SURVEY OF SUITABLE PLANTS FOR CAL POLY’S GREEN WALL

By

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ABSTRACT

Green wall technology is a growing industry in the United States and has been very successful for several years throughout Europe. The objective of this survey was to study the success of several different species of plants on a vertical wall facing south at Cal Poly’s Horticultural Department Unit. At first the focus was aimed at using California native species, because it was thought that natives would be better acclimated to the exposure in this specific location. It became apparent that plants should not be selected for the wall based just on the fact that they are California natives. A new selection of plants was based on growth habit and requirements. The ideal growth habit for plants on this wall creates a creeping, or dense mat that does not extend more than two feet from the wall; bunch grasses and perennials are good examples, which also grow in low water, high light conditions.
ACKNOWLEDGEMENTS

I would like to thank several people who helped during the process of writing this handbook.

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Tiffany Faulstich, Dr. John Peterson, and Chris Wassenberg all played a huge part in the construction and long-term maintenance of the living wall. Without them and the funding from Cal Poly’s Horticulture Department, this wall and my senior project would not have been possible.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Introduction</td>
<td>7</td>
</tr>
<tr>
<td>II. Literature Review</td>
<td>7</td>
</tr>
<tr>
<td>Interior Green Wall Systems</td>
<td>7</td>
</tr>
<tr>
<td>Exterior Green Wall Systems</td>
<td>8</td>
</tr>
<tr>
<td>Plant Selection for Green Walls</td>
<td>9</td>
</tr>
<tr>
<td>Plant Selection for Cal Poly’s Green Wall</td>
<td>10</td>
</tr>
<tr>
<td>III. Materials and Methods</td>
<td>10</td>
</tr>
<tr>
<td>IV. Results and Discussion</td>
<td>11</td>
</tr>
<tr>
<td>V. Conclusion</td>
<td>14</td>
</tr>
<tr>
<td>Literature Cited</td>
<td>15</td>
</tr>
<tr>
<td>Appendix A</td>
<td>16</td>
</tr>
<tr>
<td>Appendix B</td>
<td>20</td>
</tr>
<tr>
<td>Appendix C</td>
<td>25</td>
</tr>
<tr>
<td>Appendix D</td>
<td>26</td>
</tr>
</tbody>
</table>
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Original plant placement design for wall</td>
<td>24</td>
</tr>
<tr>
<td>2. Comparison of plant health and vigor of species on wall over a period of eleven months</td>
<td>24</td>
</tr>
<tr>
<td>3. Revised plant placement design for wall</td>
<td>24</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1.</td>
<td>Interior green wall air filtration system</td>
</tr>
<tr>
<td>2.</td>
<td>Levels of radiation follow the rise and fall of temperature</td>
</tr>
</tbody>
</table>
I. Introduction

Green walls are, ideally, self-sustaining garden systems that can be designed on the exterior or interior walls of a building. Walls can be categorized into two different types. Intensive green walls have the plants grown in a system built within the reinforced wall, rather than on wall surface. The plants are allowed to grow to full potential because there is a constant source of water and nutrients available either through hydroponics or media acting as soil to maximize vitality. Most intensive green walls consist of a metal frame, waterproofing membrane to prevent leaks from ruining building infrastructure, special growing media, automatic irrigation systems, suitable plants, and UVB/UVA lighting when maintaining interior areas. Extensive green walls, on the other hand, are more superficial. Plants like ivy or other climbing vines that can attach to building walls without support structures are used to create a façade. These types of walls are easy to create with enough patience and time. Any homeowner can create a unique cottage feel to a track home by installing these types of perennials at the base of exterior walls. These walls create epically picturesque scenes by using a variety of colors and textures within the plant palette. Green walls are aesthetically pleasing as well as beneficial to our environment. These walls have many of the same benefits as green roofs, including regulating the building’s internal temperature, cleaning the air, and for exterior systems, retention and cleaning of the runoff rainwater. Plants must be specifically selected for the container and microclimate of the area surrounding the wall. It is especially important to take note of the direction the wall is facing and wind factor when selecting plants that will adapt and thrive on a vertical wall.
II. Literature Review

An interior green wall will clean the air, acting as a bio-filter, while regulating the ambient temperature within the building. A green wall system designed for interior spaces can be applied in such spaces as office buildings, malls, and large estates. Interior systems are also hydroponic, but the water re-circulates from a fountain at the top of the wall and is collected and recycled in a gutter, that runs along the bottom of the wall. Fabric holds the media and plants together behind the support structure of the wall. As plants absorb CO₂ and carbon monoxide, the microbes that live within the media remove volatile organic compounds that originate in the material used for carpet, furniture and other common building materials. A fan built into the wall draws the fresh air produced by the plants into a ventilation system, which distributes the clean air throughout the building. Figure 1 displays this system. When choosing plants for an interior space, it is important to use plants that can not only tolerate, but also thrive in low-light conditions. Ideal plants should be adapted to growing with little to no soil, and a shallow root system.

It is important to research what type of exterior living wall best suits a specific installation area in outdoor green wall applications. There are modular systems that require several shallow boxes, which hang on a preexisting wall or fence. These boxes are made out of anything from recycled nylon to metal that are filled with media and plants. Weight can be a major disadvantage when installing modular systems, which in turn restricts the plant palette that can be utilized. Patrick Blanc developed Le Mur Végétal, which mimics nature by allowing plants to grow freely over a wall without any space restrictions (*Vertical Garden Patrick Blanc*). A frame consisting of two layers of fabric, which acts as media for the plants, is fitted onto the building attaching at specific points. The key to success with this type of system is to constantly have a source of water pumped with nutrients for the plants, so they do not need to spend energy into
creating a hearty root system. These systems require maintenance during the first year after installation to guarantee acclimatization. Usually after this initial period the walls will be self-sufficient, and only require emergency or annual check-ups. Many of these systems now have off-site monitoring that allows the company to ensure the best quality of product at all times. These computer systems are generally unique to the company producing the green wall system, and are created by placing sensors into the wall. These sensors track media moisture and irrigation pipes so any trouble can be viewed instantly from home or office (GSky). Yet another type of green wall is the freestanding type, which allows the client to place a living wall anywhere. These freestanding walls are generally used indoors in areas that receive a high amount of traffic, such as lobbies, hallways, and reception areas. The wall is more of a cabinet that contains its own irrigation and pump, which recycles water through the green wall and plants (Gsky).

The success of the green wall depends on the plant selection. No matter how ingenious the infrastructure design might be, if the public does not think the wall is aesthetically pleasing, then no company will spend money on frivolous eye sores. Some walls will have sedum mats, or will have wildflower seed spread after installation; then there are walls that are directly installed with living plants that stay for an indefinite amount of time, usually selected to endure the specific microclimate of area (Francis). Plants could be selected to produce crops like tomatoes, beans, peas, and common herbs or spices. Many people are pushing now for the utilization of native species in green walls. At a brief glance this idea sounds like a wonderful way to restore native habitat, however, many of California’s native species have a very exclusive growth habitat and would not thrive in the harsh conditions, such as intense wind and sun exposure, surrounding most skyscrapers. Native species plants would need to be carefully researched in order to ensure
survival of the system. Flora is more likely to thrive when plant palettes are chosen based on its specific adaptations to the climatic factors, rather than just because it is a California native. In order to choose the ideal plants, the position and orientation of the wall should be taken into consideration. Orientation will determine how much heat and solar radiation will be absorbed into the wall. Walls facing east experience greatest temperature fluctuations during the morning, while west facing walls have the greatest heat absorption during the afternoon. North facing walls remain relatively cool all day, while south facing walls continuously absorb heat all day, remaining at higher temperatures for the longest period of time. Figure 2 shows that levels of radiation follow the rise and fall of temperature. The living wall will have the greatest cooling effect based on the orientation of the wall rather than how the wall was made. Generally areas facing the southern direction will receive the longest period of high temperatures.

Plant selection must take into account the amount of sunlight each section of the green wall receives. Wall surfaces generally receive more sun than areas on the ground because there are no trees or shrubs nearby to provided shade or evaporative cooling. The most sun loving plants should be installed at the top of the wall, while the shade and moisture loving plants should be installed near the bottom of the wall. For a Mediterranean climate, plants should be low, mat forming, or densely tufted in order to withstand wind damage and uprooting. Plants with fibrous roots that anchor into the substrate or underground storage organs are ideal for small amounts of substrate material, and less prone to drought damage. Succulent leaves, compact twiggy growth, small evergreen leaves, leaves with a thick cuticle are all adaptation to water loss, which become necessary when exposed to green wall conditions. Inrolled leaf margins, or glaucous foliage color reduce the angle of impact from solar radiation (Dunnett, Kingsbury). Plants chosen for Cal Poly’s green wall will be plants suitable for the Mediterranean climate of California specifically
within the Sunset climate zone 15. Plants in this zone have a growing season during March to December, with most of the rainfall occurring the fall and winter. Temperatures during the winter can drop below freezing, while the summers are mild due to the maritime influence (Brenzel). The plants selected were letter coded to fit into the established pattern. Table 4 lists the plants and the corresponding letters.

III. Materials and Methods

In order to construct the wall, a frame was built out of galvanized steel and horse fencing. Shade cloth was used to create layers for growing media to be filled into, after lath cloth is layered behind the pony wire so the media does not seep out of the wall. Holes are cut into the layers of the cloth before they are filled with either coconut husk, or in this specific case sterilized soil and compost from the Cal Poly Horticulture Unit. Laid laterally throughout each layer of soil is Netafim™ drip line set on an automatic timer that can be adjusted from the main irrigation box. After the soil is thoroughly wetted, slits can be cut into the shade cloth and the plants can be installed.

Now that the wall has plants installed, the observations could be conducted. Regular maintenance will be conducted on the wall throughout the research. This includes running the irrigation for ten to fifteen minute intervals at least twice a week, pruning, and any replacement of declining plants. In order to determine which plants grow best on this type of green wall, plant survival will be recorded for every species. Percentage of coverage for herbaceous plants versus woody plants will be calculated at installation, and then at the end of the first six months. This will show whether woody or herbaceous species are better adapted for growing vertically. In addition plant
color and vigor will be recorded, determining the overall health of species. The health of the plants will be based on a one to five scale; one being dark green or the other wise natural color; two being light green; three being mild chlorosis/wilting; four being distinct marginal or interveinal chlorosis, leaf discoloration; five being chlorotic leading to necrosis. It is important to take note of the establishment of any invasive species, although the chances of this occurring are slim due to the fabric sheltering most of the soil.

IV. Results and Discussion

After the original installation was completed the plants were monitored for eleven months. The color and species vigor was rated and recorded each month in order to create a comparison chart (Table 2). The chart tracks the vegetation and vigor from March 2012 to February 2013 showing the comparison by rating the appearance on a zero to six scale, six being dead, one being healthy with new growth. Differences in plant health became apparent by the third month, or by May. By this time it was obvious that the *Arctostaphylos uva-ursi* was a poor choice for this green wall because there was no new shoot or root growth on any of the individual plants, and severe necrosis. The *Erigeron glaucus* plants were also infected by powdery mildew during the moist rainy season of March and April and by May the decline was noticeable and so were the powdery mildew spores. There were two times that the irrigation was shut off, and not turned back on for several weeks by accident, which can explain the high ratings on Table 2 in August and October. Luckily the plants were going to be removed were already dead by then and the other species recovered. By far the *Carex divulsa* and *Teucrium chamaedrys* plants did the best, only turning brown when the irrigation was interrupted, but otherwise did great in the summer heat and bright light. After the first eleven months there was about 50% coverage of woody species, 30% coverage of herbaceous species, and 20% coverage of empty canvas.
After a year had past following the first installation, it was clear several species were not well adapted for vertical walls. The *Arctostaphylos uva-ursi* plants were completely dead and when removed from the wall, had little root growth establishment. The *Arctostaphylos uva-ursi* plants were planted near the bottom of the wall, and were probably receiving too much water. Since the water moves down through the wall, the lower on the wall, the moister the soil. *Arctostaphylos uva-ursi* requires low water and has a shallow root system, so this species might have been better used on the top of the wall. Since *Arctostaphylos uva-ursi* are such slow growing woody species, it is crucial that this species be grown in shallow soil that has little irrigation. The *Erigeron glaucus* was also installed on the lower portion of the wall; however it was Powdery Mildew that made this species unsuccessful. Fortunately the Powdery Mildew did not spread to any other species throughout the year, so the infected *Erigeron glaucus* plants were left in the wall without treatment. *Erigeron glaucus* species are not tolerant of the continuously moist soil that occurs on this portion of the wall, especially during winter. When grown with poor cultural methods, *Erigeron glaucus* plants become prone to infectious spores, such as the Powdery Mildew. On the other hand, *Scabiosa* ‘Blue Butterfly’, which is usually a fairly hardy species, could not recover after the second irrigation break. Also, this species was prone to geotropism and looked ragged only a few weeks after deadheading. A sage species with more of a ground cover growth habit would be better suited for the vertical face of a wall.

Both the *Linum lewisii* and the *Yarrow* ‘Lilac Beauty’ species survived the first year but were not aesthetically pleasing after the first six months. Although both species produced bloom all year round, it was the upkeep of the foliage that proved difficult. *Linum lewisii* had the same problem as the *Scabiosa* ‘Butterfly Blue’, tending to look sparse and prone to geotropism. While the *Yarrow* ‘Lilac Beauty’’s foliage was dense but the old growth persisted on the stems after it had
died. The Yarrow ‘Lilac Beauty’ required pruning at least once a month in order to remove dead foliage and stems growing vertically instead of against the wall.

After the first year all plants were removed except for the Carex divulsa and Teucrium chamaedrys. Both of these species did fantastically well and after a year on the vertical wall have not shown geotropic symptoms and are overall very healthy. The Carex divulsa plants grew to about two feet by two feet and required trimming about once a month. Fortunately the Teucrium chamaedrys grows a little slower and only really requires deadheading after bloom. This species grows about one foot in height and spreads to create a dense mat that can reach four feet wide. The Muhlenbergia rigens was planted directly in front of the wall, not in the wall, and is doing great and will be kept for at least another year. The growth habits of the Muhlenbergia rigens plants are similar to the Carex divulsa, reaching about two or three feet tall and about a foot and a half wide. However, the Muhlenbergia rigens requires deadheading only once a year in the fall after the bloom cycle. The ideal growth habit for this wall is thick foliage that stays close to the surface. However, it is important that the maintenance requirements be minimal, due to limited employee help servicing the wall and plants.

With this in mind, the wall was redesigned with a new selection of plants. This time the plants selected were mostly grasses and groundcovers focusing mainly on the foliage color and texture rather than blooms. Table 3 gives the Latin names of updated plant list. Due to time constraints, instead of tracking the new selection of plants over a year period, the plants will be tracked for the first month. Pictures of the newly planted wall will be taken once a week for four weeks. The species Stachys byzantina, Carex testacea, Festuca glauca ‘Silver Heron’, Teucrium fruticans ageratum, and Sesleria caerulea will also be documented through pictures for the first month as
well. This will help portray which of the newly planted species establish roots in a month’s time. Root growth can be determined by the health of the plant and as well as new growth.

V. Conclusion

In hopes of creating a more sustainable green wall, a maintenance and irrigation schedule should be created by the faculty supervisor in charge of servicing the wall. This is important for proper establishment of grass species especially because they will require regular dead heading and water. Currently the irrigation schedule is set for establishing plants, irrigating fifteen minutes twice a day, five days per week. Once the new plants are established, irrigation can be reduced to ten minutes, twice per day, four days per week during the growing season. Water should be monitored and shut off in the winter as necessary with adequate rainfall. Although some of these species are California natives, this is not a key factor in plant selection. Selection should be based on growth habits and requirements, while keeping in mind that the plants should be able to thrive in the appropriate Sunset climate zone. If, after monitoring the updated species for a year, it becomes apparent that a couple species are not suitable for this wall, there are a few more plants that may work in this situation.

*Mimulus* spp., otherwise known as Sticky Monkey Flower, keeps a round shape that only reaches a foot and a half in height and two feet in diameter. Another great option is *Erigeron glaucus karvinskianus*, which creates a creeping mat with fine textured foliage and bright white flowers that bloom year round. With this species it would be prudent to order a non-invasive variety, so it would not reseed in unwanted areas. For future plant design options review the Proposed plant design in the included Excel spreadsheet. While this report focuses mainly on the survey of plant species, the wall can be redesigned for accurate data analysis if so desired. Building this wall was
extremely beneficial as a learning experience, and will provide years of experimental education for students if properly maintained.
Works Cited


Dunnett, Nigel, and Noel Kingsbury. *Planting Green Roofs and Living Walls*.


APPENDIX A.

Week 1: February 14, 2013
Week 3: March 1, 2013
Week 4: March 8, 2013
APPENDIX B.

Stachys byzantina

Week 1

Week 2

Week 3

Week 4
Carex testacea

Week 1

Week 2

Week 3

Week 4
**Festuca glauca 'Silver Heron'**

Week 1  

Week 2  

Week 3  

Week 4
Teucrium fruticans ageratum

Week 1

Week 2

Week 3

Week 4
Sesleria caerulea

Week 1

Week 2

Week 3

Week 4
APPENDIX C.

Table 1. Original plant placement design for wall

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<td>Linum lewissi</td>
<td>Yarrow 'Lilac Beauty'</td>
<td>Teucrium chamaedrys</td>
<td>Erigeron glaucus</td>
<td>Arctostaphylos uva-ursi</td>
<td>Carex divulsa</td>
<td>Scabiosa 'Butterfly Blue'</td>
<td>Muhlenbergia rigens</td>
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Table 2. Comparison of plant health and vigor of species on wall over a period of eleven months

![Vegetation Color & Vigor Chart]

Table 3. Revised plant placement design for wall

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<th>A</th>
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</thead>
<tbody>
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<td>Teucrium chamaedrys</td>
<td>Carex testacea</td>
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<td>Carex divulsa</td>
<td>Festuca idahoensis 'Tomales Bay'</td>
<td>Teucrium fruticans ageratum</td>
<td>Stachys byzantina</td>
<td>Muhlenbergia rigens</td>
</tr>
</tbody>
</table>
APPENDIX D.

Figure 1 (Fernandez-Canero). Interior green wall air filtration system

Figure 2 (Eumorfopoulou). Levels of radiation follow the rise and fall of temperature