# EARTHWORMS AND THE DECAY OF PLANT LITTER AND DUNG-A REVIEW

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#### I. POPULATIONS

Where exotic herbage plants are grown in southern Australia and New Zealand, European lumbricid worms are often numerous. They tend to replace the indigenous earthworm species (Miller, Stout, and Lee 1955), as well as other litter feeders such as the Termitidae that are adapted to the natural grasslands.

Earthworms are abundant not only in moist localities, but also under annual pastures in areas where they have to survive dry summers. Although some species tunnel into the subsoil to avoid drought, the more commonly found lumbricids remain in the dry top soil where they survive the loss of three quarters of their water content. At the other extreme, prolonged flooding causes death, but earthworms tolerate short periods of flooding, and very large numbers are found under pastures irrigated by flood methods.

#### II. FOOD INTAKE

The feeding habits of different groups of soil animals have been described by Birch and Clark (1953). It is clear that earthworms should be regarded as only one example of the wide variety of animals that ingest litter, dung, and dead roots.

Little is known about the amount of leaf litter or dung ingested by particular animals in Australian soils. When given a choice between herbage litter, dead roots, and dung, the lumbricid *Allolobophora caliginosa* (Sav.) ingests 1% of its own weight of dung per day (Barley 1959). At Adelaide a population of 80 g/sq.m. is active for 150 days per year on pasture land, and the corresponding estimate of the rate of consumption of dung is 120 g/sq.m. (1,000 lb/acre). This estimate suggests that earthworms may bury a significant amount of dung in the field.

#### III. INFLUENCE ON MINERALIZATION

Questions such as "What proportion of decay is brought about by soil animals compared with microbes?" or "How much decay is brought about by this particular animal?" are naive, as ony one kind of animal has to be considered as a member of a food chain. The transformations undergone by leaf litter or **dung** in a food chain may be compared if the quantities are measured in energy units, and the energy is partitioned between respiratory heat, faeces, and living

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tissue. However, not nearly enough is known in practice to construct quantitative energy diagrams, and for the present we have to be content with measurements of heat production or oxygen consumption of particular **decomposers**. Fortunately, for longer lived animals respiration is the major component.

The direct contribution made by earthworms to decay can be estimated from respirometer data. At 15°C the oxygen consumption of worms of bodyweight 0.2g—a mean commonly found for field populations-is in the region of  $100 \,\mu l$ per g bodyweight per hr. The metabolic rate in the field is likely to be less than that measured in a respirometer, and a generous estimate is 50  $\mu$ l per g per hr. For a population of 80 g/sq.m. active for 150 days this rate corresponds to an oxygen consumption of 14 l./sq.m./year. This figure may be compared with the total amount of oxygen consumed in decay each year on pasture land at Adelaide. A pasture producing 7,000 lb dry matter per acre (8,000 kg/ hectare) returns the following amounts ('000 lb/acre) of material to the soil: herbage litter, 3.5 (Carter 1962); dung, 1.4 (Hutchinson and Porter 1958); dead roots, 1.4 (root:shoot ratio 1: 5); total 6,300 lb/acre. The increase in residual organic matter per year, corresponding to an addition of 0.004%nitrogen in the top 6 in. of soil, is 1,600 lb/acre. The amount of material oxidised is 6,300-1,600 = 4,700 lb/acre  $\approx 500$  g/sq.m. This is nearly equivalent to the weight of oxygen consumed or to a volume of  $\frac{500}{32} \times 22.4 = 350$  l./sq.m./year. Thus, neglecting other members of the food chain, earthworms bring about only a small fraction, of the order of 4% of the total decay.

The important process carried out by earthworms, together with certain other members of the macrofauna, is the incorporation and mixing of litter **and** dung with the soil. The process often enables soil microbes and other decomposers to act more rapidly. In pot culture earthworms have been found to produce a 160% increase in the net rate of mineralization of herbage clippings (Russell 19 10), and to bring about an increase in oxygen consumption twice that which could be attributed to the worms themselves (Barley and Jennings 1959). Large effects on decay may be found in the field, particularly when the soil animals remove litter and dung from an intermittently dry surface and mix the material with moist earth.

Although field data are available for forest soils (van der Drift 195 1; Kurcheva 1960) little field data on the role of the invertebrate fauna have At Hindon, New Zealand, the introduction of the been obtained for pastures. lumbricid, A. caliginosa, into sown pastures has led to the mixing of lime and litter lying on or near the surface with the top 6 in. of soil (Stockdill 1959). On the Riverine Plain in Australia it has been found that a mat of leaf litter and dung accumulates when dry grasslands are first irrigated and sown with exotic pasture plants. The endemic fauna that incorporates litter does not appear to be effective on the irrigated pastures, and it has recently been shown (Barley and Kleinig 1964) that the establishment of a dense population of A. caliginosa leads to the disappearance of the mat. As the mat contains as much as 130 lb/acre (147kg/hectare) of nitrogen in organic forms, there will be much interest in measuring any change in mineralization rate that may accompany earthworm activity.

Bornemissza (1960) drew attention to the long period-six months or more-during which dung pads remained on top of the ground at Boolarra, Victoria. He suggested that the endemic coprophagous insect fauna was not well adapted to the dung of introduced livestock, and that the introduction of new scarab species might lead to more rapid incorporation of the dung. In the present stage of knowledge a broad view of any possible deficiencies in the Australian invertebrate soil fauna is desirable, and observations should not be confined to one or two families of soil animals.

## IV. IMMOBILIZATION OF NUTRIENTS IN WORM TISSUE

We have seen that the direct effects of earthworms on decay are small, but the indirect effects may sometimes be large. We should also consider the amount of nutrients that may be incorporated in or released from body tissue when the animals increase or decrease in weight. As the total nitrogen content of the soil fauna in temperate grasslands is of the order of 50 lb/acre (57kg/hectare), such changes may not be entirely negligible in relation to amounts of nitrogen available for pasture growth.

Young, growing worms can digest a large part of the organic nitrogen in ingested litter (Needham 1957). Only about 5% of the organic nitrogen ingested is excreted in water soluble forms (Barley and Jennings 1959). When the worms are gaining weight and feeding on litter of moderate nitrogen content the rate of excretion of nitrogen in the urine is about 5  $\mu g/g/hr$ .(Haggag and El-Duweini 1959). After the worms have been fasted for several days there is a two to three fold increase in the rate of excretion (Cohen and Lewis 1949).

When earthworms. are feeding on litter or dung and increasing in weight, they temporarily immobilize nutrients in their own tissue. For example, on pastures at Palmerston North, New Zealand, the weight of the earthworm population increases from a minimum of 140 g/sq.m. in summer to a maximum of 300 g/sq.m. in the early winter (Waters 1955). This corresponds to the incorporation of 3.5 g/sq.m. (30 lb/acre) of nitrogen in worm tissue. Transformation to worm tissue may partly account for the lag in plant response to the return of dung-nitrogen in the experiments of Sears and Newbold (1942).

### V. EFFECTS ON PASTURE PRODUCTION

Where earthworms are absent or few in number, it will usually be found that the soil is not suitable or that there is insufficient food to support larger numbers. The mere addition of more worms will not lead to any permanent increase in the population. In what circumstances, if any, is the deliberate introduction of earthworms likely to lead to a permanent increase in worm numbers, and perhaps to an increase in productivity? There may be some possibilities, particularly where previously unsuitable areas have been changed in ways that make them suitable for 'earthworms. As the rate of spread of earthworms is slow, a long period may elapse before worms fully occupy new areas. For example, when previously arid lands are developed for the production of irrigated pastures, conditions suitable for dense earthworm populations are likely to be created. However, if the area is isolated, more than 10 years may elapse before suitable species are accidentally introduced, and a further period of 10 years may be required before populations build up to high levels (Barley and Kleinig 1959). There may be other situations where there is a lag between the establishment of favourable conditions and the arrival of adapted earthworm species : for example, after the drainage of previously swampy lands, after the liming of acid soils, or after the change-over from scrub lands to productive pastures.

There is evidence from field trials in New Zealand to show that the introduction of earthworms of southern European origin can increase the yield of sown pastures (Hamblyn and Dingwall 1945; Richards 1955; Stockdill 1959). In the New Zealand experiments, begun in 1926, earthworms were introduced into areas that were isolated, or where the soils were naturally acid and had recently been limed. Th populations spread from inoculated sites at the rate of 10m./year, and after four to eight years the areas populated by the worms were producing an additional 2,000 lb/acre (2200kg/hectare) of the dry matter in the winter-spring period.

It has yet to be shown whether the introduction of new members of the soil fauna has changed, or is likely to change, the productivity of Australian pastures.

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