

Systems Sustainability Service Learning Project

Growth study of Garberia (*Garberia heterophylla*), Lovegrass (*Eragrostis elliottii*), and Narrowleaf Silkgrass (*Pityopsis graminifolia*) on an Extensive Green Roof in a sub-tropical climate

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Introduction



Figure 1. A 16th-century hand-colored engraving of the "Hanging Gardens of Babylon" by Martin Heemskerck. [Source: http://en.wikipedia.org/wiki/File:Hanging_Gardens_of_Babylon.jpg]

Green roofs or rooftop gardens are in its simplest form-- roofs covered with a plant and soil layered system. It is known for its ecological, economic, and social benefits when incorporated into an urban environment, such as on a college campus.

Even though green roofs are not as widespread in the United States as in Europe, green roofs are not new with one of the oldest and most notable green roofs dating back to 500 B.C.E. with the Hanging

Gardens of Babylon where the stone roof held layers of reeds, tar and soil, climbing plants, and trees. Since then green roofs have been adapted to a variety of building structures all over the world (Wanielista et al 2008). As our natural areas are rapidly being developed into urban centers covered with impenetrable concrete surfaces it becomes apparent how important recovering those lost green spaces are for protecting the environment and our overall well-being (Rowe et al. n.d.).

However over the years the concept of the green roof has continued to change and evolve. Today contemporary society has altered these ancient roof gardens to meet the needs and limitations of modern architecture and societal needs (Oberndorfer, et al., 2007). When a building is erected there is inevitably damage to the flora and fauna beneath it. This damage can be mitigated by growing plants on the rooftop. As urban development proliferates, forest and farmlands are replaced with impervious surfaces. It is becoming increasingly necessary to recover lost green space in order to maintain critical health for our ecosystem services. One of

the leaders in green roof technology, research, and usage is Germany. Its green roof industry is growing at 10% to 15% per year with an estimated 12% of green roof coverage for all of its flat roofs (Rowe et al.). Germany, in particular, has led the way exploring how green roofs may provide fire retardation and alleviate sun degradation to roof structures (Koeler 2003).

According to the Environmental Protection Agency (EPA), a greenroof consists of vegetation and soil (minimum depth of 3”)—or an artificial vegetation mat, planted over a series of layers underneath including a combination of the following:

drainage layer, root barrier, waterproof membrane, cover board, thermal insulation, vapor barrier, and structural support as illustrated in Figure 2

(<http://www.epa.gov/>).

Today, there are primarily two types of green roofs known either as extensive or intensive. Extensive green roofs, such as the one utilized in this study, commonly have shallow substrates with a range of 2-20 cm, necessitate less maintenance, and serve to be more functional than intensive green roofs (Dunnett and Kingsbury 2004). Their primary purpose is to be functional versus aesthetic, provide storm water management, thermal insulation, and fireproofing.

Extensive green roofs generally fit within the given structural requirements of buildings and

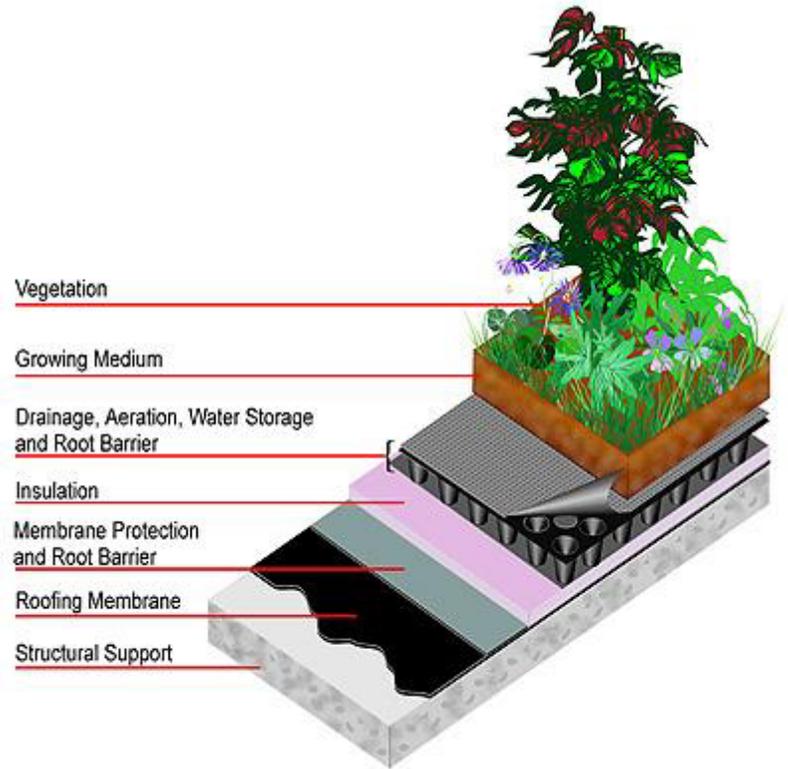


Figure 2. Example greenroof cross-section
[Source: <http://email.asce.org/ewri/LIDInitiatives.html>]

utilize a lightweight substrate. The flora used tends to be low growing and drought resistant and requires little irrigation. As a rule, the cost of an extensive green roof, beyond the water proofing membrane, is less expensive.

Intensive green roofs provide a greater aesthetic quality and offer increased living space. More planning is needed when creating an intensive roof as the weight load may require additional reinforcement of the roof. The substrate may be 20 cm or more and the plant restrictions of intensive green roofs are only limited by the physical restrictions of the substrate depth and irrigation capabilities of the facilities (Oberndorfer, et al. 2007). By measuring the growth of native plants on the green roof vs. normal ground level growing conditions we are able to shed light on the species (including threatened Florida native *Garberia*) and feasibility of urban green roofs which have long lasting tangible effects on the heat reduction in building roofs, etc. This study was created in order to determine, what, if any endangered, threatened or native plants species can be effectively grown on a green roof. Specifically, can the species of *Garberia heterophylla*, *Eragrostis elliottii*, *Pityopsis Graminifolia – var. tracyii* and be grown, either from seed or seedling, on the University of Central Florida’s Plant Sciences extensive green roof?

Garberia (*Garberia heterophylla*) also known as *Garberia fruticosa*, is an endemic, state listed threatened, Florida native which lives in the sand ridges and hills of central and northeast peninsular Florida. *Garberia heterophylla* (pronounced gar-BEER-ee-uh het-tur-roe-FIL-lu) is a small perennial woody shrub distinguished by its dull green/grey foliage and alternate leaves hidden behind the lavender flowers which are visible in Fall (see Figure 3). It



Figure 3. *Garberia heterophylla*

attracts butterflies, can be used as a reclamation or border plant, and provides habitat for native Florida fauna (Gilman 2007).

According to the University of Florida Institute for Food and Agricultural Sciences

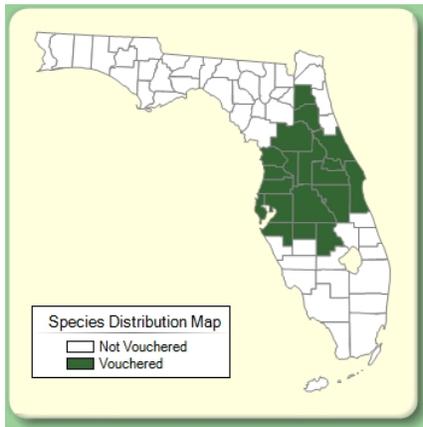


Figure 4. Distribution of *Garberia heterophylla* in FL (Source: Atlas of Florida Vascular Plants)

(Gilman 2007), *Garberia heterophylla* tolerates drought and prefers acidic sandy soils. The recommended plant spacing is 36 to 60 inches in full sun and the plant can grow up to 4 to 8 feet in height (Gilman 2007). Figure 4 illustrates the confirmed distribution of *Garberia heterophylla* in Florida, but also shows how, as an endemic species, it needs particular habitat characteristics found only in central and

northeast Florida (Atlas of Florida Vascular Plants n.d.). The establishment of seeds seems to be intimately connected to

the presence of fire, albeit in different ways than other species, as *Garberia* begins the seedling development and flowering later and lasts longer than the other *Eriogonum* species (Carrington 1999). Furthermore, it has demonstrated strong re-sprouting characteristics after a fire, with individuals flowering by five months after exposure to fire in Ocala, FL and continuing to flower more than the *Chapmannia* species two years later (Carrington 1999). *Garberia*'s life history strategy is a post-fire flowerer, which means it has a strong seedling establishment after a fire followed by re-sprouting and flowering.

In order to learn more about the germination and transplantation success of *Garberia heteropylla* compared to other species planted on the roof, we chose to germinate and transplant two other Florida natives, *Eragrostis elliottii*, and *Pityopsis graminifolia* – var. *tracyii*. *Eragrostis elliottii*, commonly known as love grass, blue love grass, or Elliot’s lovegrass is a widespread drought tolerant Florida native. It is distinguished by its low, fine-textured, warm season grass that typically grows to be 6-18 inches tall and can be typically found in pineland, prairie, and open coastal habitat (see Figure 5). It prefers well-drained moist to wet soils and grows well in nutrient poor soils in the full sun. The white flowers from July to October precede the seeds which serve as a food source for birds (Gann et al 2012).



Figure 5. Lovegrass (*Eragrostis elliottii*)

Pityopsis graminifolia, also known as Narrowleaf Silkgrass or Golden Aster, is a drought tolerant Florida native plant in the same family, Asteraceae, as *Helianthus debilis debilis* which was used as a pilot plant on the same green roof in 2011. This tough, vigorous, semi-evergreen

ground cover perennial is adapted to drought and fire and has a pH tolerance of 5.8 to 7.0. This silvery green, grass like plant’s daisy-like flowers (see Figure 6) bloom in August-November which attracts butterflies and is a source of nectar for wildlife (Lady Bird Johnson Wildflower Center). One interesting consideration is that this plant acts as a perennial in southern Florida but as a reseeding annual throughout central Florida, which means we will likely



Figure 6. Narrowleaf Silkgrass (*Pityopsis graminifolia*)

have to take greater care for its growth and seeding since it may only last one season (versus a perennial lasting all year round). Furthermore, according to the research conducted at the University of Central Florida Physical Sciences building roof, *Helianthus debilis debilis* not only is a viable green roof species because of its well matched tolerances for sunlight, drought, salt, and wind conditions, but also its high performance in regulating below system temperatures as compared to *Muhlenbergia capillaris*. Its past performance has shown benefits including reducing energy costs by reducing the temperature difference between the roof and the building interior (Cade 2010).

Research about the germination and transplantation success of these three Florida native species is important to contribute to UCF's land management and protection of threatened native plants in central Florida. On a larger scale, this helps Florida keep its unique botanical heritage.

Ultimately to do this, it is necessary to acquire target habitats of these declining species (by federal, state, or local agencies), to properly manage for protection, and to educate the public about Florida's imperiled native flora as it is a team effort (Ward n.d.).

This study of plant growth and success on the Physical Sciences green roof incorporates several aspects of sustainability in the ever growing and well-populated University of Central Florida campus. Since our project aims to apply sustainability to a real-life project we are able to learn first-hand about how the three legs of sustainability and other factors influence our community's ability to become more sustainable, and thus conserve our natural resources for a better future.

There are three components of sustainability: economic development, environmental protection, and social justice. A substantial campus such as the University of Central Florida (UCF) adds to the economic development of the surrounding community by creating a way to conserve the money spent on purchasing seeds or seedlings from outside sources. By growing endangered,

threatened, and/or native species on a green roof, the university creates its own sustainable source for seeds or seedlings of those specific species grown in the community. The plants from the green roof can be used as a seed bank source or transplanted on campus grounds for restorative or beautification purposes. Green roofs are one approach to sustainability which offers many potential economic as well as ecological benefits including, but not limited to: managing the storm water runoff, conserving energy, mitigating the urban heat island effect, increasing the life of a rooftop surface, on top of providing a more pleasant environment for people (Rowe et al.).

The act of reducing the temperature difference with establishing a green roof saves a significant amount of money on the cooling and heating costs of each building. For example, the Chicago City Hall green roof measures almost 80°F (40°C) cooler than the adjacent conventional roof as pictured in Figure 7 below.



Figure 7. Temperature Differences between a Green vs. Conventional Roof [Source: W

Another advantage is the potential to extend the life of the roof which in turn reduces the costs of roof repairs and future replacement. A green roof extends approximately 20-30 years of longevity to a standard roof due to the reduced direct sun exposure and insulating properties of the plant and substrate layers.

Green roofs also help to protect the environment. As stated previously, green roofs provide a natural layer of insulation on top of the building. This cuts the cooling and heating costs, thus conserving the amount of energy used and pollutants released into the environment. Greenhouse gases, theoretically, are causing a change in the global climate which is leading to global warming. If more buildings were built or installed with a green roof, this effect may be dramatically reduced by reducing the carbon footprint generated by the building. An important environmental service is also provided by green roofs: storm water management. The green roof slows down the runoff from rain and is able to filter out some of the pollutants from rainfall. When this water finally does runoff into the natural green space, the water is clean, preventing pollutants from entering the natural environment. Another benefit of green roofs to environmental protection is the reduction of the heat island effect. In an urban environment, the more green space that is incorporated, the greater the reduction of the heat island effect. Depending on the type, extensive or intensive, green roofs also serve as a habitat for small birds, animals, and insects.

As for the social justice component of sustainability, green roofs bring the aesthetic qualities of the natural environment back to the urban areas where we live and work. By growing and revitalizing many plant species, green spaces such as green roofs will increase providing the community with a beautiful, natural place to feel rejuvenated. By using green roofs to grow native, endangered, or threatened plant species, these green spaces can remain beautiful and flourish with the transplantation of those aesthetically pleasing plants. Another aspect of social justice is the fact that the potential to provide a new market of “green collar jobs” that allows people who may have previously been unemployed to enter the workforce and to experience greater job security in a local job that will not be outsourced. They would have great satisfaction

in their work knowing that their effort is contributing to the sustainability of the current urban environment for a long time and making it healthier for themselves and their children to come who will likely work and live in an urban area. Similarly the authors of “Ecosystem Services in Urban Areas”, stress that we cannot separate our advanced urban lifestyles from nature because we are ultimately very dependent. The benefits we receive from the surrounding natural ecosystems and urban ecosystems are irreplaceable and must be actively protected. If you take a closer look at Stockholm, a modern developed city, we see that intimately intertwined in the concrete jungle is the following supportive ecosystem services: air filtration, micro climate regulation, noise reduction, rainwater drainage, sewage treatment, and recreation/cultural services (Bolun and Hunhammar 1999). It is even more important because of how fast the modern world is urbanizing. According to the UN, by 2030 60% of the world’s population (which is now around 7 billion) will live in cities around the world (Bolund and Hunhammar 1999). By looking at the social, economic, and environmental impacts of green roofs and the native plants we intend to grow on it we are able to contribute to the current literature about what is feasible and desirable in today’s construction heavy university campus setting.

Methods

The study was conducted on the campus of the University of Central Florida’s Physical Sciences I building. Twenty four recycled growing trays were utilized from an existing modular green roof. The dimensions of the trays were two feet by four feet with a depth of four inches. As described by Cade, twelve of the trays contained an initial layer of 1mm synthetic fabric to act as a filtration layer and root barrier. Atop this fabric, a one inch stratum of expanded clay and crushed rubber was placed to function as a water pollution control layer. Next, an additional layer of 1mm fabric was used as a pollution control layer from the substrate above. Finally, these

twelve trays contained a three inch layer of expanded clay and organic compost (“Black and Gold” proprietary blend) which was used for the growing substrate (Cade 2010). The remaining twelve trays consisted of four inches of commercial grade compost, hence forth referred to as “compost.”

The three species chosen for the experiment were Garberia (*Garberia heterophylla*), Silver Lovegrass (*Eragrostis elliottii*) and Narrowleaf Silkgrass (*Pityopsis Graminifolia – var. tracyii*). All plants were Florida natives known for their sun and drought tolerance. Half of the species were planted from seed and half from plants purchased from Green Images nursery of Central Florida with the exception of *Garberia heterophylla*. While local *Garberia heterophylla* seed was used, cuttings were collected from populations found in the Natural Lands on the UCF Orlando Campus (see Figure 8 below) since it is commercially unavailable.

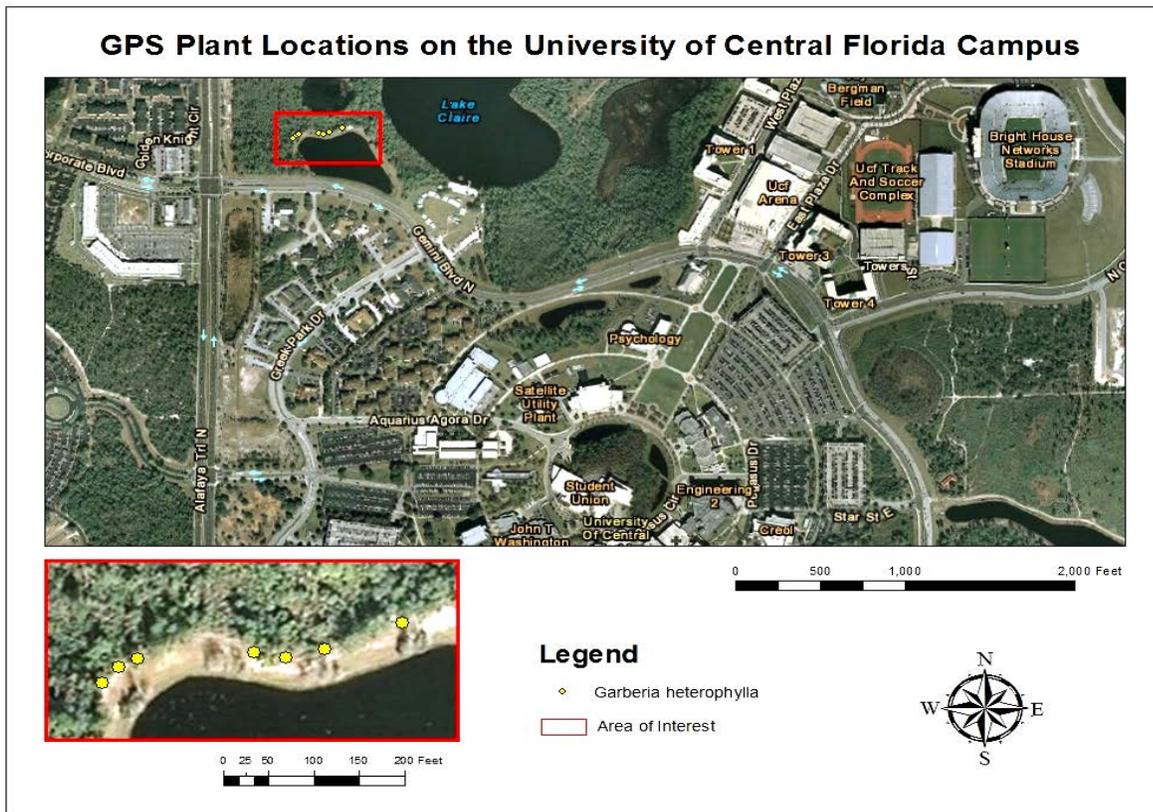


Figure 8. *Garberia heterophylla* Sample GPS Locations on UCF Campus

Two sites were used for the experiment. The first experimental treatment site was utilized for germination and healthy establishment of seedlings and also as a control for ground level growth. This site was located under a shade structure in the UCF Arboretum and consisted of twelve trays filled with Black & Gold medium and twelve trays of the commercially available compost. Eight trays of each of the three species were planted in both mediums so that four trays received seed and four trays received seedlings or cuttings (See Figure 9).

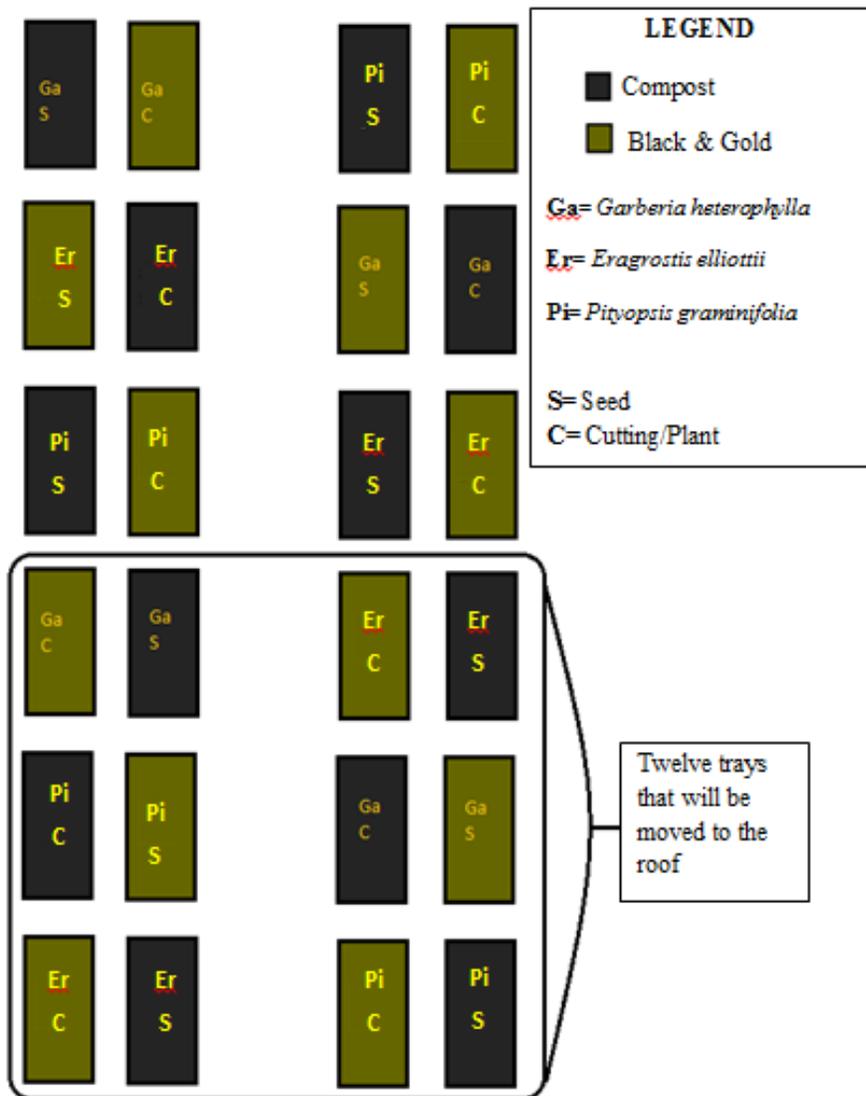


Figure 9. Roof tray setup on ground level indicating growing medium and plants



Figure 10. UCF Arboretum shade structure for plants [Courtesy of S. Fiondella and R. Papson]

Upon initial planting, each *Eragrostis elliottii* plant was trimmed to a height of twelve inches and each *Pityopsis graminifolia* was trimmed to fifteen inches in order to establish a base height from which to measure growth. *Garberia heterophylla* cuttings were cut at a standard length of five inches. Ten seeds of each species were planted.

Additional measurements taken include soil temperature, soil moisture, survival, and sun exposure observations (See Figure 11). Soil temperature was measured once a week by inserting a General Tools™ 20 inch by 2 inch

Dial™ Soil Thermometer into a tray. Soil moisture readings were done by insertion of a soil moisture meter into three separate locations within a single tray once a week. An average of the three moisture readings was taken per tray with a final average taken for all trays measured. pH levels were taken upon initial planting and at the end of the experiment.

All the species were planted October 5th, 2012. On October 19th, 2012 the drip irrigation system was installed with a timer that watered the plants for six minutes twice a day. At this time, the measurements of the trays began. An existing drip-line irrigation system was utilized to water the rooftop plants. The twelve rooftop-bound trays were transported on November 5th, 2012 in order to begin data collection on the growth of the plant species on the roof versus ground levels. Final measurements were taken on November 21st, 2012.

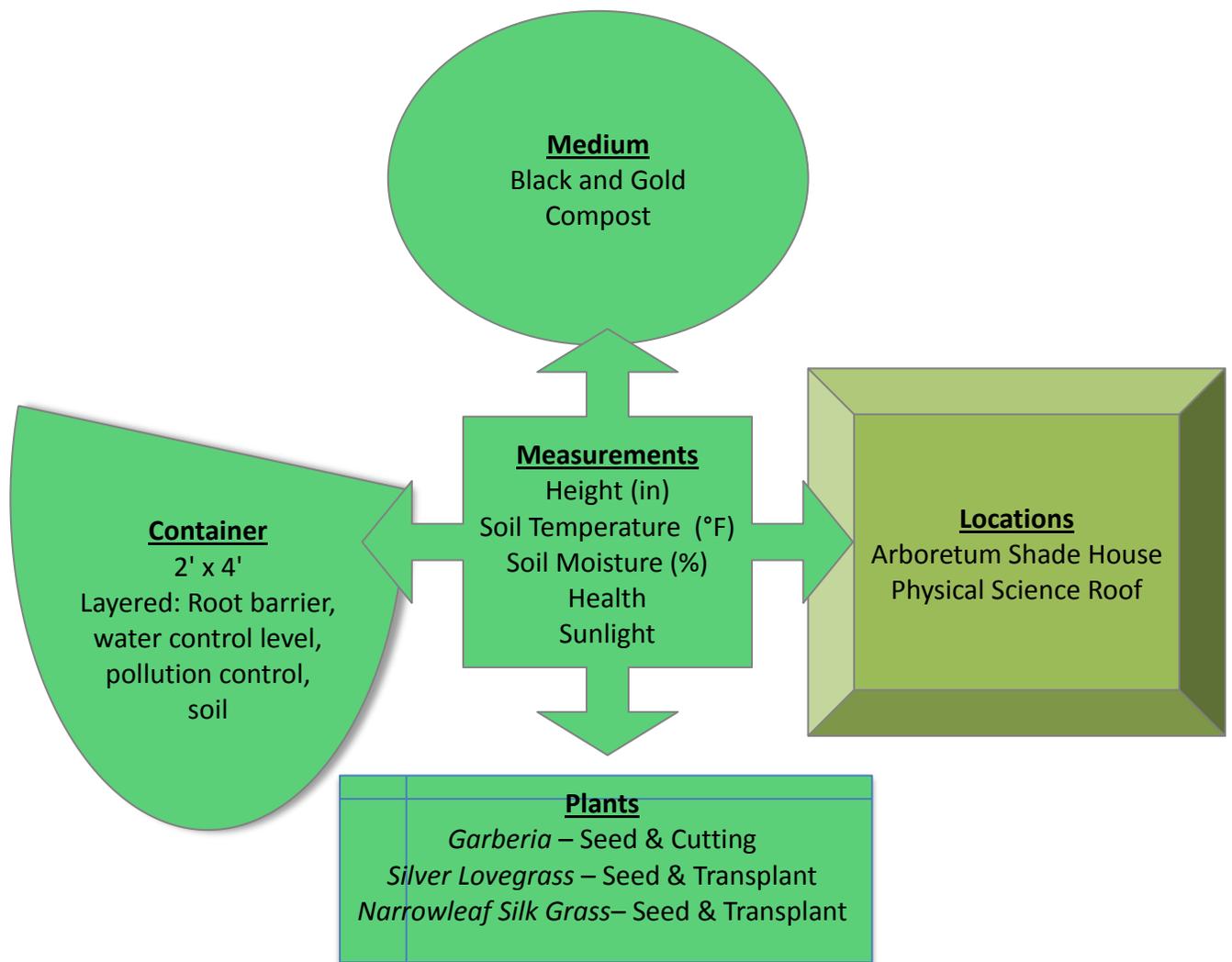


Figure 11. Visualization of Methods

Results

Temperature

The mean temperature for the Black & Gold medium on the ground was 63° F. The mean temperature for the compost medium on the ground was 63° F (Figure 12). The mean temperature for the Black & Gold medium on the roof was 64° F. The mean temperature for the compost medium on the roof was 66° F (Figure 13).

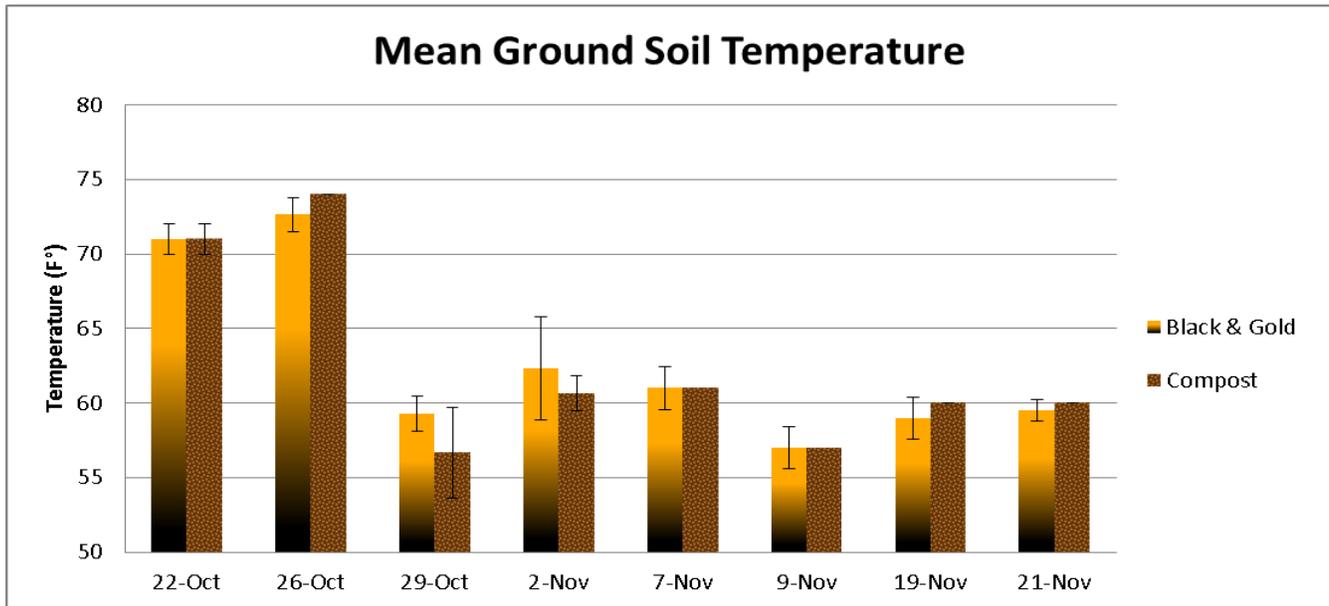


Fig.12. Means and standard deviations of ground soil temperatures

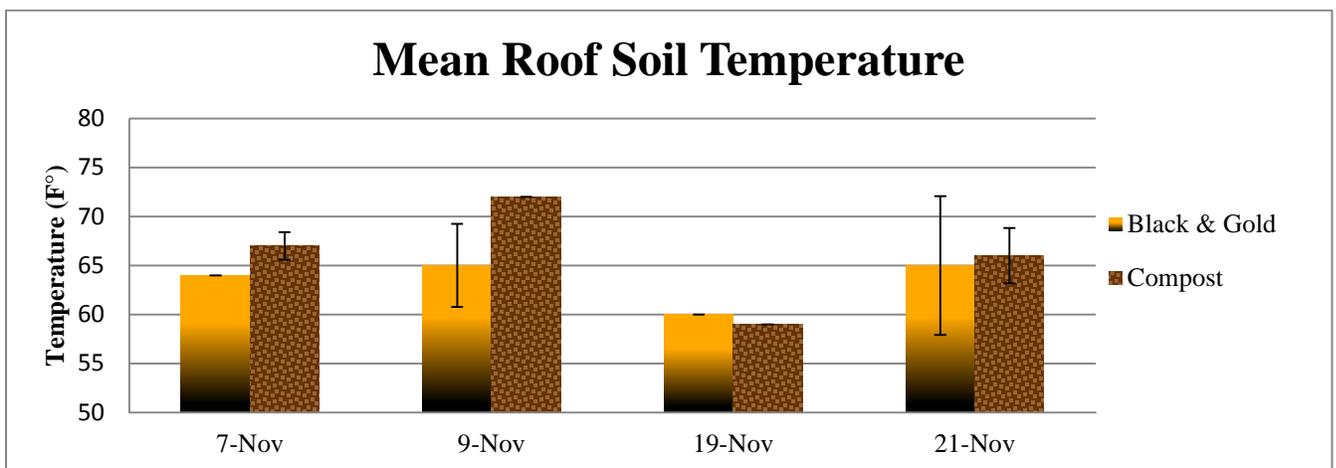


Fig.13. Means and standard deviations of roof soil temperatures

Substrate Moisture

The average soil moisture for Black & Gold medium on the ground was 6.5%. The average soil moisture for compost medium on the ground was 9.4%. The average soil moisture for Black & Gold medium on the roof was 6.6%. The average soil moisture for compost medium on the ground was 8.0% (Figure 14).

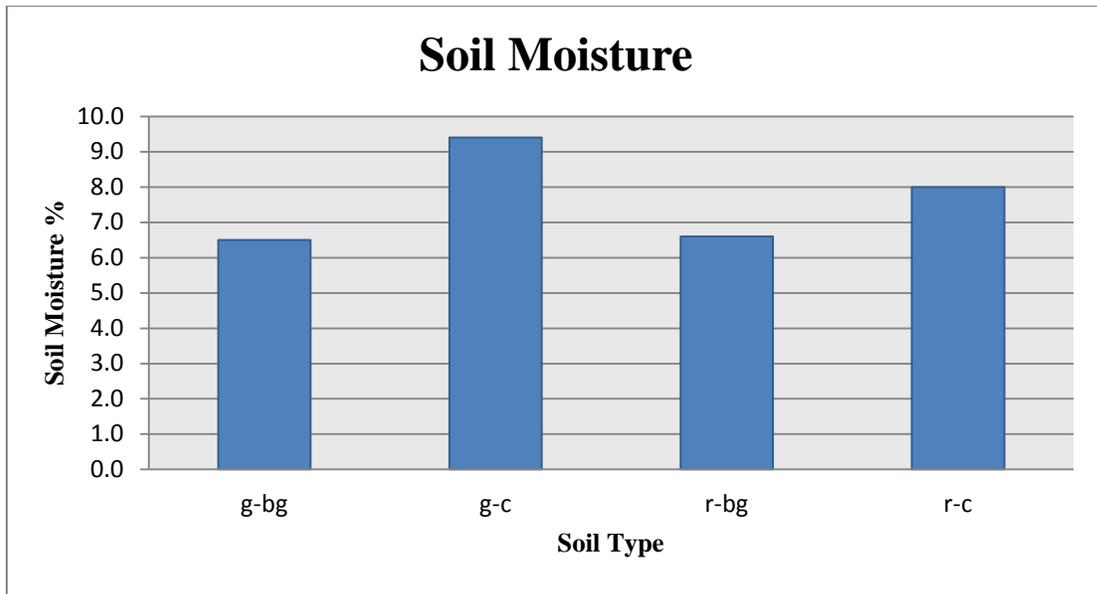


Fig.14. Mean soil substrate moisture for ground(“g”) and roof(“r”) for each medium type Black & Gold(“bg”) and compost (“c”).

Height and Survival

Fifteen cuttings of *Garberia heterophylla* were planted in Black & Gold medium and ten died by the end of the experiment. Fifteen cuttings of *Garberia heterophylla* were planted in compost medium and eleven died by the end of the experiment. Ten seeds were planted of *Garberia heterophylla*, *Eragrostis eliottii* and *Pityopsis graminifolia* in Black & Gold medium and compost respectively. None of the seeds sprouted. The original height of *Pityopsis graminifolia* was trimmed to 15 inches. The median height at the end of the experiment for *Pityopsis*

graminifolia on the ground in the Black & Gold medium was 16.1 inches. The median height at the end of the experiment for *Pityopsis graminifolia* on the ground in the compost medium was 16.85 inches.

The original height of *Eragrostis eliottii* was trimmed to 12 inches. The median height at the end of the experiment for *Eragrostis eliottii* on the ground in the Black & Gold medium was 17.85 inches. The median height at the end of the experiment for *Eragrostis eliottii* on the ground in compost was 18.9 inches.

Two of the *Pityopsis graminifolia* plants on the roof died. After removing these two plants from the mean height, the median height at the end of the experiment for *Pityopsis graminifolia* on the roof in the Black & Gold medium was 15.75 inches. The median height at the end of the experiment for *Pityopsis graminifolia* on the roof in the compost medium was 15.2 inches.

The median height at the end of the experiment for *Eragrostis eliottii* on the roof in the Black & Gold medium was 14.4 inches. The median height at the end of the experiment for *Eragrostis eliottii* on the roof in compost was 16.5 inches. It is important to note that the *Pityopsis graminifolia* had decreases in height because the tallest part of some of the plants died. We measured the living parts of the plant so the living leaves were usually substantially lower, and *Pityopsis graminifolia* had more plants that remained the same overall with no change in height(possibly to spend its energy creating flowers) which reveals the complexity in measuring the growth of different plants in colder weather.

The pH of both mediums remained the same throughout the experiment. The pH for the Black & Gold medium was 8 and for the compost medium 7(slightly more acidic).

Discussion

The brevity of our study, seasonality, and the lack of replication gives cause to further research candidate species for green roofs in a subtropical climate.

Growth on the green roof is important in supporting our hypothesis that different native Florida species will flourish there. It is important in establishing future green roofs at UCF with greater knowledge of which types of plants will be ideal for green roofs. According to our results, *Eragrostis* and *Pityopsis* showed increased final growth height. However, *Eragrostis* appears to be a more suitable candidate for future use on the green roof. This plant began in the trays on the ground at a height of 12 inches. The final measurements showed an average growth of 3.45 inches on the roof. This supports further research utilizing this plant species on the green roof due to a greater increase in height compared to *Pityopsis*. It is possible that the initial trimming used in order to form a base height had a negative effect upon the final height of the *Pityopsis*. Further experiments without such stress on those plants may provide a more precise and robust growth rate.

The compost had greater water retention than the Black and Gold medium on both the roof and the ground. The greater growth in the compost medium suggests that water retention promotes plant growth and temperature regulation. The high specific heat index of water (requiring 4.18 Joules of energy before it increases by 1 degree Celsius) helps maintain a more stable soil temperature which lowers the temperature differential between the atmosphere and the roof. This provides a greater stability for root growth. In addition, a greater depth of compost medium may have allowed for further root growth versus the shallow substrate of Black and Gold.

The viability of *Garberia* as a green roof candidate species cannot be absolutely determined due to the high mortality rates of the cuttings in both locations. This suggests that *Garberia* cuttings during this time of year are not a suitable propagation method regardless of growing on the ground or roof.

Due to widespread sprouting throughout the seed trays beyond the marked planting areas, the seed germination rate for these three species remains inconclusive. Because of the short experimental period, the seeds did not have substantial time to germinate and mature to an identifiable and quantifiable level. The short time frame affected the overall experiment.

Our results suggest that the established plants exhibited more growth than the cuttings on both the roof and ground. The observed growth rate was likely negatively affected by the combination of weather conditions, unfavorable growing season, and interrupted irrigation schedule.

Furthermore, time was certainly a factor. Given more time to perform the experiment, it is possible that there would have been a greater chance for conclusive results. Additionally, more accurate methods and technology should be developed so as to provide a more precise way to measure growth.

Deeper research into the proper species selection and the seasonality thereof would have greatly benefitted the experiment. Significant experimental time was lost due to changing the species at the beginning of the experiment. This restricted potential growth and observation time for the chosen plants and seeds.

Finally, irrigation hardware malfunction during an extended period of time affected the results. Had the timer not malfunctioned further growth may have been observed. This malfunction was

not discovered until the following week when the potential damage to the plants as a result of a lack of proper watering had already occurred.

For future green roof studies, we strongly suggest trying multiple native species and planting them at seasonally appropriate times. Much like Cade's study on the Physical Sciences I green roof, the grasses (not limited to Muhly grass) seem to outlast the flowering *Helianthus debilis debilis*. While grasses grow better, it would be suitable to find flowering plants that also thrive on the green roof for aesthetic purposes (Cade 2010). Another suggestion would be to target plants with different root systems that would do well in shallow green roof trays and hold the soil and moisture better so that issues with irrigation and inclement weather do not preclude the health of the vegetation on the roof. Further research into creating a sustainable rooftop ecosystem by observing the butterflies, birds, insects, and other wildlife that may colonize on the roof with the existing green roof plants is warranted. All of these research studies are essential to creating and managing the most efficient ecologically sound green roof system.

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