Urban Forestry & Urban Greening 13 (2014) 892–899

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Short communication

Green roof vegetation type affects germination and initial survival of colonizing woody species

Lori E. Miller, Amy E. Heim, Jeremy Lundholm *

Department of Biology/Environmental Science, Saint Mary's University, 923 Robie St., Halifax, NS, Canada B3H 3C3

ARTICLE INFO

Keywords:
Biodiversity
Green roof
Maintenance
Plant canopy
Tree establishment
Unwanted vegetation

ABSTRACT

Green roofs provide a number of valuable ecosystem services compared to conventional roofs, but may require yearly maintenance. Trees and other woody plants that persist on the roof may damage or overload shallow-substrate green roofs and their removal is a standard maintenance procedure. The germination potential of colonizing species may differ depending on the vegetation surrounding them. The aim of this study was to determine whether the germination of colonizing tree species (*Picea glauca* and *Ulmus glabra*) will vary depending on which plant species form the established vegetation seeds land in. To determine germination success, survival, and seed capture ability of the plant canopy, tree seeds were added either directly to the growing medium or atop the plant canopy, in replicated monocultures of 14 species native to Nova Scotia. When seeds were added directly to the soil, no significant difference was detected between the monocultures for germination success or survival for *U. glabra* or *P. glauca*. However, when the seeds were added atop the plant canopy, percent germination of *U. glabra* was significantly higher in *Carex argyrantha* green roof modules. Overall, sod forming graminoids showed higher germination of *U. glabra*. The number of seeds reaching the soil was typically lower in vegetation with a denser canopy. This study demonstrates that some vegetation repels colonizing tree species by reducing ground contact. Although these effects differed according to tree species, non-vegetated substrates enhanced seedling persistence. Additionally, the majority of tree seeds that germinated failed to survive a single growing-season on shallow-substrate green roofs.

Introduction

The maintenance required for extensive green roofs (substrate depth <20 cm) can be minimal, with inspections usually occurring no more than once or twice a year. The tasks completed during these inspections can vary from roof to roof but procedures recommended in the FLL guidelines (an internationally recognized green roof construction standard) include the removal of unwanted vegetation and seeding/planting of bare patches (FLL, 2002). Since these tasks take time and resources, increasing the resistance of a roof to unwanted colonizing species will reduce the resources required to remove this unwanted vegetation and fill in the subsequent bare patches.

Few studies mention spontaneous or unwanted vegetation arising on green roofs. Those studies that address this issue found that seeds tend to arrive on the roof via wind, but larger seeds are capable of reaching the roof via dispersal through birds, bats, humans or other small animals (Archibold and Wagner, 2007; Dunnett et al., 2008; Berndtsson et al., 2009; Jim and Chen, 2011; Nagase et al., 2013). Spontaneously colonizing plants can lead to blocked exterior drains which can lead to structural difficulties, leaking and further unwanted plant growth (Archibold and Wagner, 2007). Colonizing species can also work their way beneath root barriers or drainage mats and damage roof membranes (Luckett, 2009; Snodgrass and McIntyre, 2010). Additionally, these colonizers compete for resources with the desired green roof flora which may decrease their success (Nagase et al., 2013). Since particular types of vegetation are more effective at performing beneficial green roof functions (Schroll et al., 2011; MacIvor and Lundholm, 2011; Nagase and Dunnett, 2012), a decrease in coverage of desirable species could be detrimental to green roof performance.

Trees prove to be particularly problematic, because once tree roots are firmly rooted in place, it is difficult and costly to remove them. Additionally, tree roots will aggressively seek out water, penetrating the seams of water proofing membranes and compromising their integrity (Snodgrass and McIntyre, 2010). While trees are unlikely to become dominant on extensive green roofs with shallow substrates, due to high levels of abiotic stress (e.g.

* Corresponding author. Tel.: +01 9024205506.
E-mail addresses: jeremy.lundholm@smu.ca, jlundholm@smu.ca (J. Lundholm).

http://dx.doi.org/10.1016/j.ufug.2014.10.001
1618-8667/

Grime, 2006), individual tree seedlings can become established despite stressful roof conditions (Archibold and Wagner, 2007). Unwanted species establishment on green roofs varies depending on climatic conditions, how the green roof was constructed, substrate type/depth and vegetation types (Emilsson, 2008; Dunnett et al., 2008). Spontaneous establishment can be higher in the spring than the autumn, and some tree species (*Betula* spp. and *Acer campestre*) are known to become established, but survival is low (Emilsson, 2008). For extensive green roofs, growth of unwanted species is often limited, because supplemental irrigation and bare space on the substrate are not available (Rowe et al., 2012). Conversely, facilitation of colonizing seedlings by established green roof vegetation could allow less drought-tolerant species to gain a foothold (e.g. Butler and Orians, 2011; Heim et al., 2014). Unwanted species can survive in extensive green roof conditions and their removal is a standard green roof maintenance procedure (Archibold and Wagner, 2007; Luckett, 2009).

The colonization of green roof systems by unwanted vegetation is similar to any biological invasion involving plants. The factors determining successful colonization include propagule pressure (Davis et al., 2000; Lockwood et al., 2005), invader characteristics such as seed size and growth rate (Foxcroft et al., 2011), and the susceptibility of the existing plant community to invasion (Davis et al., 2000; Levine et al., 2004; Foxcroft et al., 2011). Invading species are expected to perform best with access to light, nutrients, water, and a bare soil surface so vegetation that greatly reduces resource availability should be less invasible (Lozon and MacIsaac, 1997; Davis et al., 2000; Rejmanek et al., 2005). A region's climate and a roof's location will affect which species can colonize a roof. For example, roofs in wetter climates and/or roofs adjacent to trees would be more susceptible to colonizing tree seedlings. In Halifax Nova Scotia seedlings of *Ulmus*, *Fraxinus excelsior* and *Betula papyrifera* have all been observed growing on green and conventional roofs in the city (personal observation).

The purpose of this experiment was to determine whether monocultures of vegetation composed of species native to Nova Scotia will show variability in colonization by unwanted tree species on an extensive green roof. Monocultures were studied because, even roofs with diverse plant mixtures, contain areas where plants of the same species grow in monodominant patches. (Snodgrass and McIntyre, 2010). Additionally, by using monocultures we can understand how individual species may affect colonizer germination and survival, and make generalizations about the plant traits involved. We predicted that the monocultures with the greatest overall plant cover would result in lower germination success and lower overall seedling survival of the introduced species. It was also predicted that the monocultures with the most canopy biomass would be the best at keeping the seeds from reaching the soil resulting in less germination.

Material and methods

Germination tests

Germination tests were completed in the laboratory from June to early July 2011 for three tree species of interest: paper birch (*B. papyrifera* Marshall), white spruce (*Picea glauca* (Moench) Voss), and Scots elm (*Ulmus glabra* Huds.). These species were chosen based on their high frequency in the region and large range in seed weights and availability (*U. glabra* 11.54 mg, *P. glauca* 2.27 mg, *B. papyrifera* 0.104 mg). *U. glabra* seedlings are commonly removed from green roof vegetation at Saint Mary's University, *B. papyrifera* occasionally colonizes conventional and green roofs locally and *P. glauca* is a common tree in the region (personal observation). Seeds of all three species have appendages to facilitate wind dispersal. *B. papyrifera* and *P. glauca* seeds were purchased commercially and stored at 4 °C until their use (Bonner and Karrfalt, 2008; Zhang, 2003) *U. glabra* seeds were collected on June 21, 2011 from several trees on or surrounding the Saint Mary's campus (44°39′N, 63°35′W). These seeds were allowed to dry at room temperature for 48 h under full-spectrum grow lights before storage at 4 °C for 1 day (Bonner and Karrfalt, 2008). Seeds were placed directly on moistened Whatman filter paper in petri dishes. Owing to a size differential, ten seeds were tested per petri dish for *B. papyrifera* and *P. glauca* and only five seeds were tested for *U. glabra*. These petri dishes were sealed with parafilm to avoid contamination, and placed under full-spectrum fluorescent growth lights (light for 16 h/day). Petri dishes were checked for germination every two to three days for several weeks.

Based on the germination test 200 seeds of *B. papyrifera*, 30 seeds of *U. glabra* and 24 seeds of *P. glauca* would be required to produce 20 seedlings. Due to seed availability only 50 seeds of *B. papyrifera* were added to each packet (this would result in 5 viable seeds). 118 seed packets were prepared each containing 50 *B. papyrifera* seeds, 30 *U. glabra* seeds and 24 *P. glauca* seeds.

Field tests

On July 1, 2011 a modular green roof system was assembled using modules from a previous experiment (MacIvor and Lundholm, 2011) (Fig. 1). Each free draining module was 36 cm × 36 cm (Botanical Nursery LLC, Wayland, MA, USA) and lined with a composite non-woven water-retention layer (Huesker Inc., Charlotte, NC, USA) an Enkamat drainage layer, a site attachment for plant roots and a filter layer (Colbond Inc., Enka, NC, USA). The substrate was 6 cm deep and composed of a (1:4) mix of Pro-mix potting soil (Premier Tech, Riviere-du-Loup, QC, CA) and Sopraflor X growing medium (Soprema Inc., Drummondville, QC, CA). Sopraflor X consisted of crushed brick blond peat, perlite, sand, and vegetable compost, with a pH of 6.0–7.0, a total porosity of 60–70%, a bulk density of 1150–1250 kg/m^3, and an organic matter (dry weight) content of 5–10%. The trial was conducted on the roof of the five story Atrium building located at Saint Mary's University in Halifax, Nova Scotia (44°39′N, 63°35′W). This region has a 203 day (5° basis) growing season with a yearly average of 480 mm of precipitation between May and September (Webb and Marshall, 1999). The 2011 growing season had seasonally equivalent average daily temperature for July (18.8 °C) cooler average temperatures for August (18.5 °C) and warmer average temperatures for September (16 °C) and October (10.4 °C). For precipitation July (94.3 mm) and September (43.1 mm) had seasonally lower total precipitation and August (135.6 mm) and October (334.8 mm) had seasonally higher total precipitation (Climate Canada, 2014a,b). The nearest stands of *B. papyrifera* trees were 200 m away, *U. glabra* trees were 50 m away and *P. glauca* trees were 200 m away from the roof site. Each of the tested species naturally germinate in the spring-early summer (Bonner and Karrfalt, 2008).

The plants used in this study were established in the summer of 2009 by planting each with a monoculture of plants from one of 14 native species. These plants were established from cuttings or seed and grown in a greenhouse between December 2008 and April 2009 before planting in late April 2009. During the summer of 2009 the plants received water through precipitation or artificial watering events. The artificial watering consisted of adding 1.3 kg of water to each module once a month from May to September. After this date the modules only received water from precipitation.

Native graminoids, creeping shrubs and forbs were tested (Appendix 1). Additionally, a substrate-only control was included for comparison. Out of the tested species, *Festuca rubra* and *Empetrum nigrum*, are known to be allelopathic (Tybirk et al., 2000; Weston, 2001). For this study, each module received no more than