T	0.25	0.26	0.23	0.25	0.05
hexazinone	0.29*	0.44	0.55	0.49	0.09
2,2-DPA	0.37	0.23	0.30	0.25	0.05
glyphosate	0.39	0.32*	0.33*	0.51	0.10
propazine	0.41	0.41*	0.37	0.49	0.09
simazine	0.44	0.46	0.38*	0.49	0.09

* significantly different, ($P < 0.05$) from control in a one-sided t-test.

At 1 and 10 ppm, the growth of the worms was in some cases significantly lower than the control. This occurred where there was high growth rate of the control (see aziprotryne) or low variance in the treatment and control.

Worm growth in the untreated soil varied between experiments. Reduced growth in the untreated soil on some occasions was also reflected in the lower concentration of carbofuran required to give zero growth (e.g. see table for linuron, amitrol and 2,2-DPA). If this were taken into account the position in the table of some herbicides would be changed. However, these changes in position would be small compared to the possible major changes in ranking of the herbicides which could result from their different patterns of field use.

DISCUSSION

Whether a herbicide which kills one earthworm species at a particular concentration in a laboratory test will kill the earthworms in an asparagus bed depends on many factors. These include the species of earthworm present, the mode and rate of application, the time of year and probably the type of soil. In addition herbicides at concentrations lower than those causing mortality could reduce the fecundity and therefore earthworm populations.

Caseley and Eno (1966) and Ghabbour and Iman (1967) compared the effects of herbicides on several species of earthworms using representatives of the Lumbricidae and other families. The papers showed that, in laboratory experiments, the lumbricid earthworms were not consistently more or less tolerant of the herbicides than the representatives of other families. However, even within a family such as the Lumbricidae there is considerable variation in the susceptibility of species to pesticides in laboratory tests (Stenersen 1979).

In practice herbicides may be incorporated into the soil or applied as a spray onto the soil surface. This can affect the concentration to which earthworms are exposed and the chances of exposure. Analysis of the more detailed results with carbofuran, which is very toxic to earthworms, provides a reference point for the subsequent discussion of other chemicals. In the laboratory test, 0.1 ppm of carbofuran caused zero growth in *A. caliginosa* while the worms died in less than 7 days when exposed to 5 ppm. A high proportion of this species was killed in field trials when carbofuran was broadcast or mixed into the soil at 2 kg/ha (Martin 1976, 1980). Trifluralin was the most toxic herbicide tested. It is normally incorporated into the top 5 cm of soil. At 1 kg/ha this would result in concentrations of 2-4 ppm, depending on the bulk density of the soil. The present laboratory experiments suggests that this concentration is unlikely to affect the growth or mortality of *A. caliginosa*. In a field trial where trifluralin 0.6 kg/ha and propachlor 2.2 kg/ha were used together no change in the same season was detected in the earthworm population which included *A. caliginosa*, *Allolobophora longa* and *Lumbricus terrestris* (Finlayson *et al* 1975). On the other hand if the herbicide was concentrated in the top millimetre of soil or onto the dead herbage on which the earthworms were feeding then toxic levels could be reached.

Despite this, the chance of a topsoil-mixing worm such as *A. caliginosa* coming into contact with the herbicide is small because of its behaviour and distribution which varies with the time of year. *A. caliginosa* is active only in the wet season and feeds mainly on organic matter within the topsoil (Martin 1978). However, it is occasionally vulnerable to surface applied herbicides because it can feed on surface organic matter, such as dead leaves. In the winter and spring sub-adult and adult worms will move across the soil surface in very wet weather (Martin 1976). If herbicides at the top of Table 1 are used under those conditions on asparagus fields with *A. caliginosa* then reduced growth and perhaps mortality could occur. Herbicides used at the end of picking are unlikely to have any effect on *A. caliginosa* because then the soil is often too dry for earthworm activity and most egg laying will have occurred.

Deep burrowing, surface worms such as *A. longa* and *L. terrestris* could be beneficial in asparagus beds. The *L. terrestris* used by Caseley and Eno (1966) for toxicity tests was probably mis-identified *L. rubellus* as it was called the "red wriggler"

and was only 120mm long. *L. rubellus* is a superficial species unlikely to be important in asparagus beds. However, the paper did show the effect of soil type on herbicide earthworm interaction. Soils rich in organic matter, which support rapid worm growth and breeding decrease the toxic effects of herbicides including amitrol, bromacil and diuron.

A. trapezoides, a common topsoil mixing species in the North Island was probably used by Ghabbour and Iman (1967). Worms were immersed in solutions of herbicides, including amitrole, simazine and 2,4-D and the time until death recorded. The data from these tests are difficult to interpret and apply to field practice.

CONCLUSIONS

It is not possible from a seven day laboratory test to predict the effect of the herbicides on earthworms in the field. A species such as *A. caliginosa* which feeds primarily on the topsoil is less vulnerable to surface applied herbicides than surface feeding species such as *L. terrestris*. *A. caliginosa* is most vulnerable in the wet season when it occasionally feeds on surface litter or migrates across the soil surface. For this reason herbicides used prior to spear emergence are likely to be more hazardous to the worm than those used at the end of picking. The effect of any herbicide on the fecundity of *A. caliginosa* is unknown. However, based on the present laboratory tests and the recommended methods and rates of use it can be concluded that it is unlikely that any of the herbicides currently registered or tentatively proposed for use on asparagus beds will reduce populations of the earthworm *A. caliginosa*. It is not possible though to apply these results with certainty to other potentially beneficial species.

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