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Research article

Habitat template approach for green roofs using a native rocky sea coast plant community in Japan

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ABSTRACT

The present study examined whether it is possible to simulate a local herbaceous coastal plant community on a roof, by studying the natural habitats of rocky sea coast plants and their propagation and performance on a green roof. After studying the natural habitat of coastal areas in Izu peninsula, a germination and cutting transplant study was carried out using herbaceous plants from the Jogasaki sea coast. Many plant species did not germinate at all and the use of cuttings was a better method than direct seeding. The green roof was installed in the spring of 2012 in Chiba city. Thirteen plant species from the Jogasaki sea coast, which were successfully propagated, were planted in three kinds of substrate (15 cm depth): pumice, roof tile and commercial green roof substrate. The water drainage was restricted and a reservoir with 5 cm depth of water underlaid the substrate to simulate a similar growing environment to the sea coast. Volcanic rocks were placed as mulch to create a landscape similar to that on the Jogasaki sea coast. Plant coverage on the green roof was measured every month from June 2012 to October 2014. All plants were harvested and their dry shoot weight was measured in December 2014. The type of substrate did not cause significant differences in plant survival and dry shoot weight. Sea coast plant species were divided into four categories: vigorous growth; seasonal change; disappearing after a few years; limited growth. Understanding the ecology of natural habitats was important to simulating a local landscape using native plant communities on the green roof.

1. Introduction

Green roofs are an important strategy to improve the environment in big cities (William et al., 2016; Mesimäki et al., 2017). Recently, the use of native plants on green roofs has attracted much attention (Butler et al., 2012). A native plant can be defined as a plant species that has developed over hundreds or thousands of years in a particular region or ecosystem (United States Department of Agriculture, 2017). Butler et al. (2012) summarized the reasons for promoting native plants on roofs; aesthetic (native plants provide a sense of place and blend into the natural landscape), adaptation (native plants are adapted to the local environment and consequently require less water, fertilizer, maintenance), habitat (native plants function as habitat for native fauna and serve to increase biodiversity), invasiveness (Native plants are less likely to become invasive than non-native plants). However, they emphasized that there was not enough research to support these reasons. Moreover, the growing conditions on green roofs are different from those on the ground; native plants are not always suitable for green roofs. The green roof environment can be harsh for plants; limited water availability, wide temperature fluctuations, and high exposure to wind and solar radiation, create a highly stressful and sometimes disturbed environment (Nagase and Dunnett, 2010). It is necessary to match plant communities with environmental conditions in the built environment that mimic conditions in their original habitats. This concept has been called the 'Habitat template approach' (Lundholm, 2006). The term 'Habitat template' refers to the matching of plant communities with environmental conditions in the built environment that mimic conditions in their original habitats (Lundholm, 2006). According to Dunnett and Kingsbury (2008), mountain environments, high-latitude environments, coasts, limestone vegetation and semi-desert are potential habitats that contain plants that could be suitable for green roofs. There are some previous studies on native plant species evaluating the habitat template approach. Some showed the potential of native

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plant assemblages such as open habitat in South France (Van Mechelen et al., 2014), and prairies or grasslands in North America (Sutton et al., 2012; MacDonagh and Shanstrom, 2015). Some tested survivability and performance in native costal regions of Atlantic Canada (MacIvor and Lundholm, 2011) and plains grasslands, coastal dunes and salt lake communities in Australia (Rayner et al., 2016) and Michigan native plants (Monterusso et al., 2005). In Japan, the idea of habitat template is still relatively unexplored although some papers on native coastal regions in urban landscapes have been published in Japanese language journals (Kondo et al., 2002; Komine et al., 2005).

Although there are many potential plant species to grow on green roofs, many native plants are hard to obtain from commercial nurseries (Snodgrass and McIntyre, 2010). One of the reasons for this difficulty is that little research has been carried out on propagation methods for native plants. Many plant species have dormant seeds, since this feature represents an important survival strategy in environment typified by ecological disturbances (Hilhorst, 1996). Currently, germination ecology and vegetative propagation for native plants are available in some books such as Baskin and Baskin (2014) and some journals such as Journal of Native Plants (e.g. Thetford and Miller, 2002). However, little research on native plant propagation has been available for use in urban landscapes including green roofs. Benvenuti et al. (2016) studied germination characteristics of Mediterranean xerophytic species for the purpose of urban greening. Kondo et al. (2002) studied two sand dune plant species, *Calystegia soldanella* and *Lathyrus japonicus* for conservation and use in landscaping in Japan. Understanding propagation methods is essential for further development of native plants on green roofs.

In this study, we focused on a sea coast plant community. Coastal plants are appropriate for green roofs because of strong winds, salt-laden air and very free draining sandy soils (Dunnett and Kingsbury, 2008). Coastal environments can be extremely taxing for plants because of: (1) rapid drainage through sandy soils, (2) high evaporation rates due to strong winds, and (3) the presence of salt in the form of spray or seeping sea water, reducing the osmotic absorption of water (Nellis, 1994). Coastal plants are endangered by human activities in many countries (Nordstrom et al., 2009; Panayotova et al., 2008). According to Yura (2014), the main reasons for declines in sea coast plant communities were trampling by people, construction of embankments, typhoons and garbage. Green roofs using regional plants can be part of nature restoration and even potentially help counteracting the destruction of natural habitats if local or regional species are used (Francis and Lorimer, 2011; Oberndorfer et al., 2007; quoted from Van Mechelen et al., 2014). Moreover, green roofs using sea coast plants may play an important role in environmental education.

The aim of the current research was to establish greening technology for green roofs using sea coast plants in Japan. First, natural habitats of sea coast plants were studied to understand the current situation and simulate visually similar environments on the roof using these sea coast plant communities. Native plants used on many green roofs often originate from a wide area; for example, some plants come from the mountains and others from the coast. The mixture of native plants from different habitats may have aesthetic benefits, however, it is necessary to study plant communities from a particular location to simulate landscapes similar to the natural sea coast environment. Second, propagation methods were studied. As it was mentioned above, only limited research has been carried out on native plants for green roofs. Ideally, plants would be obtained and propagated locally. Third, sea coast plants were evaluated in different types of substrate on a semi-extensive green roof. The choice of appropriate substrate for green roofs is important for long term success. In this study, an irrigation system was installed because previous studies showed it was difficult for many non-succulent plants to survive without irrigation in the areas which experience high temperatures and prolonged drought over summer (Sutton et al., 2012; Xiao et al., 2014).

2. Methods

2.1. Targeted natural habitats

Izu peninsula in Japan was chosen for an experimental site because this is one of the closest natural sea coasts to Tokyo and Chiba. Jogasaki sea coast in Izu peninsula was chosen to simulate landscape on green roofs in the experimental site (Fig. 1). Jogasaki sea coast is in Ito city, Shizuoka prefecture, located on a weathered lava field (Fig. 2). The dominant vegetation of the area is mainly evergreen broad-leaved forest (Hosoya et al., 2006). The habitat of the sea coast plants is dominated by open rock, with plants sparsely distributed and rooted between cracks of rocks. They may receive occasional splashes of seawater in stormy days but there is no regular tidal inundation. Thirty sea coast plant species were observed at the Jogasaki sea coast during this study, which was much higher than in other rocky sea coast sites in Japan. Yura (2008) studied 202 rocky sea coasts in Japan and they found that only 3% of sites contained more than 10 species. The list of sea coast plant species is shown in Appendix 1. Four plant species are categorized as threatened species and five plant species are categorized as near threatened species in Shizuoka, Tokyo and Chiba prefecture (Association of Wildlife Research and Envision Conservation Office, 2017). The climate in Izu is relatively mild, with a mean annual temperature of 15–17 °C and annual precipitation of 2000 mm. Maximum and minimum temperatures and precipitation at Ajiro for each month are shown in Fig. 3.

2.2. Propagation

2.2.1. Germination study

Ripe seeds of five species were collected from the natural vegetation at the Jogasaki sea coast on August 11, September 5, October 4, November 3, and December 4 in 2011. The collected seed plant species were *Crepidiastrum keiskeanum, Crepidiastrum keiskeanum, Crepidiastrum keiskeanum, Hemerocallis fulva* var. *littorea* and *Rosa luciae*. It was impossible to collect seeds from all species because some plants only flower over a limited time and many seeds had dispersed during strong winds. The collected seeds were dried at room temperature (about 20 °C) for one week and then kept in a refrigerator at 3 °C. Fifty seeds of each plant species were placed in a petri dish on 9-cm filter paper moistened with distilled water. On December 28, 2011, they were placed in an incubator at 20 °C (12 h light, 12 h dark). There were three replicate plates for each plant species. Germinated seeds were counted daily.

2.2.2. Cutting study

Fourteen species of plants were collected from Jogasaki on February 27, 2011 (winter collection) and April 29, 2012 (spring collection). The collected species and number of plants are shown in Table 1. Only aboveground parts were removed by scissors since most species were growing roots between rocks and it was difficult to remove whole plants with the roots intact. After being taken from their natural habitat, the collected plants were cut by scissors