THE ROLE OF EARTHWORMS IN NITROGEN RELEASE FROM HERBAGE RESIDUES

A Thesis presented in partial fulfilment
of the requirements for the degree
of Master of Agricultural Science in Soil
Science at Massey University

Belarmino Emilio Ruz Jerez

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ABSTRACT

Decomposition and nutrient release from pasture litter were examined in two biotic systems; either with or without large organisms ("macrobes"). Earthworms were the test macrobe and nitrogen (N) the test nutrient.

This experiment addressed the hypothesis that consumption of herbage residues by macrobes, as opposed to microbes, should result in more of the contained N becoming available for uptake by plants or for loss processes, because macrobes oxidise a greater proportion of the contained carbon (C) by energetics.

Earthworms influenced both soil metabolism and mineral N availability, irrespective of litter type (ryegrass or clover) and temperature (15 or 22.5 C). Carbon dioxide evolution and oxygen consumption increased by 26% and 39%, respectively, in the presence of earthworms. After an 11-week incubation about 50% more mineral N was recorded in the soils containing earthworms. Moreover, less microbial biomass was recorded in the presence of worms.

This influence of macrobes carried over into a subsequent, exhaustive cropping experiment, using ryegrass as the test plant. Where soils had been previously influenced by earthworms, there was a significant increase in plant growth and N uptake.

Carbon dioxide evolved during incubation was highly correlated with soil mineral N ($r= 0.84^{**}$) present at the conclusion of incubation, and also with subsequent plant dry matter yield ($r= 0.75^{**}$) and plant N yield ($r=0.85^{**}$).

The link between elaborated C and contained N has long been recognised as providing stability to organic residues in soils. In the design of this experiment, other influences of macrobes (e.g.

mixing or structural influences) were largely obviated, so one can conclude that nitrogen availability was increased primarily through carbon respiration by the macrobial population. These results offer a fresh perspective on the balance between mineralisation and immobilisation in the soil-plant complex and, hence, on the dynamics of nutrients contained in organic matter. Better understanding of these relationships may allow improved management of the dynamics of soil organic matter in temperate grassland ecosystems.

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GENERAL INTRODUCTION

"Biological" soil fertility involves nutrient release by decomposition of pasture litter and mineralisation of resident organic matter. Consideration of this complex topic, as it relates to well-developed grass-clover pastures in New Zealand is the central focus of this study.

In spite of the comparative success of clover-based pastures in facilitating a high level of production from ruminant animals (Levy, 1970) most NZ soils in their improved state still exhibit a considerable degree of nitrogen (N) deficiency, at least seasonally (Field and Ball, 1978; Steele, 1982). To overcome this problem, fertiliser N may be introduced periodically (Ball and Field, 1982). However, the escalating cost of fertilisers, increased transport and spreading costs, the potential for suppressed exploitation of symbiotic N-fixation (Ball and Crush, 1986) and the risk of contaminating freshwaters (Burden, 1982) have all drawn attention to studies into improving the efficiency with which N is cycled in pasture soils (and also other nutrients contained in organic matter, notably P and S), and the prospect for exploitation of biological fertility.

Nutrient cycling in grassland ecosystems is of major importance to the build-up and maintenance of soil fertility. This is because only a small fraction of net primary production is consumed and respired by domestic herbivores; the greater proportion is transferred to the soil system. Thus, the soil decomposers are responsible for processing most of the primary biomass production within the ecosystem. However, this pronounced accumulation of organic matter in grassland soils does not neceassarily imply any immediate improvement in supply of nutrients to plants, since the nutrients are substantially stabilised with C in elaborated organic compounds. Jackman (1960) highlighted the substantial quantities of N, P and S immobilised in soil organic matter during the early phases of pasture development; for N some 110 kg N/ha/yr. Therefore, it is important to consider how organic residues are incorporated by the decomposer network and how the subsequent activities of organisms effect C oxidation and hence mineralisation of essential elements, so releasing them for recycling within the ecosystem.

It has often been assumed that nutrient mineralisation is mainly a result of the activity of microflora (bacteria and fungi), while the soil fauna is considered to have only a minor direct influence (Barley, 1961; Golebiouska et al., 1977). Most attempts to quantify the role of the soil fauna in organic matter decomposition have concentrated on measures of respiratory metabolism. On this basis the macrobes (larger organisms) have been classed as insignificant in effect, and their ecological role has tended to be obscured. While it is known that metabolic activity is a key feature in determining mineralisation rates, it is still not possible to relate metabolism rates to nutrient mineralisation rates in quantitative terms, for all the major components of a soil population. It should not be assumed that a unit of respired energy from microbes is equivalent to the same unit of energy respired by heterotrophic invertebrates in terms of an absolute rate of mineralisation. One technique for evaluating the effect of macrobes in plant litter decomposition is to compare the release of plant nutrients following the mineralisation of plant materials.

O'Neill and De Angelis (1981) presented a general analysis of the role of macrobes in litter decomposition, and they suggested that the biomass of macrobes expressed as a proportion of primary production is inversely related to accumulated organic matter. This indicates that despite the small contribution of macrobes, directly, to decomposition, they either stimulate microbial decomposition (Anderson et al., 1983) or are correlated with it. The outcome is a more rapid organic matter turnover and nutrient cycling where the faunal contribution is maximal (Heal et al., 1984).

Among macrobes, the largest decomposer dominating mull soils in temperate grasslands are earthworms. Densities of the order of 5 to 7 million individuals per hectare have been recorded in Europe by Satchell (1967) and in NZ by Sears et al. (1953). The size of earthworm populations has been closely related to pasture productivity in NZ (Sears et al., 1953; Waters, 1955; Stockdill 1966). By contrast, in soils without earthworms Stockdill (1966) concluded that much of the fertility was locked-up in the peaty layer of dung and dead plant material that accumulates at the soil surface. Decomposition became very slow and there was a definite break in the "fertility cycle".

The purpose of this study was to evaluate decomposition and nutrient release from pasture litter in two biotic systems; either with or without large organisms ("macrobes"). Earthworms were the test macrobe and N the test nutrient.

This project addressed the following hypothesis:

> "That consumption of herbage residues by macrobes, as opposed to microbes, should result in more of the N contained in litter becoming available for uptake by plants or for loss processes, because macrobes oxidise a greater proportion of the contained C by energetics."