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Investigation of plant growth and flower performance on a semi-extensive green roof

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ABSTRACT

Understanding of plant growth and flower performance is crucial for appropriate planting design. This study was aimed to understand characteristics of growth pattern and flower performance in green roof plants and how plant species diversity effect these characteristics. A semi-extensive green roof was installed in 2005 and 54 species plant species were planted in 10 cm and 20 cm of the substrate in Rotherham, UK. Thirty-two quadrats (50 cm × 50 cm) were set up through the combinations of plant species diversity (high and low), planting density (high and low). Percentage of coverage and height of each species were recorded at every month from February to November 2006 in these 32 quadrates. Flowering time of each species was studied every two weeks from February to November 2006. Flowering time was various from plants; some showed a very long flowering time, over five months whereas some finished flowering within two weeks. The growth characteristics of individual plant species over time were categorized into six patterns of coverage and vertical growth pattern. Spread of individual plants was larger in high diversity of plants than those in low diversity of plants. Number of flowering was higher and overall flowering term was longer in the quadrats of higher plant species diversity than those of lower plant diversity. However, these tendencies were affected strongly by the combination of species used. Therefore, it is important to be aware of individual plant growth characteristics such as plant size, growth pattern and flower performance for planting design.

1. Introduction

Green roofs receive considerable attention because they are important strategies for solving urban environment problems, such as the heat island effect (Speak et al., 2013) and excessive water runoff (Nagase and Dunnett, 2012; Versini et al., 2015), and they create habitats that increase biodiversity (Baumann, 2006; MacIvor and Lundholm, 2011). Generally, green roofs are referred to as extensive or intensive. Extensive green roofs are characterized by shallow substrate depth, light-weight, low maintenance requirements and reduced need for irrigation and can be applied to existing buildings; however, plant selection is limited. *Sedum* spp. are the most widely used plants for extensive green roofs because they can adapt to harsh environments, including shallow substrate depth, limited water availability, wide temperature fluctuations and high exposure to wind and solar radiation (Nagase and Dunnett, 2010).

In contrast, intensive green roofs are characterized by thick substrate, heavy-weight, high maintenance requirements, and they generally require irrigation systems; they accommodate various plant types, including trees and shrubs. Therefore, intensive green roofs can be designed as roof gardens and are appropriate for accessible places such as commercial buildings. However, high initial cost, high maintenance and usually regular irrigation compromise their sustainability in comparison with extensive green roofs (Van Mechelen et al., 2014). Semi-extensive green roofs, sometimes called semi-intensive green roofs, combine the best features of extensive and intensive, with the same low or no input philosophy of the extensive roof and use similarly light-weight technologies. However, their slightly deeper layers of growing medium (100–200 mm) can accommodate a greater range of plant types (Dunnett and Kingsbury, 2008; Hopkins and Goodwin, 2011), and its instalment and maintenance are less expensive than those of intensive green roofs. Semi-extensive green roofs are relatively light weight and suitable for large-span roofs and retrofitting of commercial buildings (Hopkins and Goodwin, 2011). Moreover, semi-extensive green roof plants are predominantly herbaceous perennials, have long flowering and various leaf texture and colour.

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They are appropriate for accessible places and/or places that are visible from a small distance (Dunnett and Kingsbury, 2008).

Recent studies have investigated the benefits of high plant diversity on green roofs (Cook-Patton and Bauerle, 2012; Van Mechelen et al., 2015). Ecological studies showed benefits of high plant diversity, for example, better water capture, evapotranspiration and temperature reduction (Wolf and Lundholm, 2008; Lundholm et al., 2010), drought tolerance (Nagase and Dunnett, 2010), reduced water runoff and summer roof temperatures and greater biodiversity (Brenneisen, 2006). From an aesthetic viewpoint, diverse planting is recommended. Lee et al. (2014) studied green roof preference using photographs and showed increasing diversity was associated with higher preferences overall. More complex plant combinations may comprise various forms that enhance visual and structural diversity of the planting, and well-selected combinations provide diversity of form and colour and offer a long cumulative flowering season (Dunnett and Kingsbury, 2008). Therefore, studies on green roof plants are rapidly expanding the choices of plants for extensive green roofs. For example, survivability and growth on extensive green roofs have been studied under varying conditions of substrate type (Nagase and Dunnett, 2011; Razzaghmanesh et al., 2014), substrate depth (Boivin et al., 2001; Rowe et al., 2012) and irrigation (Kanechi et al., 2014). However, plant studies tend to be focused on survivability and function, with little consideration for planting design. Growth patterns and flower performance through growing seasons can be crucial factors in creating compatible combinations of species that together have long display seasons (Dunnett, 2004). As Snodgrass and McIntyre (2010) pointed out, percentages of various species change depending on the season, temperature, rainfall and various other variables. For example, some plants adapt well and spread quickly, whereas others require longer and some gradually die out. Hence, knowledge of plant growth pattern and flower performance could be used to inform formulations of plant combinations with continuous flowering periods and colour combinations and leaf textures (Kircher, 1998). Previous studies of annuals (Nagase and Dunnett, 2013a; Benvenuti, 2014) and geophytes (Nagase and Dunnett, 2013b) on extensive green roofs report flowering times and plant growth over

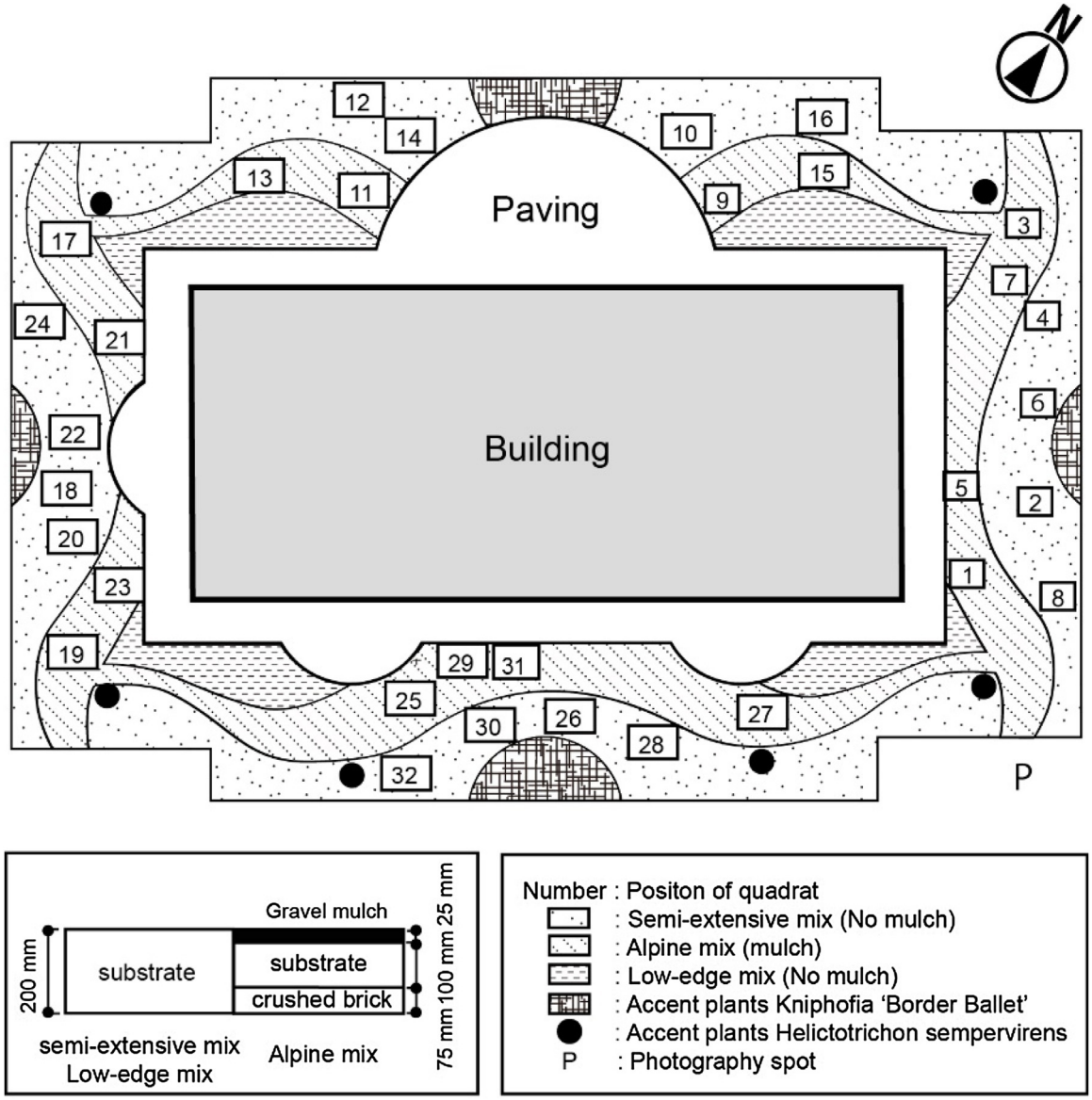

Fig. 1. Floor plan and cross section of green roof.

Adapted from Nagase et al. (2013).