EARTHWORMS IN NEW ZEALAND AGRICULTURE

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Summary

The importance of earthworms in New Zealand agriculture is considered and the role of topsoil-mixing species such as *Allolobophora caliginosa* in pasture is outlined. The annual cycle of *A. caliginosa* and *Lumbricus rubellus* in New Zealand pastures is described. This is related to practical aspects of sampling earthworms in trials containing earthworm-toxic pesticides. Plot size, number and size of samples, and methods of sorting samples are commented upon.

INTRODUCTION

It is generally accepted that earthworms are beneficial animals and important for the maintenance of 'healthy' soil. Unfortunately many exaggerated and confusing claims are made about the wonders performed by earthworms so that care needs to be taken to untangle the threads and gain a balanced view of their real worth in New Zealand agriculture. Most people are only familiar with soils where earthworms are present and in such soils it is very difficult to work out exactly what the earthworms are doing and to establish the separate role of each species of earthworm. There are, however, still areas of pasture without earthworms and adjacent areas with only one species of earthworm present, and these have allowed an assessment of the effect of these species on the pasture. Pastures without earthworms develop a surface peaty layer, composed of partly decayed leaves, roots and animal dung. This layer, or turf mat, impedes the penetration of rain, fertilisers, and insecticides (Stockdill and Cossens 1966). *Allolobophora caliginosa*, a widespread and common species, can remove the turf mat thus improving the soil structure and especially the water holding capacity (Stockdill and Cossens 1966). Other less common topsoil-mixing lumbricid earthworms can also remove the turf mat. However none of the few indigenous species which occur in New Zealand pasture can prevent a turf mat from forming, nor can some of the surface feeding lumbricids such as the widespread and common *Lumbricus rubellus*. This species buries dung as do the topsoil-mixing species (Martin and Hendrie 1978).

From this kind of observation it can be deduced that topsoil-mixing earthworms are necessary in pastures where it is not desirable to cultivate every 2-3 years, as within this time the turf mat starts forming. Conversely these earthworms are apparently not necessary where annual cultivation takes place and the plant litter is mechanically buried. The effect of earthworms on soil structure is still being debated. Some aspects of the effect of cultivation on soil have been studied in England by Low (1976). He looked at the effects of long periods in pasture on 34 mineral soils by contrasting some of their physical, chemical and biological characteristics with similar soils of the same locality which had predominately arable history in living memory. The old grassland soils contained more organic matter, more total pore space, had aggregates of greater water-stability, held more water at both the sticky point and lower plastic limit, contained

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more worms but had smaller bulk density. The water stability of old grassland soil aggregates was correlated with the clay content of the soil. Low (1976) attributed most of the improved soil structure to the plant roots but Swaby (1950) showed that the action of earthworms is important in forming water-stable aggregates. He also found that earthworm casts from pastures were much more stable than those from cultivated soil. Swaby's experiments suggested that this was due at least in part to the presence of more dead plant material in the pasture soil than the cultivated soil. He showed that when earthworms feed on soil rich in organic matter their casts contain high populations of bacteria which are believed to produce gums and so stabilise the casts. It is difficult to determine clearly the relative effects of earthworm and plant roots on the formation of good soil structure because most old established temperate grasslands have developed with earthworms.

As well as altering the physical properties of the soil earthworms play an important role in the decomposition of organic matter. A study of Polish sheep grazed pastures where *A. caliginosa* was the dominant earthworm (Nowak 1975) has revealed some subtle details of the relationship between the earthworm population and the nutrient flow in the soil. He concluded that in fertile pastures the most important effect of earthworms is the retardation of organic matter degradation. Earthworms achieve this by storing organic matter in their bodies as they grow and by stimulating the growth of micro-organisms. The nutrients are then released slowly to the plants through the metabolism and death of the earthworms and micro-organisms. This slower release, allows a greater proportion of nutrients to be utilized by plants and reduces nutrient loss from the soil through leaching. The habit of earthworms casting on the soil surface may however contribute to loss of some nutrients, especially phosphorus, when surface water run-off occurs (Sharpley and Syers 1976).

ANNUAL CYCLE AND FIELD TRIALS

Most of the easily accessible literature on earthworms in pasture concerns work in England where the dominant earthworm is the large surface-feeding species *Lumbricus terrestris*. This species is rare in New Zealand pastures where the common species are the topsoil-mixing species, *A. caliginosa* and the dung- and surface-feeding worm, *L. rubellus*. Because of these differences it has been necessary to adopt different sampling techniques (Martin 1976; and below) and to establish the annual life cycles of the important species present in New Zealand. The several topsoil-mixing species have similar annual cycles, so that, while it is desirable in trial work with earthworm-toxic pesticides to distinguish between each species, they can be considered together. They should, however, always be distinguished from surface-feeding species such as *L. rubellus* which has a different effect on the soil as well as some differences in its annual cycle. Fig. 1 shows the similarities and differences between the life cycles of *A. caliginosa* and *L. rubellus*. Both species are active only when the soil is moist and during the first half of the wet season their biomass increases. Both species produce most of their eggs during the spring, but all the *A. caliginosa* eggs hatch during the late spring and early summer, whereas most *L. rubellus* eggs hatch in the autumn when the soil is wet again. A high proportion of large *A. caliginosa* worms survive the summer, coiled up in cells in the soil, whereas very few large *L. rubellus* survive a normal summer. Highest mortality in both species occurs during the dry summer months. In a wet summer more small *A. caliginosa* survive and grow into the middle immature class. Where the number of worms present in the winter is much higher than average for a particular paddock, early depletion of food, low egg production and high mortality in the late spring occurs. This happened in some trial plots near Hamilton in 1976.

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FIG. 1: Generalised annual cycles of *A. caliginosa* and *L. rubellus* in pasture soil.

- a. Changes in biomass during the wet and dry seasons;
- b. *L. rubellus*, numbers;
- c. *A. caliginosa*, numbers.

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SAMPLING CONSIDERATIONS

Timing

Consideration of the annual cycle of *A. caliginosa* provides some guidance to the timing of sampling and interpretation of the results of field trials with earthworm-toxic pesticides. When the pesticide is applied in the autumn there is no natural change in numbers of earthworms until the late spring when eggs start hatching. Therefore the post-treatment samples need only be taken once during this time unless the pesticide is suspected of having a delayed effect. If sampling is left until the winter the small worms should have grown into the middle immature class and this will make sorting of samples easier and more accurate. If biomass is also being estimated and sampling is left until late winter or early spring, some allowance has to be made for compensatory growth of the surviving earthworms in the treated plots. The second post-treatment sample should be taken the following winter when the next generation of worms is present. Sampling in the late spring and early summer should be avoided because the high number of very small worms extracted will bear little relation to the number of worms which will survive the summer.

Plot size

Pitfall trapping in Auckland has confirmed that clitellate and submature *A. caliginosa* move over the pasture surface during very wet weather. Treatment differences in small plot experiments can be masked by this behaviour (Martin 1976). Experience has shown that plots 3 and 5 m wide are too narrow to prevent immigration from masking the effects of earthworm-toxic pesticides. The minimum width has not yet been determined experimentally.

Number and size of samples

None of the populations of *A. caliginosa* examined was normally distributed and all the sample data needed the square-root transformation. Even after this, the sampling error remained high and estimates of the number of samples needed to achieve a 10% standard error of the mean were often high for the amount of work involved in processing the samples. However the distribution of the biomass within the samples was sometimes normal or almost so. If 15-20 samples per treatment are taken major differences between *A. caliginosa* populations should be detected. Low mortality due to pesticides does not appear to be of consequence when compared to natural population fluctuations.

Sample sizes used were a 178 mm spade square (0.03 m²) and a 10 cm diameter soil corer (Kain and Young 1975). While both tools have been used to estimate earthworm populations no comparison has been made at the same time on the same site.

Extraction

The different techniques for extraction of earthworms are described by Edwards and Lofty (1972). The simplest and quickest technique which suits most New Zealand conditions (where the eggs are not required) involves hand-sorting part of the sample in the field and washing the remaining earthworms out of the turf in the laboratory. Soil samples should be 150-200 mm deep. The top 40-60 mm of the sample is put in a plastic bag. The remaining portion is broken up on a tray and hand sorted for earthworms which are put in a small jar containing 5% formaldehyde. In the laboratory the turf is broken into small pieces each of which is washed on a sieve (aperture about 1mm). The worms found are put with the previously collected specimens. After 4-5 days the worms will have hardened and can be identified (Martin 1977) and weighed. The live

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weight of *A. caliginosa* is about 1.33 times the wet weight after storage in 5% formaldehyde.

While recent work has provided some practical guidance for trials with earthworm-toxic chemicals, there are still a few areas where further work is needed. These include the development of a laboratory screening procedure to discover which pesticides are toxic to topsoil-mixing earth-worms such as *A. caliginosa*.

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