European Journal of Soil Biology 87 (2018) 46–52

Contents lists available at ScienceDirect

European Journal of Soil Biology

journal homepage: www.elsevier.com/locate/ejsobi

Effects of composted green waste on soil quality and tree growth on a reclaimed landfill site

Frank Ashwood[a,*], Kevin R. Butt[b], Kieron J. Doick[a], Elena I. Vanguelova[a]

[a] *Forest Research, Alice Holt Lodge, Farnham, Surrey, GU10 4LH, United Kingdom*
[b] *University of Central Lancashire, Preston, Lancashire, PR1 2HE, United Kingdom*

ARTICLE INFO

Handling editor: Stefan Schrader

Keywords:
Acer platanoides
Alnus cordata
Aporrectodea longa
Earthworm
Organic waste
Soil quality

ABSTRACT

The addition of composted green waste (CGW) into soil-forming materials during land reclamation can benefit tree growth by improvement of soil properties and provide an effective waste management solution. CGW addition may also assist the establishment of earthworm populations, which in turn aid soil development through their burrowing and feeding activities. An experiment was set up on a reclaimed landfill site, to measure the effects of CGW addition on soil physical and chemical quality and subsequently on the survival and growth of two tree species (*Acer platanoides* and *Alnus cordata*). A further objective was to measure the influence of earthworm (*Aporrectodea longa*) addition on the above. CGW addition led to significantly greater *A. cordata* growth (height and diameter) and increased survival rate. No benefits from CGW addition were observed on *A. platanoides* growth or survival, although this is likely due to soil drought conditions during establishment. CGW addition significantly increased levels of organic carbon and essential plant macro-nutrients in the reclaimed soil. Soil pH rose slightly across all treatments, with highest final pH under the control treatment. Earthworm inoculation, as used, was unsuccessful at increasing population density of *A. longa*. This experiment showed that CGW application can effectively improve tree establishment and soil quality on reclaimed landfill; however tree species selection is an important consideration, based on individual species tolerance and sensitivity to certain soil conditions. These findings will be informative to decisions on soil amendment and afforestation activities on similar reclaimed landfill sites.

1. Introduction

There is scientific and industry-based interest in improving the soil materials used in land reclamation for soft-end use projects, particularly through the addition of organic matter (OM) from waste streams such as composted green waste (CGW) [1–3]. Benefits of CGW in soil improvement include a source of plant nutrients such as slow-releasing nitrogen and high OM material input improving soil physical structure and water retention [3]. Despite availability of guidance regarding the amendment of soil-forming materials with organic wastes [2,4–6], these materials are not typically used during the creation of community woodland [7]. Little research currently exists which has specifically investigated CGW interactions with trees on reclaimed land. In one of the few relevant studies, Foot et al. [8] conducted a field experiment investigating the effect of CGW incorporation on soil development and establishment of sycamore (*Acer pseudoplatanus*) and Italian alder (*Alnus cordata*) on a capped landfill. Incorporation of CGW to 0.6 m depth and high rates of application (500 t ha^{-1}) of CGW were beneficial to the establishment of both tree species. Improved tree growth was attributed to provision of nitrogen to the N-limited sycamore and improving soil structure, enabling deeper root penetration and subsequently greater opportunity for nitrogen fixation by alder [8]. Reclaimed soils are widely heterogeneous [9], and tree survival and growth on reclaimed sites is based on individual species tolerance for soil conditions [10]. Further research is needed to build an evidence base for CGW effects on tree species and reclaimed soils, to inform and substantiate future land reclamation activities.

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 [11–13]. On reclaimed sites, the addition of OM to soil may benefit earthworm populations [14,15] and a range of organic waste types including CGW have been investigated for their suitability [15–17]. It has been shown that certain earthworm species (such as the deep-burrowing *Aporrectodea longa*) actively incorporate and mix organic waste materials into and within soils, improving mineralisation and benefiting soil fertility [14,18]. The supplementary addition of earthworms may therefore be an effective way of enhancing the benefits of organic waste utilisation during land regeneration. However,

* Corresponding author. Soil Sustainability Research Group, Forest Research, Alice Holt Lodge, Farnham, Surrey, United Kingdom.
E-mail address: francis.ashwood@forestry.gsi.gov.uk (F. Ashwood).

https://doi.org/10.1016/j.ejsobi.2018.05.003
Received 18 January 2018; Received in revised form 8 May 2018; Accepted 13 May 2018
Available online 22 May 2018

little research exists which investigates CGW interaction with earthworm populations in reclaimed soils [15,19,20]. The few available studies suggest that CGW can promote the development of earthworm populations on reclaimed sites, and may help promote soil development and tree growth; however uncertainties exist over species-specific earthworm interactions with CGW and tree species, particularly on reclaimed land.

An experiment was therefore set up on a reclaimed landfill site with the objectives to measure i) changes in soil physical and chemical quality over a two-year period following CGW addition, ii) the effects of CGW addition on the survival and growth of two tree species, and iii) the influence of earthworm addition on tree survival and growth, and on soil condition.

2. Material and methods

2.1. Study site

The experiment was conducted at Ingrebourne Hill Community Woodland, a 54 ha area of reclaimed land in Rainham, Essex, UK (51.527°N, 0.198°E). The area receives approx. 1500 h sunshine and < 600 mm rainfall per annum, and a mean daily maximum temperature of > 14 °C [21]. The site is a former gravel extraction and inert waste disposal landfill (1950s-1990s). It underwent clay capping, followed by placement of screened construction waste materials as soil substrate between 2000 and 2007. Soils at Ingrebourne Hill are comprised principally of sandy clay loam materials, with a high stone content [22]. Despite loose-tipping practices during site restoration, a survey 5 years after soil placement revealed heavy compaction (soil bulk density of > 1.5 g cm^{-3}) and a shallow tree rooting depth (0.1–0.3 m). Soils were slightly alkaline with a pH of 7.9 and average soil organic matter (SOM) was 4%. Soil extractable total N was low at 0.19 mg l^{-1}, with a C:N ratio of 29. Metal contents were within the UK soil guideline values for non-residential uses, and not considered to be at levels harmful to fauna and trees [23].

2.2. Experimental design

Fig. 1 shows the layout of the experiment, which consisted of five blocks, each containing a randomised arrangement of four 100 m^2 treatment plots: i) CGW addition only; ii) earthworm inoculation only; iii) both CGW addition and earthworm inoculation; and, iv) no treatment (control) (20 plots in total). Each 100 m^2 plot contained two monoculture planting stands (one per tree species, with 1 m planting distance between trees), separated by a 2 m intra-plot buffer zone to prevent mixed-species interaction effects. Prior to tree planting, each plot underwent complete cultivation of soil to 0.5 m depth by digging and mixing the soil with a 3 tonne 27 horse-power hydraulic excavator, to relieve soil compaction. For plots receiving CGW treatment, cultivation also included its incorporation into the soil, through surface application followed by thorough mixing during cultivation. A physical barrier to earthworm ingress/egress from experiment plots was installed during cultivation. This consisted of sheets of LDPE damp-proof membrane buried to 0.5 m depth, with 0.2 m above-ground along the perimeter of all experimental plots, considered suitable to prevent species movement between plots (after Bohlen et al. [24]). The whole experimental area was also surrounded by a conventional fence to prevent tree damage by the public and browsing animals (e.g. deer). The experiment was set up in April/May 2013 and ran for 24 months.

2.3. Experimental treatments

For CGW-treated plots, soil cultivation included incorporation of screened 0–25 mm PAS 100 "Soil Improver" grade CGW (courtesy of Viridor Waste Management Ltd, Croydon, UK) at a rate equivalent to 500 kg Total N ha^{-1} following legal limit set by Nitrates Directive (91/676/EEC) for the site which is in a Nitrate Vulnerable Zone (NVZ), and in keeping with guidance by Taylor [25] and Bending et al. [9]. Each CGW treatment plot received approximately 1 tonne CGW. Due to potential difficulty in mass determination of one tonne of CGW in the field, 2 m^3 of CGW (one digger bucket) was added to each plot, which equals approximately 1 tonne. At 10% N availability, this provided each 100 m^2 plot with 0.62 kg available N and 305 kg C. This application rate is equivalent to 30.5 kg C m^{-3}, resulting in an average initial total soil C concentration of 17.6% in CGW plots. A full summary of CGW nutrient content is provided in Table 1.

Amended soils were allowed to settle for one week prior to tree planting. Tree species selected for this experiment were Italian alder (*Alnus cordata* (Loisel.) Duby) and Norway maple (*Acer platanoides* L.); two species recommended for planting on reclaimed or industrial land based on their tolerance for high soil pH and dry soil conditions [10]. One-year-old root-trainer seedlings (the standard age for trees planted for forestry purposes) were obtained from nursery stock. Seedlings of both tree species (n = 21 per species) were planted in each plot (20 plots × 21 trees = 420 per species) as shown in Fig. 1.

This experiment also investigated the activity of the earthworm *Aporrectodea longa*, an anecic earthworm species previously identified as suited to land reclamation sites and involved in physical and chemical soil development [19]. Baseline survey post-cultivation revealed low numbers of *A. longa* (1 m^{-2}) across the experimental plots. In July 2013, one week after tree planting, the earthworm treatment plots were inoculated with additional *A. longa* to boost the population density. For inoculation, adult *A. longa* were collected using a mustard suspension vermifuge at a concentration of 50 g to 10 L of water, applied liberally to the soil surface in areas of earthworm casting in surrounding, non-experimental parts of Ingrebourne Hill Community Woodland. Adult earthworms of this species were visually identified in the field during collection, washed to remove vermifuge and briefly stored in trays containing freshly dug soil. In total, 4,200 adult *A. longa* were collected and transported to the experiment. As appropriate, earthworms were randomly assigned to trees, at a rate of five earthworms per tree. The inoculation consisted of earthworms being added to 5 cm deep freshly dug holes at the base of each tree, the soil replaced and soaked with fresh water. This inoculation rate tripled the baseline *A. longa* density in earthworm treatment plots to 3 m^{-2}.

2.4. Sampling and measurements

Tree survival and growth (height and ground-line diameter) were measured at six month intervals. Diameter was measured using callipers at the ground-line of trees, which is defined as the point on the main stem 2 cm above the soil surface [26]. To account for asymmetrical stem growth, diameter was measured twice, at right angles to each other, and the mean value recorded. The baseline diameter measurements were taken 2 weeks after tree planting, to allow soil at the base of the trees to settle. Tree height was measured using a tape measure, recording the vertical distance from the base of the tree to the uppermost point or tip.

At 0, 6, 12, 18 and 24 months, soil samples were taken from within each experimental plot for chemical analysis. This followed a 'W-shaped' sampling approach, whereby in each plot 21 samples were collected from 0 to 20 cm depth using a soil auger, and bulked into one sample per plot. This method ensures sufficient sampling cover per plot to account for the spatially heterogeneous nature of the soil [27]. Bulk soil samples had total C and N concentrations determined using a C:N Elemental Analyser (Carlo Erba (THERMO), FLASH EA 1112 Series), and total major elements (P, K, Ca and Mg) by inductively coupled plasma-optical emission spectrophotometry (ICP-OES) analysis after sulphuric acid digestion of the soil. Soil Moisture Content (SMC) was analysed by oven drying at 105 °C for 24 h; OM content was determined by loss-on-ignition (550 °C for 2 h), and soil pH was measured in water suspension. Extraction by 1M KCL-extraction was used on fresh soil for