Evaluating Performance of a Green Roof System with Different Growing Mediums, *Sedum* Species and Fertilizer Treatments

Gibbs, J.[1], K. Luckett[2], V. Jost[3], S. Morgan[4], T. Yan[5], W. Retzlaff [1,6]

[1]Environmental Sciences Program; [2]Green Roof Blocks™, St. Louis MetalWorks, Inc.; [3]Jost Greenhouses; [4]Civil Engineering; [5]Mechanical Engineering; [6]Department of Biological Sciences; Southern Illinois University Edwardsville

ABSTRACT

Although green roofs have been utilized in Europe for many years, the technology is relatively new to the Midwestern United States. Forests and grasslands are rapidly being replaced with impervious surfaces as urbanization increases. This increase in impervious surface area can cause an increase in storm water runoff and the urban heat island effect. I have evaluated the effects of fertilizer treatment, *Sedum* species, and growing medium on green roof performance on the roof of the Engineering Building on the Southern Illinois University Edwardsville campus since September 20, 2005. At the end of a 10-week establishment period, *Sedum hybridum immergrauch* has the greatest growth index value. Plant performance and green roof coverage were the greatest when IBDU fertilizer was utilized. Green roof coverage and plant performance were the greatest when pumice was utilized as the growing medium. We will continue to monitor and evaluate the green roof systems in this study for the next two growing seasons.

INTRODUCTION

Urbanization increases the area of impervious surfaces therefore decreasing infiltration of precipitation and increasing runoff (Dunne and Leopold, 1978; Gordon et al., 1992; Leopold, 1994). The increase in storm water runoff increases both flood magnitude and peak discharge (Dunn and Leopold, 1978). Through the natural hydrologic cycle, streams, rivers, and underground water sources are rejuvenated from precipitation. However, an increase in impervious surface area results in reduced infiltration of precipitation to aquifers and may reduce groundwater recharge and stream base flow (Paul and Meyer, 2001). Runoff from precipitation events in the urban environment can no longer permeate the surface, but directly enters storm water drains or water bodies causing increased runoff and water pollution problems. A study performed by Zobrist et al. in 2000 concluded that pollutants from roof runoff will lower the water quality of any surrounding water bodies.

The urban heat island effect is a result of metropolitan cities loosing green space to hard surfaces composed of concrete or asphalt. These hard surfaces absorb and hold heat longer than green spaces therefore causing an increase in the temperature of the city. As a result, many communities notice an increase in energy costs from air conditioning costs. Green roofs can help replace lost green space. Results from surveys conducted on a green roof system on Chicago's City Hall have shown that the ambient air temperature around a green roof was as much as 15°F cooler than the ambient air temperature surrounding a traditional roof (Yocca 2002).

Green roofs have many benefits, such as saving on energy consumption (Niachou et al., 2001; Wong et al., 2003); increasing the life span of a typical roof; filtering harmful air pollutants (Liesecke and Borgwardt, 1997); filtration of water pollutants; decreasing the urban heat island effect; and storm water runoff mitigation. These benefits are directly linked to green roof performance. Many consider storm water mitigation to be the primary benefit of green roofs because of the prevalence of impervious surfaces in urban and commercial areas (VanWoert et al., 2005). Studies have found that a green roof can retain more rainfall (82.2%) than a gravel ballast roof (48.7%) (VanWoert et al., 2005).

Another important benefit of green roofs is reducing the urban heat island effect. Cities with an abundance of impervious surfaces notice a 2 to 10° F increase in temperatures over rural areas (USEPA 2006). As stated previously, green roof systems can reduce this temperature increase. A study performed by Niachou et al. in 2001 concluded that the external surfaces beneath a green roof are heated less than a traditional roof.

Recent research conducted by a colleague in the Green Roof Environmental Evaluation Network at SIUE revealed that some *Sedum* species died only a few weeks after planting with little explanation as to what had occurred. Some evidence indicates that a minimal rainfall activated a slow-release fertilizer and the plants suffered from fertilizer injury. Other species under the same conditions suffered no injury. This research project was designed to address this question by determining the best plant species, planting medium, and fertilizer treatment for optimal green roof performance.

MATERIALS AND METHODS

Project Setup: Green Roof Blocks™ were arranged in a completely randomized design with three replications. All 108 Green Roof Blocks™ are 2ftx2ft with 4 centimeter growing medium depth and are placed directly on the rooftop surface of the Southern Illinois University Edwardsville Engineering Building (Figure 1).

Growing Medium: Arkalyte (expanded clay), Hadite (expanded slate), Pumice, Lava

Plant Species: *Sedum hybridum immergrauch, Sedum spurium, Sedum sexangulare*

Fertilizer Application: IBDU (nitrogen-based fertilizer): approximately 3.7 grams per plant was applied; Osmocote (N-P-K ratio 15-9-12): approximately 5.3 grams per plant was applied; control (no fertilizer).

On September 20, 2005, five hundred and forty *Sedum* spp. plugs were planted into 108 Green Roof Blocks™. Each block contains five plugs of the same species randomly assigned to different growth medium and fertilizer applications.

Figure 1. Green roof project on the roof of the Southern Illinois University Edwardsville Engineering Building.

DATA COLLECTION

Green roof performance was evaluated for 10 weeks using three data collection methods: plant performance, plant growth, and green roof block coverage bi-weekly.

Plant growth rate was quantified by measuring each plant's height and width in two perpendicular directions. A growth index was calculated for each plant by averaging the three individual growth measurements (Monterusso et al., 2005).

Plant performance was quantified by rating each plant on a scale of zero to five, (0 - dead, 1 - stressed plant showing visible wilting or browning, 2 - plant that showed little change since planting, 3 - slow growth, 4 - healthy plant exhibiting a large amount of growth, and 5 - exceptional growth and fullness) (Monterusso et al., 2005).

Roof coverage was quantified using a 6 x 6 circle coverage grid (each circle is 3.8 cm in diameter) in 4 quadrants and counting the circles that have plants in them.

All recorded data has been analyzed using SAS to determine if green roof growing media, *Sedum* species, or fertilizer treatment alters green roof performance (ANOVA for a completely randomized design, $\alpha < 0.05$).

RESULTS AND DISCUSSION

Growth Index: Plant growth was not affected by growing medium for the first 10 weeks after planting (Figure 2). However, plant growth index was the greatest in *Sedum*

hybridum immergrauch after 10 weeks (Figure 3). Plants in the Green Roof Blocks™ with IBDU application had the greatest growth index after 10 weeks (Figure 4).

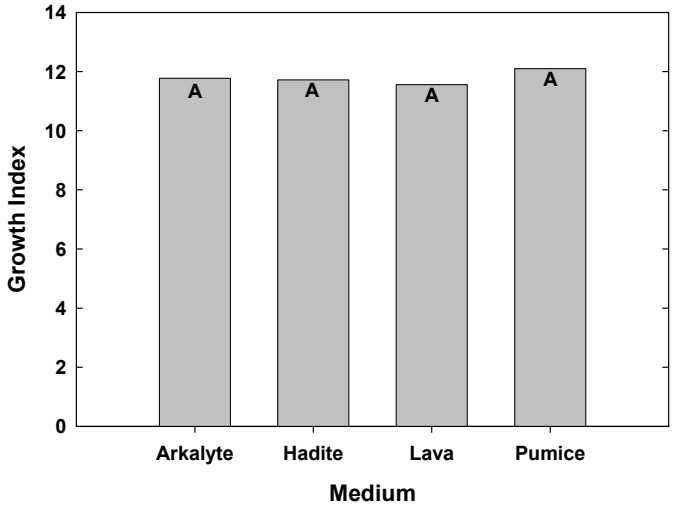


Figure 2. Plant growth index {(ht+diam1+diam2)/3} for different growing mediums after 10 weeks. (n=135) (Treatments with the same grouping letter are NOT statistically different, α=0.05).

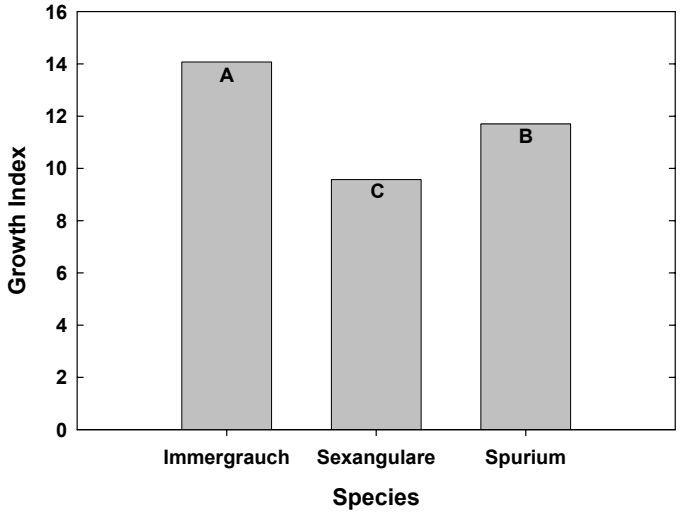


Figure 3. Plant growth index {(ht+diam1+diam2)/3} for the different *Sedum* species after 10 weeks. (n=180) (Treatments with the same grouping letter are NOT statistically different, α=0.05).

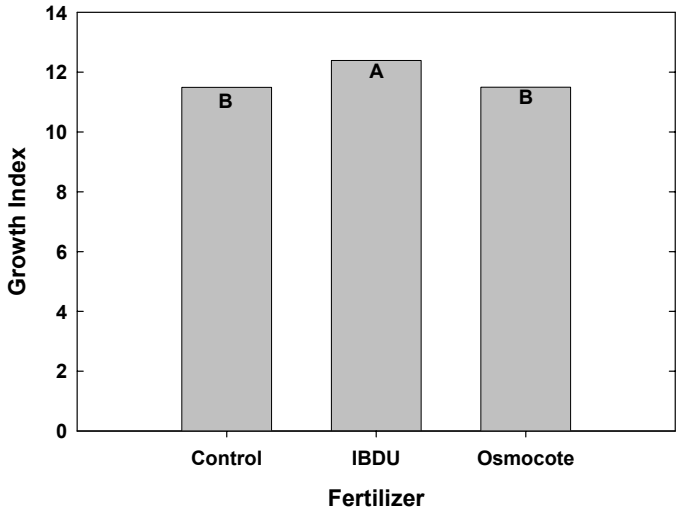


Figure 4. Plant growth index {(ht+diam1+diam2)/3} for different fertilizer treatments after 10 weeks. (n=180) (Treatments with the same grouping letter are NOT statistically different, α=0.05).

Performance: Plants in the Green Roof Blocks™ with IBDU application had the greatest performance value after 10 weeks (Figure 5). After 10 weeks, *Sedum hybridum immergrauch* had the greatest performance value (Figure 6). Plants growing in Green Roof Blocks™ with pumice growing medium had the greatest performance value 10 weeks after planting (Figure 7).

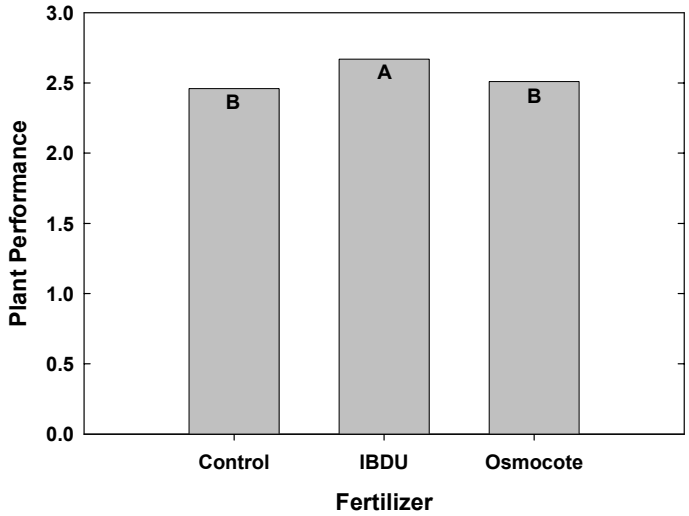
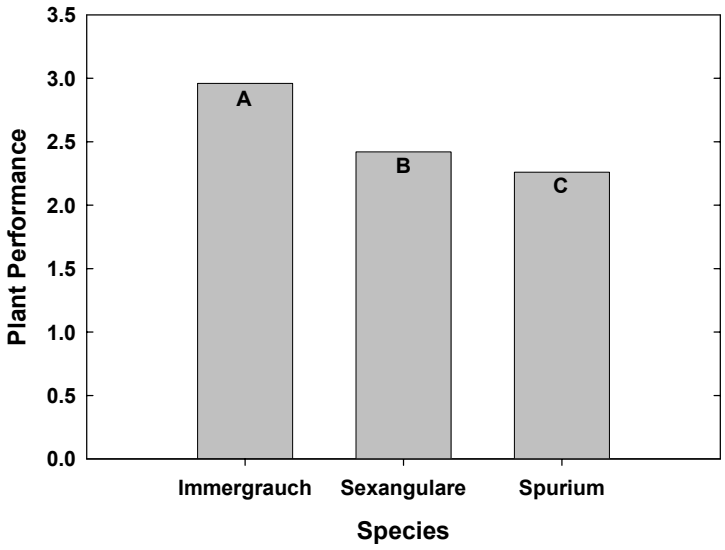


Figure 5. Plant performance ratings for different fertilizer treatments after 10 weeks. (n=180) (Treatments with the same grouping letter are NOT statistically different, α=0.05).



α

Figure 6. Plant performance ratings for different *Sedum* species after 10 weeks. (n=180) (Treatments with the same grouping letter are NOT statistically different, α=0.05).

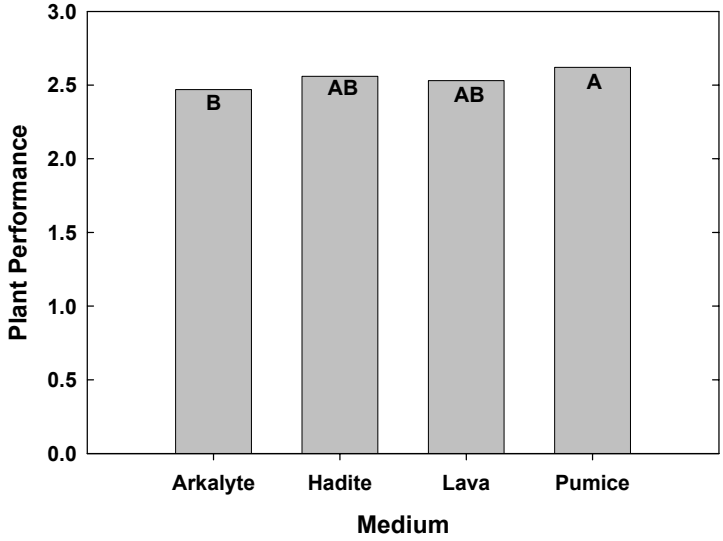


Figure 7. Plant performance ratings for different growing mediums after 10 weeks. (n=135) (Treatments with the same grouping letter are NOT statistically different, α=0.05).

Percent roof coverage: After 10 weeks, the plants in the pumice growing medium had the greatest percent roof coverage (Figure 8). *Sedum hybridum immergrauch* had the greatest percent roof coverage value after 10 weeks (Figure 9). Plants in the Green Roof Blocks™ with IBDU application had the greatest percent roof coverage value (Figure 10).

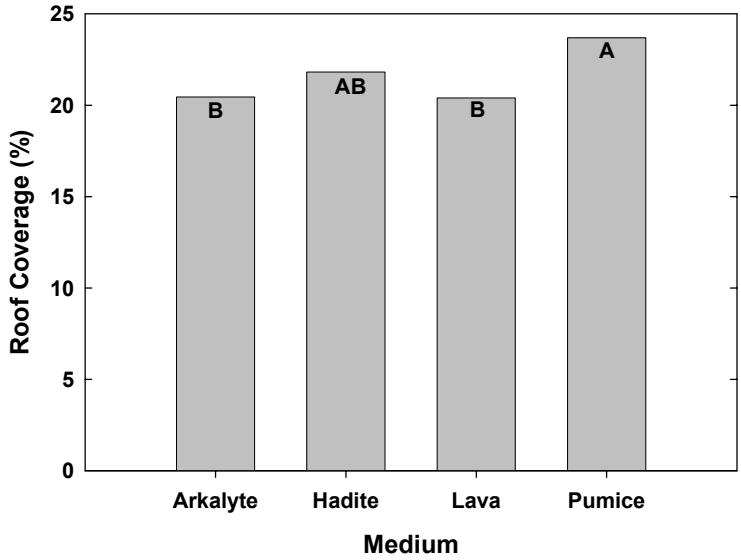


Figure 8. Percent roof coverage for different growing mediums after 10 weeks. (n=108) (Treatments with the same grouping letter are NOT significantly different, α=0.05).

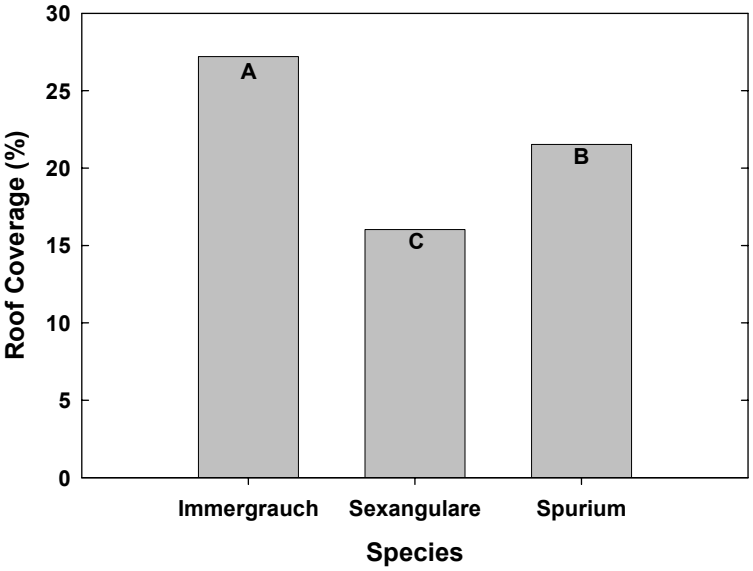


Figure 9. Percent roof coverage for different *Sedum* species after 10 weeks. (n=144) (Treatments with the same grouping letter are NOT statistically different, α=0.05).

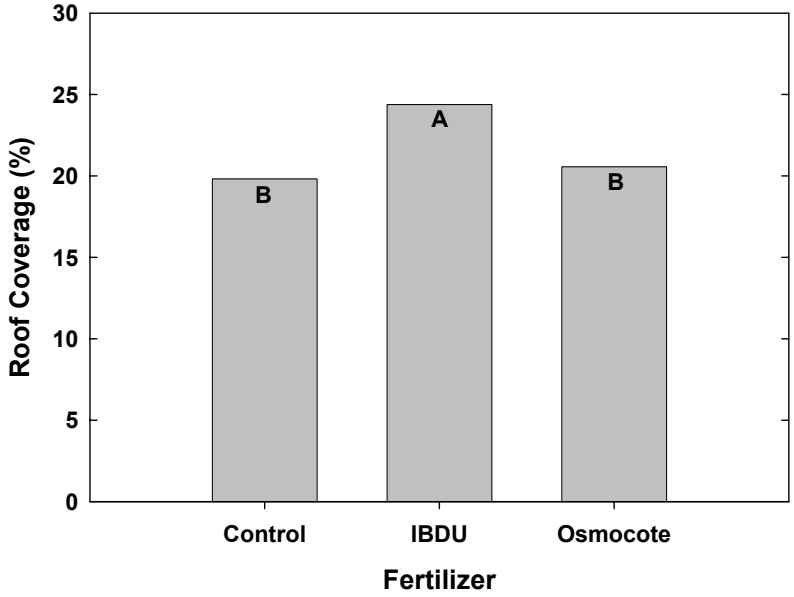


Figure 10. Percent roof coverage for different fertilizer treatments after 10 weeks. (n=144) (Treatments with the same grouping letter are NOT statistically different, α=0.05).

In this study, under the growing conditions of the Midwestern U.S., fertilizer application had an effect on percent roof coverage, plant performance, and plant growth. Results at 10 weeks indicate that IBDU may be the best fertilizer to use under these growing conditions. Results at 10 weeks also indicate that *Sedum hybridum immergrauch* may be the best species under these growing conditions. Plants in Green Roof Blocks™ containing pumice as the growing medium have greater percent roof coverage and plant performance values than other growing mediums.

CONCLUSION

The primary goals of a green roof system are to gain benefits, such as storm water runoff reduction, lowering energy costs, and extending the life of the roof. These benefits are directly affected by green roof performance. For optimal green roof performance, the best plant species, fertilizer application, and growing medium must be utilized. The goal of this study is to determine the best combination of fertilizer application, *Sedum* species, and growing medium for optimal green roof performance. At 10 weeks, results have shown that IBDU is the best fertilizer treatment and *Sedum hybridum immergrauch* is the best plant species being utilized. Growing medium has had little effect on plant growth index, but has had some effect on percent roof coverage and performance. At 10 weeks, the pumice growing medium has the best roof coverage and plant performance. This study will be monitored through April 2007 to evaluate plant growth, green roof coverage, and plant performance.

LITERATURE CITED

Dunne, T., Leopold, L.B., 1978. Water in Environmental Planning. W.H. Freeman Co., San Francisco, CA, USA.

Gordon, N.D., McMahon, T.A., Finlayson, B.L., 1992. Stream Hydrology: An Introduction for Ecologists. John Wiley & Sons Ltd., Baffins Lane, Chichester, West Sussex, England.

Leopold, L.B., 1994. A View of the River. Harvard University Press, Cambridge, MA, USA.

Liesecke, H.J. and H. Borgwardt. 1997. Abbau von luftschadstoffen durch extensive dachbegrunungen. Stadt Grun 33:245-251.

Monterusso, M.A., D.B. Rowe, and C.L. Rugh. 2005. Establishment and persistence of Sedum spp. and native taxa for green roof applications. HortScience 40(2):391-396.

Niachou, A., K. Papakonstantinou, M. Santamouris, A. Tsangrassoulis, and G. Mihalakakou. 2001. Analysis of the green roof thermal properties and investigation of its energy performance. Energy Buil. 33:719-729.

Paul, M.J., Meyer, J.L., 2001. Streams in the urban landscape. Ann. Rev. Ecol. Syst. 32, 333-365.

USEPA. 2006. Heat Island Effect. http://www.epa.gov/heatisland/

VanWoert, N.D., D. Bradley Rowe, J.A. Andresen, C.L. Rugh, R.T. Fernandez, and L. Xiao. 2005. Green Roof Stormwater Retention: Effects of Roof Surface, Slope, and Media Depth. Journal of Environmental Quality 34:1036-1044.

Wong, N.H., Y. Chen, C.L. Ong, and A. Sia. 2003. Investigation of thermal benefits of rooftop garden in the tropical environment. Build. Environ. 38:261-270.

Yocca, D. 2002 Chicago City Hall, Green Roof Chicago, IL. http://www.asla.org/meetings/awards/awds02/chicagocityhall.html

Zobrist, J., S.R. Muller, A. Ammann, T.D. Bucheli, V. Mottier, M. Ochs, R. Schoenenberger, J. Eugster, and M. Boller. 2000. Quality of roof runoff for groundwater infiltration. Water Res. 34:1455-1462.