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Research Paper

Use of inorganic substrates and composted green waste in growing media for green roofs

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Inorganic substrates are used as the primary component in green roof growing media because they can provide the desired physical properties and are thought to be physically, chemically and structurally stable over time. Inorganic substrates can be amended with organic matter to help establish vegetation on green roofs but there is little information on how this affects the physical properties; dry bulk density, water holding capacity and air filled porosity; of the resulting growing medium or whether the effects are the same for all inorganic substrates. Nine crushed brick and three crushed tile substrates obtained from five UK suppliers of aggregates were amended with 30% v/v composted green waste. The physical properties of the substrates and growing media mixes were determined using the gravitational drainage technique. Amending the inorganic substrates with composted green waste significantly improved the physical properties by reducing the dry bulk density and increasing the water holding capacity. Air filled porosity of inorganic substrates decreased with addition of fine composted green waste but aeration was always adequate for plant growth and survival. This provides evidence of the beneficial effects of inclusion of composted green waste on the physical properties of inorganic substrates for green roof growing media but highlights the fact that the responses to inclusion of composted green waste may be different for different inorganic substrates or grades of substrate.

1. Introduction

A green roof is a roof surface that has been purposely vegetated to provide economic, aesthetic or environmental benefits. Green roofs are increasing in popularity primarily because of the environmental benefits that they bring, particularly in urban areas (Dunnett & Kingsbury, 2008) where they are used to help relieve water run-off and peak flow associated with the predominance of hard landscaping (Emilsson & Rolf, 2005). Research has shown that green roofs are able to retain a substantial proportion of the annual precipitation they receive. Reported retention rates have varied from 20% (Buccola & Spolek, 2011) to 83% (VanWoert et al., 2005). The growing medium used on a green roof is influential in determining how much water is retained (FLL, 2008). The growing medium is also an important component of a green roof system because it supports the vegetation and provides habitat, particularly for invertebrates (Kadas, 2006) and birds (Fernandez-Canero & Gonzalez-Redondo, 2010).

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Low dry bulk density, high water holding capacity and high air filled porosity are the desired physical characteristics of growing media for green roofs. It is important for the dry bulk density to be low because it reduces the impact on the buildings load bearing capacity (GRO, 2011). High water holding capacity is also required to improve the water retention function of the system (Berghage et al., 2009) and support plant transpiration (Handreck & Black, 2002); it may also enable prolonged plant survival during periods of drought. High air filled porosity minimises water logging and is advantageous for gaseous exchange between the growing medium environment and plant roots (Raviv & Lieth, 2008). This is particularly important because green roofs often have very restricted growing media depths, sometimes as little as 25 mm, to reduce the impact on the buildings load bearing capacity. The entire growing media profile would therefore be water logged following rainfall events unless coarse materials are used. These properties can be found in organic substrates such as composted green waste but organic matter is not typically used as the primary component of growing media for green roofs. Organic matter content in growing media for green roofs greater than 12% mass is thought to present a fire risk (FLL, 2008). Organic matter can also decompose rapidly (Emilsson & Rolf, 2005) and can encourage excessive production of vegetation biomass which is then vulnerable to adverse environmental conditions such as drought (Nagase & Dunnett, 2011).

In comparison to organic matter, inorganic substrates are presumed to be physically (Weiler & Scholz-Barth, 2009), chemically (Friedrich, 2005) and structurally (FLL, 2008; Snodgrass & McIntyre, 2010) stable over time. Because of this, in Germany (FLL, 2008) and the UK (GRO, 2011) inorganic granular substrates are typically used as the primary components of growing media for green roofs. It is thought that inorganic granular substrates can provide many of the appropriate physical characteristics for a green roof growing medium (Dunnett & Kingsbury, 2008; Molineux, Fentiman, & Gange, 2009).

The inorganic component of growing media for green roofs is often chosen because of its low bulk density. For example, an accessible roof should have a minimum distributed loading capacity of 0.9 kPa (Sorrill, J., 2012. Pers. Comm. Mr J. Sorrill is the Manager of The Green Roof Centre, Sheffield, UK the national centre of excellence for green roofs). Based on this loading capacity the maximum bulk density of growing media at a depth of 75 mm when fully saturated with water would be 1200 kg m^{-3}. The dry bulk density of lightweight aggregates such as crushed brick and crushed tile is generally between 700 kg m^{-3} and 1800 kg m^{-3} (FLL, 2008); therefore, only lightweight aggregates with the lowest dry bulk densities would be suitable for use as growing media materials on a roof with this loading capacity without being amended with lower density materials.

Amending inorganic substrates with organic matter can favourably influence the physical properties of the resulting growing media because each component contributes its physical properties to the mix (Pokorny & Henny, 1984). Amending inorganic substrates with organic matter will often reduce the dry bulk density (Grosbellet, Vidal-Beaudet, Caubel, & Charpentier, 2011); increase the water holding capacity (Nagase & Dunnett, 2011) and increase the air filled porosity (Papadopoulos, Bar-Tal, Silber, Saha, & Raviv, 2008). Blythe and Merhaut (2007) observed that the dry bulk density of 127 horticultural growing media was negatively related to both water holding capacity and air filled porosity. The observed negative relationship suggests that water holding capacity and air filled porosity should increase when composted green waste is incorporated into a substrate with a higher dry bulk density because the dry bulk density of the resulting medium is lower than that of the original substrate.

Composted green waste is a recycled material which can be produced locally, adding value to the environmental credentials of a green roof system. As the organic component of green roof growing media, composted green waste can contribute positively to the physical requirements due to its low dry bulk density with high air filled porosity and water holding capacity (Raviv & Lieth, 2008). In addition it can contain nutrients for plant growth and survival (Raviv & Lieth, 2008). These will not typically be provided by an inert inorganic substrate and will help establish vegetation (Emilsson & Rolf, 2005).

There is little published research which addresses the changes in physical properties that occur when inorganic substrates for green roof growing media are amended with organic matter. This study, therefore, tested the null hypotheses:

- Type of inorganic substrate and inclusion of composted green waste have no effect on the physical properties; dry bulk density, water holding capacity and air filled porosity; of growing media for green roofs.
- There is no relationship between the physical properties of an inorganic substrate and a two component growing medium made with an inorganic substrate and composted green waste.

A laboratory experiment was conducted at Harper Adams University, Shropshire, UK to test these hypotheses on crushed brick and crushed tile inorganic substrates mixed with two grades of composted green waste. Inorganic substrates marketed for use as a primary component of growing media for green roofs and composted green waste were selected based on advice received from The Green Roof Centre, Sheffield, UK (Sorrill, J., 2009. Pers. Comm.).

2. Materials and methods

2.1. Inorganic substrates

Nine crushed brick and crushed tile inorganic substrates were obtained from five UK suppliers of aggregates (Table 1). The substrates were six types of crushed brick and three types of crushed tile. They were all marketed as being suitable for use as a primary component of green roof growing media.

2.2. Organic materials

Fine and coarse grades of composted green waste were obtained from the composting company, Vital Earth Ltd,