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Investigating tree foliar preference by the earthworms *Aporrectodea longa* and *Allolobophora chlorotica* in reclaimed and loam soil

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ABSTRACT

Afforestation can improve the delivery of ecosystem services from reclaimed landfill sites. Tree health is a key determinant of ecosystem service delivery, and is directly impacted by soil quality; which is driven by biological processes in the soil, reliant on leaf litter inputs to function. Different tree species have different litter quality, affecting the degree to which they support biological processes in soils and the development of abundant and diverse soil faunal communities. In recognition of their key role in improving soil structure and fertility—key attributes of soil quality, earthworms have often been the subject of research as a part of land reclamation, and these organisms have displayed preferences for specific types of leaf litter. This work utilised a choice chamber design to measure the foliar material palatability of two tree species used in land restoration (*Alnus cordata* and *Acer platanoides*) as a food source for two common European earthworm species (*Aporrectodea longa* and *Allolobophora chlorotica*), and the effect of a reclaimed soil quality on earthworm growth, survival and feeding preferences. The research revealed that both earthworm species initially preferred the foliar material of *A. cordata* over *A. platanoides*, with the leaves of the latter requiring higher degradation to become palatable to earthworms. The consumption of fresh leaves showed these are a suitable food source for earthworms in choice chamber experiments, which historically have instead relied on senescent leaf litter. Finally, high survival rates of both *A. longa* and *A. chlorotica* in the reclaimed soil treatment, in addition to consumption of leaf material of two tree species now widely used on reclaimed landfill sites, demonstrated that these earthworm species are suitable candidates for inoculation to reclaimed land.

1. Introduction

The afforestation of reclaimed land, such as former landfill, can provide improved biodiversity, contribute toward climate change mitigation and adaptation, and improve the delivery of ecosystem services from the site (Bullock et al., 2011). In restored woodland, as with natural woodland, a key source of organic matter addition to the soil is from deposited leaf material (Lukac and Godbold, 2011). Tree species differently influence soil quality and soil faunal population development through the quality and quantity of their leaf and root litter (Swift et al., 1979a; Pigott, 1989; Muys et al., 1992; Reich et al., 2005; Rajapaksha et al., 2013). It is therefore of value, when planning woodland restoration, to understand whether the tree species planted are likely to provide litter which enables and encourages soil faunal communities to establish, thus supporting soil development and ecosystem service provision (Kibblewhite et al., 2008; Rajapaksha et al., 2013). Certain tree species, such as *Alnus cordata* and *Acer platanoides* are recommended for planting on reclaimed or industrial land, based on their tolerance for high soil pH and dry soil conditions (Hibberd, 1986). There is, however, currently a paucity of knowledge regarding the interaction between these two non-native tree species and native UK soil biota, making these important tree species to investigate further and compare to previous research with similar native species (Rajapaksha et al., 2013).

In recognition of their role in improving soil structure and fertility, earthworms have been the subject of research during land reclamation for over 50 years, e.g. (van Rhee, 1969; Curry and Cotton, 1983; Curry, 1988; Butt et al., 1995). Earthworm-mediated mineralisation of organic matter, improvement in nutrient availability, and subsequent improvements in plant growth, are likely to be greater in nutrient-poor soils (Jana et al., 2010). It has been demonstrated that certain earthworm species can distinguish

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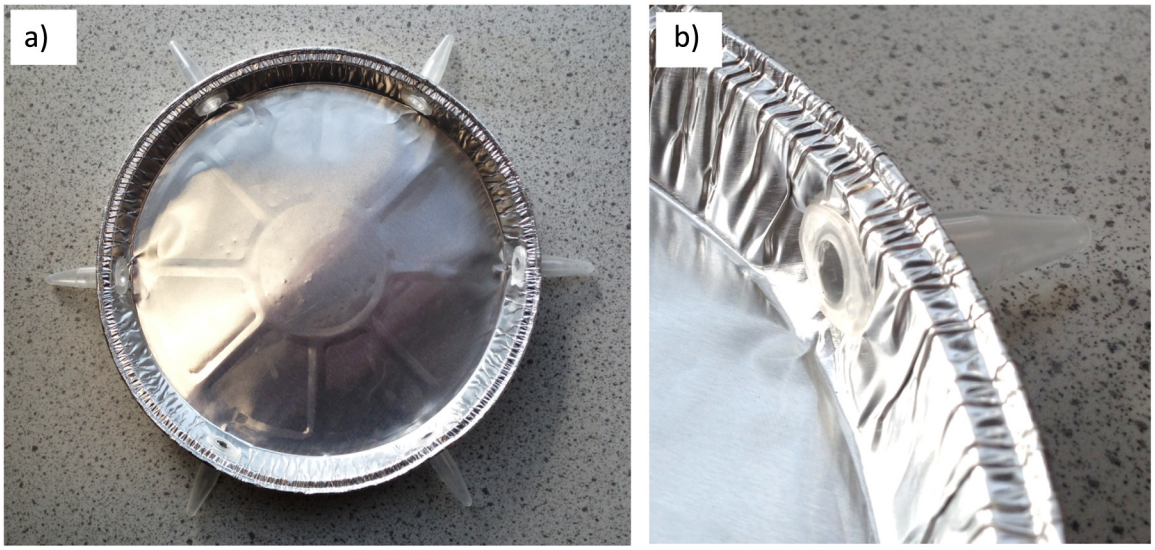

Fig. 1. a) Empty choice chamber prior to use in an earthworm-based foliar preference experiment, b) detail of empty Eppendorf tube food vessel fixed to the wall of a choice chamber via drilled cap.

between, and may show a preference for, specific types of leaf litter (Darwin, 1881; Satchell and Lowe, 1967). The chemical composition of litter appears to strongly influence earthworm selectivity, in particular aspects such as the C:N ratio and the content of nitrogen, calcium, lignin and polyphenols (Satchell and Lowe, 1967; Hendriksen, 1990). Earthworm preference has been observed for litter decomposed by micro-organisms and fungus, which is more palatable over fresh litter material (Satchell and Lowe, 1967; Wright, 1972; Cooke and Luxton, 1980; Cooke, 1983). However, there is also an indication that the higher nitrate content in dried green leaves can make these a superior quality food for earthworms than dried, senescent and weathered leaves (Butt, 2011a), yet little research has been conducted on this.

To date, the majority of laboratory-based earthworm feeding preference studies have either looked at how earthworm species respond to non-tree leaf material, or how the well-documented earthworm species *L. terrestris* responds to tree litter (Satchell and Lowe, 1967; Doube et al., 1997; Neilson and Boag, 2003). A notable exception is a choice-chamber study by Rajapaksha et al. (2013), which investigated how four European earthworm species respond to the litter of a set of common temperate tree species (common alder, common ash, silver birch, sweet chestnut and sycamore) and an exotic Eucalyptus species, using standard Kettering loam soil as a substrate. However, these results do not necessarily represent the activity of the same earthworms in woodland on reclaimed landfill sites, where alternative tree species and more inhospitable soil materials are likely to be present. Additionally, and to the authors knowledge, there is currently no information on how a combination of anecic and endogeic earthworm species perform in choice chamber feeding experiments, which would provide results more comparable to field conditions, where these two ecological groups often coincide (Lavelle, 1983). Whilst senesced leaf litter has been used as an experimental food source in previous choice chamber experiments (e.g. Rajapaksha et al., 2013), due to seasonal unavailability of such material this experiment adopted the use of freshly collected tree foliar material. Since green tree leaves have not been investigated in earthworm choice chambers to date, this provided the opportunity to gather novel information on this material as a food source for earthworms.

Therefore, the objectives of this study were to:

1. Measure the foliar material palatability of two tree species used in land restoration as a food source for earthworms, and influence on earthworm mass and survival,
2. Measure the effect of reclaimed soil on earthworm mass, survival and foliar selection behaviour, compared to a control (Kettering loam) soil,
3. Obtain data on the above from a combination of endogeic and anecic earthworm species relevant to landfill conditions.

2. Materials and methods

2.1. Choice chamber and experimental design

This experiment utilised the choice chamber design described by Rajapaksha et al. (2013), which is a modified version of Doube et al. (1997) and Rief et al. (2012). This design allows for earthworm food preference to be regularly monitored and quantified by removal of feeding tubes, with minimal disturbance to the central chamber and resident earthworms. The addition of soil to the central chamber rather than moist filter paper (e.g. Doube et al., 1997) provides more natural environmental conditions for endogeic and anecic earthworm species, and in this experiment also allowed for comparison between two soil types. This experiment investigated tree foliar preference by two species of earthworm; *Allolobophora chlorotica* (endogeic) and *Aporrectodea longa* (anecic); both as monocultures and as a combined species treatment. Two soil treatments were investigated; Kettering loam and reclaimed soil. Five trays (replicates) were set up for each combination of soil treatment and earthworm culture (5 replications × 2 soils × 3 earthworm combinations = 30 trays in total). Six food tubes containing leaf material from two different tree species litter (e.g. three tubes per tree species) were arranged alternatingly around each tray, and the average mass loss of these per tree species per tray was measured.

The choice chamber design consisted of a circular aluminium foil tray (0.16 m diameter and 0.03 m depth) with standard Eppendorf tubes (0.01 m diameter and 0.04 m depth) spaced equally around the choice chamber and embedded into the tray walls as food containers (Fig. 1a). To enable the tubes to be affixed to the choice chambers and allow earthworm access to tube contents, the caps were removed from the tubes and a hole of