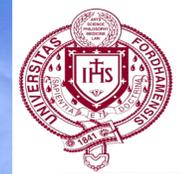




NYC green roofs: How do growing medium properties affect native plant assemblages?



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Introduction

Green roofs, a largely untapped technology in New York City, require a better understanding of what abiotic factors affect plant assemblages on these rooftops. This study explores the effects of abiotic factors: depth and pH of the growing medium on native plant assemblages. Green roofs provide many financial and ecological benefits such as habitats for animals, air-quality improvement, reduction of the urban heat-island effect, lower energy costs and repair bills, as well as reduced runoff, which can reduce the likelihood of overflowed combined sewage systems (Getter and Rowe, 2006; Porsche and Köhler, 2003).

In this study, we experimented on extensive roofs, which vary in depth from 2 to 20 cm. Green roof growing media are generally composed of mineral based substrates and minimal quantities of organic matter (Oberndorfer et al., 2007). Studies have shown that native plants on green roofs often fail, but these native plants are often chosen for reasons other than their habitat suitability (Butler, Butler & Orians 2012). Our study seeks to determine if Hempstead Plains (HP) and Rocky Summit (RS) species would be successful on New York rooftops under different growing medium conditions. HP species are from Nassau County; they grow at sea level and on flat surfaces. RS grassland plains species, on the other hand, are more adapted to the mountainous, higher elevation areas of upstate New York. Among the plants selected were grasses, forbs (non-grassy, non-woody plants) and nitrogen-fixers.

Many abiotic factors such as growing medium properties like depth and pH of the growing medium affect green roof plant assemblages (Durham & Rowe 2007; Thuring, Berghage & Beattie 2010; Olly et al. 2011). In a previous study on the roofs we will be using, it has been shown that growing medium depth and pH effects varied based on plant species and roof location, respectively (Aloisio et al. 2016).

In this current study, we hypothesize that: 1) as growing medium depth increases, percent cover and sward height would increase, while percentage of bare ground would decrease; 2) the less the pH of the growing medium deviates from industry standards, 7.8 (Schulze-Ardey & Schroder 2008), the greater the percent cover and sward height, while percentage of bare ground would decrease. We expect similar results for both plant assemblages.

Methods

Experimental Design:

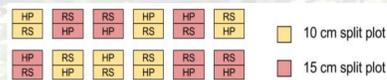


Figure 1: Each plot on one of the 10 rooftops received one of four treatments: 10 cm of growing medium with HP plants, 15 cm of growing medium with RS plants, 10 cm of growing medium with HP plants, and 15 cm of growing medium with RS plants. The plots have been unmaintained since 2012.

The growing medium (NYC Parks, New York, NY, USA) used for the 10 green roofs are composed of 4% organic material, 6.8% silt, 36.2% sand, and 57% gravel.

Plant Coverage Estimate: We surveyed plant species abundance and richness by identifying each living plant containing and estimating the area of the plot it covered. The amount of dead material, moss, bare ground, and total living cover within each split-plot was also identified.

Sward Height: The method used to measure sward height was a "direct measurement method," which consisted of taking a meter stick to 4 corners and the center of each split-plot (Stewart Bourm & Thomas 2001). The meter stick was placed on the growing medium and we slid our hands down the meter stick until our hands touched 80% of the living material in that area.

Growing Medium Depth: We measured 45 centimeters diagonally from each corner of the split-plot. Then we inserted a metal nail as far as we could and measured the portion of the nail that was in growing medium.

pH: We collected growing medium samples from the middle of each split-plot on the green roofs. Each sample was then sifted through a 4 millimeter sieve and measured 2 grams of growing medium and added it to a small beaker along with 10 milliliters of water. The sample was then agitated for 30 mins by a shaker, and its pH was measured using a pH meter (Robinson Coleman & Bledsoe, 1999) (Milwaukee Instruments, Rocky Mount, NC).

Data Analysis: We used the program R for finding Pearson's correlations and creating our figures.

Results

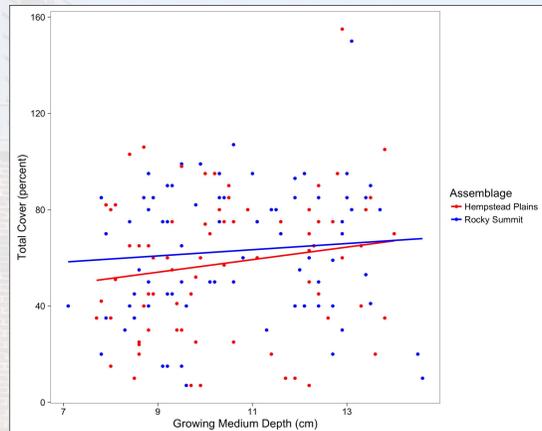


Figure 2. Growing medium depth has a slight positive correlation with total cover in both the HP and RS plots, but neither correlation is significant (HP: $r=0.165$, $p=0.157$; RS: $r=0.087$, $p=0.452$).

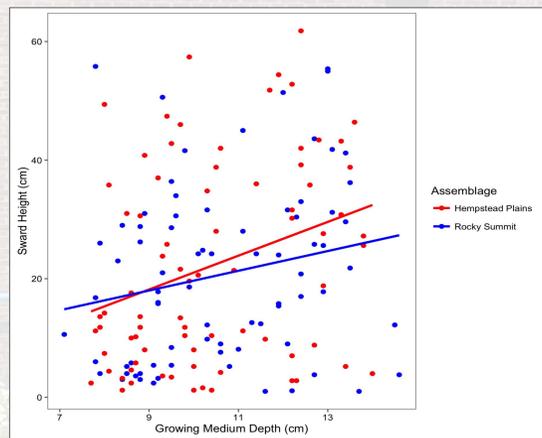


Figure 3. Growing medium depth and sward height display positive correlations in both HP and RS plant assemblages, the correlations in both assemblages are significant (HP: $r=0.280$, $p=0.014$; RS: $r=0.365$, $p < 0.001$).

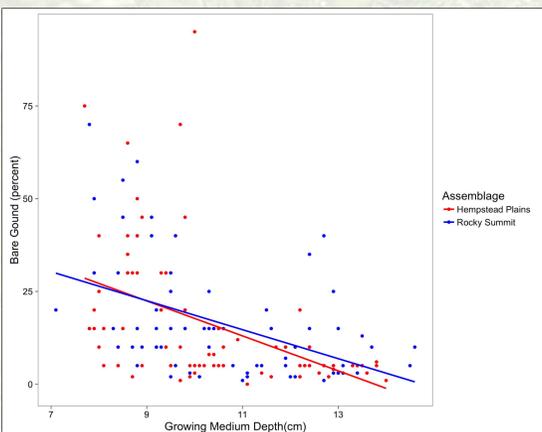


Figure 4. Growing medium depth and bare ground exhibit negative correlations in both the HP and RS plant assemblages, both correlations are significant (HP: $r=-0.506$, $p < 0.001$; RS: $r=-0.482$, $p < 0.001$).

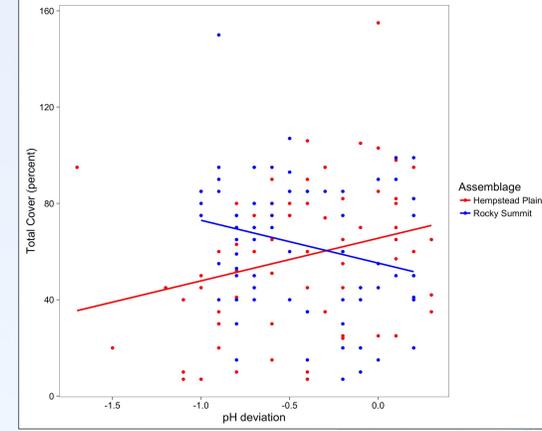


Figure 5. pH deviation has opposite effects on the total cover of HP and RS plots. While pH deviation and total cover have weak and not significant correlations in both plots, the correlation is positive in the HP plots and negative in RS plots (HP: $r=-0.086$, $p=0.4644$; RS: $r=0.090$, $p=0.438$).

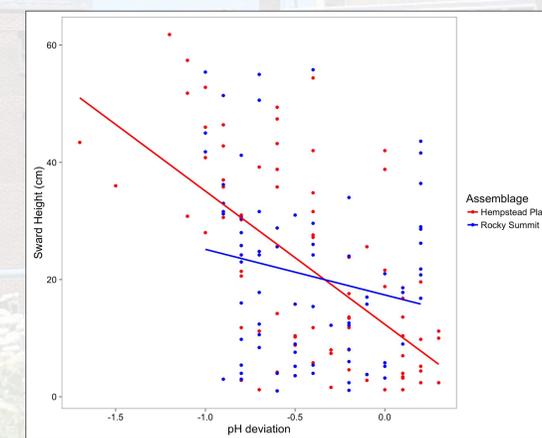


Figure 6. pH deviation is negatively correlated in both HP and RS plant assemblages and the correlations are both significant (HP: $r=-0.456$, $p < 0.001$; RS: $r=-0.482$, $p < 0.001$).

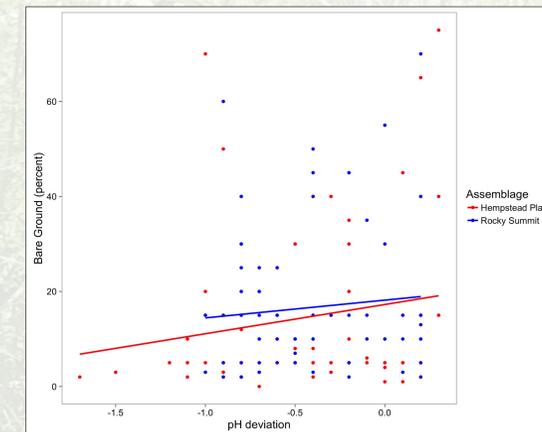


Figure 7. pH deviation and is positively correlated with bare ground in both plant assemblages with the results being significant (HP: $r=0.278$, $p=0.01555$; RS: $r=0.386$, $p < 0.001$).

Discussion

Effects of soil depth: Growing medium depth was weakly positively correlated with total cover and sward height, tentatively supporting the first two parts of our first hypothesis (growing medium depth and total cover: HP: $r=0.165$, $p=0.157$; RS: $r=0.087$, $p=0.452$; growing medium depth and sward height: HP: $r=0.280$, $p=0.01372$; RS: $r=0.365$, $p < 0.001$) (Figures 2 and 3). While plots of different depths are equally covered, it is likely that they are populated with different species. Greater forb cover can explain this because as depth increases so does sward height (the forbs selected used were usually taller than the grasses). Further analysis suggests that the percentage of forb and grasses increases and decreases, respectively, as growing medium depths increase in both assemblages.

Our findings tentatively supported the third part of our first hypothesis, as we saw a moderate negative correlation between growing medium depth and bare ground that proved to be significant (HP: $r=-0.506$, $p < 0.001$; RS: $r=-0.482$, $p < 0.001$) (Figure 4). While bare ground cover decreases, we found little increase in total cover. This can be attributed to dead material that is not accounted for in total cover. A moderate positive correlation exists with regards to the amount of dead material in the RS assemblage as depth increases. Deeper plots may not foster more living material, but they do foster more total biomass which can explain why less bare ground was found in those plots.

Effects of pH: Our results indicated that pH influenced both the RS and HP plots, but that the influence varied with plant assemblage. With minimal pH deviations in Hempstead Plains plots, there was a weak positive correlation with total cover, but the trend was reversed for Rocky Summit plots (HP: $r=-0.086$, $p=0.464$; RS: $r=0.090$, $p=0.438$) (Figure 5). It seems that HP plant assemblage favors a more basic growing medium, while RS plant assemblages appear to grow better in more acidic growing medium as evidenced by the increase of total cover. Sward height was negatively correlated to pH deviation, contrary to our hypothesis (HP: $r=-0.456$, $p=0.016$; RS: $r=-0.482$, $p < 0.001$) (Figure 6). As the pH deviates from 7.8 to a more acidic pH sward height increases slightly and significantly for the RS and HP assemblages, respectively. Taller plants in both assemblages seem to prefer a more acidic growing medium. pH deviation had a weak positive correlation with percent bare ground in both HP and RS plots (HP: $r=0.278$, $p=0.01555$; RS: $r=0.386$, $p < 0.001$) (Figure 7). This can suggest that bare ground is not affected by pH and is dependent with another factor.

Conclusions

- Soil depth seems to be a moderate predictor of sward height and bare ground coverage, but a weak predictor of total cover.
- pH does not appear to be a predictor of total coverage or bare ground coverage however is a weak predictor of sward height, specifically for HP plant assemblages.

Literature cited

Aloisio, J. et al. (2016) Spatially-dependent biotic and abiotic drivers of survivorship and physical structure of green roof vegetation. Unpublished Manuscript.
Butler, C., Butler, E. & Orians, C.M. (2012) Native plant enthusiasm reaches new heights: perceptions, evidence and the future of green roofs. *Urban Forestry and Urban Greening*, 11, 1-10.
Durham, A.K. & Rowe, D.B. (2007) Effect of substrate depth on initial growth, coverage, and survival. *HortScience*, 42, 588-595.
Getter, K.L., Bradley Rowe, D. & Clegg, B.M. (2009) Solar radiation intensity influences extensive green roof plant communities. *Urban Forestry Urban Greening*, 8, 269-281.
Oberndorfer, E. et al. (2007) Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services. *BioScience*, 57(10), 823. doi:10.1641/B571005
Porsche, U. & Köhler, M. (2003, December 1-5). Life Cycle Costs of Green Roofs: A Comparison of Germany, USA, and Brazil. Paper presented at RIO 3-World Climate & Energy Event, Rio de Janeiro, Brazil, 461-467.
R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org/>
Robertson, G.P., Coleman, D.C. & Bledsoe, C.S. (1999) Standard soil methods for long-term ecological research. LTER Oxford University Press, New York, NY.
Schulze-Ardey, C. & Schroder, M. (2008) Guidelines for the planning, construction and maintenance of green roofing—green roofing guideline. (ed. T.L. D.L.R.S. (FLD)). The Landscape Development and Landscaping Research Society, Germany.
Stewart, K.E.J., Bourm, N.A.D. & Thomas, J.A. (2001) An evaluation of three quick methods commonly used to assess sward height in ecology. *Journal of Applied Ecology*, 38, 1148-1154.
Thuring, C.E., Berghage, R.D. & Beattie, D.J. (2010) Green roof plant responses to different substrate types and depths under various drought conditions. *HortTechnology*, 20, 395-401.

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