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Comparison of establishment methods for extensive green roofs in southern Sweden

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Abstract

The most common technique for establishment of thin extensive green roofs in Sweden has been using prefabricated vegetation mats. Our study investigated (1) how the establishment of green roofs in Sweden was influenced by the establishment method (prefabricated vegetation mat, plug-plant, shoot), substrate composition and species mixture, and (2) whether on-site construction was a possible alternative. The establishment of the vegetation, which in all cases consisted of succulent species, was recorded using the quadrate point intercept method in fixed plots and the success measured as frequency cover.

Prefabricated vegetation mats had higher succulent plant cover than on-site constructed roofs. There was no difference in succulent plant cover between plots established using plug-plants compared to shoots. Shoot-established plots had more moss than the other establishment methods. The commercial substrate 'Roof soil' had significantly higher succulent plant cover than the other substrates, which might be related to a higher nutrient content. The organic content of the non-commercial substrates was rapidly decomposed. The standard species mixture produced a higher cover than both the mix developed for northern conditions and the mix with an increased proportion of big leaved species. The total cover of the plots was mainly dependent on the cover of two species: *Sedum album* (L.) and *Sedum acre* (L.). Few species managed to establish spontaneously but the establishment of woody species highlighted the need for proper maintenance.

Keywords: Crassulaceae; On-site construction; Sedum; Vegetated roofs

Introduction

Green roofs are becoming increasingly popular in many countries. The interest for green roofs has been related to their capacity to reduce stormwater runoff volumes and peak flows (Bengtsson, 2002), mitigate urban heat island effects (Akbari et al., 2001) and cool buildings during summer months (Eumorfopoulou and Aravantinos, 1998; Onmura et al., 2001). Green roofs can also be designed to improve urban biodiversity (Mann, 1998; Brenneisen, 2003).

Installation of green roofs requires larger investments than conventional roofs (Wong et al., 2003). Systems with thick substrate layers and large plants are especially expensive since they generally require reinforcement and reconstruction of the building unless it was designed for the extra load from the start. Thin extensive systems can generally be built without making any adjustments to buildings and this reduces the cost of the system and increases the number of possible roofs that can be vegetated. Even though the initial cost is high,

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calculations have shown that the life cycle cost of extensive green roofs can be lower than the cost of conventional roofs (Wong et al., 2003). This is due to the extended life expectancy of the roofing membrane and to the reduced energy consumption related to summer cooling, which might be an important factor even in countries like Sweden where cooling during summer is becoming increasingly important in office buildings (Nilson et al., 1997; Wong et al., 2003). Still, the high investment can be seen as a barrier to a widespread use of green roofs and much would be gained if extensive green roof systems could be installed at a lower cost.

A fundamental part of the success of an extensive green roof installation is connected to the establishment and development of the plant material. Failure of the vegetation during the initial phase means that new plant material has to be brought to the site at an additional cost, and there is also a risk for erosion of the substrate if it has a lower cover during an extended establishment period (Wolfgang, 2002). The goal of establishment is a high cover of the desired vegetation but also survival of the established plant species. The guidelines developed by the German organisation Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau E.V (FLL), focus on high cover and state that a green roof should have a projective cover of at least 60% one year after establishment (FLL, 2002).

Green roofs can either be established on-site or by bringing prefabricated vegetation to the roof. In Germany, where most of the development of technology related to production and establishment of green roofs has taken place, green roofs are most often constructed on-site. On-site construction is generally achieved by pumping or lifting the substrate onto the roof and then distributing shoots, seeds or plug plants. In Sweden, green roofs are mainly applied as prefabricated vegetation mats, which is generally one of the most expensive ways to vegetate buildings but also a method that has a low risk of failure and that ensures instant high plant cover (Krupka, 1992; Schade, 2002; Dunnett and Kingsbury, 2004). Vegetation mats are composed of plants grown in a substrate that is fixed onto a carrier material, e.g. geotextile, plastic net or coconut net. The vegetation mats are lifted to the roof as fully established vegetation during construction of the system. Vegetation mats are currently used in southern Sweden and Denmark but there are no comparative studies reported where the less expensive technique of on-site establishment has been tested in this climate. The climate is less extreme in southern Sweden compared to Germany but the winters are slightly colder. This might influence the survival-rate of the newly established succulent species, since decreased substrate depths increases freezing injuries of succulent plants (Boivin et al., 2001). Little is known about how establishment of the on-site constructed systems compares to the cover of a prefabricated vegetation and what type of cover and plant composition the consumer can expect when deciding to use one or the other system.

Substrates are generally the same regardless of establishment method. The main component in substrates is inorganic material with a high water-holding capacity and low density such as pumice, lava, or expanded clay (Roth-Kleyer, 2001). Recycled material such as crushed roof tiles has also been used as a component in roof substrate, even though the density is higher than in pumice or expanded clay (Roth-Kleyer, 2001). The use of recycled material can be a way to reduce the need for transport and to find use for a locally available material that is otherwise worthless. The composition of commercial substrates is surrounded with secrecy and patents, while at the same time the basic idea of substrate composition is readily available in guidelines developed in Germany during the past 15–20 years (FLL, 2002). Our study is comparing two substrates containing crushed roof tiles with a commercial substrate. One of the substrates was designed strictly according to the German guidelines and the other was designed with a slightly increased organic content since this would increase the water and nutrient holding capacity of the substrate and possibly improve establishment. Higher water and nutrient holding capacity of the substrate might on the other hand increase the possibility for establishment of weeds that would influence the aesthetic characters of the roof negatively.

The plants used on thin green roofs are succulents belonging to the *Crassulaceae* family. The plants are able to withstand sustained periods without water through both biochemical and morphological adaptations. The thin substrate dries out rapidly but the succulent morphology of the plants enables them to store large amounts of water and thereby cope with drought situations. Two of the plants commonly used, *Sedum album* and *Sedum acre*, are known to express crassulacean acid metabolism (CAM) during drought periods (Sayed, 2001). Again, little information is available on the survival and establishment rates of different succulents in the Swedish climate. Most species combinations have been developed in Germany and few systematic studies on plant performance have been performed in Sweden. The species mixes that were tested in our study have been designed for both rapid cover and aesthetics, and all have a high proportion of ground covering *Sedum* species, *S. album* and *S. acre*, in the mix. Our aim was to test how a standard mix commonly used in Sweden and Germany compared to a mix composed for more northern conditions and a more aesthetically pleasing mix with a higher proportion of big-leaved and more flowering species.

The overall aims of our study were: (1) to describe the effects of establishment method, substrate composition