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Short communication

Exploring the use of edible and evergreen perennials in living wall systems in the Scandinavian climate

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ABSTRACT

We have performed a field experiment to investigate the survival and vitality of perennial plants in a living wall installed in an industrial area in Malmö, southern Sweden. The main aim of the study was to investigate the possibility of growing edible and evergreen perennial plants in living wall systems in the Scandinavian climate. We conclude that the edible perennial plants *Allium schoenoprasum*, *Calamintha nepeta*, and *Fragaria vesca* are feasible in living wall systems in the Scandinavian climate. *Thymus vulgaris* is sensitive to the Scandinavian climate, and performed equally poorly in Rockwool panels and in soil-filled containers (controls). We also conclude that the evergreen perennial plant species *Chamaecyparis pisifera*, *Euonymus fortuneii*, *Euphorbia polychroma*, *Vinca minor*, and *Waldsteinia ternata* can be grown in green walls, and that the edible evergreen plant *Vaccinium vitis-idea* is highly suitable for living walls in this climatic region. *A. schoenoprasum*, *C. pisifera*, *E. fortuneii*, *I. crenata*, *L. sylvatica*, *V. minor*, and *V. vitis-idea* showed 100% survival rates, however, the visual quality of e.g. *I. crenata* and *L. sylvatica* was not acceptable for ornamental purposes.

1. Introduction

Living wall systems provide alternative greening systems in which plants are anchored vertically without the need for rooting space in the ground (Koehler, 2008; Francis and Lorimer, 2011; Perini et al., 2011a). The long-term goal of living walls should be to create attractive vegetation systems that are long-lasting, resource efficient, and that contribute to ecosystem services in areas or locations where other types of green systems cannot be installed due to limited ground space. The technology is still under development, and living walls in their current form require substantial resources during installation and maintenance (Perini and Rosasco, 2013). Vertical greening has several benefits, such as noise mitigation (Van Renterghem et al., 2013) and improvements in local air quality (Ottele et al., 2010; Sternberg et al., 2010). Potentially, these vertical systems can also have a role in developing urban agriculture networks (McLain et al., 2012). Living wall systems can thus be used to improve the built environment and how it is experienced as they provide an alternative way of greening dense urban areas. However, only small and local reductions in temperature in urban areas have been reported in globally widespread studies covering a variety of climates (Onishi et al., 2010; Wong et al., 2010; Perini et al., 2011b; Hunter et al., 2014).

Few studies have been carried out on plant species that are suitable for living wall systems. In the Mediterranean area, *Myrtus communis*, *Cistus x purpurescens* and *Teuchrium x lucydris* have been shown to perform well in living wall systems (Devecchi et al., 2013; Larcher et al., 2013). Although these species cannot be expected to perform well in the Scandinavian climate, it has recently been found that a number of perennial plants survive and perform well in living wall systems in the Scandinavian climate (Mårtensson et al., 2014). The use of Edible and evergreen plants would be highly interesting in living wall systems, since edible plants contribute to urban ecosystem services through flowering and the possibility to harvest fruits or leaves, whereas evergreen plants contribute with year-round aesthetics. Both these characteristics have been stressed as important to achieve a marketable system.

The cost of installing living wall systems is sometimes high, which means that they are installed on high-profile buildings to add spectacular effects to the urban landscape. Living walls can also incur substantial cost for maintenance from replanting, pruning and in particular irrigation which have implications for the overall sustainability performance of the system (Perez-Urrestarazu et al., 2014). It is therefore important that these walls have a pleasing

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visual appearance throughout the entire year. Many plants adapt to colder climates by entering a dormant phase during the cold season. The vulnerability of the system to sudden drought, as a result of failure in the irrigation system, will also influence the visual appearance of a living wall, and thus the perception of their value by citizens and city planners. It is therefore important to identify evergreen plants that can withstand the temperatures or water availabilities below or above the normally expected, in a living wall system in colder climates. The use of edible perennials in living wall systems also enhances their visual and social function, providing not only an appealing appearance, but the opportunity to harvest berries, fruits and aromatic leaves from walls on street level.

The aim of this study was to investigate the possibility of growing edible and evergreen perennial plants in living wall systems in the Scandinavian climate. We hypothesized that edible and evergreen perennial plants can survive in, and are a viable option for, living wall systems in the Scandinavian climate, and that the composition of the plant system will change after reduced irrigation.

2. Materials and methods

2.1. Experimental set-up

This full-scale field experiment was carried out in an industrial area in Malmö, SW Sweden (GPS WGS 84 decimal lat. N55.6108, long. E12.9896). The living wall system was installed on the masonry wall of a building completed in 1937, facing a southern direction (172. The panels were installed with the lower edge approximately 0.5 m above ground and the upper edge approximately 3.5 m above ground. The upper panels were reached by use of a ladder. The wall location means that they are almost entirely shielded from precipitation. The site is located in a region with a humid continental climate (Peel et al., 2007), with a local mean annual temperature of approximately 8 °C and a temperature range approx. from 30 °C to −15 °C (SMHI, 2014). The maximum temperature in 2013 was higher than normal and the precipitation in July lower than normal. The local annual precipitation in 2013 was 596 mm, which is common in the region. The local annual precipitation in 2014 was much higher 809 mm. This was in part due to a wet August with 203 mm precipitation which mostly fell during 48 h.

Sixteen Rockwool panels (Vertigreen^{TM}, Zinco GmbH) measuring 70 × 50 × 7 cm were installed two columns were covering an area of 1.4 m^2 and one column covering 2.8 m^2. The panels were randomly planted with 7 edible, 7 evergreen and one species that is both edible and evergreen. The edible plant species were: *Acinos alpinus* (Rock thyme, *N* = 9), *Allium schoenoprasum* (Chives, *N* = 9), *Calamintha nepeta* (Lesser calamint, *N* = 9), *Fragaria vesca* (Wild strawberry, *N* = 9), *Hyssopus officinalis* (Hyssop, *N* = 9), *Rubus stellarcticus* (*Rubus arcticus*, Arctic raspberry × *Rubus stellacticus*, Alaskan raspberry, *N* = 9), and *Thymus vulgaris* (Thyme, *N* = 9). The *evergreen* plant species were: *Chamaecyparis pisifera* (Ball Falsecypress, *N* = 9), *Euonymus fortuneii* (Fortune's spindle, *N* = 9), *Euphorbia polychroma* (Cushion spurge, *N* = 8), *Ilex crenata* (Japanese holly, *N* = 9), *Luzula sylvatica* (Greater wood-rush, *N* = 11), *Vinca minor* (Lesser periwinkle, *N* = 9), and *Waldsteinia ternata* (Barren Strawberry, *N* = 10). *Vaccinium vitis-idea* (Lingonberry, *N* = 18) was also included as this species is both edible and evergreen.

2.2. Planting

Cylinders with a diameter of 75 mm were drilled in the mineral wool in the panels down to a depth of approximately 6 cm. The material removed was used to fill the void next to the roots in the hole when necessary to improve stability. One plant was planted in each hole. When plants were delivered in pots with a larger diameter than the holes, excess soil was removed from the root systems to make the roots fit the planting hole. The panels were generously irrigated before and after planting. Planting was carried out on 28 and 30 May, and 11 June 2013. Control plants (*N* = 5) were planted in wooden boxes measuring 0.8 × 1.2 × 0.4 m, lined with a weed control membrane in order to retain the soil in the boxes (Mypex), on the ground with standard construction soil (AMA A) as growth substrate (Svensk Byggtjänst, 2008). This soil is composed of a mineral base shown to have a texture that is suitable in urban environments, and has an organic content of approximately 5%.

2.3. Irrigation and fertilization

The Rockwool panel system was irrigated for 10 min, three times a day: in the evening, during the night and in the morning during the initial establishment period. The irrigation system was set to deliver 4.6 l/min. This irrigation ensures unlimited supply of water to the plants but results in runoff. Runoff water was not recycled. Approximately 20 ml liquid fertilizer (Blomstra, Cederroth Sverige AB) was added to each panel one week after planting and in the beginning of July. During a period of 40 days between 29 June and 8 August 2013 the irrigation delivery rate was reduced to 0.8 l/min but with the same three cycles as before. This period is defined as a reduced irrigation treatment. The panels were saturated prior to this "simulated" drought period. This reduced irrigation treatment generated minimal runoff and was designed to test the outer limit of plant survival. This irrigation treatment corresponds to a daily approximate application of 4 mm water per m^2. From the beginning of 2014, the system was irrigated for 15 min twice a day, in the evening, and in the morning again ensuring unlimited water supply. The irrigation was running as soon as temperatures reached 4 °C. Approximately 16 ml liquid fertilizer was added to each panel in April 2014. The plants in wooden control boxes received no supplemental irrigation after the first two months of establishment.

2.4. Data collection & statistics

Plant visual quality was assessed on a scale from 0 to 4 on 3 July, 28 August, and 24 September 2013, and 15 April 2014, as described in Zollinger et al. (2006). The scores were based on the proportion of dead or wilted leaves: 0 = 100%, 1 = >50%, 2 = <25%, 3 = <10%, and 4 = 0%. The *area covered by vegetation*, expressed as % of the total area, was determined by processing photographs in Image J. The photographs were taken on 26 June and 28 August 2013. The visual quality was also used as the main criteria for evaluating the edible plants. On this scale horticultural production was not seen as important as the visual and pedagogical value of including edible plants. Thus no measurements were taken on horticultural production. The Wilcoxon signed rank test (IBM SPSS Statistics 20) was used to test for differences in visual quality between plants growing in the Rockwool panels and plants growing in the control containers, and to test for differences in coverage between June and August. Friedman's test (IBM SPSS Statistics 20) was used to test for differences in visual quality of each plant species between different dates during the growing season.

3. Results

3.1. Visual quality

No statistically significant differences were found in the visual quality of the 15 plant species in the experimental Rockwool wall and in the control system in July 2013, just after planting (Table 1). In August 2013, following the drought, *H. officinalis*, *T. vulgaris* and *L. sylvatica* had significantly better visual quality in the control growth