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Performance of geophytes on extensive green roofs in the United Kingdom

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ABSTRACT

Dwarf geophytes have great potential for use on extensive green roofs because they often come from arid areas and can survive dry and hot summer in a dormant state. However, there has been little research regarding geophytes on green roofs. This experiment was conducted to study the performance of 26 species of geophytes on a green roof during 2005–2006 in Sheffield, UK. The geophytes were grown at two substrate depths (5 cm and 10 cm) of substrate on a green roof without irrigation. To investigate the susceptibility of geophytes to competition from a covering of permanent plants, the geophytes were grown with or without a surface vegetation layer of *Sedum album*. Overall, the growth, survival rate, regeneration and flowering of geophytes were more successful at a substrate depth of 10 cm than of 5 cm, probably because of improved moisture retention, fewer temperature fluctuations and the protection from digging by animals. The flowering period was limited to spring, therefore, it is recommended to combine with other plant species such as covering plants. Geophyte species did not compete much with *S. album* and *Sedum* cover had no significant effects on the growth, survival rate, regeneration and flowering of geophytes in most species. *Iris bucharica*, *Muscari azureum*, *Tulipa clusiana* var. *chrysantha*, *Tulipa humilis*, *Tulipa tarda* and *Tulipa turkestanica* had good performance at the substrate depth of 5 cm. In addition, *Narcissus cyclamineus* 'February gold' and *Tulipa urumiensis* exhibited a successful performance at the substrate depth of 10 cm.

Introduction

Green roofs have gained global acceptance as a technology with potential to help mitigate the multifaceted and, complex environmental problems of urban centres (Clark et al., 2008). Extensive green roofs are characterized by their light weight, low maintenance requirements, little or no irrigation systems requirements and thin substrate depths (2–20 cm). They are widely used because they are easy to install on existing buildings without structural modifications and they are inexpensive (Oberndorfer et al., 2007). The most commonly used species on extensive green roofs are *Sedum* spp. because they can tolerate extreme temperatures, high winds, low fertility and limited water supplies (Durhman et al., 2006, 2007; Van Woert et al., 2005). Recently, biodiverse roofs are often used for extensive green roofs. This type of extensive green roof is used to recreate conditions found in typical urban brownfield sites in order to enhance their potential biodiversity value (Dunnett and Kingsbury, 2008). However, both *Sedum* roofs and biodiverse roofs often lack aesthetic appeal. *Sedum* spp. are usually evergreen, however, they only flower for a limited period and change little throughout a year (Kadas, 2006). Biodiverse roofs often lack the lush green appearance of green roofs and have an appearance similar to that of brownfields (Dunnett and Kingsbury, 2008). The visual appearance may not be a concern if the roof is generally not visible and is installed primarily for its functional attributes such as storm water retention (Getter and Rowe, 2006). However, aesthetics may be important if green roofs are visible and actively used.

Geophytes are important plants species that can adapt to harsh environment found on extensive green roofs. They are plants with a swollen storage organ, such as true bulbs, corms, tubers and rhizomes (Raunkiaer, 1934; Mathew and Swindells, 1994). Bulb (e.g. *Narcissus*, *Tulipa* and *Lilium*) has a short stem surrounded by fleshy scale leaves or leaf bases. Corm (e.g. *Crocus*, *Colchicum* and *Gladiolus*) consists of a swollen stem base covered with scale leaves. Rhizome (e.g. *Iris*) has a continuously growing horizontal underground stem which puts out lateral shoots and adventitious roots at intervals. Tuber (e.g. *Begonia*, *Anemone* and *Cyclamen*) has a thickened underground part of a stem (Oxford dictionaries, 2010). The structures are different, but these plants act in the same manner,

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i.e. these structures all play the role of storage organs that allow plants to retreat underground for long periods of dormancy (Garrett and Dusoir, 2004). There are several benefits of using geophytes on extensive green roofs. First, their ecological characteristics are appropriate for the green roof environment. Some geophytes are highly drought tolerant and may perform well on extensive green roofs without irrigation in the UK. These drought-tolerant geophytes often come from dry climates, such as South Africa, the Mediterranean basin and Central Asia (Kingsbury, 1996), where winters are wet and summers are hot and dry, with a short spring (Phillips and Rix, 1989). These plants can grow, flower and seed during cool moist seasons and disappear into the comparative cool of the earth during hot summers (Kingsbury, 1996). The growing season is short, and the plants use their stored energy to flower and quickly set seed during spring (Blamey and Blamey, 1979). Second, they produce colourful flowers early in the season when many herbaceous plants have not started growing. The early flowering of geophytes provides colours and is also very useful for providing nectar sources at a time of year when little else may be flowering on a green roof. The first spring-flowering geophytes are a lifeline for overwintering insects in search of nectar after a long period of dormancy (Dunnett, 2004). Third, they require little maintenance and their storage organs often act as a means of propagation (vegetative reproduction). Geophytes grow and flower for a short time after planting. After planting, geophytes usually require little maintenance while some multiply rapidly when the growth conditions are suitable. For example, *Muscari armeniacum* proliferated rapidly after appearing spontaneously on an over 30-years-old extensive grass roof in the UK (Dunnett and Kingsbury, 2008).

However, there are also disadvantages of using geophytes because the flowering periods of individual plants are relatively short and they become unsightly after flowering. In addition, geophyte species that are potentially suitable for extensive green roofs tend to exhibit winter to early summer growth. Thus, it is recommended that they are combined with other plants, such as like plants that cover the ground throughout the year. Mathew (1997) discussed the benefits of using creeping or carpeting plants with geophytes; the flower stems of geophytes receive some support and blooms are protected from soil splashes during heavy rain. However, it is necessary to avoid vigorous plants for cover plants with geophytes (Elliott, 1995). Previous studies have shown that the growth of geophytes was reduced because of competition with covering grass (Hughes, 1986). In a study of the competition between *Allium vineale* and *Lolium perenne*, emergence and growth of *A. vineale* were affected (Lezenby, 1961). These studies were conducted on the ground, but, it is predicted that vigorous covering plants may lead to nutrient removal and moisture stress (Hewson and Roberts, 1973).

Although there has been little research on how geophytes perform on extensive roofs, geophytes have been used on extensive green roofs. *Allium* spp. is one of the most commonly encountered geophytic genus on extensive green roofs (Dunnett and Kingsbury, 2008). Long-term research on extensive green roofs in Berlin showed that *Allium schoenoprasum* was the most dominant plant species throughout 20 years because of self-seeding (Köhler and Poll, 2010). *Lilium auratum* has been used in traditional thatched roofs in Japan for reinforcement and for its aesthetics. Dwarf geophytes may be more appropriate for extensive green roofs because they are more drought tolerant than large hybrids (Glattstein, 2005; Snodgrass and Snodgrass, 2006). Short species may also be better at withstanding wind on green roofs, whereas tall or top-heavy flowers would not withstand on a windy site (Rees, 1992). Storage organs of dwarf geophytes are also small; therefore, they can tolerate a shallow planting and are expected to be better adapted to thin substrates.

The aim of this study was to identify appropriate geophyte species for extensive green roofs and to investigate how substrate depth and covering plants of *Sedum* spp. may affect the performance of geophytes on extensive green roofs. The effect of substrate depth was studied because it often limits the root growth and the availability of water and nutrients and it may be an important factor that affects plant performance on extensive green roofs (Dunnett et al., 2008; Olly et al., 2011; Rowe et al., 2012). *Sedum* spp. were used as covering plants because they are one of the most frequently used species for extensive green roofs. In addition, compared with other plants, *Sedum* spp. are expected to offer less competition to geophytes because they are low growing plants with shallow roots and require little water and nutrients.

Methods

Experimental setup

The experiment was initiated in December 2004 on the roof of a four-storey commercial building near the city centre in Sheffield, UK. The green roof was framed by timbers and consisted of root protection barriers, drainage layers (Floradrain FD 25/25-E) and a commercial green roof substrate composed of crushed recycled brick and 10% organic material (Zinco sedum substrate and Zinco semi-intensive substrate 1:1, $\leq$7–15%, in which the granules measured <0.063 mm in diameter; salt content $\leq$2.5%; porosity 63–64%; pH 7.8–7.9; dry weight 940–980 kg/m^3; saturated weight 1240–1360 kg/m^3; maximum water capacity 25–42%; air content at maximum water capacity 22–38%; water permeability $\geq$0.064–0.1 cm/s) (Alumasc, 2006). Zinco substrate was obtained from Alumasc (Northamptonshire, UK). The substrate depth (5 cm and 10 cm) and covering plants (with and without *Sedum album*) were the variables. We tested substrate depths of 5 cm and 10 cm because a depth of at least 5 cm was necessary to cover geophytes. It was estimated that the substrate depth of 5 cm depth was too thin to allow the sufficient growth of some geophytes; therefore, a substrate depth of10 cm depth was also tested. Half of plots were left without covering plants to test whether *Sedum* spp. affect the performance of geophytes on extensive green roofs. There were three replicates for each combination; hence, a total of 12 plots were arranged randomly (Fig. 1). These plots received similar length of sunlight. Each plot measured 60 cm × 145 cm and was divided into 30 subplots (12 cm × 24 cm) (Fig. 1). Each plot was framed by timbers, however, there were no partitions between each subplot. In each subplot, three individual geophytes from a single species were planted in a line. Twenty-six plant species were planted as underground storage organs on January 14, 2005. Storage organs were small; from 1.5 cm to 3.0 cm. Therefore, subplots provide enough space to grow geophytes. Name of plants and their characteristics are described in Table 1. Geophytes were obtained from Dutchbulbs (Manchester, UK). They are popular plants for typical gardens and they are easy to get and low price. These plants were expected to be well-adapted to extensive green roofs because they naturally in European or Asian alpine regions mainly with rocky or stony substrate and relatively low temperature. They tended to be short height, which is appropriate for green roof environment to resist strong wind. Twenty-six subplots were used out of 30 subplots. 4 subplots were left empty. The empty subplots were chosen in random. The geophytes were planted at a depth of 3 cm below the substrate surface using two different total substrate depths, i.e. 5 cm and 10 cm (Fig. 1). *S. album* seeds (0.5 g) were sown in *Sedum* cover plots on April 30, 2005 as covering plants. The seeds were obtained from Jelitto (Schwarmstedt, Germany). *S. album* seeds were too small to distribute over the plot; therefore, they were mixed with horticultural sand. It took 1 year for *S. album* to cover