Burial of lime by earthworms in acid soils in Western Australia

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Abstract

Two exotic earthworms, *Aporrectodea caliginosa* and *A. trapezoides*, are patchily distributed throughout agricultural fields in the higher rainfall regions of southern Australia, where soil acidity frequently limits agricultural production. The abilities of *A. caliginosa* and *A. trapezoides* to bury surface-applied lime and thus help ameliorate soil acidity were measured in cages in two pastures on acid soils in Western Australia (at Jennacubbine and Kojonup). The experiments ran for three months in winter-spring. Both earthworm species increased lime burial down to 10 cm depth at Jennacubbine (soil pH up approximately 0.5 of a unit). *A. trapezoides*, but not *A. caliginosa*, also increased lime burial to 10 cm depth at Kojonup. Agricultural management practices which enhance the abundance of these earthworms and introductions of them to sites where they have yet to establish could help reduce soil acidity.

Key words: earthworms, soil acidity, lime burial, pastures, Western Australia

Soil acidity is a major contributor to soil degradation and reduced plant production in several million hectares of agricultural land in Australia (9). Lime is commonly added to the soil surface to offset this acidity, but can be slow to be incorporated to the depths where it is most needed (11). Overseas, some earthworm species (most notably *Aporrectodea* spp. from Europe) have proven capable of significantly enhancing the burial of surface-applied lime and ameliorating soil acidity (14, 15). These same species have been accidentally introduced into agricultural soils in southern Australia, but their current distributions are patchy and their population numbers are generally low (1, 7). Recent CSIRO research (1, 3, 6, 8) has focussed on the abilities of these earthworms to bury lime in pastures and croplands in south-eastern Australia. This paper reports the results of two field experiments run in 1996 in south-western Australia. The work is part of an overall program aimed at improving the management of earthworms as a resource in agricultural soils in southern Australia (1, 2).

Materials and methods

Field cage experiments were established at two sites in Western Australia, one used for wheat, lupins and pasture at Jennacubbine and the other for permanent pasture at Kojonup. The site at Jennacubbine had volunteer pasture in 1996. Average annual rainfall at Kojonup (550 mm) is higher than at Jennacubbine (425 mm). Cages were constructed from 25 cm sections of 30 cm diameter PVC pipe, inserted 20 cm into the soil in September 1995 (see Baker *et al.* (4) for method). There were 72 cages at each site. Curtain mesh was strapped taut across the bottom end of the PVC pipe in all cages in March 1996, when most resident earthworms were likely to have burrowed deeper than 20 cm into the soil to aestivate (5). Thirty adults of two earthworm species, *Aporrectodea caliginosa* and *A. trapezoides* (Lumbricidae), were added to 18 cages, respectively, at each site in July, 1996, when the soils were moist. The worms were collected from pastures near Adelaide, South Australia. No earthworms were added to the remaining 36 cages at each site (controls). Lime (equivalent to 4 t / ha) was then added to the soil surface of all cages that received worms and half the control cages. For half the cages in each treatment, curtain mesh was strapped taut across the top end of the PVC pipe (*i.e.* above ground) to prevent the worms escaping whilst they established their burrow systems. The centres of the mesh were later removed, leaving a hole of approx. 20 cm diameter to allow plant growth. The other half of the cages within each treatment had mesh bags draped over metal frames (30 cm high) and strapped at their open ends to the top of the PVC pipe. This alternative design also restrained the worms, as well as allowing plant growth.

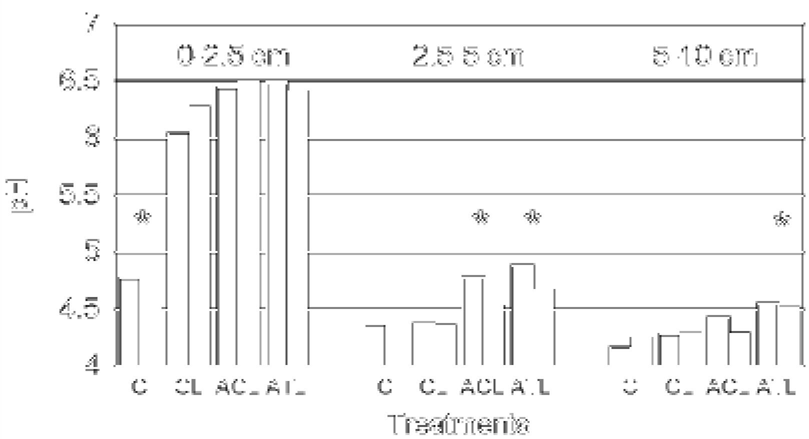
In October 1996, two soil cores (5 cm diam, 10 cm depth) were taken centrally within each cage with a metal corer. These soil cores were divided into sections of 0-2.5, 2.5-5 and 5-10 cm depth. The paired soil samples for each depth within a cage were bulked, air-dried and then lightly ground (<2 mm). Soil pH was measured in 0.01 M $CaCl_2$ (soil : solution ratio of 1:5). The remaining soil within all cages was hand-sorted for earthworms.

Results

The soil was still moist at Kojonup in October and earthworms were active within the cages and adjacent pasture. Few local worms (*A. trapezoides*, *A. caliginosa* and *Microscolex dubius*) contaminated the control cages (< 1 worm / cage). The numbers of *A. trapezoides* and *A. caliginosa* recovered from the other cages were much higher (12.0 / cage for *A. trapezoides* and 13.6 / cage for *A. caliginosa*), suggesting that survival of the introduced worms was about 40-45%. The recoveries of worms did not vary between species (ANOVA $F = 0.43$, $P > 0.05$), nor with cage design ($F = 0.43$, $P > 0.05$).

The soil at Kojonup was acidic (Fig. 1a). Liming increased soil pH substantially at 0-2.5 cm depth ($F = 128.60$, $P < 0.001$). At 2.5-5 cm depth, liming in the presence of *A. trapezoides* and *A. caliginosa* increased soil pH ($F = 13.60$, $P < 0.001$), but without the added worms no effect of liming was recorded. At 5-10 cm depth, liming increased soil pH in the presence of *A. trapezoides*, but not *A. caliginosa* ($F = 7.15$, $P < 0.001$) (Fig. 1a). There was no significant effect of cage design on soil pH ($F = 1.46$, $P > 0.05$).

(a)



(b)

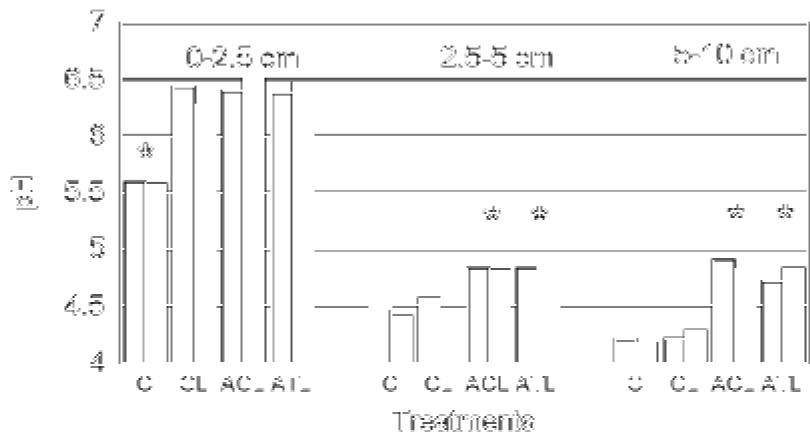


Figure 1: Soil pH at different depths within cages at (a) Kojonup and (b) Jennacubbine. C = Control, no

lime; CL = Control + Lime; ACL = *A. caliginosa* + Lime; ATL = *A. trapezoides* + Lime. * = significantly different from CL treatment. Shaded columns = flat mesh tops on cages; open columns = high mesh tops.

The soil at Jennacubbine had dried by October. No earthworms were found in the control cages and only a few in the other cages (4.5 / cage for *A. trapezoides* and 5.8 / cage for *A. caliginosa*, *i.e.* about 15-20% survival). All worms were inactive, aestivating in spherical chambers near the bottoms of the cages. Substantial evidence of earthworm burrowing was, however, observed in the cages where worms had been added, suggesting survival earlier in the experiment had been high. The recoveries of worms did not vary between species ($F = 0.31$, $P > 0.05$), nor with cage design ($F = 0.18$, $P > 0.05$).

The soil at Jennacubbine was also acidic (Fig. 1b). Again, liming increased soil pH at 0-2.5 cm depth ($F = 29.22$, $P < 0.001$). Both earthworm species increased soil pH at 2.5-5 cm depth ($F = 8.17$, $P < 0.001$) and 5-10 cm depth ($F = 13.23$, $P < 0.001$), but the addition of lime without worms had no effect at these depths (Fig. 1b). Cage design did not alter soil pH ($F = 0.02$, $P > 0.05$).

Discussion

A. trapezoides increased soil pH down to 5-10 cm depth at both sites in Western Australia, within three months. *A. caliginosa* also increased soil pH down the profile, but not as extensively (*e.g.* only down to 2.5-5 cm depth at Kojonup). These results match similar findings in pasture and cropped soils in South Australia and Victoria (1, 3, 6, 8).

There is no evidence to suggest that earthworms can alter soil pH in the absence of added lime, at least not in the time frame and on the scale (volumes of soil) used for the field experiments described here (3, 4). It is therefore reasonable to conclude that the observed increases in pH below the soil surface reflected enhanced burial of the surface-applied lime due to worm activity. The lime was probably washed down the earthworm burrow systems by rain water.

Another introduced lumbricid, *A. longa*, burrows deeper than *A. trapezoides* and *A. caliginosa* and thereby enhances deeper burial of lime (1, 6). Field studies in South Australia, Victoria and Tasmania have also shown that all three species can significantly increase pasture production (6, 17). Baker (1, 2) has suggested that introductions of these species to pastures lacking them in southern Australia could prove highly profitable, as it has with other earthworm introductions overseas (16).

Many field trials have been conducted in Australia to evaluate pasture and crop responses to liming acid soils (10, 12, 13). Lime movements down the soil profile and plant yields have been very variable, both between years and between sites. Very rarely have variations in the abundance of soil fauna, such as earthworms, been considered when explaining these differing responses. The present study suggests they should be.

Baker *et al.* (3, 4, 6, 8) have used cages with either flat or high mesh tops separately at different sites to assess the survival of introduced earthworms and their impacts on lime burial and plant production. G. Baker and V. Barrett (unpublished data) have found that soil moisture tends to be slightly higher in the cages with flat tops, but the results reported here suggest that varying the design of the cage top has no effect on worm survival nor on lime burial.

The earthworms survived poorly during the experiments, especially at Jennacubbine. Several factors could have contributed to the poor survival (e.g. damage during collection and transport of some of the worms from South Australia, insufficient food in the cages to support all the worms that were added, soil too dry in the cages). The latter was very probably important at Jennacubbine. The soil was already quite dry there in October when earthworm survival was assessed. Many earthworms may have died as a consequence of this. The presence of aestivating worms at the bottoms of the cages suggested that the normal retreat of worms to greater depths in the soil in summer to escape aridity (5) had been prevented by the curtain mesh.

Conclusions

The exotic earthworms, *A. trapezoides* and *A. caliginosa*, can increase the burial of surface-applied lime in acid, agricultural soils in southern Australia. Introduction of these earthworms to sites which lack them and management practices which increase their abundance are likely to significantly assist in reducing soil acidity.

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