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Salvador N. Lindquist

University of Nebraska-Lincoln, saln.lindquist@gmail.com

Richard K. Sutton

University of Nebraska-Lincoln, rsutton1@unl.edu

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Storing Carbon in Green Roofs: Above- and Below-Ground Biomass of Blue Grama and White Stonecrop

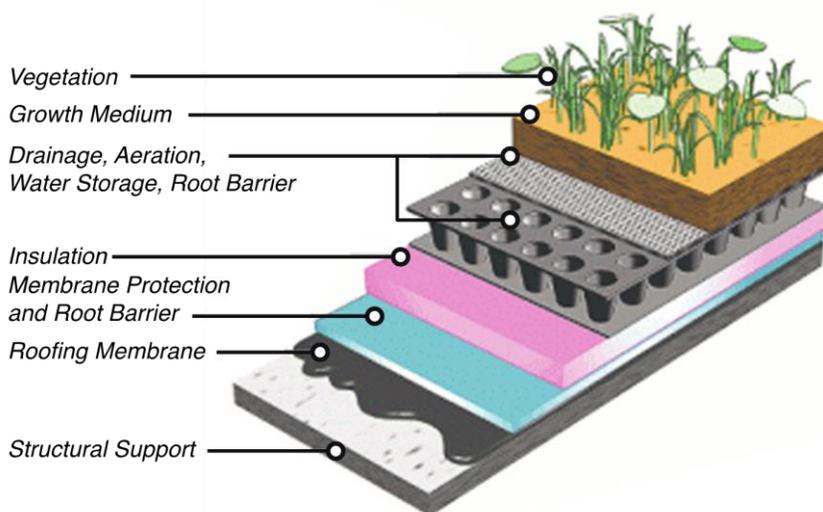
Cover Page Footnote

I would like to thank the Undergraduate Creative Activities and Research Experience (UCARE) program at the University of Nebraska – Lincoln for providing a funding stipend to conduct this research. I would also like to thank Dr. Richard K. Sutton for the help provided in the development of this research experiment as well as for the assistance in participating in the tedious task of root and shoot cleaning.

1. Introduction

Although the term “green” has become commonplace when referring to the rise in environmentally friendly technologies, corporations, and policies, “green roof” refers specifically to a roofing technology that allows for the growth of vegetation on rooftops (Snodgrass and MacIntyre 2010; Weiler and Scholz-Barth 2009). The environmental benefits of green roofs include improved stormwater management, increased energy conservation, mitigation of urban heat island effects, increased longevity of roofing membranes, reduction in noise and air pollution, carbon sequestration, and increased urban biodiversity (Oberndorfer 2007). The public realm benefits from green roofs through a higher return on investment compared to traditional roofs, improved visual appeal, and providing recreation opportunities.

Typically constructed of several layers of materials in order to facilitate vegetative growth, the composition of the green roof will depend on building load capacity, purpose of the project, and manufacturer. These layers (Figure 1), which sit above the roof structural support, typically include a waterproof roofing membrane, a membrane protection and root barrier, insulation, drainage and aeration layer, growth medium, and some sort of vegetation. The growth medium, or substrate composition varies, but due to structural limitations, the primary component is a lightweight, mineral based material, such as heat-expanded shale mixed with compost for nutrients.



Source: Earth Pledge

Figure 1. Typical layers found within a green roof system.

Green roofs are designed as either “intensive” or “extensive”. Intensive green roofs include shrubs and trees commonly found naturally at the ground level (Cardinal Group 2008). As such, they require substrate depths greater than 15 cm and have more “intense” maintenance needs. In contrast, extensive green roofs consist of herbaceous perennials, annuals, or succulents and use shallower media depths (less than 15 cm) and require less maintenance (FLL 2002). With the current growth of the green roof industry in the United States, partly due to a number of incentive programs, questions have arisen concerning the feasibility of retrofitting green roofs onto buildings with limited structural capacity. In these circumstances, extensive green roofs are utilized to minimize the amount of structural load, but such lighter weight green roofs result in limited biodiversity. *Sedum* has become the *de facto* plant genus of choice because it is able to use Crassulacean Acid Metabolism (CAM) physiology (Castillo 2004), providing a unique biochemical cycle that limits its loss of moisture. *Sedum*'s root system, however, appears minimal thus limiting its potential for garnering moisture and nutrients and use as a carbon sink (Whittinghill 2012).

Plant roots play a role in carbon sequestration. This process uses photosynthesis to remove carbon dioxide from the atmosphere storing it in plant biomass, a process commonly referred to as terrestrial carbon sequestration (Getter 2009). The length of time that carbon remains in the soil before decomposition has yet to be quantified for green roofs, although green roofs have the potential to become a short-term carbon sink if net primary production exceeds decomposition (Getter 2009). Increased interest in reducing carbon emissions correlates with the credit trading programs associated with regulations put in place to mitigate greenhouse gases and hence climate change. Most research on carbon sequestration has been conducted within natural landscapes and agricultural lands, but recent research has focused on the ability of various urban landscapes to sequester carbon (Whittinghill 2012).

Sutton (2013) outlines a series of concerns arising from primarily studying above-ground biomass in green roof research and suggests there are a variety of factors in addition to below-ground plant biomass contributing to carbon sequestration; these include species diversity, plant physiological characteristics, species abundance, and climate (Kucharik et al. 2003; Matamala et al. 2008; Sandermann and Amundson 2009; Tilman et al. 2006). Increased plant biomass, both above- and below-ground, has been shown to be an indication of greater amounts of carbon sequestration.

While green roofs are often utilized for energy savings and heat island mitigation, this technology hasn't been extensively promoted for its ability to mitigate climate change (Getter 2009). Green roofs have the potential to significantly reduce the amount of carbon dioxide in the atmosphere through carbon sequestration. Researchers at Michigan State University have concluded that green roof carbon sequestration amounts to approximately 1.52 metric tons of carbon per acre (375 grams of carbon per square meter). This study also approximated the total carbon sequestered if all 36,409 acres of commercial and industrial rooftops in the Detroit metropolitan area installed green roofs; their plants and growing

media combined would sequester 55,252 metric tons of carbon, equivalent to taking more than 10,000 midsize sport utility vehicles or trucks off the road for a year (Garrison 2012).

This study focused on two low maintenance plant species commonly found on extensive green roof systems, blue grama (*Bouteloua gracilis*) and white stonecrop (*Sedum album*). Its objective was to quantify the above- and below-ground biomass of those two species to provide greater understanding of their carbon sequestration potential. Based on the results of Whittinghill (2012), we hypothesize that blue grama will produce greater overall root and shoot biomass than white stonecrop.

2. Materials and Methods

Prior to the initial set up of this experiment, blue grama and white stonecrop were each grown in 32-flat-cells for six months. The plants were then transplanted, into 30 trays measuring 30 by 20 cm and filled to the depth of 7.5 cm with Midwest Trading Extensive Green Roof Media (substrate). Two blue grama and white stonecrop plants each were transplanted into 15 trays. The arrangement of the trays within the green house was randomized (Figure 2) and plants were watered daily from transplanting to final harvest (July 15, 2013 – December 17, 2013).

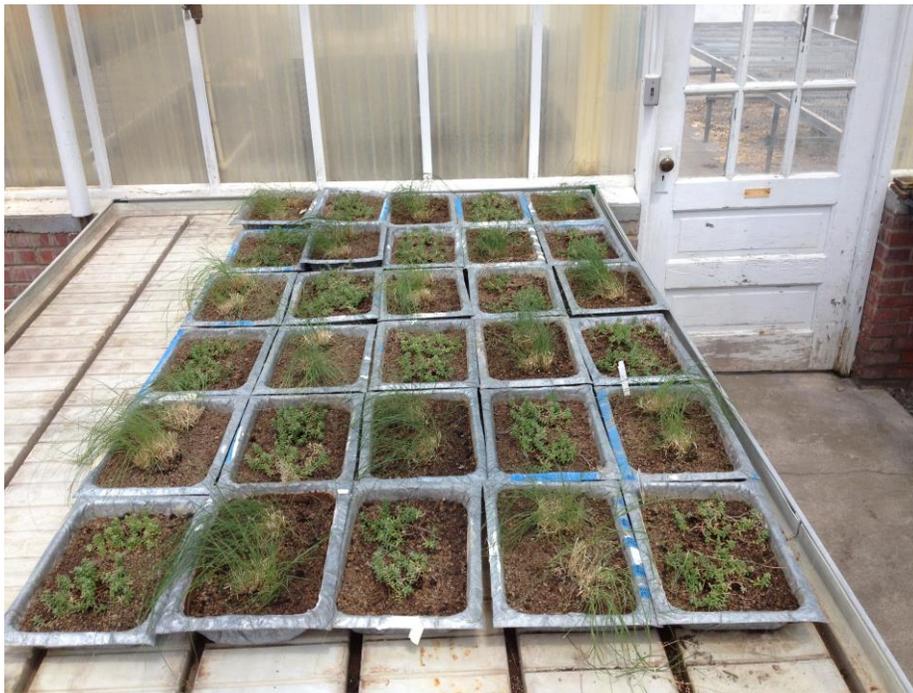


Figure 2. Randomized trays planted with blue grama (*Bouteloua gracilis*) and white stonecrop (*Sedum album*)

After five months of growth in the greenhouse, plants were harvested to determine the above- and below-ground biomass of the two species. This process included washing the plants in a bucket to remove potting soil and other particles (Figure 3). Plant roots were then separated from the above-ground mass using a scissors to clip the stem at the base of the shoots. The separated roots and shoots of the individual plant species were then placed into named and numbered paper bags and dried for three days in a convection drying oven at 100° C.

Above- and below-ground tissues from each tray were then weighed to a 0.01 g precision (Figure 4). Biomass data was then compared among species using analysis of variance in JMP 10.0 Statistical package (SAS, SAS Institute Inc. Cary, NC 27513)



Figure 3. Process of sifting roots to separate plant biomass from soil substrate.

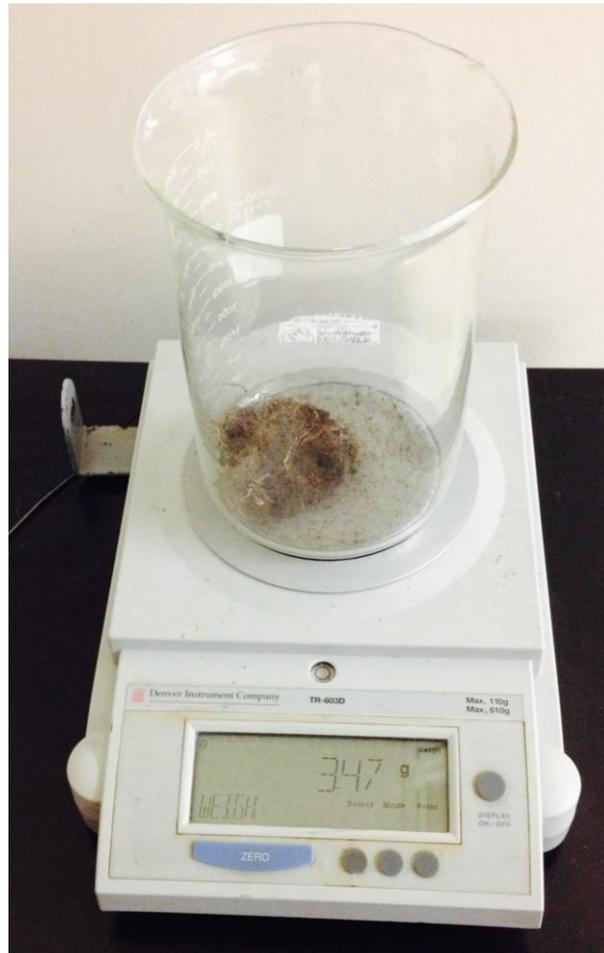


Figure 4. Process of weighing the plant roots and shoots.

3. Results and Discussion

Least square means of above-ground biomass of blue grama ($21.29 \pm 1.66\text{g}$) was more than twice as great as that of white stonecrop ($6.40 \pm 1.66\text{g}$, Table 2). Similarly, blue grama root biomass was more than twice as great ($14.84 \pm 1.32\text{g}$) as that for white stonecrop ($6.83 \pm 1.32\text{g}$). However, shoot to root ratio did not differ significantly between species (2.05 and 2.32 for blue grama and white stonecrop, respectively).

Table 1. Shoot and root weight raw data

Sample	<i>B. gracilis</i> Shoots	<i>B. gracilis</i> Roots	<i>S. album</i> Shoots	<i>S. album</i> Roots	<i>B. gracilis</i> Shoot:Root	<i>S. album</i> Shoot:Root
1	38.33	16.46	4.65	1.76	2.33	2.64
2	16.51	12.53	7.06	1.18	1.32	5.98
3	12.05	6.01	5.57	1.11	2.00	5.02
4	28.89	11.09	9.51	15.24	2.61	0.62
5	29.83	24.47	7.38	15.65	1.22	0.47
6	13.93	17.41	4.97	4.36	0.80	1.14
7	15.11	17.97	7.34	14.09	0.84	0.52
8	25.79	19.65	4.82	5.00	1.31	0.96
9	12.93	11.18	5.51	3.27	1.16	1.69
10	20.11	13.70	7.06	9.19	1.47	0.77
11	25.43	18.33	6.26	3.57	1.39	1.75
12	13.27	11.51	5.71	7.81	1.15	0.73
13	32.95	20.51	9.93	11.38	1.61	0.87
14	31.40	14.20	5.58	7.16	2.21	0.78
15	12.78	7.56	4.63	1.72	1.69	2.69

Table 2. Least squares means (\pm standard error) of blue grama and white stonecrop shoot and root biomass (g/2 plants) and shoot:root ratio.

Genus	Samples	Mean (Shoot Wt.)	Mean (Root Wt.)	Mean (Shoot:root)
<i>B. gracilis</i>	15	21.29 \pm 1.66	14.84 \pm 1.32	2.05 \pm 0.46
<i>S. album</i>	15	6.40 \pm 1.66	6.83 \pm 1.32	2.32 \pm 0.46

Table 3. Root Weight Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
<i>Species</i>	1	480.72	480.72	18.35
<i>Error</i>	28	733.57	26.2	Prob > F 0.0002
<i>Total</i>	29	1214.29		

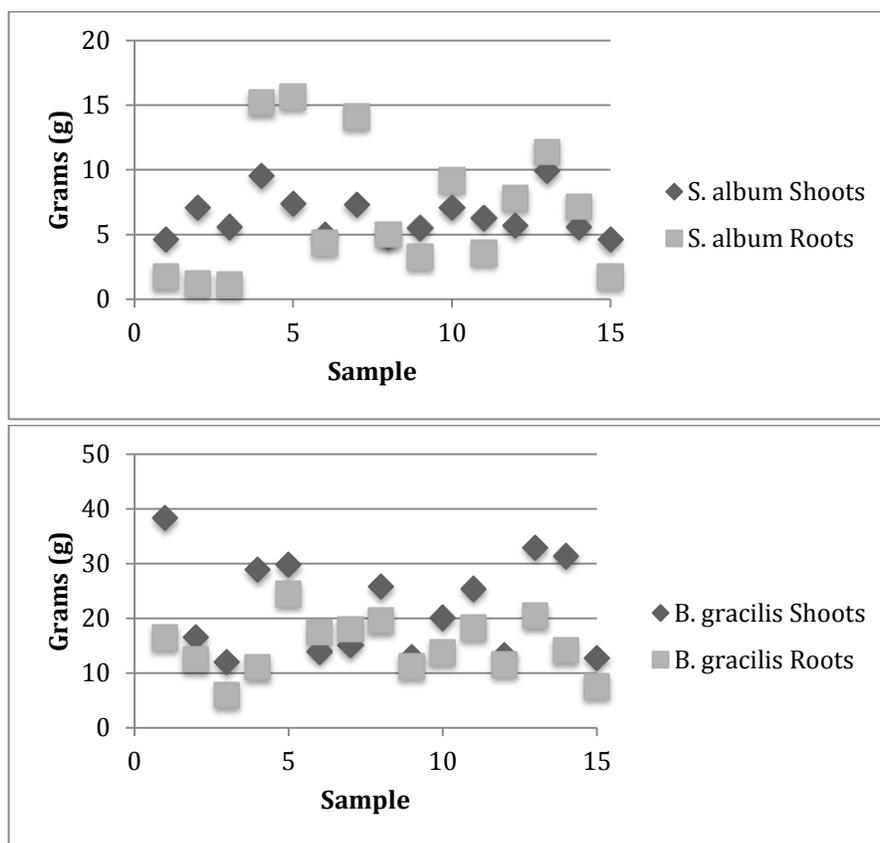


Figure 5. Scatter graph charting the weight from the raw root and shoot weights from *B. gracilis* and *S. album*.

Overall, blue grama yields greater above- and below-ground biomass than white stonecrop. If increased storage of carbon and organic matter in green roof substrate is a desired outcome, then blue grama is a more valuable species than white stonecrop. The resulting analysis also suggests that plant material should be considered in regards to the management and installation of green roofs to maximize the benefits of carbon sequestration. In order provide more thorough information on delineating between the biomass of native grass species and *Sedum* species, it will be necessary to conduct further studies and analyze a larger variety of plants. In future experiments, it will also be beneficial to reduce inconsistencies in biomass weight by improving the root cleaning process.

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